SECTION C – DESCRIPTION/SPECIFICATIONS

THE SALIENT CHARACTERISTICS SET FORTH BELOW REFLECTS THE MINIMUM NEEDS OF THE GOVERNMENT.

1. SALIENT CHARACTERISTICS

1.1 SCOPE - These salient characteristics cover portable abrasive blast equipment for use in removing lead contaminated paint in an open dry-dock environment. This equipment is required to control the emission of fugitive dust as required by the Puget Sound Air Pollution Control Agency (PSAPCA), Regulation I and minimize the generation of hazardous waste.

2. EQUIPMENT DESCRIPTION - The equipment, new and unused, shall meet the salient characteristics contained herein.

2.1 SALIENT CHARACTERISTICS - The abrasive blast equipment shall be adaptable to permit the removal of surface coatings without damage to the base material. Base material will range from steel to fibrous glass. Adaptation of the blasting action will be accomplished by air pressure regulation and abrasive selection. Air pressure shall be adjustable over a range of between 30 and 110 psig. The equipment must permit the use of multiple abrasive types, which range from 7 to 120 mesh size.

Each blast unit shall include, as a minimum:

a. SKID MOUNTING,
b. BLAST POT,
c. RUST INHIBITOR INJECTION,
d. CONTROL ADJUSTMENT,
e. UTILITY CONNECTIONS.

2.1.1 SKID MOUNTING WITH PADEYES - The skid shall be complete with forklift rails for transporting with a 10,000 pound capacity forklift, and four (4) padeyes (strong enough to support the lift of a fully loaded abrasive blast unit) for lifting with a crane.

2.1.2 BLASTPOT - The blastpot shall be ASME certified with an allowable vessel pressure of 175 PSI and a minimum capacity of 11.3 cubic feet. Mixing of abrasive with water shall occur in the blastpot, so as to ensure 100% wetting of the abrasive, and to permit reusing wet abrasive. Water use rate shall not exceed 25 gallons per hour during blasting operations.

2.1.3 INHIBITOR INJECTION - Injection ration of liquid rust inhibitor to water will be adjustable to accommodate various manufacturers. On/off controls will permit selection of inhibitor injection during wet abrasive/air and water/air evolutions.

2.1.4 CONTROLS - Air and water controls shall provide independent adjustments and control of abrasive/water mixture ratio, water and air. Remote controls, located a minimum of 200 feet from the blast unit, to permit a single operator to select wet abrasive/air, water/air, air only and on/off pressure control the blast hose.

2.1.5 UTILITY REQUIREMENTS - Utility connections to allow connection to 120 psig air, 60 psig water and 110 volt electrical sources. Abrasive hose used with the unit shall be 1 1/2 inches in diameter.

3. TECHNICAL DATA

3.1 TECHNICAL MANUALS - Three sets of technical manuals written in the English language shall be furnished for each make, model, and serial numbered piece of equipment supplied under the terms of the contract and be delivered in accordance with the attached DD1423.

The contents of a complete set of technical manuals shall include, as a minimum, the following:

a. Setup and operating instructions.
b. Maintenance, service and repair instructions.
c. Illustrated parts list, including:

    1. Part numbers.
    2. Part nomenclature.
    3. Cross-reference number applicable to location/function in the equipment/system procured.

Technical manuals will be bound or otherwise securely enclosed in an oil and moisture resistant binder(s). Each binder cover shall indicate in bold type the manufacturer's name, contract number, model number, equipment serial number and equipment name.

3.2 SPARE/REPAIR PARTS LIST, NON-PROVISIONED - The spare/repair parts list shall include parts that the manufacturer recommends be stocked for support/ maintenance for one year following expiration of contract warranty period. The spare/repair parts list shall be delivered in accordance with the attached DD1423.

Field Demonstration of Clean Technologies for Removal of Lead-Based Paint

Environmental Quality Management, Inc.
U.S. Environmental Protection Agency, NRMRL
U.S. Army Corps of Engineers, USACERL
Keizer Technologies Americas, Inc.
TDJ Group, Inc.
NexTec, Inc.

EQ

Study Objectives

- Evaluate the effectiveness of wet abrasive blasting with a lead-stabilizer compound added to an abrasive to remove LBP from exterior wood siding.

- Evaluate the effectiveness of wet abrasive blasting of a lead-stabilizing surface coating to remove LBP from exterior wood siding.

EQ

Study Objectives

- Evaluate the effectiveness of each technology to stabilize the lead in the resultant LBP abrasive blasting debris.
- Evaluate the airborne lead levels (personal and area) generated by each technology.

EQ

Technologies Evaluated

- Coating Removal

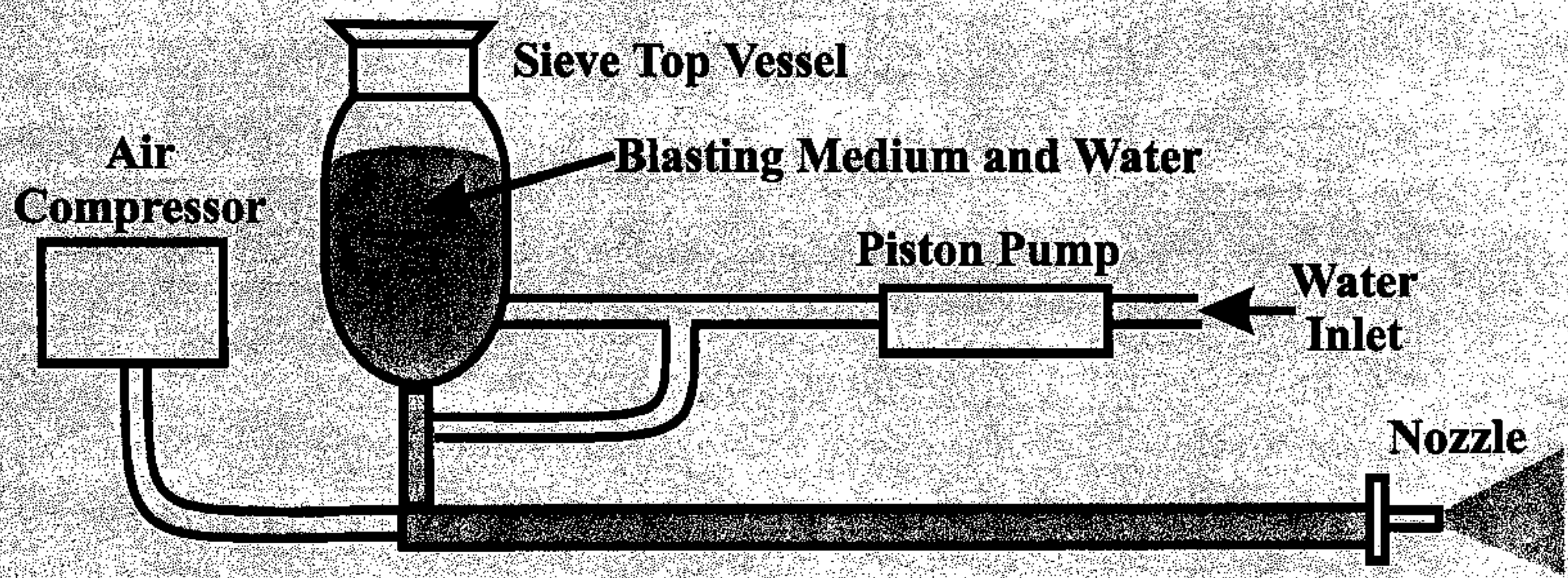
  Torbo® Wet Abrasive Blasting System

- Lead Stabilization

  1. Abrasive media additive — Blastox ®
  2. Cementitious surface coating — PreTox 2000®

EQ

Torbo® Wet Abrasive Blasting Technology



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Sampling Strategy

- Paint film thickness: pre-removal
- Paint removal effectiveness
  - Lead in paint (XRF): pre/post removal
  - Lead in paint chip (ICP-AES) : pre-removal
  - Lead in substrate chip (ICP-AES) : post-removal
- Air lead levels during removal
  - Personal and area samples
- Waste characterization

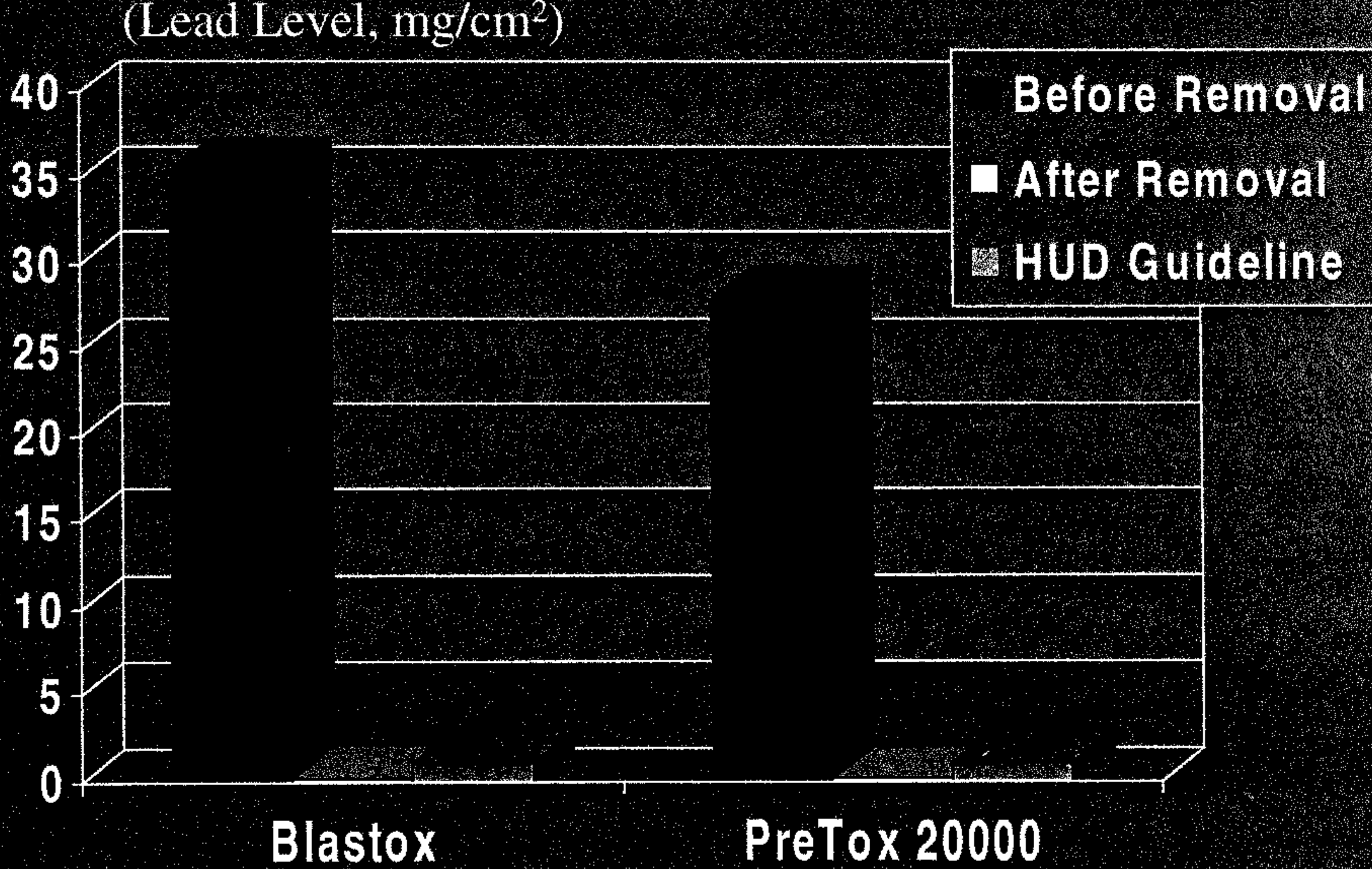
EQ

Methods

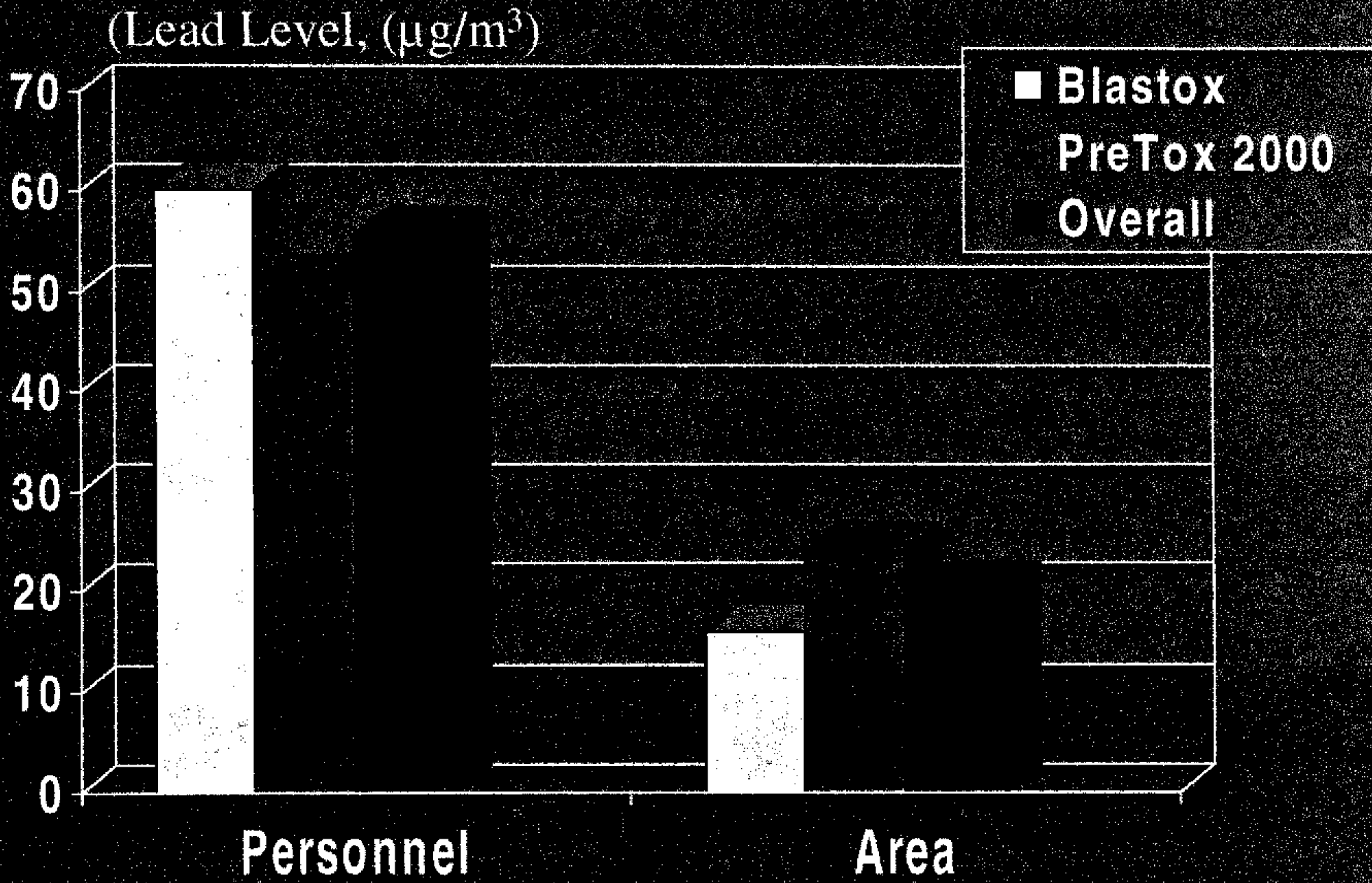
Paint film thickness	ASTM D-4138-88
Paint film (lead)	XRF (NITON 703-A)
Paint chips (lead)	EPA SW-846 3050/6010
Bare substrate (lead)	EPA SW-846 3050/6010
Air (lead)	NIOSH 7300
TCLP (lead)	EPA SW-846 1311/3015/6010

EQ

XRF Lead Analyses



Lead Levels (8 hour TWA)



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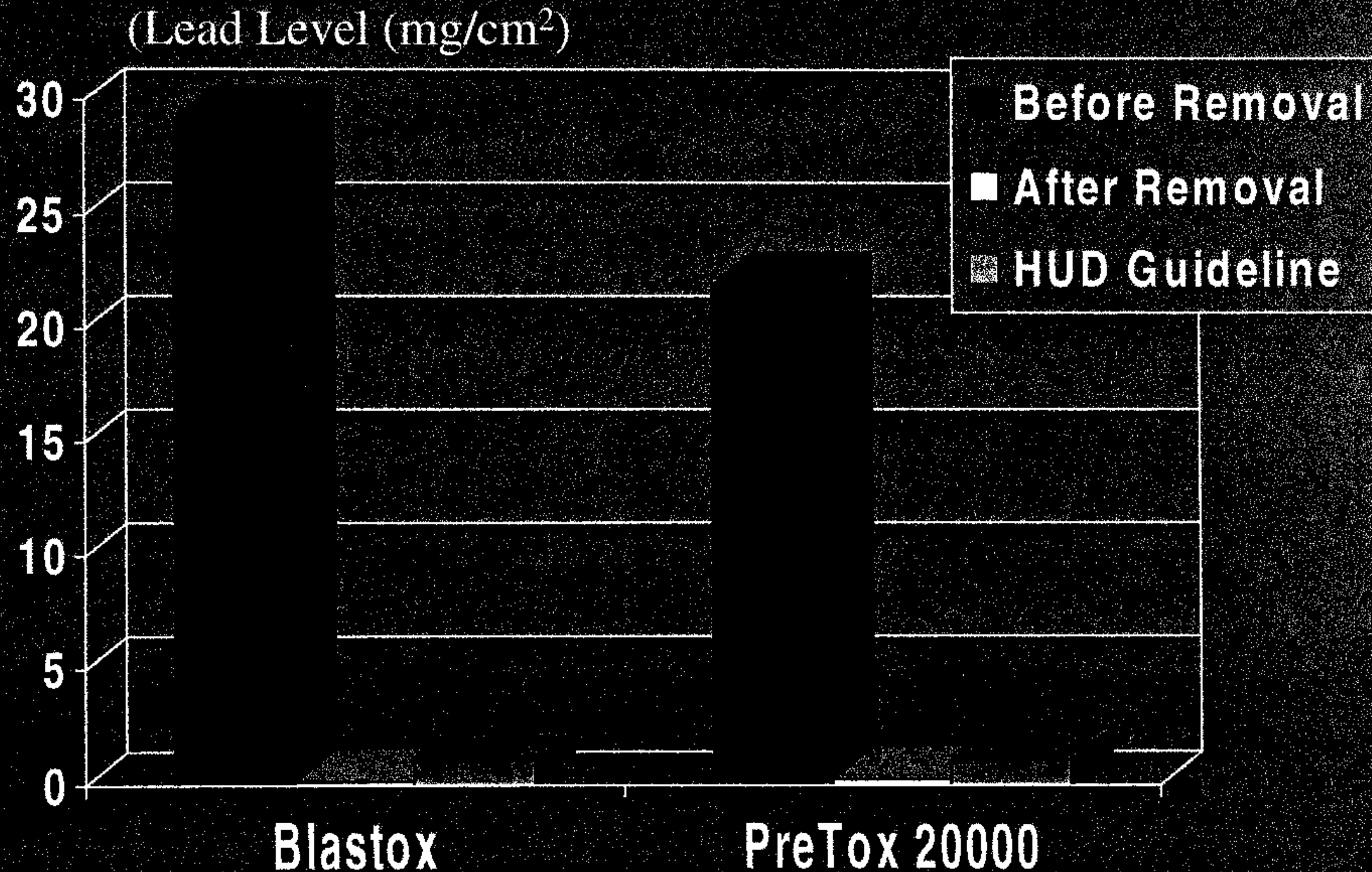
ICP Lead Analyses



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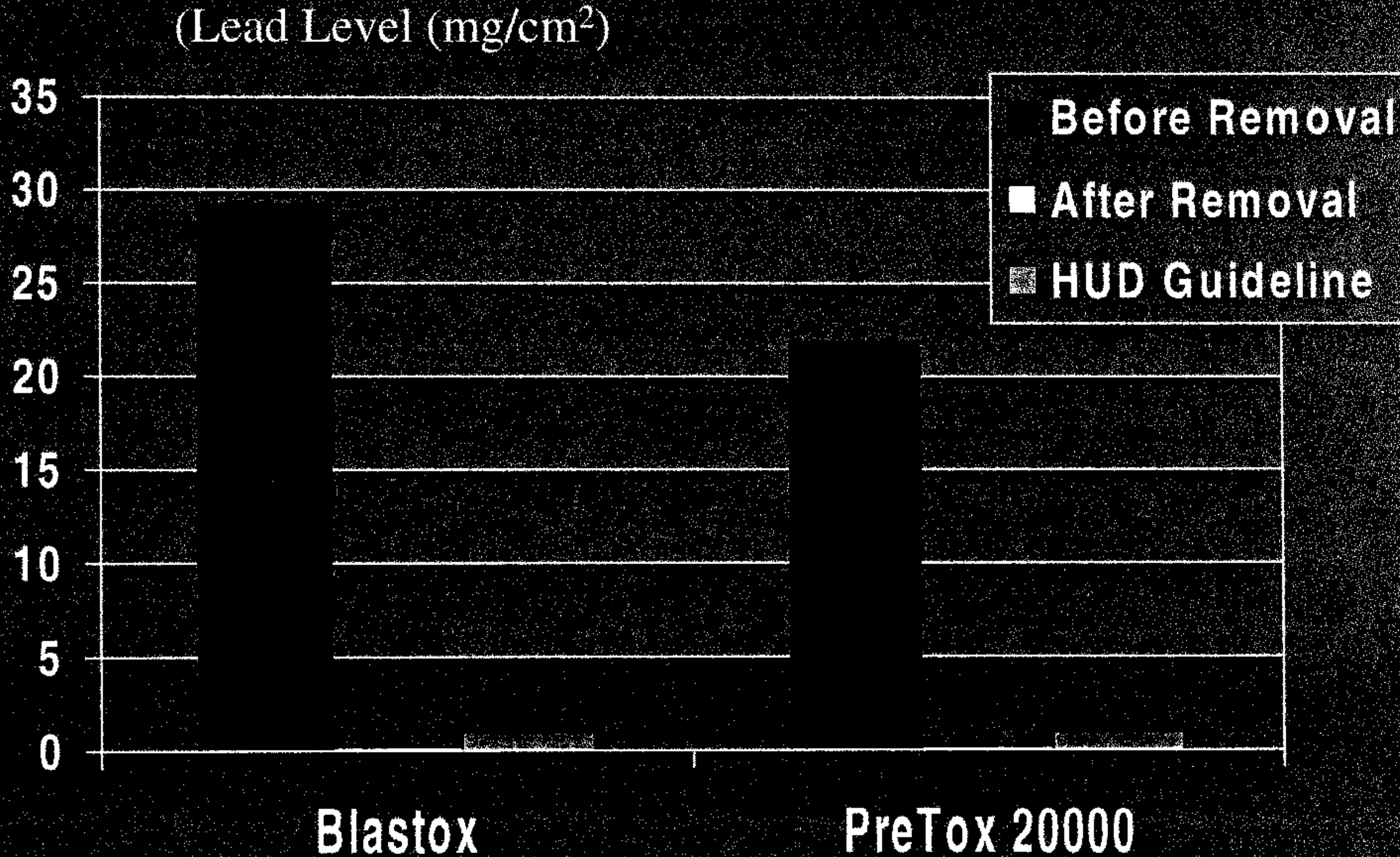
ICP Lead Analyses



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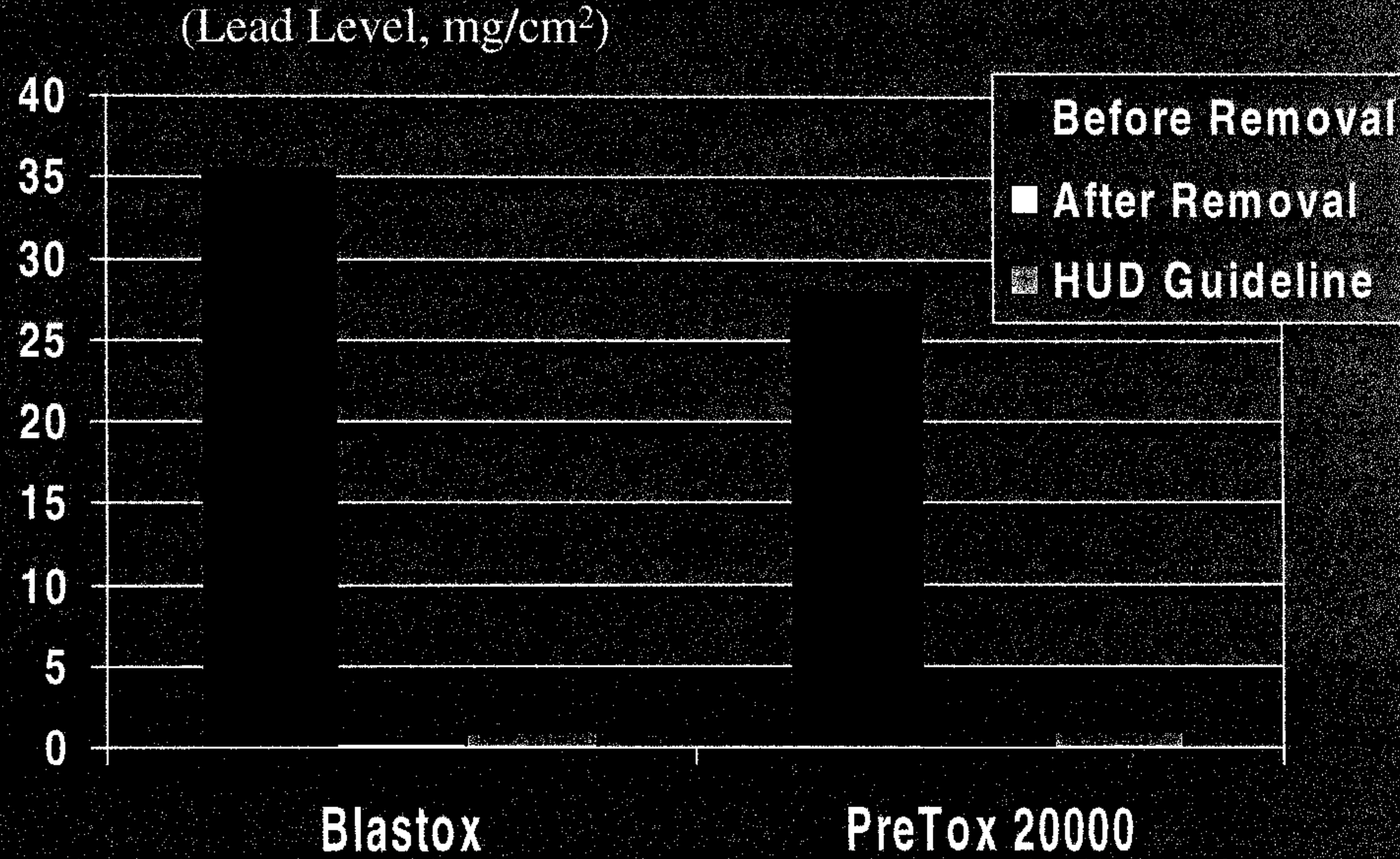
XRF Lead Analyses



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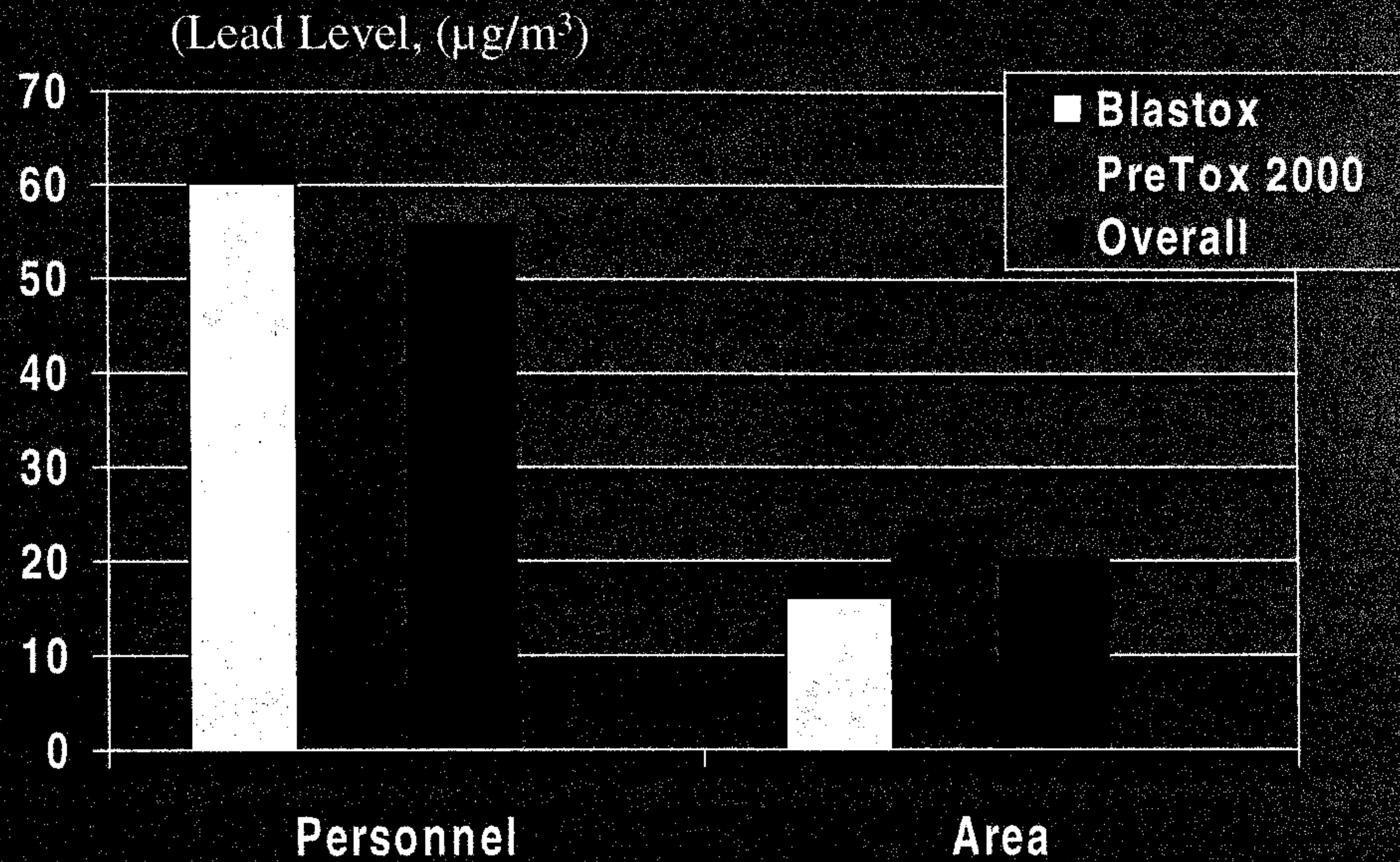
Lead Levels (8 hour TWA)



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TCLP Analyses (mg/L) of LBP Blasting Debris

Stabilization Method	N	Geometric Mean	95% UCL
Blastox	12	0.0	0.0
PreTox 2000	12	0.0	0.0
RCRA Criterion		5.0	

EQ

Conclusion

Torbo® wet abrasive blasting of a lead-stabilizing surface coating (PreTox 2000®) effectively removed LBP from exterior wood siding. The surfaces were rendered lead hazard free (HUD Guideline) and suitable for re-painting.

EQ

Conclusions

- Personal exposures to airborne lead exceeded the OSHA PEL by a factor of approximately 1.1.

- Fugitive levels of airborne lead were less than the OSHA action level.

EQ

Field Demonstration of Clean Technologies for Removal of Lead-Based Paint

John R. Kominsky
ENVIRONMENTAL QUALITY MANAGEMENT, INC.
Alva Edwards-Daniels and *Patrick J. Clark*
U.S. ENVIRONMENTAL PROTECTION AGENCY, NRMRL
Vincent F. Hock and *Susan A. Drozdz*
U.S. ARMY CORPS OF ENGINEERS, USACERL

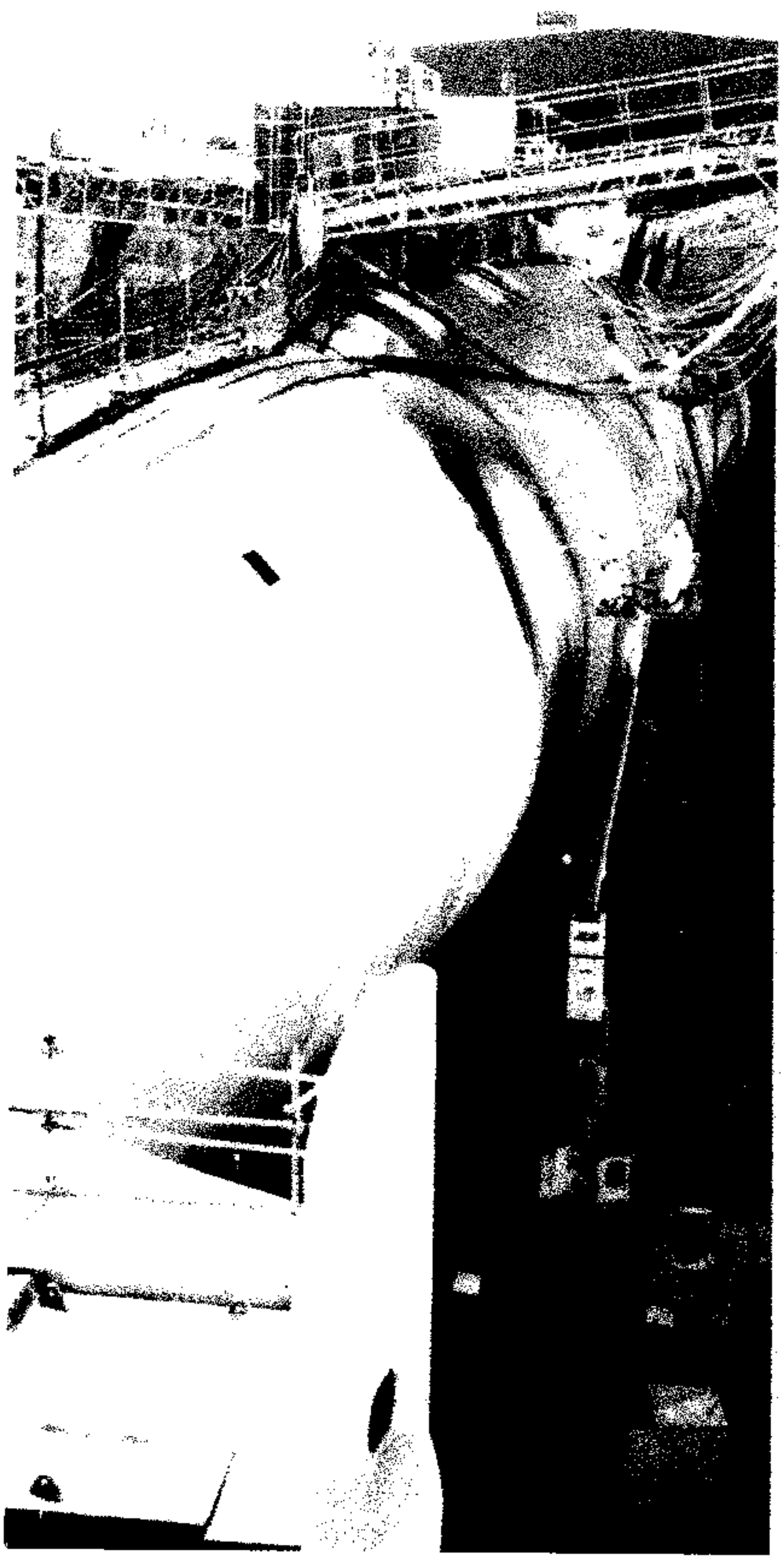
EQ

Conclusion

Torbo® wet abrasive blasting with a lead-stabilizer compound (Blastox®) added to an abrasive effectively removed LBP from exterior wood siding. The surfaces were rendered lead hazard free (HUD Guideline) and suitable for re-painting.

EQ

Blastox® and Torbo® Team Up to Remove Lead Paint from Trident Nuclear Subs



Blastox® and Torbo® have made believers out of the Navy. The USS Ohio was blasted with straight slag abrasives and full containment, with waste disposal costs as high as $375 per ton. When they added Blastox to the slag, the waste was declared non-hazardous and beneficially reused for $20 per ton — with the added benefit of no liability in landfills. The USS Michigan was then blasted at the Trident Refit facility in Bremerton, WA using slag and Blastox with the Torbo wet abrasive blast system. The results? Abrasive consumption was cut in half, and the need for containment was eliminated because Torbo and Blastox reduced airborne lead particulates *down to 4-6 micrograms/m3 per 8-hour TWA*! The waste was non-hazardous and again beneficially reused through a cement kiln.

TRF says "We were able to finish the project in just 14 days. This saved 10,000 man hours and nearly half a million dollars."

You can enjoy the benefits of Blastox and Torbo on your job, too, including:

- ✓ **No hazardous waste**
- ✓ **Minimized (or eliminated) containment**
- ✓ **Reduced abrasive use (50% less than dry systems)**
- ✓ **Improved productivity**
- ✓ **No water to clean up or dispose of. Torbo systems use just ONE PINT of water per minute!**
- ✓ **Lead in the air generation below the OSHA action level**
- ✓ **Beneficial reuse of spent material reducing liability**

Now, there's no need to invest in costly equipment and 100% containment. So for your next lead paint project, contact **The TDJ Group** at 1-800-BLASTOX, or **Keizer Technologies** at (817) 685-7090.

Stop by and see us at SSPC Booth #245

TDJ

torbo®
WET ABRASIVE BLASTING SYSTEMS

The TDJ Group, Inc.
760 Industrial Drive, Unit K
Cary, IL 60013
(708) 639-1113
FAX (708) 639-0499

Keizer Technologies, Inc.
10908 S. Pipeline Rd., Suite 7,
Euless (Fort Worth), TX 76040
(817) 685-7090
FAX (817) 685-9190

Circle 66 on Reader Service Card.

3 Emerging Technologies for LBP Removal Paint From Nonsteel Substrates (Task 3)

CERL has evaluated environmentally acceptable chemical strippers and alternative blast media technologies for the removal of lead-based paint from DoD buildings and structures. The technologies evaluated include cryogenic blasting, laser paint removal, chemical stabilizers, alternative chemical strippers, and confined hydraulic blasting. A sponge media blasting technique appeared to be particularly promising for LBP removal from surfaces of buildings. Soft sponge media abrasive products have been developed to address issues of worker and public safety, hazardous waste minimization, and pollution prevention. The sponge medium consists of a matrix of water-based urethane foam within which abrasive particles are dispersed. The medium can be wet with water or chemical solutions to increase productivity. The aggressiveness of sponge media can be tailored for the specific application by changing the characteristics of the abrasive particles inside the urethane foam. However, during field testing, it was determined that sponge blasting caused unacceptable damage to historical wooden structures.

Granulated carbon dioxide (CO_2) blasting and pelletized CO_2 blasting have been evaluated for removing LBP from interior architectural wood components (Kominsky, Hock, and Daniels 1997). The CO_2 blast medium is a soft abrasive that removes the LBP by mechanical impact and thermal expansion mechanisms. The spent media evaporates directly to a gaseous state and dissipates, leaving only paint solids as waste. However, it was found that both the granulated and pelletized CO_2 proved ineffective in removal of the LBP from interior wooden components without severe damage to the underlying substrate. Also, residual lead levels of 6 mg/cm^2, as determined by an XRF spectrum analyzer, exceeded the HUD guideline of 1 mg/cm^2 (U.S. Public Law 102-550, 1992).

The Torbo^{Ò} wet abrasive blasting system, manufactured by Keizer Technologies America, Inc., uses conventional blast abrasives (such as coal slag or silica sand) mixed with water (80 percent abrasive to 20 percent water). The abrasive-water slurry mixture is fed through a blast nozzle system designed, in principle, to encase every particle of the abrasive in a thin layer of water. Water pressure forces the slurry into a compressor-generated airstream where it is accelerated to the blast nozzle. The LBP is removed by the kinetic energy and mechanical abrasion of the blast media striking the paint. Blastox^{Ò}, a chemical stabilizer, was added to the slurry mixture prior to blasting in order to create an "engineered abrasive," that would react with the lead in the paint chemically in order to stabilize the leachable lead as lead silicate, with stabilization mechanisms similar to those of portland cement. The wet abrasive blasting technology used with the engineered abrasive efficiently removed LBP from exterior architectural wood components to bare substrate with no apparent damage, and yielded a substrate ready for repainting (Kominsky, Hock, and Daniels 1997). Overall, the residual lead levels as determined by XRF were 0.93 mg/cm^2, which is below the HUD guideline.

Encapsulant paint removal technology effectively employs a two-part liquid system consisting of potassium hydroxide and a proprietary polymer, which are sprayed with an applicator gun that uses an external mixing technique. The dwell time is dependent on time and number of layers of paint, temperature, and other environmental factors. After the paint is absorbed into the remover matrix, the resulting residue is removed as a semi-solid material using a putty knife. Encapsulant paint removal technology has been used to remove LBP from interior architectural wood components to bare substrate with no apparent damage. The residual lead levels as determined by XRF were found to be 0.8 mg/cm^2 (Kominsky, Hock, and Daniels 1997).

Reduced-toxicity chemical strippers are sometimes referred to as "environmentally acceptable (EA)" strippers. These chemicals are of interest because of their low volatility and low toxicity. They are noncorrosive and not caustic to humans. Typical EA strippers are based on ingredients that have low environmental impact, such as citric acid and N-methyl pyrrolidone (NMP). Where they can be used effectively, these products eliminate the need for sodium hydroxide and methylene chloride strippers. However, these new formulations require long dwell periods; consequently, in exterior applications, their performance is vulnerable to degradation by rain, wind, and low temperatures. Of the six EA strippers investigated in the laboratory, only NMP-based strippers performed comparably to conventional solvents and caustic strippers (Drozdz and Engelage 1996).

Laser paint removal systems have been designed and built for use on fragile historic wood structures. These systems contain a CO_2 pulse laser and beam delivery system. Evaluation of the paint removal system by CERL showed potential as a paint removal technology for use on historic wood structures. Advantages include no containment costs, no requirements for worker protection, and reduction of hazardous waste compared to chemical paint strippers. However, further engineering enhancement will be necessary to make the process cost-effective.

Emerging technologies evaluated under this project have been documented in the following publications:

Boy, J., and A. Kumar, "Lead-Based Paint Hazard Mitigation" in *The Encyclopedia of Environmental Analysis and Remediation*, Robert A. Meyers, ed. (John Wiley and Sons, Inc., 1998) pp 2501-2516.

Drozdz, Susan A., and Jennifer D. Engelage, *Evaluation of Reduced-Toxicity Chemical Paint Strippers*, UR 96/111 (CERL, September 1996).

Kominsky, J., V. Hock, and A. Daniels, *Field Demonstration of Clean Technologies for the Removal of Lead-Based Paint from Residential Housing in Buffalo, New York*, draft report (U.S. Environmental Protection Agency, March 1997).

Hock, V.F., C.M. Gustafson, D.M. Cropek, and S.A. Drozdz, *Demonstration of Lead-Based Paint Removal and Stabilization Using Blastox*, FEAP TR 96/20 (CERL, October 1996).

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Clean Alternatives to Sandblasting

by

LT Kent W. Kettell

Puget Sound Naval Shipyard

December 1995

Approved: ____________________ Date: 30 NOV 95
CAPT G. Groh
EDQP Counseling Officer

Forwarded: ____________________ Date: 30 Nov 95
CDR J. Wilson
EDQP Coordinator

Certified: ____________________ Date: 11/30/95
CAPT D. Baugh
Shipyard Commander

Biography

LT Kent W. Kettell of Clarks Summit, Pennsylvania, enlisted in 1978 as a submarine designated Nuclear Machinist's Mate. As an MM2 he received a SECNAV appointment to the Naval Academy Preparatory School, and followed through to be inducted into the US Naval Academy in 1981. In 1985 Kent graduated with a BS degree in Marine Engineering and married Karen Berkemeyer. He and Karen now have four children, Kent William, Grace, Austin, and Grant.

He reported to the USS Andrew Jackson (SSBN-619) at Groton, CT and served as Electrical Division Officer. During preparations for overhaul the START Treaty was impetus to cancel the overhaul and begin the decommissioning of the USS Andrew Jackson at Charleston Naval Shipyard. During the 19 month decommissioning, he qualified in Submarines on the USS Tecumseh (SSBN-628), and later served as MPA on the USS John C. Calhoun (SSBN-630).

While pursuing a Master's degree in Mechanical Engineering at the Naval Postgraduate School, LT Kettell was selected for the Engineering Duty Officer community. He also graduated with the degree of Mechanical Engineer in the Total Ship Systems Engineering program in September, 1993.

After completing the Engineering Duty Officer Basic Course, LT Kettell reported for duty at Puget Sound Naval Shipyard, Bremerton, Washington in December, 1993. He has served as Reactor Plant Zone Manager for Plant #2 and as Assistant Project Superintendent (Combat Systems) for the USS Nimitz (CVN-68) Extended Drydocking Selected Restricted Availability. He then served as the Nuclear Project Engineer for the USS California (CGN-36) Selected Restricted Availability and is currently serving as Nuclear Project Engineer for the USS Parche (SSN-683).

LT Kettell is authorized to wear the Navy Achievement Medal and other unit awards.

ABSTRACT

Future surface ship and submarine dry-docking availabilities will require more stringent environmental and occupational controls on hull depainting. The current paint removal process, which is contained dry abrasive blasting, is costly with respect to personnel and environmental compliance. If Puget Sound Naval Shipyard is going to take the lead in reducing both cost and hazardous waste generation while taking the lead in industrial environmental compliance, the shipyard needs to change the process for paint removal.

Puget Sound Naval Shipyard is the demonstration site for a closed loop, Ultra-High Pressure Waterjet Stripping System, UHP WJS. This system is intended to remove paint without contaminating the atmosphere with dust or the dry dock basin with copper or lead impregnated paint chips or blast grit. Since the blasting water is recycled within the system, the only addition to the hazardous waste stream is the ion filter media. The Trident Refit Facility performed the first complete submarine hull preservation using the TORBO Wet Abrasive Blasting System with Blastox.

This paper compares these two new methods with the current method of dry abrasive blasting inside a containment. Considering an analysis of costs, environmental and personnel safety, waste generation, and project duration, it is recommended that the TORBO system be used to augment the UHP WJS in future depainting work.

CLEAN ALTERNATIVES TO SANDBLASTING

I. Background

The U. S. Navy requires a system capable of removing coatings from underwater hull areas without polluting the environment or adding to the waste stream. Top level design requirements for life cycle maintenance address the need to remove the paint from the hulls of all ship types such as aircraft carriers, cruisers, frigates, and submarines for hull inspection and preservation. Advancements in marine coatings have introduced complex paint systems that contain lead, copper, and cadmium as a means of reducing the growth of marine life on hulls. When advanced paint systems are not used, the hulls require more frequent cleaning to maintain the ship's rated speed capability.

The standard methods of paint removal have been dry abrasive blasting with synthetic grit or copper slag, steel shot blasting, and chipping or sanding. Recent dry dock effluent requirements have prohibited the continuation of open air blasting methods used in the last century. Open air sand blasting created dust clouds that covered the nation's industrial facilities. Those crude methods also permitted the blast grit and paint chips to fall to the dry dock floor and remain there until resources were available for cleanup. To responsibly remove paint systems with dry abrasives, a physical containment is needed. Workers are required for manufacturing, erecting, certifying, maintaining and dismantling the containments. The cost of containing dry blasting operations has become prohibitive.

The human resources which are required to build, certify, maintain, and remove containments are greater than those required to accomplish the paint removal. For example, when the USS Ohio (SSBN 726) hull was sand blasted in 1993 it took 1500 man-days to manufacture, install and remove the blasting containment in Dry Dock Two. It took only 287 man-days to sand blast the hull. At the current man-day rate of $467 per man-day, the containment alone would cost the customer $700,500. This was not an isolated case. The containments used in blasting the keel block settings for the USS Nimitz (CVN 68) consumed 360 man-days of resources, while the paint removal took 140 man-days. Once the paint is removed from the hull, it needs to be handled responsibly.

Since open air dry grit blasting is now restricted by environmental regulations and dry dock cleanliness requirements, a new method of depainting ship's hulls is required. Health factors affecting some sand blasters have driven facility managers nationwide to seek options other than dry abrasive blasting. New systems which could eliminate the use of blast media are under test and evaluation. Normally blast media is expended at 14 to 16 $lb./ft^2$, but as much as 20 $lb./ft^2$ of hazardous waste can be generated during dry abrasive blasting[1]. Timely innovations in this industry are needed. There is no doubt that the days of open air sandblasting are over, but the optimum replacement has not yet been determined. This paper compares two new methods that have been introduced successfully in the public dry docks of the Pacific Northwest.

The Puget Sound Naval Shipyard was the initial validation site for one innovative concept to advance depainting technology. The closed loop, Ultra-High Pressure Water-

Jet System (UHP WJS) for depainting large ships is part of the U. S. Navy Advanced Technology Development (ATD) Program. This closed-loop system is capable of removing coatings from underwater hull areas using recycled ultra-high pressure water. The need for the system was initially addressed for the Navy by researchers at the David Taylor Research Center in Bethesda, Maryland. They found that high-pressure cavitating water jets offered the best alternative to abrasive blasting for underwater hull paint removal.[2] Later as higher pressures were implemented, it was found that the high pressure alone was sufficient to erode the paint. The UHP WJ System has proven itself successful in cutting the cost of depainting the hulls of several ships. In an example to be addressed later, it is shown that this developmental system is capable of reducing the cost in half.

The TORBO Wet Abrasive Blasting System has been used successfully at the Bangor Submarine Base's Trident Refit Facility, TRF, to depaint the hulls of submarines. First introduced in the European market in 1984, the TORBO system was finally brought to the United States in 1992 when it was presented at a national conference of the Steel Structures Painting Council. It is used by the Departments of Transportation in many states in the process of preserving bridges. Because of this new system, the TRF dry dock is now capable of open blasting based on the nearly complete elimination of particulate emissions. An additive to the abrasive grit, such as Blastox captures the lead and binds it so that it is no longer hazardous. The TORBO system reduces dust emissions by 95%, allowing 100% open blasting. The TORBO is also a simple design. This simplicity has not only significantly reduced the acquisition cost, but has reduced the maintenance costs.

Although the TORBO system is versatile in the types of abrasives that it can support, it is restricted to dry docks which have a closed loop drainage system. Following a brief explanation of the requirements, the documented success of the TORBO system on the USS Michigan (SSBN 727) hull will be addressed. By keeping the system simple and capturing lead in the Blastox, the cost of depainting can be reduced to one fourth of that which was necessary to sand blast the hull of the USS Ohio.

II. REQUIREMENTS ANALYSIS

A. Mission Need

The U.S. Navy needs a system capable of removing coatings from underwater hull areas. This portion of hull preservation occurs only while the ship is in dry dock. With a limited number of public dry docks there is an urgency to complete the work quickly to allow the next docking to take place. Whatever process is employed, it must proceed in parallel with the other work taking place during the dry docking period.

A Requirements Definition and Needs Analysis was prepared by United Technologies, Pratt & Whitney Waterjet Systems, Inc. for the Air Force Materiel Command Wright Laboratory Manufacturing Technology Directorate and the Naval Surface Warfare Center Carderock Division under a joint initiative. The requirements definition and needs analysis process is required under Department of Defense Directive 5000.1, "Defense Acquisition" and Department of Defense Instruction 5000.2, "Defense Acquisition Management Documentation and Reports." The paint removal system would be deployed to remove paint from submarines, frigates, cruisers, amphibious support ships, auxiliary support ships, and aircraft carriers. Substrates on these ships are normally limited to aluminum and steel. If the system were capable of meeting these requirements, then it is assumed that it would be capable for use in other situations not involving ships. For instance, the system could possibly be used for depainting dry dock caissons and the bulkheads of floating dry docks.

B. Spatial Characteristics

The distance from the keel of the ship to the dry dock floor could range from less than four feet to greater than 12 feet. The dry dock wall to vessel distance or the vessel to vessel distance in the case of a multiple ship docking could be as little as eight feet. The equipment must be capable of accommodating a 15 foot horizontal and vertical radius of curvature. The system would need to accommodate 1/2 inch protuberances and 12 inch openings. A 4.0 square feet per minute stripping rate is desired with the minimum specification set at 2.5 square feet per minute.

C. Dry dock Requirements

The total system shall be self-sufficient and self contained with respect to preventing spills. While some dry docks have water filtration systems, Dry dock floors are not even plane surfaces and may have grates, curbs or tracks. No utilities or services are available in the dry docks, but service galleries near the dry dock coaming provide potable water, feedwater, high and low pressure air, 120 volt and 440 volt electrical power and low pressure steam. Maintenance of the equipment may have to be performed locally in the dry dock without the benefit of sheltered facilities. It is desirable to perform any maintenance and repair on station so that other shipyard resources do not need to be diverted for lifting and handling.

D. Lifting and Handling

The equipment must be road worthy and transportable to the dry dock at least by towing. If more than one trailer is needed, the trailers should be able to be attached.

Trailers should be towable with a 12,000 lb. forklift from either direction and steerable from both ends. Lifting lugs are desired on all non-palletized equipment, to reduce the risk of losing components when spreader bars are used. The weight per lift should not exceed 100,000 lb. Dry dock depths from the coaming to the basin do not exceed 61 feet. Because of the uneven surface of the dry dock floors, it is recommended that tire widths be at least four inches wide.

E. Process

Paint and primer should be removed, leaving a near white metal finish. The effectiveness of the stripping is determined by visual inspection. To minimize corrosion, a rust inhibitor should be applied to the bare metal. When no waste water treatment facility is available as a part of the dry dock drainage system, there must be another means of removing the solid and liquid waste. The solid should be able to be separated into a 55 gallon drum for lifting from the dry dock by cranelift. Considering the content of the drum, the waste will be disposed of as hazardous waste or treated at the industrial waste water treatment plant. If the paint system is determined to be non-hazardous industrial waste, larger transportation containers may be more suitable for material handling.

F. Personnel and Environmental Safety

Noise levels must meet OSHA standards such that 85 dB would not be exceeded on each component. Spark arresting mufflers are required on the exhaust systems of engines. Hydraulic equipment must contain its own leakage of hydraulic fluid. The optimum system will be a closed-loop system that does not interact with the environment

III. ALTERNATIVE CONCEPTS

This section explains the Ultra-High Pressure Water-Jet System and the TORBO Wet Abrasive Blasting System. In order to clearly understand the advantages and disadvantages of these systems, the reader must have a good understanding of the systems under comparison.

A. *Ultra-High Pressure Water-Jet System*

The closed-loop, Ultra-High Pressure Water-Jet System, UHP WJS, is composed of three major subsystems: a nozzle mounted on a six axis manipulator, a high pressure hydro-pump, and a mobile water recovery subsystem. Ultra-high pressure water from the

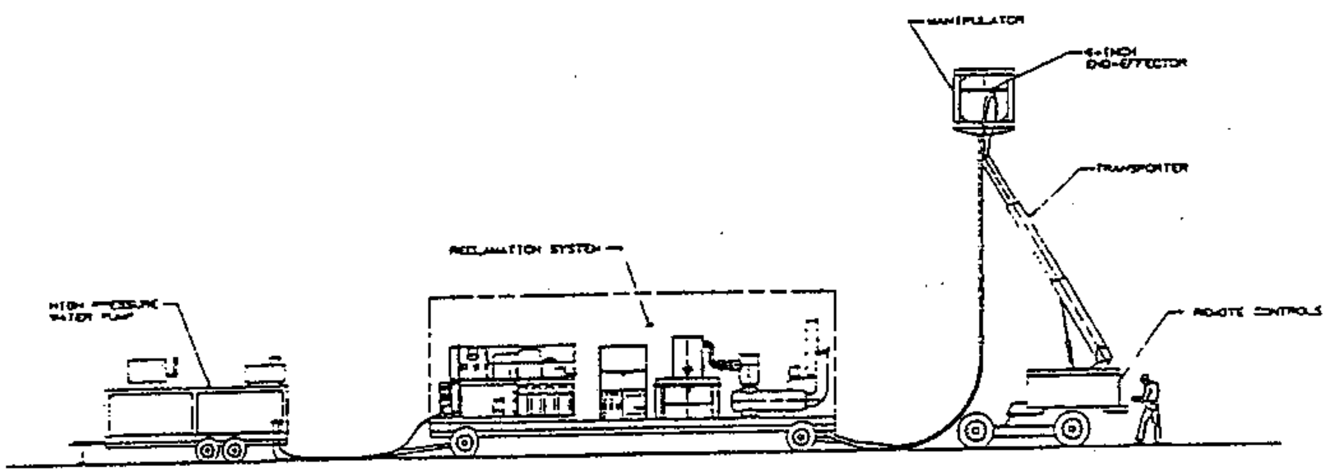

***Figure 1 Navy Waterjet Demonstration System*[3]**

pump is sprayed onto the hull, with sufficient force to displace the paint. Paint and primer are removed, leaving a near white metal finish. Several rust inhibitor additives are being considered for inclusion in the blasting water to preserve the white metal finish. The loose particles of paint and primer are vacuumed into the return line of the mobile recovery unit and processed out as a sludge. The water in that return line is processed for reuse. The goal is to have 100% recovery of the process water and to recirculate that water to the maximum extent possible.

This total system was originally designed as a Large Aircraft Robotic Paint Stripping System and is now being demonstrated as the Automated Robotic Maintenance System (ARMS™) as part of the Navy's Advanced Technology Development (ATD) Program. The first system was completed in June 1994 and was validated during a five day Acceptance Test at the Waterjet Systems, Inc. facility in Huntsville, Alabama in July 1994. This working prototype was shipped to the demonstration site at Puget Sound Naval Shipyard, PSNS, in Bremerton, Washington, where it was proved from July through September 1994. The system was first tested on portions of the under water hull and flight deck of the USS Nimitz (CVN 68) in Dry Dock Six. The following tests were performed on the USS Sturgeon (SSN 637) in Dry Dock One and various plate specimens for PERA-CV and Naval Surface Warfare Center. The system and the factory trained PSNS operators were then flown to Pearl Harbor Naval Shipyard for their first full scale project on the USS Leftwich (DD 984).

1. End Effector Subsystem

This is the focal point of the total system. It is in this robotically controlled subsystem that the six inch waterjet nozzle is mounted and rotated for transversing a 52 inch by 78 inch area. The waterjets of the nozzle are effective in fully removing, salt, rust, grease, and various paint systems. The nominal pressure of the water at the nozzle is 36,000 psi. Industry standard presently sets 25,000 psi as the lower limit for ultra-high pressure water jetting. Water jetting in the range of 10,000 to 25,000 psi is considered high pressure water jetting. Any process below 10,000 psi is considered a cleaning versus a jetting process.[4]

Advancements in computational fluid dynamics have resulted in new nozzle designs. Nozzle simulation and design technology has just recently been coupled with a means to actually manufacture durable nozzles that are capable of precision stripping of multiple layers of the paint system. DTRC has shown that the paint removal is accomplished by not only the erosive force of the waterjet, but by the energy of imploding cavitation of bubbles.[5] As the water pressure is increased, less cavitation is needed to produce the same effect. As higher pressures are achieved, less water is needed for the same effect. This in turn means that the recovery system will not be tasked as much. Waterjet technology and hydro-pump technology have overcome the pressure barrier reducing the risk of implementing this new technology.

It is with this subsystem that the recovery system shroud interfaces to recover all of the water. The waterjet nozzle is moved over a preprogrammed stripping path by a hydraulically driven motor through a belt and pulley arrangement. The recovery system contains and vacuums the residual paint chips and the effluent waste water through two concentric annular rings that surround the nozzle. It is also imperative to remove the effluent mixture to prevent any interference with the nozzle spray which could reduce the nozzle efficiency. Robotic controls at a remote control station maintain a compliant standoff distance for optimum paint removal and capture of effluent water.

2. High Pressure Pump Subsystem

The high pressure pump subsystem consists of dual, intensifiers mounted on a trailer. These Hydro-Pac pumps deliver a non-pulsating flow of water to the supply lines. Experimental research showed that optimum paint removal rates could be achieved by evenly distributing the water energy at the highest achievable pressure. Associated water lines, hoses, valves and fittings were designed to minimize pressure losses. The water supply is provided by the recovery system. The minimum specifications for water pressure and flow rate are 36,000 psi at 10 gpm in order to achieve the desired removal rates. These specifications drove the design requirement to a hydraulic pumping system powered by a 325-horsepower diesel motor. Since maintenance costs could be prohibitive, the acceptance criterion for choosing the variable displacement intensifier was that the maintenance cost per hour of operating time be minimal for the replacement of the high pressure seal.

3. Mobile Recovery Subsystem

This subsystem consists of the mobile vacuum recovery unit that recovers the water from the blast head and processes it for reuse. The effluent containment device surrounding the water-jet blast nozzle has a strong vacuum that is capable of containing all of the process water and paint chip residue and preventing it from falling to the dock floor. The mobile recovery unit has various interconnected subsystems, such as the diesel-powered electric generator, air compressor, vacuum unit, liquid/solid separator, water recovery/recirculation system, and deionization system, all mounted within the utility trailer. The liquid/solid separator removes suspended particulate from the effluent stream prior to entering the water reclamation unit. In the reclamation unit the water is processed through a centrifugal separator and several purification filters before it is deionized. The mobile recovery system segregates, filters, purifies, and deionizes prior to return to the nozzle through the high pressure pump. The requirement for the hydro-pump to need minimal water filtration drove the criterion for accepting only water with particles greater than one micron.

4. Manipulator

The six axis manipulator is mounted on the boom of the transporter and is the framework on which the end effector is positioned. The electrically powered manipulator provides the end effector with two axes of motion in the 52 inch by 78 inch work envelope. Control hardware and software signal drive mechanisms move the end effector through preprogrammed sequences called the stripping path. The end effector can be moved at 10 to 180 inches per minute in either manual or automatic control from the remote control panel. The control panel is the main operating station for the whole paint removal operation. It is from this station that the manipulator frame is repositioned.

5. Transporter

The remotely controlled transporter is a slightly modified, off the shelf unit that has the high lift basket replaced with the manipulator frame. The manipulator support frame is positioned manually from ground level by adjusting the transporter and the boom extension through a 40 feet reach. The manipulator is positioned in various subzones,

zones and stations as required by dry dock configuration, objects of interference, and the length of the service lines supporting the manipulator. When the manipulator is finished with a subzone, it is moved to another subzone by operator commands at the remote control station. After all of the subzones are depainted in a zone, the transporter is moved to the next zone. The trailers are only repositioned to another station when the zones within the station are complete.

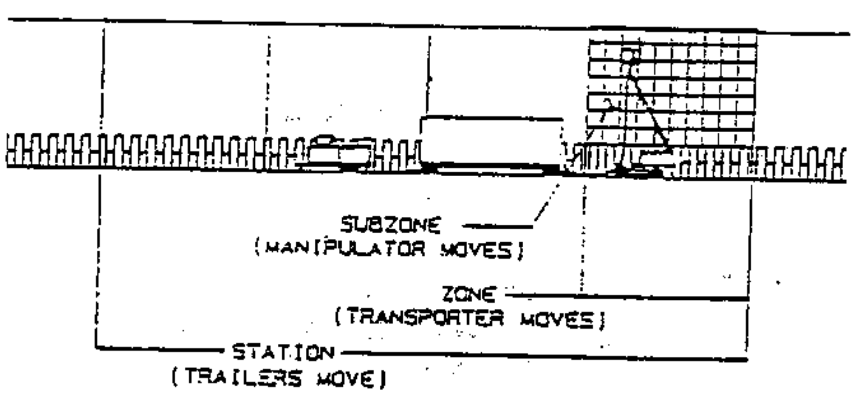

Figure 2 Layout of Stations, Zones and Subzones[6]

B. TORBO

The TORBO Wet Abrasive Blasting System has been used successfully at the Bangor Trident Refit Facility, TRF, to depaint the hulls of submarines. The TRF dry dock is capable of open blasting because of the nearly complete elimination of particulate emissions. The TORBO system consists of a pressure vessel assembly, a loading hopper assembly, a control cabinet assembly and support components. A unique safety innovation only available with TORBO equipment is the Control Magnet. The Control

Magnet is fastened to the wrist of the operator and functions to shut down the system if the operator looses control and the blasting hose begins whipping out of control. This significant improvement in the area of control, coupled with the unique design of the equipment which reduces airborne particulate, makes open air blasting possible again. Two other items of safety equipment, which are required in addition to the standard personal protective equipment, are a respirator and protective coveralls. These are required because of the high volume of mist containing paint particulate and Blastox.

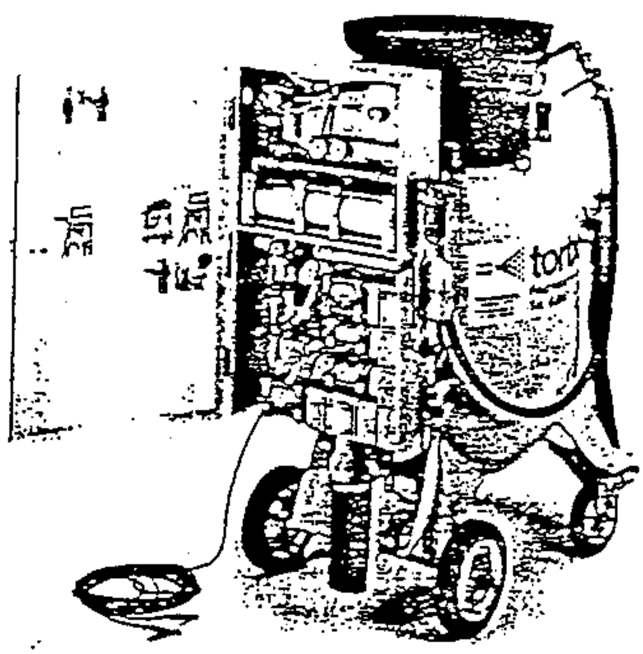

Figure 3 The TORBO Wet Abrasive Blasting System

This wet abrasive system is much simpler than the UHP WJS. The simplicity of the design reduces the up front cost and the maintenance requirement. Although it is versatile in the types of abrasives that it can support, this system is restricted to dry docks which have a closed loop drainage system. Because the TORBO system does not have its own water reclamation system, it is restricted to dry docks with such a system. It could be used in a partial containment which has the capacity for recycling the blast water and preventing runoff to the dry dock drain system. While copper slag is strictly prohibited from use in the PSNS dry docks because of the dry dock effluent discharge requirements, the TRF dry dock can readily accommodate the use of copper slag. There are other types of blast media available which have nearly the same removal efficiency as the copper slag.

Compared to dry blasting, the cleanup time is much shorter for wet blasting. The shorter cleanup time is due to the reduced amount of abrasive required to perform the job and due to the reduction in airborne particulate. Additionally, the workers can wear more comfortable protective clothing, reducing fatigue that occurs during dry abrasive blasting. Although the TORBO blasting process significantly reduces airborne particulate, full-face air supplied respirators are required below the maximum beam line because of the mist.[7]

1. Pressure Vessel and Loading Hopper

The pressure vessel is the primary component of the TORBO system. The loading hopper is used with the installed water pump for loading the abrasive into the pressure vessel. Water and abrasive are washed together through the hopper into the pressure vessel. As indicated, the abrasive does not have to be dry, but can be wet when loaded in the hopper. The vessel has a sealing disc that shuts against water pump pressure. The pressure of the vessel and the flow rate of blast water is controlled at the control panel

2. Control Panel

The control panel consists primarily of gages and valves to regulate the air and water pressures and flow rates. The system is activated at the nozzle when the Control Magnet is placed in the receptacle on the 3-Way Remote Control Switch. The switch is turned off by removal of the Control Magnet from the switch. The three blasting options are Blast Mode, Blowdown Mode and Washdown Mode. Although this system is much simpler than the UHP WJ System, the operators require significantly less training in the proper control settings and blasting methods.

3. Blast Media

The TORBO unit may be used to blast with various media. While TRF uses copper slag mixed with 20% Blastox, PSNS could easily obtain other media more compatible with the environmental requirements for dry dock discharge water samples. Blastox is a cement-like material containing calcium silicates and calcium aluminates. The TDJ Group, Inc. has patents pending on the proprietary chemistry of this mix that was introduced in 1991 as a chemical stabilizer. The environmental Protection Agency, EPA, and the Naval Sea Systems Command have both approved of Blastox for unrestricted use without hazardous waste treatment permits. It is the standard on which the current Best Demonstrated Available Technology, BDAT, as reported on the EPA RCRA Hotline, is based. Furthermore, a blend of abrasive media with 15% Blastox used at 8 lb./sq. ft. will reduce leachable lead levels from as high as 100 mg/liter to below 5 mg/liter (5 ppm), which is the EPA limit. The blast process is safe and has been proven to consistently stay well below the 0.030 mg/m^3 OSHA action level. The Army Corps of

Engineers has been using Blastox for lead abatement in Army housing tracts. The lead paint on the homes was blasted off with a Blastox mixture, ensuring a non-hazardous waste for disposal.

Although the cost of adding Blastox to the abrasive media adds at least $60/ton to the cost, the savings in hazardous waste disposal costs can be as much as 75%. This cost savings is an important factor when added to the environmental benefit of lead encapsulation. Because the wet TORBO - Blastox mix when sprayed against the hull leaves a mist, the mist needs to be washed off the hull at least shiftly. Pressure washing the hull adds to the facility's water treatment costs, but ensures that the hull's surface is not adversely affected by the Blastox film.

IV. PERFORMANCE ASSESSMENT

A. Paint Removal

It was originally estimated based on the data of Table 1 that as much as three barrels of solid waste might be generated in an eight hour shift with the Ultra-high Pressure Water Jet Blaster.[8] There was concern that the waste handling process be adequate to support the depainting process.

Assumptions	
Paint Coating Thickness	50 mils
Marine Growth Thickness	125 mils
Total Thickness	175 mils
Calculations	
Subzone Size	4 feet by 4 feet
Dry Volume per Subzone	48 in x 48 in x 0.175 in = 403.2 in^3
Liquid Content	10%
Wet Volume per Subzone	403.2 in^3 x 1.10 = 443.5 in^3
Stripping Rate	3.5 ft^2/minute
Setup Time per Subzone	2 minutes
Time to Strip Subzone	4 feet x 4 feet/(3.5 ft^2/min.) = 4.5 minutes
Time to Setup and Strip Subzone	4.5 minutes + 2 minutes = 6.5 minutes
Rate of Wet Volume to Drum	443.5 in^3/6.5 minutes = 68.2 in^3/minute
Volume of 55 Gallon Drum	231 in^3/gallon x 55 gallons = 12705 in^3
Time to Fill One Drum	12705 in^3/68.2 in^3/minute = 186 minutes (or 3.1 hours)
Barrels Filled per Shift (with no down time)	8 hours/3.1 hours = 2.6 Barrels

Table 1 Solid Waste Calculation

The UHP WJS has been used on hulls with less sea growth, resulting in a much lower rate of waste accumulation. It has been evident that the expected stripping rate and time requirement to set up the end effector in each subzone has not been realized. At 6.5 minutes per subzone, it was hoped that 200 subzones could be depainted in a 10 hour shift. This would amount to 3200 sq. ft. per shift with the 48 inch by 48 inch manipulator frame. With the 52 inch by 78 inch manipulator frame, the most productive shift for the UHP WJS wrought only 951 sq. ft. of depainted surface. If the paint removal rate of the above example is achieved, there should not be an overload for the worker processing the hazardous waste.

The TORBO system had a high paint removal rate when depainting the USS Michigan. The nozzles were capable of blasting 120 to 150 sq. ft. per hour. When six blast nozzles were used in parallel, the TRF paint team could depaint in one hour the same area that it takes one shift to depaint with the UHP WJS. This leads to the point that the UHP WJS must increase its productivity rate in order to be a strong competitor in this aspect of the depainting process. Even though the TORBO is a good system for complete depainting to bare metal, it is not capable of partial depainting or selective stripping.

Even though the UHP WJS is advertised to be capable of selective stripping, it has been found that the results vary. For example, when selective stripping was attempted on the under water body of the USS Nimitz, the nozzle pressure was varied to observe the result. The visual results documented in Figure 4 show that no specific water-jet pressure could selectively strip individual coats. There was always at least 5% of the area that was not evenly depainted. While uneven depainting is not a major concern, it indicates that selective stripping can only be performed well if the original paint layers were applied evenly.

red (anti-foul)	
black (anti-foul)	12 ksi (deeply pitted red)
red (anti-foul)	
black (anti-foul)	16 ksi (70% black - 30% red)
gray (anti-corrosive)	20 ksi (95% gray - 5% red)
red (anti-corrosive)	25 ksi (50% gray - 50% red)
HULL	38 ksi (15% red left)

Figure 4 Typical Paint System: USS Nimitz (CVN 68) Underwater Hull Coating

B. Comparison of surface finish

Both the UHP WJS and the TORBO unit are capable of cleaning the surface of paint, sulfates and chlorides and should be used with a rust inhibitor. Dry abrasive blasting tends to trap contaminants in the crevices as the blast material impinges on the surface.[9] Howlett and Dupuy have also shown some other facts regarding the UHP WJS process that would indicate that an optimum surface would be obtained with the use of garnet injected into the jet stream. For example, water jetting alone will not create or change the surface profile of the blasted area. The visual appearance is not that of the white metal finish left by abrasive blasting. If the area has rough mill scale, the surface may still need to be prepared by hand prior to painting to ensure an adequate surface finish. Since the UHP WJS process does not leave a surface profile as does the abrasive blasting process, it should be used only on materials that have been previously blasted.[10]

C. Effect of Containments on Paint Removal Process Rate

Data from recent dry docking availabilities at PSNS have shown that containments have been a necessary but costly part of doing business. Table 2 below shows that the process rate for depainting the keel block setting is nearly a third of that for the entire ship. For the USS Ohio, the data is for depainting the entire hull while the data for the USS Nimitz job was only for the keel block settings. The installation and removal of the containment also includes blast protection, foreign material exclusion, staging installation and containment certification. The depainting process includes sea growth removal, dry abrasive blasting, grit processing and cleanup. The man hour expenditures are for all individuals involved in the process. This makes sense because of the space restrictions under the keel. Note that this table does not take into account the cost of abrasive grit purchase or disposal, the material cost of the containments, or the utility costs.

	USS Ohio (SSBN 726) Hull Exterior	USS Nimitz (CVN 68) Keel Block Settings
Area Depainted	65,000 sq. ft.	6,200 sq. ft.
Install/Rmv Containment	12,003 man-hours	2874 man-hours
Depainting	2,298 man-hours	1116 man-hours
Total	15,001 man-hours	3832 man-hours
Depainting Rate	28.3 sq. ft./ man-hr	5.55 sq. ft./ man-hr
Total Process Rate	4.3 sq. ft./ man-hr	1.62 sq. ft. / mn-hr

Table 2 The Effect of Containment Installation and Removal on Performance.

The fact that the UHP WJS can operate without the need for containment in any dry dock is one of its most important features. While the TORBO system with Blastox is capable of lead abatement, there is only one dry dock presently suitable for this type of open-loop wet abrasive blasting. The remaining five dry docks are scheduled for drain modifications that will allow waste water to be collected and processed.

D. *Work Schedule and Manning*

When the UHP WJS was used at a location other than PSNS, the system was operated for two ten hour shifts per day for six days per week. The minimum work crew consisted of one paint supervisor from Shop 71, two Shop 71 equipment operators, and two Shop 06 maintenance mechanics. The crew was augmented with one additional equipment operator per shift to assist in guiding the blast frame onto the hull and reduce operator fatigue. If the pay rate was equal, the seven person crew would cost 40% more than a five person crew. The augmentation issue should be seriously evaluated.

The Shop 71A painters at TRF, Bangor worked two 12 hour shifts, around the clock for 14 days. To support six blasters in operation, TRF purchased eight TORBO units. Each shift had six painters who stripped the hull with their individual blast nozzles. Additionally, there averaged four support personnel for delivering and filling hoppers with blast media and cleaning up the grit as the stripping progressed. The support personnel were also used for cleaning the TORBOs as the cement-like Blastox solidified in vessel. The team was well coordinated and factory trained in order to support this type of accomplishment in such a short time frame.

E. *Maintenance and Performance in the Industrial Environment*

Because of the complexity of the UHP WJS, there are many subsystems within systems allowing ample opportunity for equipment malfunction or shutdown for repair or preventive maintenance. The list below documents some of the difficulties with this highly complex system over the past year of evaluation:

Fasteners broken/loosen during shipping	Sheared bolt on intensifier
Diesel for air compressor failed to start	Dri-prime pump discharge clogged with paint chips
Conductivity meter pegged high	Dead battery on intensifier support diesel
Micro separator centrifuge required cleaning	Shaft seal failure on six nozzle drive's motors
Lifting lug crack needed repair	Nozzle rotation problem limits travel speed
Centrifuge filled with paint chips	Transporter cable needed repair
Paint chip barrel filled with water	Spurious shutdown of end effector drives
Leak in swivel body shaft seal	Loose bearing on frame tilt mechanism
Intensifier hydraulic cylinder leak	Broken suction piping
Intensifier check valve failures	Make-up water pump did not cycle on to fill tank
Boom failed to extend	Z-axis retraction repair
Proximity switch leak on intensifier	Failed UHP water lines (13 hoses)

The UHP WJ System was documented to have some frequent problems with the intensifier during the depainting projects on the USS Leftwich and USS Paul Foster. During the 464 hours of operation as indicated by the hour meter, there were 15 occasions of work stoppage due to hydro-pac problems. The operator's logs document that the mean time to failure was 31 hours and the mean time to diagnose and repair was 57 man-hours. (Note that the units of hours and man-hours are different.) Table 3 gives a performance correlation for the 94 shifts that were worked on the USS Leftwich project. Because of other major maintenance on the project and the lack of dedicated crane support to move the equipment around interferences, there was no paint removed on 41% of the shifts. However, 13.3% of all the paint was removed in three shifts.[11]

# of Patches/Shift	# of Occurrences (shifts)	Man-hours Expended (man-hours)	Area Blasted (ft^2)	Removal Rate (ft^2/man-hr)
0	39	1,547	0	0.0
1-5	10	290	583	2.0
6-10	9	328	1,683	5.1
11-15	16	430	4,434	10.3
16-20	8	268	3,274	12.2
21-25	5	182	2,463	13.5
26-30	4	136	2,486	18.3
30+	3	84	2,291	27.3
Overall	94	3,265	17,214	5.3

Table 3 USS Leftwich Performance by Shift (1 NOV 94 to 13 JAN 95)[12]

Since the TORBO system was not specifically designed for shipyard industrial use, there are some aspects of the system that are still not fully adequate. The TORBO system is shutdown every 45 to 60 minutes for replenishment of the blast media. The workers would prefer a system that let them blast for at least 150 to 200 minutes before having to refill the vessel. The nozzles used for blasting the USS Michigan experienced some erosion which has occured after a longer period when blasting with river sand.

F. *USS Leftwich Depainting Project*

Lessons that were learned from maintenance items and technical difficulties while stripping the USS Leftwich have been incorporated into system modifications. The cost of repair parts was $28,230. The intensifier was also rebuilt by the manufacturer. While the prototype did have some significant downtime, it has validated the concept of high production paint stripping with water. In one very good 10 hour shift 921 ft^2 of paint was removed. If that rate could have been sustained, the project could have completed in 20 shifts instead of 94 shifts. From the depainting of 17,214 ft^2 of the hull eight 55 gallon drums of paint chips were generated.

G. USS Michigan (SSBN 727) Depainting Project

The first sand blasting ever accomplished in the TRF dry dock was the initial use of the TORBO Wet Abrasive Blasting System to depaint a submarine hull. Although documents vary slightly on the details, Table 4 shows some of the documented results from using six TORBO units to depaint the entire hull of the USS Michigan (SSBN 727).

Area Depainted	65,000 sq. ft.
Time Frame / Schedule	14 days / 2 twelve hour shifts
Deployment	6 of 8 TORBOs stripping
Depainting Rate	120 to 150 sq. ft. / hr
Blast Media Rate	2 to 4 lb. / sq. ft.
Blast Media	Copper slag with 20% Blastox
Water Rate	5 gallons / hr / machine
Inhibitor	1:250 Rust-Lick-B
Depainting	3464 man hours
Media Disposal	96 tons @ $54/ton = $5184

Table 4 TORBO Wet Abrasive Blasting System usage on at TRF, Bangor

Normally during dry blasting the blast media is used up at a rate of 14 to 16 lb./ ft^2. The 2 to 4 lb./ ft^2 media rate is a significant factor in cost reduction and waste stream reduction. The paint on the hull was sampled and determined to contain greater than 1% lead[13]. The used blast grit was analyzed and disposed of as "non-hazardous waste." The waste was sampled for arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, aluminum, copper, iron, nickel, zinc and pH using the Toxicity Characteristic Leaching Procedure, TCLP. In most cases the levels were below the detectable level and in all cases were below the limits. The combination of more efficient blasting with the TORBO and the chemical stabilization of the lead in the paint chips with the elimination of the requirement for full containment is claimed to have saved TRF 10,000 man hours and nearly $500,000 dollars.[14]

V. ENVIRONMENTAL COMPARISON

When depainting hulls there are numerous regulations that must be adhered to beyond those to produce a technically suitable surface finish. The worker safety is covered by OSHA regulations that set Permissible Exposure Limits and Action Limits. These limits are determined by test samples at the work site which are used to determine the Time Weighted Average concentrations of lead, copper and chromium. The environment is protected by regulations covering the air, water and waste management system. The Federal Code of Regulations associated with hazardous materials management sets forth rules governing the handling, storage, transportation and disposal of the lead and chromium based paint.

The Toxicity Characteristic Leaching Procedure, TCLP, test is used to measure the stability of waste laden with heavy metals to determine whether it is safe for disposal in an ordinary public landfill. To simulate 500 years in a sanitary landfill, the Blastox mix has shown stability when tested five times consecutively. In the test for long term stability, Blastox has exceeded the expectations by still meeting the short term limit. Strategic planners expect that disposing of the blast grit as non-hazardous waste, based on the TCLP data, will not have future implications or liabilities. The engineers planning the paint removal process must still be reminded that the originator of hazardous remains responsible forever under the Comprehensive Emergency Response, Compensation and Liability Act, CERCLA.

VI. COST COMPARISON

The cost comparison performed in this chapter could have been accomplished for just about any type of project, but the Trident submarine was chosen since there were recent projects which have accomplished the task of complete depainting and hull preservation as part of the Engineered Overhaul. The approximate hull area to be depainted does affect some of the other factors in the cost comparison. It was for this reason that the cost comparison was performed for this ship type. Figures for the dry abrasive blasting of the USS Ohio were obtained from Job Order - Key Op charges and a broader cost comparison being performed in the Industrial Engineering and Planning Division (C/248)[15]. The data for the TORBO Wet Abrasive Blasting of the USS Michigan is provided by the Trident Refit Facility. In the case of the labor charges, the 4040 man hours to TORBO blast the USS Michigan were separated into the various categories based on good technical judgment. The total labor charge of 4040 man-hours, however, remains the same. Data from the first two UHP WJS projects, the USS Leftwich and the USS Paul F. Foster, were used to extrapolate and calculate rate and cost data. While the performance data was obtained in fiscal years 1993 through 1995, the cost data for labor rate, utilities, abrasive media, and waste disposal are in fiscal year 1996 rates.

COST COMPARISON DETAIL
Dry Abrasive Blasting Vs. UHP WJS and TORBO

	Dry Abrasive	UHP WJS	TORBO
CONTAINMENT			
Containment Manuf/Install/Remove	1500 man-day	N/A	N/A
Labor	$700,500	$0	$0
Fabric Cost	$17,500	$0	$0
Containment Total	$717,500	$0	$0
PAINT REMOVAL			
Labor in Open Areas			
Removal Rate per Nozzle	261 sq. ft./hr	204 sq. ft./hr	140 sq. ft./hr
Number of Nozzles	6	2	6
Percent Time Stripping	14.5%	20.0%	27%
Number of Blasters	6	4	6
Number of Support People	3	2	6
Dry Abrasive Blast Labor Standard	25 sq. ft./man-hr	N/A	N/A
Labor Near Protrusions			
Removal Rate per Nozzle	N/A	40 sq. ft./hr	N/A
Number of Nozzles	N/A	6	N/A
Percent Time Stripping	N/A	10.0%	N/A
Number of Blasters	N/A	6	N/A
Number of Support People	N/A	2	N/A
Total Man-Days for Paint Removal	324	916	360
Depaint Labor Total	$151,300	$427,800	$168,120
Blast Material			
Abrasive Usage Rate	12.5 lb./sq. ft.	N/A	2.6 lb./sq. ft.
Abrasive Usage	406 tons	N/A	84 tons
New Abrasive Cost	$70/ton	N/A	$205/ton
Total Abrasive Cost	$28,500	N/A	$17,220
Number of Manlifts Required	N/A	N/A	6 for 2 weeks
Manlift Rental Cost	N/A	N/A	$1200/week
Total Manlift Rental Cost	N/A	N/A	$14,400
Blast Material Total	$28,500	N/A	$31,620
Utilities			
Compressed Air Required/Nozzle	250 cfm	N/A	190 cfm
Total Hours of Nozzle Time	249 hrs	N/A	454 hrs
Total Compressed Air Cost	$4,100	N/A	$5700
# of Dust Collectors	2	N/A	N/A
Dust Collector Motor Size	75 hp	N/A	N/A
Dust Collector "On" Time	289 hrs	N/A	N/A
Total Electricity Cost	$1,370	N/A	N/A
Diesel Fuel Consumption/Blast Hour	N/A	25.56 gal/hr	1.5 gal/hr/manlift
Total Diesel Fuel Cost	N/A	$6,210	$470
Utilities Total	$5,470	$6,210	$6,170

Maintenance			
Maintenance Ratio	0.30	0.20	0.07
Total Maintenance Man-hours	74.7 hrs	70.4 hrs	32 hrs
Maintenance Materials	$0.05/sq. ft.	$0.50/sq. ft.	$0.05/sq. ft.
Total Maintenance Materials	$3,250	$32,500	$3,250
Maintenance Total	$7,610	$36,610	$5,120
Waste Disposal			
Abrasive Clean-up			
Bulk Abrasive Removal Man-hours	700 hrs	0	264 hrs
Clean-up Total	$40,860	$0	$15,411
Blast Debris			
Abrasive Disposal Cost	$390/ton	N/A	$54/ton
Paint Chip Disposal Cost	N/A	$2.08/lb.	N/A
Paint Chip Weight	0.375 lb./sq. ft.	0.375 lb./sq. ft.	0.375 lb./sq. ft.
Amount of Waste Generated	418.4 tons	12.2 tons	96 tons
Blast Debris Waste Total	$163,200	$50,700	$5184
Waste Water			
Water Usage Rate	N/A	N/A	5 gal/hr
Actual Washing Time	N/A	N/A	288 hr
Hull Rinse Water	N/A	N/A	2800 gal
Total Water Used	N/A	N/A	5120 gal
Dry Dock Rinse Waste Total	$0	$0	$770
TOTAL PROJECT COST	$1,114,450	$521,320	$232,400

PERSPECTIVES

Approximate Duration	17 days	39 days	14 days
Containment Cost	$11.04/ sq. ft.	$0	$0
Blast Rate	226 sq. ft./man-day	71 sq. ft./man-day	191 sq. ft./man-day
Blast Material Cost/ sq. ft.	$0.44/ sq. ft.	$0	$0.49/ sq. ft.
Disposal Cost/ sq. ft.	$3.14/ sq. ft.	$0.78/ sq. ft.	$0.21/ sq. ft.
Project Cost/ sq. ft.	$17.15/ sq. ft.	$8.02/ sq. ft.	$3.35/ sq. ft.

Area Blasted = 65,000 sq. ft.
Labor Rate = $467/man-day
Water Processing Cost = $0.15/gal
Percent "Open" Area = 85%
Cost of Compressed Air = $0.0011/cf.
Cost of Electricity = $0.0423/kw-hr
Cost of Diesel Fuel = $0.69/gal

A. Containment

The containment labor was the actual charged labor and the fabric cost was calculated based on current fabric prices. It was assumed that the staging that supports the containment is part of the ready inventory normally available at a naval repair facility, so the cost of the staging was not included. If staging had to be purchased, this would be an additional cost. No containments are necessary for the UHP WJ System because of its design for complete water recovery. Because of the ability of the Blastox to encapsulate the lead when TORBO blasting, no containment is necessary in this case either. If the project could not give up the two weeks of blast time and needed to do concurrent work in the dry dock, that containment would be an additional cost. If an inert abrasive were not readily available, some dry docks could require partial containment to prevent the abrasive from entering the dry dock drains. This cost was not taken into account since the TRF has a water treatment facility and the PSNS dry docks are being retrofitted with special drain piping that will also allow water recovery. Also included but not specifically separated in this labor figure was the installation of temporary facilities such as lighting and breathing air associated with dry abrasive blasting in containments. It was also assumed that these temporary facilities were available at the shipyard and were not purchased for this project.

B. Paint Removal

On this project it was assumed that for the use of the UHP WJS that 85% of the areas were assessable with the manipulator frame. The inaccessible areas are depainted with three smaller hand held nozzles that can be connected to the water reclamation system. The data for the hand-held attachments is estimated, since there has been limited use of these accessories to date. The open area removal rate is based on a 1.5 inch per second automated travel speed. The percent stripping time for the UHP WJS is unfortunately much lower than was anticipated by the designers and the operators, but reflects what has been achievable to date. To date the highest percent stripping time achieved was 56% on one particular shift. The 20% stripping time is derived from the shifts on the USS Leftwich project in which some amount of depainting was accomplished. The mean stripping rate, however, was 17%. For the three best shifts, the stripping rate was 47%, while for the 12 best shifts, the stripping rate was 37%. If the 47% stripping rate could be maintained, then it would be possible with two units to strip the open area of the hull in a 12 day window as was done with the TORBO system on the USS Michigan with the keel block settings depainted in four additional days. This is merely speculation since this level of performance has not been achieved.

At the original level of performance with the 17% stripping time for the manipulator based nozzle and hand held nozzles, it would take approximately 43 days to depaint the entire ship. Considering system improvements, it is realistic that the current 20% stripping rate could be improved upon and at least a sustained 32% stripping time achieved. The 32% is determined from the 20 best operating shifts out of the 55 shifts that the UHP WJ System was operable on the USS Leftwich. If 32% stripping time were realized, then the whole hull might be depainted in 23 days of around the clock shift work. Because other work can continue while the UHP WJ Systems are in the dry dock, the depainting duration is not as critical as with the TORBO units. As with any project, a good depainting plan which includes project support with crane services is essential to a timely execution of the work.

For the dry abrasive blasting and the TORBO blasting, the percent stripping time reflects that which has been achieved. In these cases the lower rate has more to do with personnel endurance than material condition. The TORBO system currently needs to have the vessel hopper refilled every 45 to 60 minutes. At this rate the operator gets a 15 minute break while the hopper is refilled. The type of protective clothing worn by wet blasters is less oppressive than that worn by the dry blasters, attributing to a lower percent stripping time for the dry blasters.

The dry blast grit was copper slag. The abrasive used by the TORBO system in this study was copper slag with 20% Blastox. Other abrasives may have a greater or lesser removal efficiency, but would provide similar results for comparison. Note that the manlifts used to reach the hull are considered a material cost in this section. These were needed only by the TORBO blasters, since the dry abrasive process had staging inherent to the containment design and the UHP WJS has the transporter as one of the subsystems. Although 60 foot manlifts are usually readily available with advanced notice in most shipyards, the cost was included here since the UHP WJS is purchased with the transporter.

The utility figures were based on Public Works Center information provided in the C/248 cost analysis for the Puget Sound Naval Shipyard[16]. The UHP WJS is self powered by its own generator and compressor, hence diesel fuel is the only utility.

While the maintenance ratio is estimated for the dry blast and wet blast cases, the actual data for the UHP WJS is used. The notional maintenance ratio was used to extrapolate the costs from small depainting projects to the larger Trident depainting project. As improvements are made to the UHP WJS, it is expected that the maintenance down time and costs will decrease. The unproductive man-hours that accumulate during maintenance periods is included in the labor figures since it effects the percent stripping time. Since a maintenance man already supports the UHP WJS, the maintenance ratio is lower than it would be if compared equally to the other methods.

Waste handling and disposal vary significantly among the three processes. If the project was removing only lead free paint, the disposal costs would be drastically different. The dry grit disposal cost would be reduced to $22,600 from $163,200. If the paint chip residue in the 55 gallon drums of the UHP WJS were considered industrial waste, the disposal cost would be much less. Instead of costing $2.08/lb., the disposal cost would be approximately $1.49/lb. The nationwide disposal costs vary greatly based on location and availability of landfills. The significant factors in this section are the volume of the waste and the classification of the waste. Waste that can be minimized as with the UHP WJS is optimum. Cost reductions can also be achieved with the TORBO system by downgrading the waste to a lower waste classification level, as with the lead encapsulation by the Blastox.

The actual duration of the projects varied somewhat based on the resource support that the depainting team received from the rest of the project. The team required to erect the containment for dry blasting needs more people when the time in the dock is shorter.

The 17 day duration is shorter than that accomplished on the USS Ohio because there were other factors involved. For this comparison, it was assumed that 30 men per shift from various trades were available for building the containment. The containment installation team would begin three days prior to the depainting and continue through the depainting process until two days after the depainting was complete. The sand blasting process would last 12 days, if continued for three shifts per day with the nine man team. For the UHP WJS, the 39 day duration was based on the stripping rates using two systems with either two or six nozzles depending on proximity to protrusions. This duration could be reduced by the future improvements to the system which might reduce down-time for maintenance. The 14 day duration was actually accomplished at the Trident Refit Facility by the USS Michigan depainting team using the TORBO system.

In the final analysis of the systems and processes, there are several factors other than cost that must be considered. Project duration, personnel safety, and environmental protection are all factors which do not have a tangible cost. Although sand blasting has the highest blast rate, the process is significantly diminished by the high cost to contain the dust and grit. The slight increase in the purchase price for blast media blended with Blastox, is greatly offset by the reduced disposal cost. The longer duration of the project which uses the UHP WJS for depainting may or may not be constrained by dry dock availability. The fact that some dry docks can not accommodate the TORBO process without providing a partial containment must also be considered.

VII.CONCLUSION

The advantages and disadvantages need to be weighed before major decisions can be made. While the cost savings of the TORBO system are highly visible, the fact that it is not a closed-loop system is a drawback. Table 5 and Table 6 show the advantages and disadvantages of both of the systems.

ADVANTAGES

UHP WJS	TORBO
Standard Personal Protective Gear	55% Reduction in Depainting Costs
No Elements Added to Waste Stream	$37,000 Unit Cost
Closed-loop System	Lead Abatement to Non-hazardous Waste
Surface Finish is Contaminant Free	High Productivity
No Dust Emissions or Toxic Vapors	Low Maintenance Costs
Minimal Waste for Disposal	Versatile Application
Greater Personnel Comfort	Surface Finish Has Profile
Selective Stripping Option	
Other Dry Dock Work in Parallel	
No Containment Required	

Table 5 Advantages of the Ultra-High Pressure Water-Jet System and TORBO Wet Abrasive Blasting System

DISADVANTAGES

UHP WJS	TORBO
$1,333,000 Unit Cost	Noise Hazard
No Lead Abatement	Abrasive Added to Waste Stream
Low Productivity	Open-loop System
High Maintenance Costs	Operators Become Fatigued
High Depreciation Costs	Pressure Wash Needed to Remove Blast Film
High Operation Costs	Respiratory Protection Required
	Other Dry Dock Work Must Proceed in Series
	Partial Containment Needed In Some Dry Dock

Table 6 Disadvantages of the Ultra-High Pressure Water-Jet System and TORBO Wet Abrasive Blasting System

Five million dollars is currently budgeted by NSWC for the purchase of three more UHP WJ Systems for the Navy. It is expected that two systems would be used for depainting projects in the Atlantic Fleet and one more system would be delivered to

PSNS for use on ships in the Pacific Fleet. Once the systems were delivered, they would have to be depreciated. Accounting for depreciation would negate some of the cost savings realized by not having to build the containment for dry abrasive blasting. Considering only the cost savings, the only right answer is to use only the TORBO system. Other factors are involved in comparing the depainting systems based on the performance attributes and cost analysis. Table 7 shows how these factors could be rated to assist in making the decision. Weighting factors 1, 3, 5, and 7 are used to rate the general concepts. A very positive advantage is rated with a seven and a very negative disadvantage is rated with a one. In between are three and five used for the small relative advantage or disadvantage.

Factor	Dry Blast	UHP WJS	TORBO
Unit Cost & Depreciation Cost	3	1	7
Operation and Maintenance Cost	1	3	7
Personnel Safety and Comfort	1	7	5
Environmental Safety & Protection	3	7	3
Waste Generation	1	7	3
Closed-loop Vs. Open-loop System	1	7	1
Productivity & Project Duration	5	1	7
Allow Other Dry Dock Work	5	7	3
Total	*20*	*40*	*36*

Table 7 Depainting System Decision Matrix

It is recommended that the TORBO system be used for depainting on short duration projects. When the docking schedule is tight, it is imperative that the repainting of the hull be accomplished expeditiously. The TORBO system provides potential savings of 80% of the cost to depaint a Trident submarine using the dry abrasive method in a containment and 55% of the cost using the UHP WJ System. Although the TORBO systems have been used at TRF, the shipyard does not currently own any. Since the

TORBO units at TRF do have periods of idle time, it would be good use of Navy financial resources to use those units owned by TRF. This could be accomplished by contracting with TRF to provide the depainting service. Since the TORBO units are easily transportable, this concept bodes well with the Regional Maintenance concept.

Even though there are research and development funds budgeted for three new UHP WJ Systems, the technology has not been optimized to reduce the risk associated with system failure. By having a few TORBO units in the dock for blasting the areas not accessible by the UHP WJS, the risk of project failure could also be minimized. For example, if one of the intensifiers of the UHP WJS failed and a few TORBO units were already in the dock, then these units could be used to continue the depainting. This author recommends continuing with the refinement of the UHP WJS until the mean time to failure is raised from 31 hours to 300 hours and the mean time to diagnose and repair is lowered to 12 man-hours. The 300 hours will allow two weeks of continuous stripping without a delay. The 12 man-hours will minimize the loss of productivity for the three man team and limit the down time to a half shift. With one UHP WJS in operation, the open area of the hull could be stripped while the keel area is blasted with a team of men using the TORBO units. Since a partial containment might be required based on the dry dock's dewatering system, limiting the containment to the keel area would prevent an escalation in the cost of performing the work. A TORBO and UHP WJS mix could significantly reduce the cost of contained dry abrasive blasting.

ENDNOTES

[1] Design of an Ultrahigh-Pressure Water-Jet Underwater Hull Paint Removal System, David Taylor Research Center, Bethesda, Maryland, Gordon D. Smith, January, 1991, p. 2.

[2] Ibid.

[3] Requirements Definition and Needs Analysis, Report No. CDRL A020, Supplement, 16 July 1993, United Technologies, Pratt & Whitney Waterjet Systems, Inc.

[4] Pratt & Whitney WJS Evaluation Notes of August 22, 1994, Puget Sound Naval Shipyard, C/248, Darren Lutovsky, p. 3.

[5] Design of an Ultrahigh-Pressure Water-Jet Underwater Hull Paint Removal System, David Taylor Research Center, Bethesda, Maryland, Gordon D. Smith, January, 1991, p. 3.

[6] Requirements Definition and Needs Analysis, Report No. CDRL A020, Supplement, 16 July 1993, United Technologies, Pratt & Whitney Waterjet Systems, Inc.

[7] Industrial Hygienist Memorandum Ser 08-023-94, February 24, 1994, Phillip Marceau.

[8] Requirements Definition and Needs Analysis, Report No. CDRL A020, Supplement, 16 July 1993, United Technologies, Pratt & Whitney Waterjet Systems, Inc.

[9] Ultrahigh-Pressure Water Jetting for Deposit Removal and Surface Preparation, "Material Preparation", January 1993, J. J. Howlett, Jr. and R. Dupuy, p 38.

[10] Ibid, p 42.

[11] Ultra-high Pressure Waterjet Project Summary: USS Leftwich (DD 984), Puget Sound Naval Shipyard Industrial Engineering and Planning Division, Code 248, Darren Lutovsky, p. 4.

[12] Ibid.

[13] Industrial Hygienist Memorandum Ser. 08-023-94, February 24, 1994, Phillip Marceau.

[14] Refit Review, Vol. 6, Issue 17, August 30, 1994, Trident Refit Facility, Bangor, Silverdale WA, "Torbo blasting: TRF saves time and money stripping subs", page 3.

[15] Draft Cost Comparison: Ultra-High Pressure Waterjet vs. Dry Abrasive Blasting, Darren Lutovsky, Industrial Engineering and Planning Division, October, 1995.

[16] Ibid.

DEPARTMENT OF THE NAVY
COMMANDER
SUBMARINE GROUP 9
2150 THRESHER AVENUE
SILVERDALE, WA 98315-2150

1741
Ser 00J/ 1429
7 Sep 94

Jim Egan, Regional Manager
Torbo Wet Sandblasting System
P.O. Box 2030
Belfair, Wa. 98528

Keizer Technologies Americas, Inc
torbo® Blasting Systems
10908 S. Pipeline Rd., Ste. #7 • Euless, Texas 76040
817/685-7090 • 817/685-9190 Fax

Dear Sir:

This responds to your Freedom of Information Act (FOIA) request of 24 June 1994, in which you seek copies of documents relating to testing and evaluation of TORBO Wet Abrasive Blasting Systems by the Trident Refit Facility Bangor (TRF).

Enclosures (1) through (3) are released pursuant to your request:

Enclosure (1) is a memorandum prepared in response to your request. The FOIA does not require the Navy to create documents in response to a FOIA request, however, since TRF prepared the memorandum it is being released.

Enclosure (2) contains tables that reveal names of personnel who were exposed to lead and copper respectively. Upon review of these documents I determined that the names are exempt from disclosure under 5 U.S.C. 552(b)(6). Disclosure of personal exposure amounts would constitute a clearly unwarranted invasion of personal privacy. Therefore, names have been redacted from these tables.

Enclosure (3) is released in its entirety.

Because your request has been partially denied, you are advised of your right to appeal this determination in writing to the Judge Advocate General, Navy Department, 200 Stovall Street, Alexandria, VA 22332-2400.

The appeal must be received in that office within 60 calendar days from the date of this letter to be considered, and the enclosed copy of this letter should be attached along with a statement regarding why your appeal should be granted. It is recommended that the letter of appeal and the envelope both bear the notation, "Freedom of Information Act Appeal."

The releasable portions of the requested documents are enclosed. The fees associated with the processing of your request have been waived.

Sincerely yours,

L. M. Christensen

L. M. CHRISTENSEN
Lieutenant Commander, U.S. Navy
Staff Judge Advocate
By direction of the Commander

Encl:
(1) Parsons memo of 16 Aug 94
(2) Industrial Hygienist memo 5100 Ser 08-058-94 of 9 May 94
(3) Industrial Hygienist memo 5100 Ser 08-023-94 of 24 Feb 94
Copy to: [illegible]RF (Legal Office)

16 Aug 94

MEMORANDUM

From: Phillip K. Parson
To: Jim Egan .

Subj: TORBO WET ABRASIVE BLAST SYSTEM

Ref: (a) Your ltr of request of 24 Jun 94

1. Thank you for your request.

2. The Torbo Wet Abrasive Blasting System has significantly enhanced our capability in the area of coatings removal. The nearly complete elimination of fugitive dust emissions has allowed TRIDENT Refit Facility, Bangor 100 percent capabilities for open blasting in our dry dock.

3. Recently we completed a "first ever" sand blasting of a TRIDENT submarine hull in our dry dock. We sand blasted and painted approximately 70,000 square feet surface area in a 15 day time frame--a significant event achieved by using the Torbo Wet Abrasive Blasting System.

4. Our removal rate has varied between (120 to 150 square feet)** per hour, a fair trade for the environmental compliance realized. With more experience and use we are confident our blasters will increase the removal rate. Using the Torbo Wet Abrasive Blasting System, we used approximately four pounds of blast media per square foot, a significant reduction from 10 to 12 pounds per square foot under normal blasting conditions. A major reduction in the waste stream has been realized.

**This was prior to air pipe and air hose upgrades. Current footage acheived is 200-210 square feet per hour on 55-58 mil average coating thickness.

Blast specified is SSPC-SP5 (White metal)

PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS AND CONTROL MEASURES FOR TORBO-BLAST OPERATIONS

1. Outer protective clothing, such as disposable coveralls and shoe covers, shall be removed in a "clean area" next to the work area and placed in plastic bags for disposal. The "clean area" shall be clearly marked, for example with rope or barrier tape. All waste must be labeled in accordance with the requirements of Code 240.

2. Eating, drinking, chewing, smoking, and application of cosmetics in abrasive blasting areas in the dry dock is strictly prohibited.

3. All personnel working in the vicinity of abrasive blasting operations shall thoroughly wash their hands and face prior to drinking, eating, chewing, smoking, or applying cosmetics.

4. Establish a physical boundary for the Torbo-Blast process. The boundary shall be located either where the abrasive blast material falls to the ground or at the perimeter of the operations area.

5. Requirements for areas **ABOVE** the Max Beam line:

a. PPE: Workers shall wear disposable Tyvek coveralls over painters coveralls, cotton gloves, and a pair of disposable shoe covers. The minimum respirator required is the half mask with HEPA cartridges.

b. Do not take used coveralls and shoe covers out of the abrasive blast work area. Dispose of Tyvek coveralls, gloves and shoe covers when leaving the work area in plastic bags in accordance with the requirements of Code 240.

6. Requirements for areas **BELOW** the Max Beam line:

a. PPE: Workers shall wear full rain gear over painters coveralls, cotton gloves and a pair of disposable booties. The required respiratory protection is a full-face air supplied respirator.

b. Do not take used rain gear and shoe covers out of the abrasive blast work area. Rain gear can be rinsed with water in the dry dock for re-use. Dispose of gloves and shoe covers when leaving the work area in plastic bags in accordance with the requirements of Code 240.

7. Requirements for Housekeeping and Clean-up:

a. PPE: Workers shall wear disposable Tyvek coveralls over cotton coveralls, cotton gloves, and a pair of disposable shoe covers. The minimum respirator required is the half mask with HEPA cartridges.

b. Do not take used coveralls and shoe covers out of the abrasive blast work area. Dispose of Tyvek coveralls, gloves and shoe covers when leaving the work area in plastic bags in accordance with the requirements of Code 240.

8. If the operation will include both work above and below the Max Beam line, wear the PPE described in paragraph 6.

9. Tools and Equipment used in the Torbo-Blast work area shall be cleaned before leaving the area. Remove loose paint chips and dust by wiping with absorbent wetted with a cleaner, such as 409. DO NOT blow down tools and equipment with compressed air.

10. The following personal hygiene practices shall be adhered to:

a. Torbo-Blast workers shall be provided clean Tyvek coveralls, cotton gloves, and shoe covers daily; and painters coveralls weekly.

b. Employees who come in direct contact with the abrasive blast material containing Blastox shall be required to wash their hands and exposed skin with soap and water before eating, drinking, smoking or using toilet facilities during the work shift.

c. Food, drinking or smoking materials shall not be permitted in areas where Torbo-Blast operations are being performed.

11. Specific recommendations for changes to these requirements should be forwarded in writing to Code 08. If you have any questions relating to PPE requirements, contact Phillip Marceau at extension 1414.

Rev: 2/24/94

5100
Ser 08-023-94
24 Feb 94

MEMORANDUM

From: Phillip Marceau, Industrial Hygienist
To: Wayne Noll, Code 348 Shop 71A
Via: Jerry Conn, Safety Manager

Subj: WORK CONTROLS FOR TORBO-BLAST REMOVAL OF LEAD PAINT

Ref: (a) Scientific Services Laboratory Report 93-2429
(b) 29 CFR 1910.1025, Lead Standard
(c) OPNAVINST 5100.23C, Chapter 21

Encl: (1) Personal Protective Equipment and Control Measures for Torbo-Blast Operations, Rev: 02/24/94

1. Lead in excess of one percent (1%) has been identified in paint on the exterior hulls of SSBN 726 Class submarines. Sampling of exterior paint indicates that not all areas contain lead. However, until all exterior hull paint has been removed from each unit, it will be presumed that there are unsampled areas that contain leaded paint. References (b) and (c) will be used as guidance for determining control measures to be used. during Torbo-Blast operations. The Torbo-Blast method of abrasive blasting prevents the spread of airborne lead particulate material. The addition of Blastox to the abrasive blast material reduces the amount of free lead by mixing it with an inert silicate.

2. Enclosure (1) describes the personal protective equipment (PPE) needed and the work practices required when using the Torbo-Blast system. The purpose of the control measures is to prevent personnel exposures to lead. Therefore, it is very important that all personal protective equipment (PPE) and control measures are carefully observed.

3. All workers shall receive annual Lead Awareness training provided under the supervision of Code 08. If their assigned work involves disposal, added training will be provided by Code 240 and their respective Shops. All workers required to wear respiratory protection shall be trained and fit-tested by Code 08.

4. If there any questions or comments concerning these requirements or control measures, please contact me at extension 1414.

Phillip Marceau
PHILLIP MARCEAU

Copy to:
Copy 340
Code 345 Shop 72C
IAM; Lance Risch

ENCLOSURE (3)

Toxicity Characteristic Leaching Procedure (TCLP)
ICP SPECTROGRAPHIC ANALYSIS

TO: CODE 852, 240, SHOP 71A	REPORT NO. 94-1122

SAMPLE DESCRIPTION SANDBLAST GRIT (BLASTOX)	NO. OF SAMPLES 7	DATE RECIEVED 7-18-94
REFERENCE DOCUMENT: TITLE 40 CFR Ch. 1 Part 268 App. 1	JCN 68436-XMCN-A041 21037-WP01-0323	

ELEMENTS (PPM)	SAMPLE W059	SAMPLE STBD 50	SAMPLE PORT 50	SAMPLE STBD 120	LIMITS (PPM)
ARSENIC	< 1	< 1	< 1	< 1	5.0 MAX.
BARIUM	< 1	1	< 1	< 1	100.0 MAX.
CADMIUM	< 1	< 1	< 1	< 1	1.0 MAX.
CHROMIUM	< 1	< 1	< 1	< 1	5.0 MAX.
LEAD	< 1	< 1	< 1	< 1	5.0 MAX.
MERCURY	< 0.2	< 0.2	< 0.2	< 0.2	0.2 MAX.
SELENIUM	< 1	< 1	< 1	< 1	1.0 MAX.
SILVER	< 1	< 1	< 1	< 1	5.0 MAX.
ALUMINUM	< 1	< 1	< 1	< 1	------------
COPPER	< 1	< 1	3	1	------------
IRON	< 1	< 1	< 1	< 1	------------
NICKEL	< 1	< 1	< 1	< 1	------------
ZINC	< 1	< 1	< 1	< 1	------------
pH	*	*	*	*	2.0-12.5

REMARKS:

* W059 Ph:
after stirring 10.9
after HCl 3.2
after leaching 9.1

* STBD 50 Ph
after stirring 11.4
after HCl 4.0
after leaching 9.7

* PORT 50 Ph:
after stirring 11.5
after HCl 3.6
after leaching 11.3

* STBD 120 Ph:
after stirring 11.5
after HCl 3.9
after leaching 10.6

ANALYST (SIGNATURE)	CODE	DATE
	412	7-20-94

SCIENTIFIC SERVICES LABORATORY REPORT
Toxicity Characteristic Leaching Procedure (TCLP)
ICP SPECTROGRAPHIC ANALYSIS

TO: CODE 852, 240, SHOP 71A		REPORT NO. 94-1122
SAMPLE DESCRIPTION SANDBLAST GRIT (BLASTOX)	NO. OF SAMPLES 7	DATE RECIEVED 7-18-94
REFERENCE DOCUMENT: TITLE 40 CFR Ch. 1 Part 268 App. 1	JCN 68436-XMCU-A041 21037-WK01-Q323	

ELEMENTS (PPM)	SAMPLE PORT 120	SAMPLE STBD 85	SAMPLE PORT 85	SAMPLE	LIMITS (PPM)
ARSENIC	< 1	< 1	< 1		5.0 MAX.
BARIUM	< 1	< 1	< 1		100.0 MAX.
CADMIUM	< 1	< 1	< 1		1.0 MAX.
CHROMIUM	< 1	< 1	< 1		5.0 MAX.
LEAD	< 1	< 1	< 1		5.0 MAX.
MERCURY	< 0.2	< 0.2	< 0.2		0.2 MAX.
SELENIUM	< 1	< 1	< 1		1.0 MAX.
SILVER	< 1	< 1	< 1		5.0 MAX.
ALUMINUM	< 1	< 1	< 1		----------
COPPER	< 1	< 1	< 1		----------
IRON	< 1	< 1	< 1		----------
NICKEL	< 1	< 1	< 1		----------
ZINC	< 1	< 1	< 1		----------
pH	*	*	*		2.0-12.5

REMARKS:

* PORT 120 Ph:
after stirring 11.3
after HCl 2.5
after leaching 10.8

* STBD 85 Ph:
after stirring 10.5
after HCl 2.7
after leaching 8.2

* PORT 85 Ph:
after stirring 10.9
after HCl 3.2
after leaching 9.0

ANALYST (SIGNATURE)	CODE: 412	DATE 7-20-94
[illegible]		

5100
Ser 08-058-94
09 May 94

MEMORANDUM

From: Phillip Marceau, Industrial Hygienist
To: Wayne Noll/Kevin Jones, Code 348 Shop 71A Supervisors
Via: Jerry Conn, Safety Manager

Subj: INDUSTRIAL HYGIENE SAMPLING FOR LEAD, CHROMIUM AND COPPER DURING TORBOBLAST OPERATIONS ON A SUBMARINE HULL

Ref: (a) OPNAVINST 5100.23C
(b) Naval Hospital letter 5104.6, Ser 061.2C/02264 of 02 May 94
(c) 29 CFR 1910.1025
(d) 29 CFR 1910.1000, Table Z-1
(e) ACGIH, Threshold Limit Values, 1993-1994

Encl: (1) Sampling Results and OSHA Permissible Exposure Limits

1. Reference (a) requires that all operations be evaluated in order to accurately identify and quantify all potential health hazards. The workplace monitoring was performed by the Naval Hospital Bremerton Industrial Hygiene Division.

2. Industrial Hygiene sampling was performed during Torboblast abrasive blasting operations on the SSBN 729 in the dry dock during the period of 31 Jan through 7 Feb 1994. Personal samples were collected for all personnel directly involved with the blasting operation. Area samples represent an exposure potential boundary for personnel if they were on the drydock floor in the direct vicinity of the operation.

3. Reference (b) reports the findings and enclosure (1) summarizes the sampling results for lead and copper and reports them as calculated 8-hour time weighted average (TWA) concentrations. All the lead results are well below the Action level of references (a) and (c) and copper results are below the Permissible Exposure Limit of reference (d). The sample results for chromium (VI) are below the limit of detection for the analytical method used. This value is well below the 0.05 mg/M3 TWA established in reference (e).

4. The Naval Hospital letter also includes observations of inappropriate respirator usage which it describes as "multiple deficiencies in the program" per Chapter 15 of reference (a). The letter also states "the incidents include selection of organic vapor cartridges for a particulate hazard and use of a

ENCLOSURE (2)

full face negative pressure respirator without utilizing cartridges. No new/modified SOP was provided to the shop and the existing SOP required personnel to use supplied-air respirators. Enforcement of existing policy is needed to ensure respirator use is in accordance with the requirements of reference (a)." As a consequence of these observations, this office will provide the entire Shop with a one hour Respirator Refresher Training course. It is requested that this training be scheduled during the week of 23 through 27 May.

5. Reference (b) is available for review in the Safety office. If you have any questions or comments on this survey, please contact me at extension 1414.

Phillip Marceau
PHILLIP MARCEAU

Copy to:
Code 240
Code 340
File Chapter 12

TORBO GRIT BLASTING
PERSONAL MONITORING RESULTS FOR LEAD

Date	Name	Sample #	Duration (min)	Results (mg/m3)	TWA* (mg/m3)
1/31/94		31347 31348	167	<.0079 <.0081	<.005
1/31/94		31351	98	<.013	<.003
2/1/94		31356 31358	150 192	<.0084 <.0066	<.005
2/1/94		31354 31357	140 194	<.0090 <.0065	<.005
2/2/94		31365 31366	150 160	<.0083 (.006)** .0099	.005
2/2/94		31363 31364	150 160	.014 <.0078 (.0055)	.006
2/7/94		31373 31374	111 60	<.011 <.021	<.005

TORBO GRIT BLASTING
AREA MONITORING RESULTS FOR LEAD

Date	Location to blast zone	Sample #	Duration (min)	Results (mg/m3)	TWA* (mg/m3)
1/31/94	North	31349	139	<.0092	<.003
1/31/94	Behind	31350	139	<.0093	<.003
1/31/94	South	31352	139	<.0093	<.003
2/1/94	South	31362	439	.0034	.003
2/1/94	Behind	31355	435	<.0029	<.003
2/1/94	North	31359	438	<.0028	<.003
2/2/94	South	31367	415	.0057	.005
2/2/94	Behind	31369	415	<.0030	<.003
2/2/94	North	31368	415	.0092	.008
2/7/94	North South	31378 31381	233 130	<.0054 <.0098	<.005
2/7/94	South South	31377 31380	233 130	<.0053 <.0095	<.005
2/7/94	North South	31378 31381	233 130	<.0054 <.0096	<.005

* EXPOSURE LIMITS - 0.050 mg/m3 for 8 hr TWA, Action Level of 0.030 mg

** Calculated value for <Limit of Detection

ENCLOSURE (1)

TORBO GRIT BLASTING
PERSONAL MONITORING RESULTS FOR COPPER

Date	Name	Sample #	Duration (min)	Results (mg/m3)	TWA*** (mg/m3)
1/31/94		31347 31348	167 162	.012 .066	.03
1/31/94		31351	98	.46	.09
2/1/94		31356 31358	150 192	.029 .060	.03
2/1/94		31354 31357	140 194	.023 .055	.03
2/2/94		31365 31366	150 160	.057 .13	.06
2/2/94		31363 31364	150 160	.16 .050	.07
2/7/94		31373 31374	111 60	<.011 <.021	<.005

TORBO GRIT BLASTING
AREA MONITORING RESULTS FOR COPPER

Date	Location to blast zone	Sample #	Duration (min)	Results (mg/m3)	TWA*** (mg/m3)
1/31/94	North	31349	139	<.0092	<.003
1/31/94	Behind	31350	139	<.0093	<.003
1/31/94	South	31352	139	.025	.007
2/1/94	South	31362	439	.046	.042
2/1/94	Behind	31355	435	.016	.014
2/1/94	North	31359	438	.020	.018
2/2/94	South	31367	415	.037	.032
2/2/94	Behind	31369	415	.0054	.005
2/2/94	North	31368	415	.053	.046
2/7/94	North South	31378 31381	233 130	<.0054 <.0098	<.005
2/7/94	South South	31377 31380	233 130	.12 .022	.06
2/7/94	North South	31379 31382	233 130	<.0054 <.0076	<.005

*** EXPOSURE LIMIT - 1.0 mg/m3 (TWA)

SGPINNEY & ASSOCIATES, INC.

TORBO WET ABRASIVE BLASTING EVALUATION

MARCH 12, 1995

<u>Prepared for:</u>

Keizer Technologies America's, Inc.
10908 S. Pipe Line Road, Suite 6
Euless, TX 76040
and
Torbo Tech, Inc
P.O. Box 2030
Belfair, WA 98528

<u>Prepared by:</u>

Mr. Jack Boyle
Inspector

<u>Edited By:</u>

Lee Doyle
Senior Associate

J.N. 5219

20206 Evening Breeze Dr. Walnut, CA 91789 714/770-3010

S.G. PINNEY & ASSOCIATES, INC.

TORBO TECH, INC.	SGPAI/J.N. 5219
TORBO WET ABRASIVE BLASTING	P.O./TORBO FAX
EVALUATION	MARCH 12, 1995

INTRODUCTION

Keizer Technologies America's, Inc., represented by Mr. Jim Egan, Torbo Tech, Inc. retained the services of S.G. Pinney & Associates, Inc. to review the inspection records of Calnev Pipe Line Company, tanks 110 and 111 to evaluate the use of the Torbo Wet Abrasive Blasting equipment for removing the exterior lead paint the shell of the tanks.

Since both tanks were similar in design, cleaning rates and abrasive consumption were relative equal.

It is understood that this information is the sole opinion of Mr. Jack Boyle, SGPAI inspector, and is not intended as an endorsement of the equipment or process.

OBJECTIVE

To remove the lead paint to bare steel with a wet abrasive blasting system that would reduce the lead hazards to the environment, workers, and other personnel in the vicinity of the project.

REGULATION COMPLIANCE

Regardless of the stated objective, the contractor was required to comply with OSHA 29 CFR 1926.62, Lead. For worker safety, an initial exposure assessment was conducted, before safety requirements could be modified or reduced within the limits of the regulation.

The Contractor was also required to comply with all Federal Code of Regulations for hazardous materials management, including environmental air monitoring, handling, storing, transportation, and disposal of lead waste.

PROJECT LOCATION

Calnev Pipe Line Company
Colton, California

S.G. PINNEY & ASSOCIATES, INC.

TORBO TECH, INC.
TORBO WET ABRASIVE BLASTING
EVALUATION

SGPAI/J.N. 5219
P.O./TORBO FAX
MARCH 12, 1995

CONTRACTOR

AA-1 Painting Service, Inc.
Paramount, California

WEATHER

Climatic conditions were continually changing. Unpredictable, gusty 25 to 35 mile winds, rain and fog hampered this the jobs continuity considerably.

TANK DIMENSIONS

Height: 40'. Add 5' for wind girder. Circumference: 310'. = 13,950 S.F.

TANKS' PRECONDITION AND EXISTING COATING THICKNESS

The surface preparation was reported to be "pickled" by the tank fabricator, which left no substrate profile. The existing coatings averaged 10 to 12 mils dry film thickness. Some of the coating had been previously blown off to the primer by the areas prevailing (normal) strong winds. Mainly, in small areas, on the tank's north side of the shell.

METHOD OF REMOVAL

Torbo Wet Abrasive Blasting System with and addition of Oakite NRP rust inhibitor (300 parts water, 1 part NAP) included in the Torbo's rinse cycle. This inhibitor was recommended by Ameron Corporation, paint supplier for the project.

ABRASIVE USED

An 80% blend of Gordon Sandblasting, Inc., Sharp Shot F-80 (36 mesh copper slag), and 20% of The TDJ Group, Inc., Blastox.

GROUND PROTECTION

The ground from the tank exterior foundation was covered and protected for a distance of 20-feet with roofing felt, followed with a clear polyethylene .006 sheeting over the top of the felt. The polyethylene's seams and edge around the tank were sealed with Sasho Level Company's, clear sealer. Sandbags were laid end-to -end at the outer edge of the polyethylene, covered with the sheeting and sealed. Plywood panels, 4' X 8', were then laid over the polyethylene and a couple of sandbags placed on top to hold them in place. The plywood was used so the blasting debris could be swept, shoveled and placed in hazardous waste storage bins. A 40-foot OHT Plastic (safety) fence was erected around the tank and canvas tarps draped over them covering the ground 20-feet to the (and over) polyethylene. A few sandbags were also placed on the tarp's edges. The amount of water that was expended to Torbo blast, rinse cycle and power water cleaning was easily contained in the first 20-feet of ground cover, sufficiently evaporated and not hampering blasting debris removal. Power water rinsing with 3000 PSI using a ¼" tip was implemented after the Torbo wet abrasive blasting was completed to ensure that all of the abrasive and Blastox debris was removed from the tank's surfaces prior to painting.

STAGING EQUIPMENT

Two 50-foot Grove aerial lifts were used, but only one blasting operator was assigned to each lift for performing the Torbo blasting operation. The lifts 8-foot safety guard rails were shrouded with canvas to deflect the abrasive to the ground. A scissor-lift was also used, but mainly on the middle 32-foot section (Tank #111 only) of the shell. It seemed somewhat cumbersome, but did afford a 10-foot wide drop versus 7-foot with the aerial lifts. The aerial lifts were more flexible and easier to use when blasting the wind girder, stairs and platform.

TORBO BLASTING UNITS

Two units were used for the job, a model 200U, abrasive capacity, 600 lbs, and a model 320U, abrasive capacity, 1000 lbs. Each one was fitted with an automatic rust inhibitor dispenser that operated in conjunction with the rinse cycle. A new 1300 abrasive capacity unit was used a couple of days on tank No. 111. One 825 CFM, diesel fuel, Ingersoll-Rand air compressor was used to supply air to both Torbo units. Air pressure was maintained at 135 to 140 PSI. At the blasting nozzle the air pressure was estimated to be 90 PSI. Since Blastox was blended into the abrasive, it was necessary at the end of each working day to clean and remove all remaining abrasive, Blastox, and water from the Torbo

Tanks. Approximately one 100 lb. sack of abrasive was lost per tank. 1½" blasting hose and No. 8 nozzle were used. A 1" hose with a No. 7 nozzle didn't perform properly. This was changed to a 1-inch hose and a No. 8 nozzle which gave improved results. Setting Torbo control valve dials for the abrasive use rates and additional water at 5 & 2 respectively, seem to be the right setting for this abrasive blend and overall climatic conditions. While blasting the wind girders and at times the tanks platform and stairs, a water setting of 3 was used to cut down and control dust. A, so called normal setting of .006 or 1 didn't work because of unpredictable winds.

TANK NO. 110

This was the first tank Torbo blasted. Total abrasive used: 15 pallets, 30 100 lb. sacks per pallet. Simply, as a rule of thumb, on the shell surface only, each blaster used a average of 15 sacks each day, getting approximately 45 S.F.. ft. per sack which amount to 675 S.F.. ft. per man, per 5-hour blasting shift. Climatic conditions were a large negative contributing factor of waste while blasting the wing girder, platform and stairs. Add to this, first time use of Torbo blasting equipment, AA-1 switching around blasting operators and Torbo unit operators. Another factor, Torbo blasting followed by torrents of rain, sometimes for two to four days, not allowing the rust inhibitor to set up properly and in some areas washed it off, causing heavy surface powder rust which had to be removed before priming. This operation required approximately 30 gallons of water. After the surface dried, Ameron 400 was applied to the clean and dry surface.

TANK NO. 111

Total abrasive used: 13 pallets. Each blaster averaged 20 sacks each day, approximately 50 S.F.. ft. per sack which amounts to 1000 S.F.. ft. per man, per 5-hour blasting shift. Special Note: The platform and stairs took one blaster, two days and used 36 sacks. No switching around blasters or Torbo operator. Wind and rain was still a waste factor but not like Tank No. 110.

TORBO BLASTING DEBRIS

Samples abrasive debris were collected 11-21-94 by Bryan Renfro, AA-1 Painting and delivered 11-24-94 to Schneider Laboratories, Inc. Analyzed 12-01-94 - EPA Regulatory

Limit: 5 MG/1. Test Results: <0.5. Reviewed by: Michael A. Mueller. Fax No. on file 909-877-4608. Dated: 12-08-94. Time: 14:10. Copy of complete fax on file with AA-1 Painting.

CALIFORNIA PORTLAND CEMENT CO., COLTON CALIFORNIA

Their Blasting Debris letter dated December 12, 1994 - CPC Control #CW0239. Debris is accepted into their alternate raw material recycling program. Health and Safety Code 25143.2 and California Code of Regulations, Title 22, 66261.6(a) (3) as non-hazardous in accordance with 40-CFR - Parts 261, Sub-parts C. & D.

Signed: Dale Poole, Quality Control Superintendent. Copy of complete letter on file with AA-1 Painting. Special Note: Each tank's blasting debris filled two waste bins furnished by Art's Disposal Service.

AIR MONITORING

Four air monitors were strategically placed, periodically checked, and logged by AA-1 Painting, Bryan Renfro.

Schneider Laboratories, Inc., tested the air filter samples that were collected and delivered on December 14,15,& 16, 1994 by Bryan Renfro. The filters tested way below the OSHA PEL of 50 ug/m^3 for an 8-hour TWA exposure. This data was reviewed by Michael R. Muller - FAX 213/633-5718 dated: 12-2-1-94 on file with AA-1 Painting.

CONCLUSION

The Torbo Wet Abrasive Blasting System using a 80% blend of Gordon's Sharp Shot F-80 (36) and 20% of Blastox, utilized a very minimal amount of water to remove the 10 to 12 mils of coating and accomplished an average (substrate) surface profile of 4.5 Mils over a previously "pickled" steel surface.

INTEROFFICE MEMORANDUM

To: M. Burgett

From: D. Lange

Date: June 12, 1995

Subject: Electrostatic Charge Test

On Wednesday, April 26, 1995, I conducted a test to determine the electrostatic charge generated by different abrasive blasting methods. The test results are attached. Plates one and two were "dry blasted" and each developed a measurable electrostatic charge. The third and fourth plates (wet blasted) generated no measurable electrostatic charge.

There are at least three blasting methods for removing coating from a tank:

1 The "dry blast" method uses high pressure air and an abrasive.
2 The "hydro-blast" method uses high pressure water.
3 The "wet blast" method uses a mixture of water and abrasive with high pressure air.

According to GATX Terminal's Procedures, abrasive blasting is considered hot work and requires that "... Transfer operations are not in progress within the hot work area and the flow of product is locked out." Discussions with David Berg indicate that "hydroblasting" is not considered abrasive blasting. "Wet blasting" is a new technology that is closer to hydroblasting than dry abrasive blasting.

I feel, based on the results of the electrostatic charge test, that the" wet blast" method would not generate an electrostatic charge sufficient to produce a source of ignition. I believe that "wet abrasive" blasting could be done on a tank exterior during product withdrawal as long as all other safety precautions were followed.

There are other options that we could pursue.

- Abrasive blast and coat tanks that do not affect terminal operation This is a short term solution to meet our objective of painting six tanks by the end of 1995. There are six different tank in different terminals that could be taken out of service for the time needed. These tanks are the smaller tanks at these terminals and, in most cases look better than other tanks in the terminal. The same scheduling problems will still exist for 1996.

- Design and install a "Programmable Manifold". A "programmable manifold" between the tanks and the loading racks would be the best of the alternatives as it would let maintenance personnel quickly change the source tank of any loading spot. This may be the solution for 1996 cleaning and painting if completed early enough in the year.

It appears like we have two choices. Paint three tanks in 1995 that are not critical such as 121, 122, 100, 310, 211 or 501 and hope that the "programable manifold" is done early enough in 1996 to do 6 tanks or pursue defining GATX's position on "wet blasting" and the required safety precautions.

CC: J. France
E. Braithwaite
B. McGuire

FROM THE DESK OF...
DAVID LANGE
MAINTENANCE COORDINATOR
CALNEV PIPE LINE

Test Procedure

Title. **Electrostatic Charge Build up during Abrasive Blasting**

Purpose: To determine the electorstatic charge that builds up between the blasting nozzle and the material being blasted with an abrasive material. Vary the blasting conditions to ensure older and newer forms of abrasive blasting are tested.

Equipment:

1. (4) Steel Plates approximately 4' X 4' X .25" with painted surfaces. The plates are to be mounted on wood 2 X 4's to keep them electrical isolated from earth ground
2. (1) Standard abrasive blast unit including bonding cables to connect all components
3. (1) Turbo-Blast abrasive blast unit including bonding cables to connect all components
4. (1) Calibrated Digital Multimeter set to a read low ohmage range
5. (1) Calibrated Electrostatic Charge measuring device
6. (1) Calibrated Thermometer and Hygrometer

Prerequisites.

1. The Independent Inspection Firm Representative (Inspector) is at the test site and has verified the calibration of all Measuring devices.
2. The set up of both the standard and turbo blast machines is complete and both systems are operating satisfactorily.

Test Procedure.

1. The Inspector will measure the ambient temperature and relative humidity of the test area. He will record these values on Attachment 1.

2. On the first steel plate to be abrasive blasted, the inspector will verify that there is no bonding between the steel plate and the abrasive blasting set up

3. Determine the state of Electrostatic charge on the steel plate and the nozzle. The inspector will verify these reading and record them on attachment 1 as Time 0:00.

4. Start Blasting the steel plate using the standard abrasive blast unit. Every thirty seconds stop blasting and measure the electrostatic charge on the steel plate and the nozzle The Inspector will verify these readings and record them on attachment 1 Continue this step until the plate has been blasted clean.

5. On the second steel plate hook up the bonding cable between the steel plate and the blasting nozzle of the abrasive blasting unit. Measure the resistance between the steel plate and the nozzle. Acceptable ohmages will be less than 5 ohms. The Inspector will verify the readings and record it on attachment 1.
6. Repeat Steps 3 and 4 on the second steel plate.
7. On the third steel plate to be abrasive blasted, the Inspector will verify that there is no bonding between the steel plate and the turboblast wet blasting unit.
8. Repeat Steps 3 and 4 on the third steel plate using the turboblast wet blasting unit.
9. On the fourth steel plate hook up the bonding cable between the steel plate and the turboblast wet blasting unit nozzle. Measure the resistance between the steel plate and the nozzle. Acceptable ohmages will be less than 5 ohms. The Inspector will verify the readings and record it on attachment 1.
10. Repeat Steps 3 and 4 on the fourth steel plate using the turboblast wet blasting unit.

Prepared By: David Lay
Maintenance Coordinator

Approved: [signature] 17 APRIL 95
Manager of Maintenance

TEST CONDUCTED AT: AA-1 Painting Shop, 15117 Illinois Ave. Paramount, Ca. 90723-4187
PHONE NO. (213) 979-0671
FAX " 633-1903

Attachment 1

Date/time of test: 4-26-95 / 10:30 am

Ambient Temperature: 65°F Relative Humidity: 70%

Standard abrasive Blasting Torbo #2004 settings 5-1-16

Time	Plate 1 (Dry)	Plate 2 (Dry)	Plate 3 (Wet)	Plate 4 (Wet)
0:00	0-KV	0-KV	0-KV	0-KV
0:30	1-KV			
1:00	5-KV	1.5-KV	0-KV	0-KV
1:30				
2:00	15-KV	2-KV	0-KV	0-KV
2:30				
3:00	1-KV	1-KV	0-KV	0-KV
3:30				
4:00		1-KV		
4:30				
5:00				
5:30	ABOVE READINGS TAKEN BY: David Lange, CALNEV ETC. COORDINATOR			
Final	ABOVE READINGS RECORDED BY: Jack A. Boyle, S.G. PINNEY			

AGGREGATE: Gordon's Sharp Shot F-80 (36) HOSE: 1¼" BLAST NOZZLE: No.7

Plate 2 Resistance to blast nozzle: 1.8

Plate 4 Resistance to blast nozzle: 2.8 Signed: Jack A. Boyle

Calibration checked on all measuring devices: Jack Boyle, S.G. Pinney & Assoc. Inc.
Inspector

* M. Devices: Testone Autostat Model: 22LC1 - Simpson Visual Digital Multimeter Model No. 467 Series: 2T

Test Results Certified: Jack Boyle, S.G. Pinney & Assoc. Inc. Palmdale Pictures
Inspector

* Calibrated by: ....National Calibration, 4-19-95 (602) 437-8114 on File: 714-770-3010

ALSO PRESENT: (Blaster) Curtis Fox AA-1 Ptg.
Rex Johnston Sr. "
Jack Boyd "
Pat Ricciardi "
Jim Egan Torbo Regional Mgr. PH/FAX:(206) 372-2874