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Advanced Paint Stripping**

Evaluation of Vacuum Blasting and Heat Guns as Methods for Abating Lead-based Paint on Buildings

by
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The U.S. Army maintains 270 million sq ft of family housing. Sixty-five percent of these structures are more than 25 years old and are likely to have both interior and exterior surfaces painted with lead-based paint. To minimize potential health problems resulting from exposure to lead-based paint, the Army is investigating new technologies for lead-based paint abatement. This research evaluates the effectiveness, safety, and cost of vacuum abrasive units and heat guns as methods of removing lead-based paint.

Three vacuum blasting units, five types of abrasive media, and three heat guns were evaluated. The removal rate for abrasive cleaning ranged from over 3.5 to 0.1 sq ft per hour. Removal rates for heat gun cleaning were higher, at 5.88 to 1.00 sq ft per hour.

To minimize the amount of lead-contaminated waste, it is recommended that the heat gun method be used as initial treatment, followed by light vacuum blasting to remove residual paint.

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FOREWORD

This work was performed for the U.S. Army Center for Public Works (USACPW) under project 4A162784AT41, "Military Facilities Engineering Technology," work unit MB-C21, "Advanced Paint Stripping." The technical monitor was Mr. Chester Kirk, CECPW-FB-S.

The research was conducted by the Materials Science and Technology Laboratory, Georgia Tech Research Institute (GTRI) under contract No. DACA88-90-D-0006-0008, GTRI Project A-8905 and the Engineering and Materials Division (FM) of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Susan Drozdz was the Principal Investigator. Dr. Jan Gooch was the GTRI researcher. Dr. Paul A. Howdyshell is Chief, CECER-FM and Dr. Michael J. O'Connor is Chief, CECER-FL. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

LTC David J. Rehbein is Commander of USACERL and Dr. L.R. Shaffer is Director.

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1 INTRODUCTION

Background

The U.S. Army maintains 270 million sq ft* of family housing.[1] Sixty-five percent of these structures are more than 25 years old and are likely to have both interior and exterior surfaces painted with lead-based paint (LBP). The use of lead in manufactured paint has been regulated since 1973 when the Consumer Product Safety Commission (CPSC) established a maximum lead content in paint of 0.5 percent by weight in a dry film of paint.[2] In 1978, the CPSC lowered the allowable lead level to 0.06 percent by weight.

The Lead-Based Paint Poisoning Prevention Act (LBPPPA, 42 U.S.C. 4822 (d)(2)(A)) requires Public Housing Agencies and Indian Housing Authorities to conduct random sampling for lead-based paint in public and Indian housing. The Act also requires abatement when lead is present at or above an "action level" of 1.0 milligram/square centimeter (mg/cm^2) or 0.5 percent by weight—whichever is more stringent. Guidance for testing and abatement of LBP are provided in a set of comprehensive guidelines developed by the U.S. Department of Housing and Urban Development (HUD).[3] Certain states and local (county) authorities have adopted an action level between 0.7 and 1.2 mg/cm^2. Army Corps of Engineer Technical Note (TN) 420-70-2,[4] provides guidance and prescribes responsibilities for LBP testing and abatement at Department of the Army (DA) installations. The document prescribes testing and abatement in accordance with the HUD Guidelines.

When lead enters the body, it may cause damage to the central nervous system. High levels of lead may result in convulsions, mental retardation, or even death. Lower levels of exposure may result in more subtle effects such as behavior problems or lowered IQ. The developing body of a child is at greatest risk and the Army is concerned about the exposure risk of soldiers and their families. Lead is taken into the body not only when lead paint chips are eaten, but also when dust from deteriorating lead-based paint is inhaled or taken into the mouth with contaminated food, cigarettes, or other hand-to-mouth activity.

The Army is investigating new technologies for lead-based paint abatement. Abatement is defined in the HUD Guidelines as "a comprehensive process of eliminating exposure or potential exposure to lead paint and lead dust which must include testing, and measures for worker protection, containment of dust and debris, cleanup and disposal of waste, and clearance testing." Abatement includes removing paint lead from surfaces, removing and replacing leaded building components, and permanent encapsulation of leaded surfaces.

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* A metric conversion table is on p 40.

[1] *Facilities Engineering and Housing Annual Summary of Operations*, known commonly as the Red Book (U.S. Department of the Army, 1989).

[2] U.S. Consumer Products Safety Commission: *Lead-Containing Paint and Certain Consumer Products Bearing Lead-Containing Paint*, 16 CFR 1303 (1977).

[3] *Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing* (U.S. Department of Housing and Urban Development, September 1990).

[4] Technical Note (TN) 420-70-2, *Lead-Based Paint (LBP): Hazard Identification and Abatement* (U.S. Army Corps of Engineers, 2 September 1991).

Objective

The objective of this research program was to evaluate the effectiveness, safety, and cost of vacuum abrasive blast units and heat guns as methods of removing lead-based paint from typical surfaces found in residential construction.

Approach

The Georgia Tech Research Institute (GTRI) obtained painted wood, particle board, steel, galvanized steel, and aluminum substrates from the Macon Housing Authority in Macon, GA. The levels of lead in the paints were measured using an x-ray fluorescence technique.

Manufacturers' technical literature and specifications were compiled and reviewed for three vacuum blasting units, five types of abrasive media, and three heat guns selected for evaluation. Each abrasive selected is representative of a general type of abrasive. The equipment was selected based on availability and suitability for the proposed use. Researchers removed the paint from the substrates and recorded the removal rate, cost, effectiveness, condition of cleaned surface, and airborne lead concentrations during paint removal for each removal system.

Mode of Technology Transfer

It is recommended that the information in this report be used in the preparation of technical guidance for the abatement of lead-based paint on buildings and related structures. A triservice committee currently is drafting a technical manual and a guide specification.

2 MEASURING LEAD LEVELS IN PAINT

The Macon Housing Authority in Macon, GA provided full-scale lead painted test specimens of wood, particle board, steel, galvanized steel, and aluminum. Researchers analyzed the paint and substrate of each specimen for lead using an x-ray fluorescence (XRF) detection unit. This nondestructive method is generally called "field" or "*in situ*" testing to differentiate it from laboratory testing, which involves taking a paint sample from a surface and sending it to a laboratory for analysis. The presence of lead was reported in units of milligram per square centimeter. The unit was developed at GTRI by Dr. C. D. Papanicolopoulos, and is not yet commercially available. It was calibrated daily during the testing. The test specimens were either flat or round.

The XRF System

Researchers conducted *in-situ* LBP testing using a high resolution-semiconductor detector-based XRF portable system. The high resolution is provided by a 1000 mm^2 planar, high purity germanium surface. The unit contains a 3 milli-curie Gd^{153} radioactive source to provide excitation for the lead $K_a$and K_b x-ray fluorescence, and a multichannel analyzer capable of spectral analysis. This unit was assembled at GTRI of components procured from standard sources. The system's performance and analysis characteristics were monitored using the field measurement quality assurance-quality control (QA-QC) procedures discussed later in this chapter. As it pertains to LBP quantitative analysis, typical performance characteristics for the XRF system are:

Minimum Limit of Detection:	0.01 mg/cm^2 (lead concentration)
Gain Shift (spectral drift):	less than 1 channel/1000 hrs of operation
Electronic Drifts-Power Supply:	less than 1/10000
Linearity (response to different lead concentrations):	Highly linear variability less than 0.1 percent
Back-scattering Interferences:	N/A
Paint Thickness or Depth Effects:	less than 0.1 percent% (at 1.0 mg/cm^2)
Matrix Effect (software compensated):	+/- 0.5 percent at 1.0 mg/cm^2
Source From:	Radioisotope Laboratory
Electronics:	EG&G ORTEC and Conberra Company
Detector:	ORTEC Company
Software:	GTRI, Dr. C. D. Papanicolopoulos
Collimators and filters:	GTRI, Dr. C. D. Papanicolopoulos

XRF Calibration

Researchers constantly verified and monitored the XRF system's performance during testing through energy and efficiency calibration tests, and the use of reproducible geometry standards produced by lead sputtering on Mylar at the GTRI Micro-Electronics facilities. The lead layer thickness and uniformity of sputtering was thoroughly examined with transmission electron microscopy and associated x-ray energy dispersive techniques. The very uniform thickness of lead on the standards is known to an accuracy of +/- 10 Angstroms (approximately 1/25,000,000 of 1 in.). The lead concentration is calculated (and measured) to an accuracy of +/- 0.0001 mg/cm^2.

The reported errors for the LBP field measurements are conservatively high (0.2 mg/cm^2) to account for nonuniformities in the paint hidden from view.

Correction Factors

Geometry correction factors, or calibration curves, for curved or intricately shaped surfaces have been developed for the XRF system through extensive measurements of lead deposited on such surfaces by sputtering of a known number of atomic layers. These corrections, when applicable, are incorporated in the field measurements.

Figure 1 shows the standard geometry or arrangement between detector, source, and tested sample; the probe is in contact with the paint. This arrangement is used to calibrate the XRF system where lead concentration versus counted lead x-rays are recorded. The same geometry is maintained in laboratory and field measurements where the tested area is assumed to be flat and in contact with the probe at all times.

The same lead content paint sample measured in contact with the XRF head will show less lead content when measured at some distance D (see Figure 2) because the lead x-rays originated in the sample have a larger distance to transverse and their intensity as they reach the detector is less. This reduction in detected lead x-rays has a simple analogy from everyday life. The luminous intensity of a light bulb decreases based on the distance from the bulb.

In cases where the door lintel or the window lintel is to be tested, the available lintel width and the size of the XRF system's head probe creates the situation where the probe is not in contact with the testing surface. Figure 3 shows the arrangement. Part of the sample is in contact with the probe, and part of it is some distance from the probe. For the portion at a distance, the sample's lead content will be underestimated so the measurement must be increased by a factor greater than 1 to make up for the reduced lead estimate. When the sample is at an inclination to the probe's surface, it presents more of its bulk to the source and to the detector. That is to say, more of the sample (and consequently more lead) is included in the "radiation cone" of the XRF and the result is to overestimate the lead concentration/per unit area in the sample. In this case, one has to divide the result of the measurement appropriately to avoid overestimating the lead concentration.

It matters which of the two competing phenomena is the most dominant. In the case of door lintel, most of the lintel's width is covered by the door frame. The portion of the lintel accessible for LBP testing dictates a geometry as conceptually depicted in Figure 4, where the painted surface does not intercept the entire source radiation cone. In fact, most of the radioactive source activity is missing the bulk of the tested surface and it is expected that the multiplication correction factor must be larger than in the window lintel measurements.

These correction factors can be theoretically calculated. The factors were verified experimentally by reproducing various source-detector-sample geometries in the laboratory and observing through repeated measurements how far and in which direction XRF measurements deviate from standard.

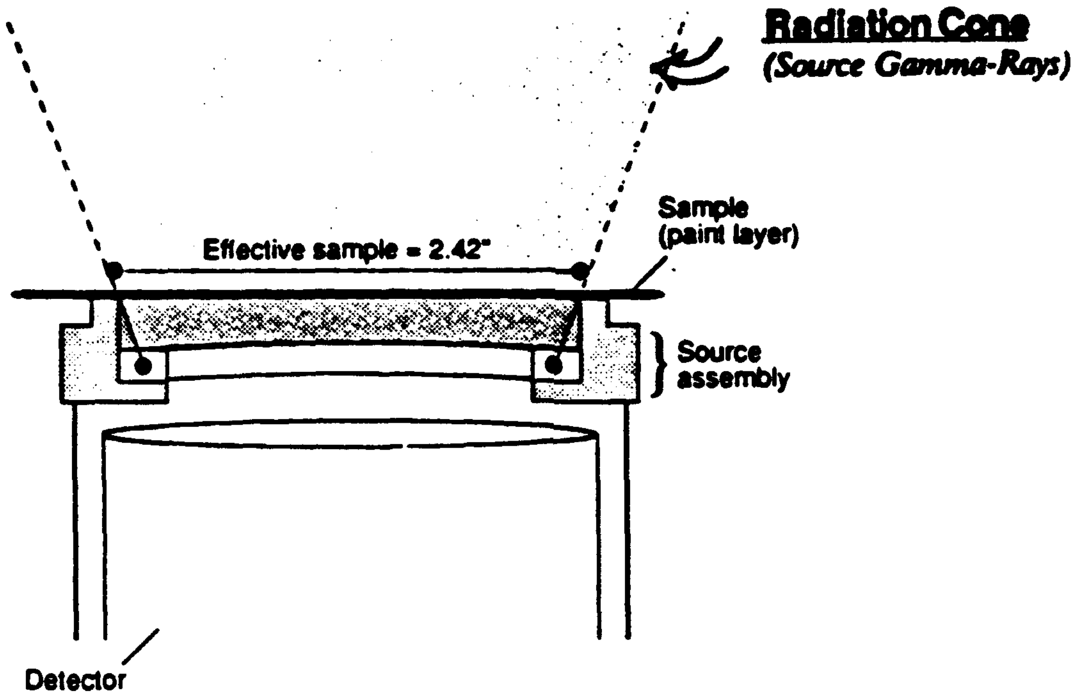

Figure 1. XRF Measurement of Flat Surface With XRF Head in Contact With Paint Sample.

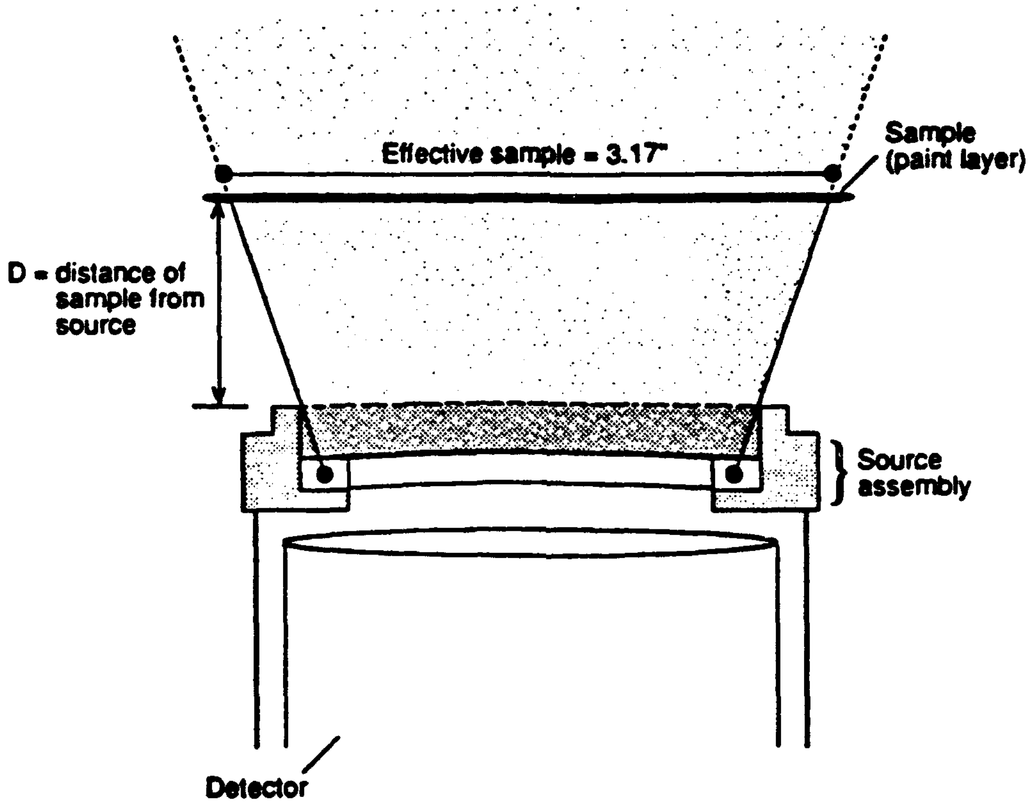

Figure 2. XRF Head at a Distance From Paint Sample.

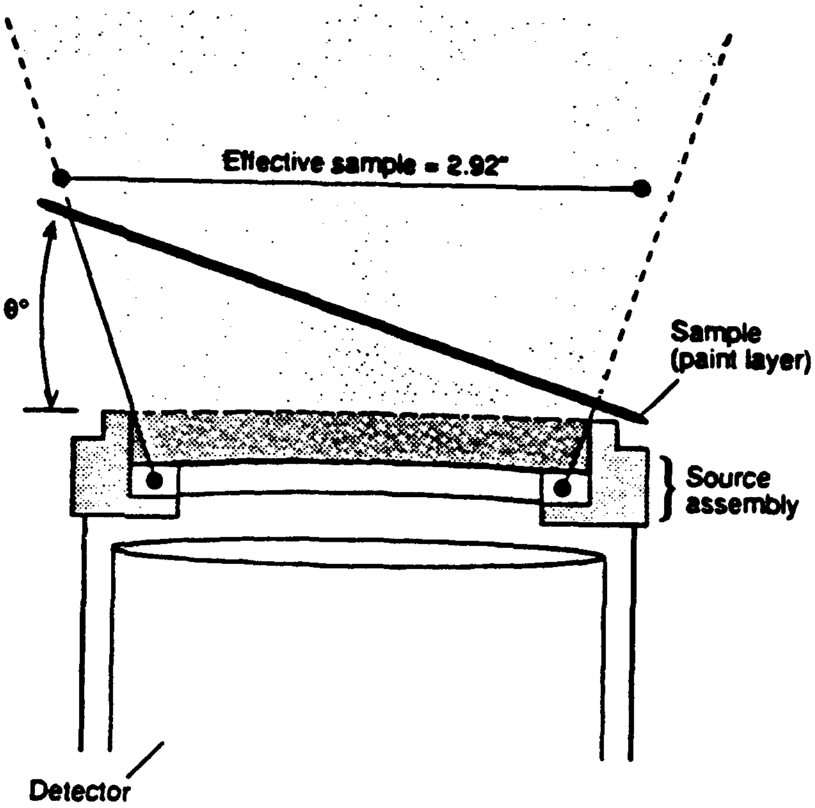

Figure 3. XRF Measurement of Window Lintel.

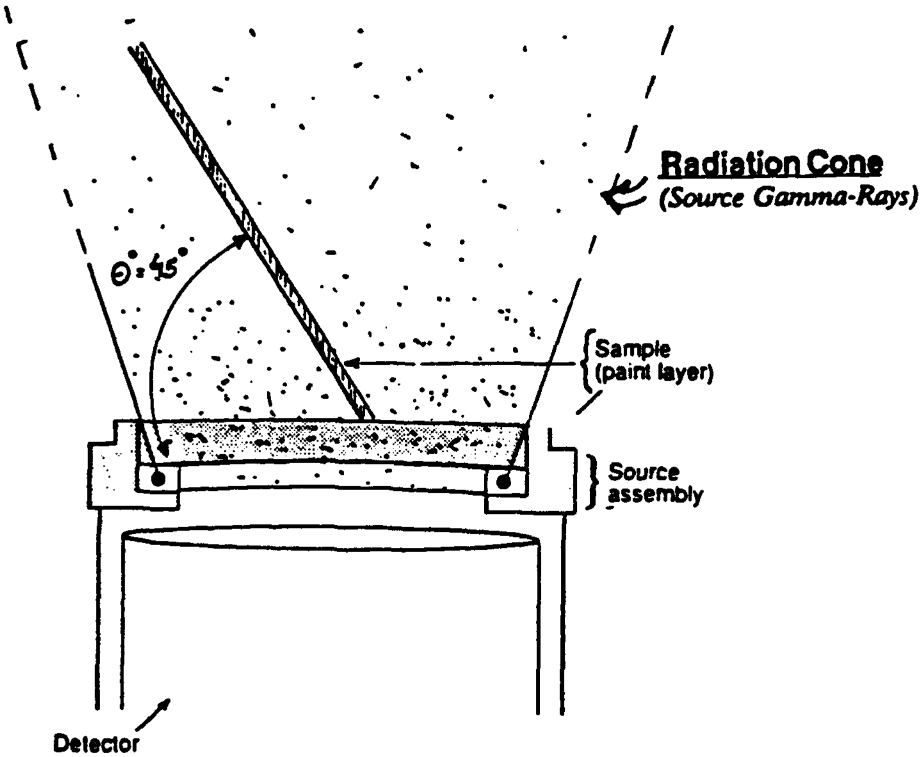

Figure 4. XRF Measurement of Door Lintel.

It was determined that the XRF system (for reasons of size of source and detector assembly) underestimates the presence of lead in the cases of door and window lintels, and backrail ties. For these cases the correction factors (CF) are:

Window lintel (Figure 3) CF = 1.8

1.8 X (measured) = corrected (mg/cm^2)

In the case of 3.0-in. outside diameter (OD) porch columns, the system overestimates the presence of lead. In this case, the correction factor is:

3.0-in. OD porch column (Figure 5) CF = 1/1.1

(measured)/1.1 = corrected (mg/cm^2)

1-1/2-in. to 1-3/4-in. OD backrail (Figure 6) CF = 1.4

1.4 X (measured) = corrected (mg/cm^2)

Door lintel (Figure 4) CF = 1.5

1.5 X (measured) = corrected (mg/cm^2)

Quality Assurance-Quality Control (QA-QC) Procedures

There are no established or proposed QA-QC guidelines for K-X-ray based XRF analysis of paint chips in the field or in the laboratory. Also no accreditation program for operators is suggested or enforced at the local, state, or national level. The same is true for field XRF testing; a set of test-calibration procedures is used as a poor substitute to proper QA-QC.

Furthermore, since the analytical technique is not commercially available and has been used uniquely in university research laboratories by experimental physicists (for measurements other than quantitative sample analysis), the need for QA-QC procedures never emerged.

By adapting the following method to routine laboratory analysis, a set of QA-QC procedures were developed with the intent to ensure accurate lead concentration analysis for paint samples.

The QA-QC procedures adopted are as follows:

1. Determine the qualifications and experience of the technical and scientific personnel involved routinely and/or supervising the laboratory analysis.

2. Properly operate, maintain, and calibrate the hardware and validate the operating software.

3. Comply with safe handling and use of licensed radioactive materials used as calibration or fluorescence sources.

4. Prevent cross-sample contamination and environmental lead contamination.

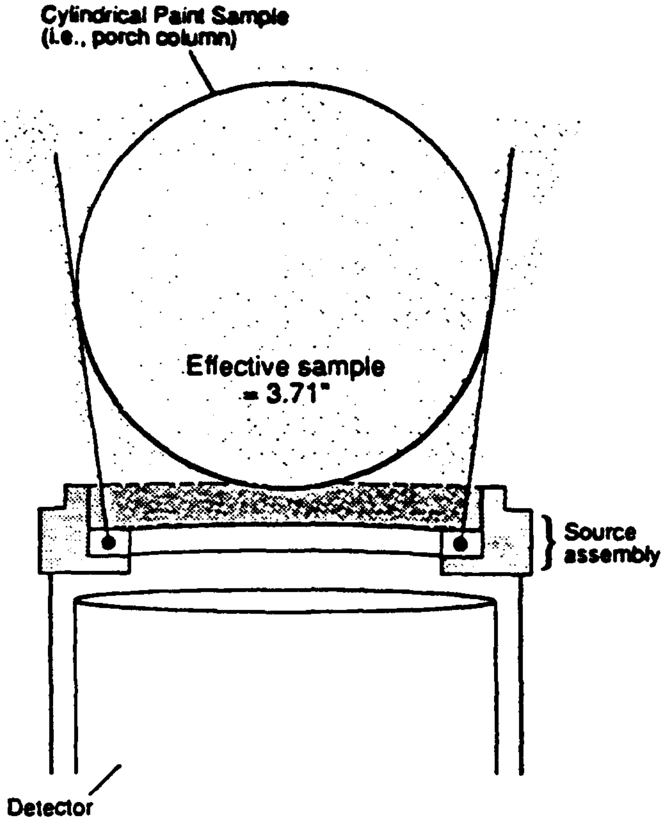

Figure 5. XRF Measurement of Porch Column.

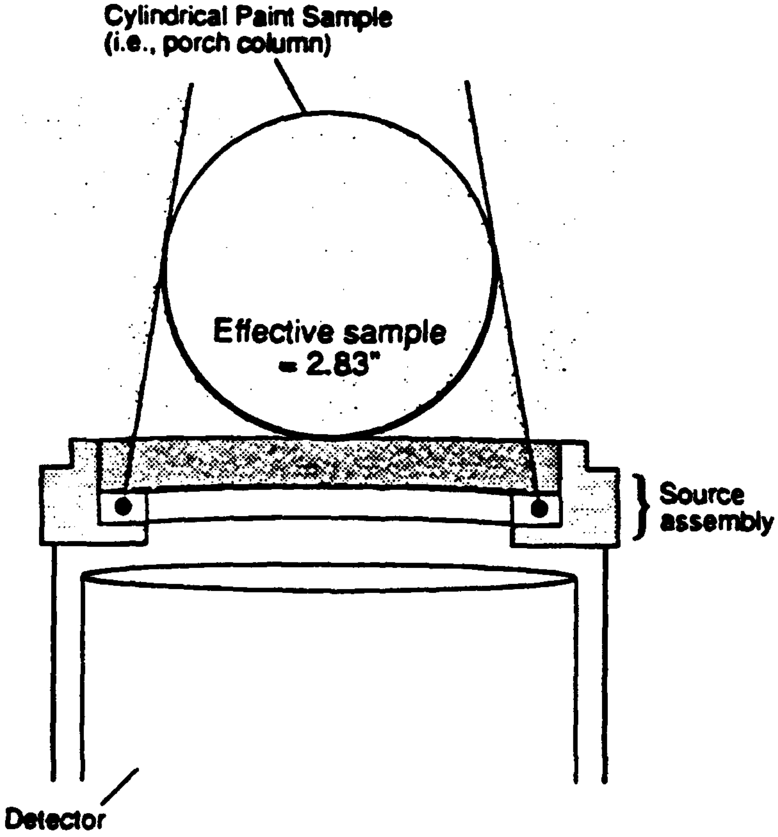

Figure 6. XRF Measurement of Backrail.

5. Verify analysis results through concentration ratios between different samples, using independent analytical techniques such as atomic absorption spectroscopy (AAS) and energy dispersive x-ray spectrometry in transmission-scanning electron microscopy.

6. Use the proper HUD standards in lead concentration calibrations for the analytical system and for the induced error.

7. Determine the overall analytical error associated with each analysis.

8. Define the frequency of inter-laboratory spot-check sample analysis by the QA-QC officer. Also define the frequency of using standards of known lead concentration during routine analysis. Maintain explicit records of evaluations and laboratory operation quality factors (personnel, equipment, and procedures).

9. Conduct an ongoing independent evaluation of the quality of analytical performance by sponsors and sponsoring agencies through a no-cost analysis of resubmitted unmarked samples, previously analyzed by the GTRI laboratory.

10. Maintain safekeeping, recording, and reporting protocols for samples.

11. Participate in intra-laboratory (round-robin) sample analysis.

12. Participate in a National Accreditation Program if and when such a program becomes available.

Deviations due to faulty instrument operation are continuously monitored (in real-time) during each sample analysis. Any detected deviation or malfunction and interference affecting the spectrum quality is identified by assembly language efficient routines that perform five different categories of quality test on the acquired spectrum at a rate of five tests per category per second.

If any interference or general system malfunction has been identified, the performed analysis is disqualified and the system interrupts acquisition. The system will then record the type of problem in a password-secure file accessible only to the QA-QC officer. The system will not operate beyond this point unless the error-record file is opened and the problem is isolated and corrected. Equipment is maintained weekly; a log book is maintained specifically for this purpose.

Cross-sample contamination of the source detector assembly is monitored every 10 samples by acquiring a "no sample present" or blank spectrum for 4 to 6 times longer than the standard sample analysis time to acquire statistically significant levels of data and to detect lead concentrations at 0.005 mg/cm^2 (approximately 20 times less than the "nominal" minimum limit of detection = 0.1 mg/cm^2).

Cross-sample contamination is prevented by cleaning the detector window surface (stretched, very thin, nonexpandable Mylar) with compressed air. Repetitive wipe-sample testing of the Mylar surface for dilapidated paint (chalked paint) over a period of 6 months and subsequent analysis by atomic absorption (AA) or atomic emission (AE, a technique 100 times more sensitive than AA) provided results below the detection limit of the AA (2 to 5 parts per million [ppm]).

HUD lead-based paint standards at 0.6, 1.53, and 2.99 mg/cm^2 were analyzed for every 20 unknown samples, and as a minimum, 3 times daily. The standards were procured from HUD, and were manufactured under contract to the National Bureau of Standards (now the National Institiue of Standards and Technology).

The time of analysis for each sample was used to correct for the continuous source decay, which results in a progressively weaker sample excitation.

3 DETECTING LEAD IN AIR

The working environment and atmosphere was analyzed for lead by filtering air close to the worker's head, then analyzing the material on the filter for lead. The lead was reported in milligrams per cubic meter. The basic procedure used to monitor air was taken from Occupational Safety and Health Administration (OSHA) Instruction CPL 2-2.20B CH-1, November 13, 1990, pp 1-1, 1-2, and 1-3.

Procedure for Personal Air Sampling

The procedure for sampling the air in the work environment consists of placing a PVC tube within 12 in. of the operator's mouth and flowing air at 2.0 L per minute into the tube and through a 0.45 micron polyvinyl chloride (PVC) filter supplied in a two-piece cassette. Air was sampled during each test and the results were extrapolated to 8-hour exposures. A MSA Flow-Lite Pro portable pump Model 484107 was used to flow the air at negative pressure through the filter from the breathing area. The filter was a Wisconsin Occupational Health Laboratory, 0.45 micron filter and the tubing was PVC from the Cole-Parmer Corporation.

Procedure for Lead Analysis

Lead particulate collected on each filter was analyzed by atomic emission spectroscopy. The procedure included digesting the filter in concentrated nitric acid to dissolve the lead compounds. The solution of lead was injected in a Perkin-Elmer Atomic Emission Spectrophotometer Model No. 2380. The total mass of lead from each filter was correlated to the total air volume and reported in milligrams per cubic meter (Tables 1 through 3).

Table 1

Results of Model 1030 Vacuum Abrasive Cleaning

Abrasive Media	Estimated Consumption of Media (lb/sq ft)	Substrate Type	Rate of Removal (sq ft/hr)	Lead Levels	
				Air (mg/m^3)	Substrate, before/after (mg/cm^2)
Coal Slag	0.35	Aluminum	2.0	<0.01	2.5/<0.1
	0.35	Galvanized	2.0	<0.01	2.2/<0.1
	0.35	Steel	2.0	<0.01	2.1/<0.1
	0.35	Exterior wood	2.0	<0.01	3.8/<0.1
	0.35	Particle board	2.0	<0.01	4.4/<0.1
Starblast	0.35	Aluminum	2.0	<0.01	2.5/<0.1
	0.35	Galvanized	2.0	<0.01	2.2/<0.1
	0.35	Steel	2.0	<0.01	2.1/<0.1
	0.35	Exterior wood	2.0	<0.01	3.8/<0.1
	0.35	Particle board	2.0	<0.01	4.4/<0.1
Steel Shot	0.35	Aluminum	0.7	<0.01	2.5/<0.1
	0.35	Galvanized	0.7	<0.01	2.2/<0.1
	0.35	Steel	0.7	<0.01	2.1/<0.1
	0.35	Exterior wood	0.7	<0.01	3.8/<0.1
	0.35	Particle board	0.7	<0.01	4.4/<0.1
Armex + 5% Starblast	0.35	Aluminum	0.1	<0.01	2.5/<0.1
	0.35	Galvanized	0.1	<0.01	2.2/<0.1
	0.35	Steel	0.1	<0.01	2.1/<0.1
	0.35	Exterior wood	0.1	<0.01	3.8/<0.1
	0.35	Particle board	0.1	<0.01	4.4/<0.1
Solidstrip	0.35	Aluminum	0.6	<0.01	2.5/<0.1
	0.35	Galvanized	0.6	<0.01	2.2/<0.1
	0.35	Steel	0.6	<0.01	2.1/<0.1
	0.35	Exterior wood	0.6	<0.01	3.8/<0.1
	0.35	Particle board	0.6	<0.01	4.4/<0.1
BX40 Silica Sand	0.35	Aluminum	2.0	<0.01	2.5/<0.1
	0.35	Galvanized	2.0	<0.01	2.2/<0.1
	0.35	Steel	2.0	<0.01	2.1/<0.1
	0.35	Exterior wood	2.0	<0.01	3.8/<0.1
	0.35	Particle board	2.0	<0.01	4.4/<0.1

Note - Minimum detection limit of lead in air is 0.01 mg/m^3. Minimum detection limit of lead in paint is 0.1 mg/cm^2.

Table 2

Results of Vac-Blast Vacuum Abrasive Cleaning

Abrasive Media	Estimated Consumption of Media (lb/sq ft)	Substrate Type	Rate of Removal (sq ft/hr)	Lead Levels	
				Air (mg/m^3)	Substrate, before/after (mg/cm^2)
Coal Slag	0.35	Aluminum	1.9	<0.01	2.5/<0.1
	0.35	Galvanized	1.9	<0.01	2.2/<0.1
	0.35	Steel	1.9	<0.01	2.1/<0.1
	0.35	Exterior wood	1.9	<0.01	3.8/<0.1
	0.35	Particle board	1.9	<0.01	4.4/<0.1
Starblast	0.35	Aluminum	1.9	<0.01	2.5/<0.1
	0.35	Galvanized	1.9	<0.01	2.2/<0.1
	0.35	Steel	1.9	<0.01	2.1/<0.1
	0.35	Exterior wood	1.9	<0.01	3.8/<0.1
	0.35	Particle board	1.9	<0.01	4.4/<0.1
Steel Shot	0.35	Aluminum	0.6	<0.01	2.5/<0.1
	0.35	Galvanized	0.6	<0.01	2.2/<0.1
	0.35	Steel	0.6	<0.01	2.1/<0.1
	0.35	Exterior wood	0.6	<0.01	3.8/<0.1
	0.35	Particle board	0.6	<0.01	4.4/<0.1
Armex + 5% Starblast	0.35	Aluminum	0.1	<0.01	2.5/<0.1
	0.35	Galvanized	0.1	<0.01	2.2/<0.1
	0.35	Steel	0.1	<0.01	2.1/<0.1
	0.35	Exterior wood	0.1	<0.01	3.8/<0.1
	0.35	Particle board	0.1	<0.01	4.4/<0.1
Solidstrip	0.35	Aluminum	0.6	<0.01	2.5/<0.1
	0.35	Galvanized	0.6	<0.01	2.2/<0.1
	0.35	Steel	0.6	<0.01	2.1/<0.1
	0.35	Exterior wood	0.6	<0.01	3.8/<0.1
	0.35	Particle board	0.6	<0.01	4.4/<0.1
BX40 Silica Sand	0.35	Aluminum	1.9	<0.01	2.5/<0.1
	0.35	Galvanized	1.9	<0.01	2.2/<0.1
	0.35	Steel	1.9	<0.01	2.1/<0.1
	0.35	Exterior wood	1.9	<0.01	3.8/<0.1
	0.35	Particle board	1.9	<0.01	4.4/<0.1

Note - Minimum detection limit of lead in air is 0.01 mg/m^3. Minimum detection limit of lead in paint is 0.1 mg/cm^2

Table 3

Results of Zero Model Vacuum Abrasive Cleaning

Abrasive Media	Estimated Consumption of Media (lb/sq ft)	Substrate Type	Rate of Removal (sq ft/hr)	Lead Levels	
				Air (mg/m^3)	Substrate, before/after (mg/cm^2)
Coal Slag	0.35	Aluminum	2.0	<0.01	2.5/<0.1
	0.35	Galvanized	2.0	<0.01	2.2/<0.1
	0.35	Steel	2.0	<0.01	2.1/<0.1
	0.35	Exterior wood	2.0	<0.01	3.8/<0.1
	0.35	Particle board	2.0	<0.01	4.4/<0.1
Starblast	0.35	Aluminum	2.0	<0.01	2.5/<0.1
	0.35	Galvanized	2.0	<0.01	2.2/<0.1
	0.35	Steel	2.0	<0.01	2.1/<0.1
	0.35	Exterior wood	2.0	<0.01	3.8/<0.1
	0.35	Particle board	2.0	<0.01	4.4/<0.1
Steel Shot	0.35	Aluminum	0.7	<0.01	2.5/<0.1
	0.35	Galvanized	0.7	<0.01	2.2/<0.1
	0.35	Steel	0.7	<0.01	2.1/<0.1
	0.35	Exterior wood	0.7	<0.01	3.8/<0.1
	0.35	Particle board	0.7	<0.01	4.4/<0.1
Armex + 5% Starblast	0.35	Aluminum	0.1	<0.01	2.5/<0.1
	0.35	Galvanized	0.1	<0.01	2.2/<0.1
	0.35	Steel	0.1	<0.01	2.1/<0.1
	0.35	Exterior wood	0.1	<0.01	3.8/<0.1
	0.35	Particle board	0.1	<0.01	4.4/<0.1
Solidstrip	0.35	Aluminum	0.6	<0.01	2.5/<0.1
	0.35	Galvanized	0.6	<0.01	2.2/<0.1
	0.35	Steel	0.6	<0.01	2.1/<0.1
	0.35	Exterior wood	0.6	<0.01	3.8/<0.1
	0.35	Particle board	0.6	<0.01	4.4/<0.1
BX40 Silica Sand	0.35	Aluminum	2.0	<0.01	2.5/<0.1
	0.35	Galvanized	2.0	<0.01	2.2/<0.1
	0.35	Steel	2.0	<0.01	2.1/<0.1
	0.35	Exterior wood	2.0	<0.01	3.8/<0.1
	0.35	Particle board	2.0	<0.01	4.4/<0.1

Note - Minimum detection limit of lead in air is 0.01 mg/m^3. Minimum detection limit of lead in paint is 0.1 mg/cm^2.

4 ANALYZING TEST SUBSTRATES

The data from analysis are presented in Tables 1 through 3. The cost of blast media for lead paint removal is shown in Table 4. The labor, which varies with geographical location and is averaged at $9.25/hour (nominal value at Macon, GA), is factored into the final cost per square foot for each method of cleaning. The total cost per square foot includes factors that affect the practical cost of removing lead paint from a residential structure, including the cost of disposal.

Samples of lead-based paint on full-size substrates were obtained from the Macon Housing Authority in Macon, GA. The "old" paint on these samples simulates normal conditions. Old paint consists of primarily pigmented oil-based alkyd paint that is usually brittle, multilayered, and often cracking and chipping. Also, the old base layers of alkyd paint are often over-coated with other types of paint such as water-based acrylic latex. The painted wood samples consisted of shelves, window sills, soffits, and doors. The metal samples consisted of vertical and horizonal metal supports and hand rails. The majority of these coatings contained alkyd and acrylic type binders. The coating thicknesses were measured using a Tooke Inspection Gauge. All of the sample pieces had multiple layers of paint (not all lead-pigmented) as determined using scanning electron microscopy (SEM) to identify individual layers of paint, and energy dispersive x-ray analysis (EDXRA) to determine the presence of lead in individual layers as listed below.

Sample	Lead Content by XRF (in mg/cm^2)	Total Layers/ Lead Layers	Total Thickness (mils)
Interior particle boad shelving	4.2-4.4	3/1	3-6
Exterior pine wood	3.8-4.0	4/1,2	5-7
Pine wood window frame	4.0	4/1,2	5-7
Exterior steel columns	2.1-2.9	8/1,2,4	8-10
Aluminum soffit vents	2.5	2/1	3-5
Galvanized steel drip cap	2.2	2/1	3-5

Researchers photographed the surfaces before and after cleaning to show the results of different methods. The photographs are discussed in the following chapter.

Table 4

Blasting/Cleaning Media and Costs (July 19, 1991)

Brand Name	Mesh	Identification	Manufacturer	Surface Profile* (mils)	Cost ($/100 lb)
Black Diamond	20/30	coal slag	Foster-Dixiana	0.5-1.0	5.25
Starblast	70/100	staurolite sand	Dupont, Inc.	0.5-1.0	5.25
Steel Shot	170	steel balls	Wheel Abrator Co.	1.4-2.0	29.00
Armex	170	sodium bicarbonate	Arm & Hammer Co.	0.3-0.5	53.00
Solidstrip	12/18	plastic media	Dupont, Inc.	0.5-1.0	205.00
BX40	30/40	silica sand	Foster-Dixiana	0.5-1.0	3.15

*This is the surface profile measured on metal and wood after cleaning.

5 USING VACUUM ABRASIVE TO REMOVE LEAD-BASED PAINT

Abrasive Cleaning Units

The results of vacuum abrasive cleaning are given in Table 1 through 3, and a description of abrasive media is in Table 4. Each test patch size was 3 in. by 12 in.; 10 patches were tested for each method.

The rates of removal for the units vary due to their size differences. The smallest paint-removing field unit was selected from each manufacturer, assuming that the smaller units would be easier to maneuver inside a house. Since the hoses on most units can be extended to reach into separate rooms of the dwelling, the larger units could have been used. The vacuum abrasive cleaning equipment tested during this study is mobile and can be used in residential structures. The LTC[5], Vacu-Blast[6] and Zero[7] units are similar with regard to operation and productivity. These units were evaluated for their individual qualities, like "ease of use," and for comparison of their individual capability to remove lead-based paint. The maximum brush (vacuum cup) diameter is an indication of the relative cleaning rate for each unit since the brush is in contact with the paint, and the abrasive material flows within the brush. The actual cleaning rate, however, is subject to the operator's habits and the removal power of the abrasive material. Some important operation parameters and cost for each unit are listed below:

	Air Pressure (psig)	Brush Dia (in.)	Weight (lb)	Cost ($)
LTC Unit Model 1030	100	3.0	75	4000
Vacu-Blast Model SB03	100	2.0	50	3235
Zero C150-3	100	3.0	40	3936

The cost figures include the basic machine with accessories, but without an air compressor. A current quote from each manufacturer will be necessary to obtain an accurate cost figure.

Abrasive Media

Abrasive media was selected on the basis of safety, efficiency, and cost for removing the lead-based paint. All media were selected because of their successful histories in abrasive cleaning operations. Silica sand (BX40[8]) was used, but further study revealed a potential health problem to workers referred to as "silicosis." (Material safety data sheets are contained in Appendix A.) This problem occurs where silica is inhaled by the workers and causes lung disorders. Even under vacuum abrasive cleaning conditions, extremely fine silica particulate is capable of entering the working area, requiring expensive fresh-air masks and protective clothing to be worn by workers. A material comparable to silica sand in efficiency, although 67 percent more expensive, is staurolite sand (Starblast[9]) which does not cause health problems. Plastic media (Solidstrip[10]) was selected because it is a mild abrasive and has a low density, which is advantageous for abrasive cleaning of wood. Steel shot[11] was selected because it is reclaimable (due to

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[5] LTC Model 1030, LTC International, Inc., 101-G Executive Drive, Sterling, VA 22170.

[6] Vacu-Blast International, Model SB-03, Vacu-Blast Corporation, 125 Market Street, Kenilworth, NJ 07033.

[7] Zero Company, Model C150-3, 313 Cheyenne Drive, La Grange, GA 30240.

[8] BX40 Silica Sand, Foster-Dixiana Corporation, P.O. Box 2005, Columbia, SC 29202.

[9] Starblast, E.I. DuPont de Nemours & Co., Inc., Chemicals and Pigments Department, Room G50374, Wilmington, DE 19801.

[10] Solidstrip, E.I. DuPont de Nemours & Co., Inc., Fabricated Products Department, Specialty Services, Wilmington, DE 19898.

[11] Steel shot, Wheel Abrator Company, LaGrange, GA.

its magnetic properties) and is a good abrasive cleaning material although it is very dense. Coal slag (Black Diamond[12]) was selected for its good abrasive properties and medium density. Bicarbonate of soda (Armex[13]) was selected because it is a mild abrasive and it is soluble in aqueous solutions and can be disposed of in municipal sewers, leaving a smaller mass of hazardous lead waste. Aluminum oxide was considered for this study, but is too dense and expensive for these applications. The advantages and disadvantages for each material are discussed below.

The mesh size (see Fine Sieves in Appendix B) of each abrasive material was selected after initial experimentation with different mesh sizes, to obtain the best cleaning quality with minimum destruction of the substrate surface. The abrasive medium was not useful if the surface was well cleaned, but was rendered too "rough" and required significant sanding and preparation before painting.

In the following study for comparing abrasive materials, each material was used for 0.5 hour to clean a surface. This period was required for the best materials to clean 100 percent of the paint from metal or wood surfaces. A comparison with accompanying photographs was made.

Starblast, Black Diamond, and BX40 Silica Sand media performed well for these vacuum abrasive cleaning units. These materials are recommended for production use. These materials flow well in the cleaning units, and are abrasive until they are too contaminated with paint chips to be useful. They could be reused if the paint could be separated. A photograph of a painted steel column (3 in. diameter) is shown in Figure 7. Test patches of the cleaning properties are shown in Figures 8 and 9 using Starblast and Black Diamond abrasive materials, respectively. No paint or lead was present (above the detection limit) on these surfaces, and the cleaned surface had a 0.5 to 1.0 mil surface profile. Another section of the same painted steel column was cleaned using each of the other materials.

Steel shot is too dense for practical purposes to use in the equipment for vacuum abrasive cleaning except in larger industrial units. A surface cleaned using this material is shown in Figure 10. This abrasive left paint on the surface; additional surface preparation would be required before painting. The surface profile of the cleaned surface was a "rough" texture 1.5 to 2.0 mils, which would require significant sanding before painting.

Armex is too soft even when mixed with five percent Starblast and requires much more air pressure than the test units could accommodate. Residual paint can be observed on the incompletely cleaned surface prepared with Armex (Figure 11). The surface profile was 0.5 mil. Possibly, the acid neutralizing (basic) properties of sodium bicarbonate could effectively neutralize acidic chemical paint strippers when mixed with a medium such as Starblast and could serve as a post-cleaning/neutralizing step.

Solidstrip is a marginal abrasive material, and it is about four times as expensive as Starblast or Black Diamond. A surface prepared with Solidstrip is shown in Figure 12; residual paint can be seen. The surface profile of the cleaned surfaces was 0.5 to 1.0 mil.

Silica Sand BX40 is an efficient and cost-effective abrasive medium that presents potential health problems. A vacuum abrasive cleaned area on steel is shown in Figure 13. The results are similar to the good results obtained with Starblast and Black Diamond. The surface profiles of metal and wood substrates after cleaning ranged from 0.5 to 1.0 mil, which require light sanding before painting.

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[12] Black Diamond, Foster-Dixiana Corporation, P.O. Box 2005, Columbia, SC 29202.

[13] Armex, Church & Dwight Co., Inc., P.O. Box CN5297, Princeton, NJ 08543-5297.

Figure 7. Exterior Steel Column.

Figure 8. Vacuum Abrasive Cleaned Steel Column, Starblast.

Figure 9. Vacuum Abrasive Cleaned Steel Column, Black Diamond.

Figure 10. Vacuum Abrasive Cleaned Steel Column, Steel Shot.

Figure 11. Vacuum Abrasive Cleaned Steel Column, Armex.

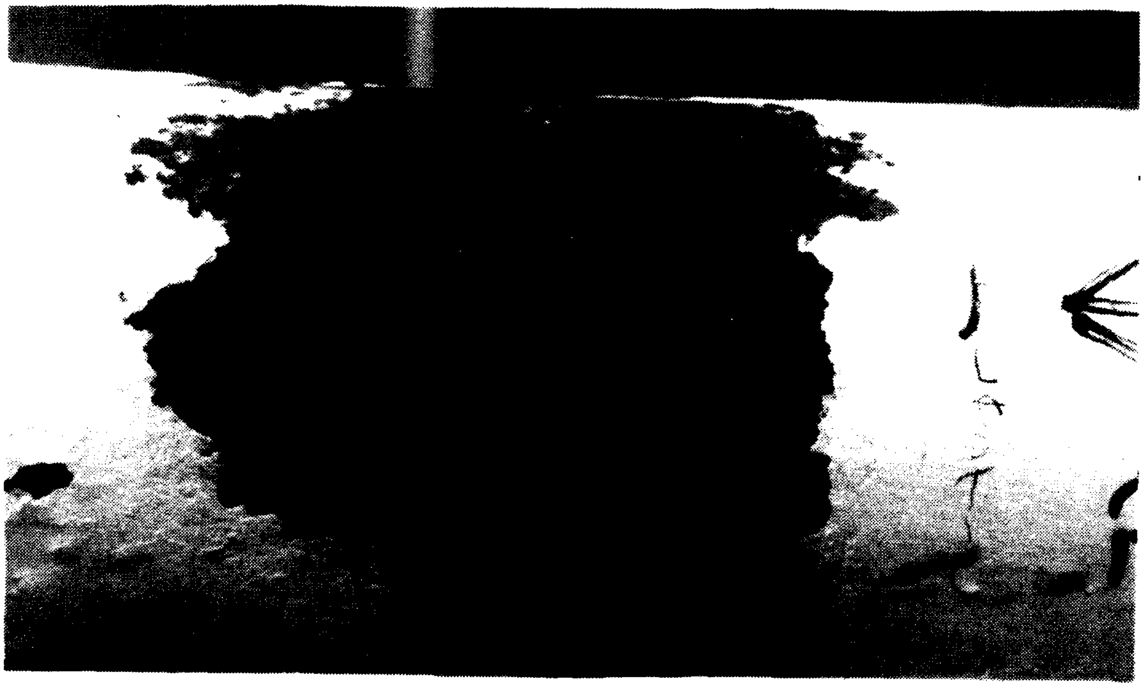

Figure 12. Vacuum Abrasive Cleaned Steel Column, Solidstrip.

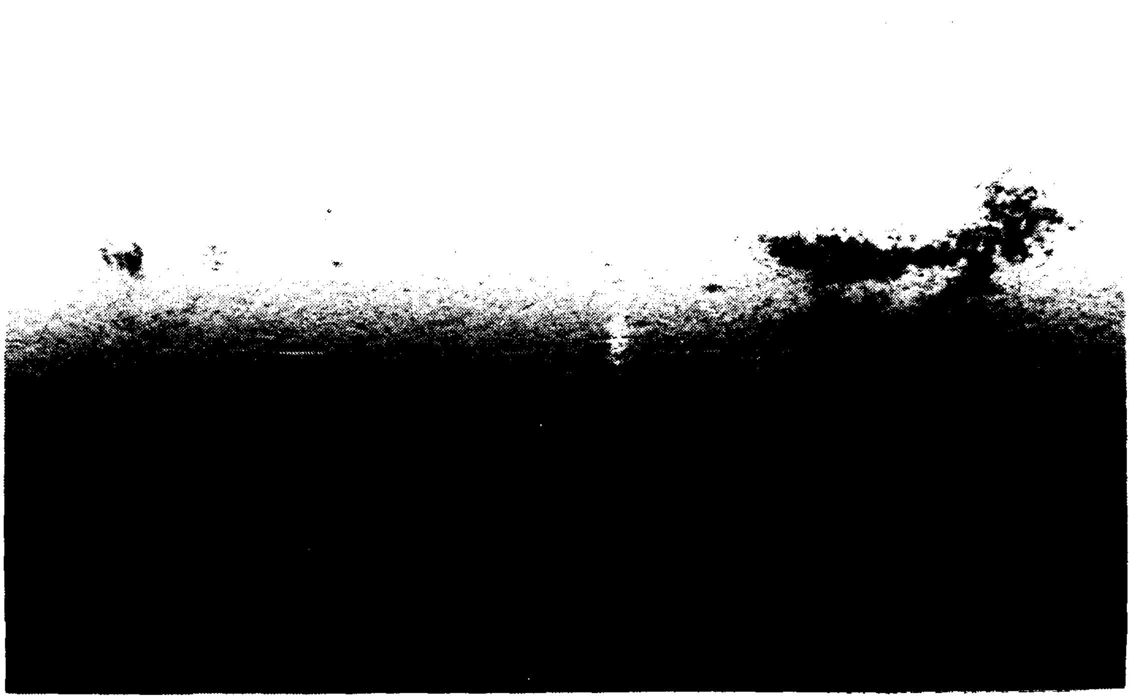

Figure 13. Vacuum Abrasive Cleaned Steel Column, Silica Sand.

In the following study, observations are based on experimental and practical experience with small vacuum abrasive units that are suitable for use on residential structures. Each of the abrasive materials was evaluated for removal rate on a range of substrates with each vacuum abrasive cleaning unit. The results are listed in Tables 1 through 3. Each abrasive material was used until the surface was 100 percent clean, or as close as possible, to evaluate the removal rates. The abrasive materials are rated below in order of decreasing rates of removal (see Tables 1 through 3).

1. Starblast, Black Diamond, BX40 Silica Sands
2. Steel Shot
3. Solidstrip
4. Armex.

The rate of consumption of abrasive media was evaluated for each abrasive. The results listed in Tables 1 through 3 are estimates based on the limited scale of this study. However, the abrasive materials were not "worn out" during the course of this study. More accurate estimates would require a much larger scale test. Based on these preliminary results, it is expected that Starblast, Black Diamond, and BX40 Silica Sand will become too contaminated with paint chips to be effective before the abrasive material is actually worn out or structurally rendered ineffective. Processing the mixture of abrasive material/paint chips to reclaim the abrasive material would prolong use of the abrasive material and reduce the mass of disposable hazardous waste. The reclaiming process and equipment require additional costs, which would have to be compared to disposing of the total mass of mixed abrasive material/paint chips. The total size of a lead paint removal contract would determine whether or not to use reclaiming equipment.

Overall Effectiveness

Each substrate, (pine, particle board, steel, galvanized steel, and aluminum) was efficiently cleaned using vacuum abrasive cleaning, but the zinc coating on galvanized steel was only partially removed to give a spotty appearance.

Where it is important to retain the thin (about 1 mil) zinc coating on galvanized steel, it is recommended that another method be used to remove the paint. For example, heat gun or chemical stripping treatment could be used to remove most of the paint, followed by very lightly cleaning the surface with vacuum abrasive cleaning. Cleaned aluminum surfaces appeared bright, smooth, and had an average of 1 mil surface profile. Any flat or round surface, regardless of material, can be cleaned with the proper brush accessories to produce a surface near-ready for painting (requiring only light sanding).

Any wood or metal surfaces that have pits or other surface irregularities will create a cleaning problem due to inaccessibility to the irregular surfaces. These irregularities include holes, punctures, and many other types of damage and would have to be addressed as they appear.

The differences between the vacuum abrasive cleaning units was "rate of removal." The units are listed below in order of decreasing rates of removal (Tables 1 through 3).

1. LTC Model 1030 and Zero Model C150-3
2. Vacu-Blast Model SB-03.

The units are mobile and capable of being used inside typical residential housing. Each manufacturer produces larger industrial units, which are too bulky to use inside houses. The LTC Model 1030, Zero Model C150-3, and Vacu-Blast SB-03 are recommended. Table 1 shows the Vacu-Blast unit is slightly slower (1.9 sq ft/hr) than the other units (2.0 sq ft/hr).

The film thickness of the paint on each substrate was not as important as the adhesion to the substrate, which was greater for aluminum, galvanized steel, and steel as compared to pine and particle board substrates. The differences in rate of paint removal were less important with abrasive cleaning of substrates, but the heat gun study reported in Chapter 6 will reveal significant differences.

General Safety

The general safety of each vacuum abrasive unit is reflected in the lead monitoring data presented in Tables 1 through 3. The lead levels near the operator were below the detection limit. The working environment is very safe for operators and other workers since insignificant levels of lead enter the atmosphere. With the exception of silica sand, none of the abrasive media posed a potential health problem.

The machines were pneumatic and did not require electrical power near the work. The air pressure was supplied by compressors outside the shop and can likewise be supplied for residential housing. The vacuum abrasive machines can be operated inside or outside of a house with complete safety.

As a precaution, it is recommended that the operator of the vacuum abrasive cleaning equipment use a dust filtering (below 1.0 micron) mask that fits over the nose and mouth.

The maximum distance from the vacuum cup to the substrate surface is critical since it was demonstrated that abrasive media mixed with lead-based paint could leak into the work area. More specifically, when the vacuum cup was suddenly withdrawn more than 2 inches from the substrate, surface particulate fell on the floor. This potential problem could be eliminated by installing a vacuum pressure switch near the cup, so that when the cup is withdrawn more than 2 inches from the surface, the air pressure supplying the flow of abrasive media would be shut off.

6 USING A HEAT GUN TO REMOVE LEAD-BASED PAINT

All metal substrates had the same effect of acting as a "heat sink" for the heat guns, and the effect was to reduce the heating rate and increase the time required to reach blister temperature. Ten test patches of 3 in. by 12 in. were used in each case.

Blister Temperature

Tests for "time to reach blister temperature" were performed to determine the relative speed of paint removal. These tests were performed because it was observed that the paint was removed at the "blister temperature." In each case, the paint consisted of an alkyd resin binder on painted metal and wood surfaces. A calibrated thermocouple attached to a unit with a digital temperature scale was placed directly on the surface. The temperature and time were recorded when the paint blistered. The results follow:

Aluminum, Galvanized and Steel Substrates	
Black & Decker Model 6750[14]	212 °C/25 sec.
Milwaukee Model 750[15]	240 °C/100 sec.
Master Model HG501A[16]	230 °C/15 sec.

Particle Board and Pine Wood Substrates	
Black & Decker Model 6750	200 °C/20 sec.
Milwaukee Model 750	218 °C/28 sec.
Master Model HG501A	210 °C/10 sec.

The lesson from this test was that a metal substrate requires 5 to 72 seconds more cleaning time and 22 to 28 °C greater temperature compared to a less thermally conductive substrate such as wood.

Overall Effectiveness

All wood test patches showed signs of over-heating as judged by darken areas. Particle board proved to be the most heat-sensitive substrate. Figure 14 shows a photograph of the particle board surface before testing. Figure 15 (Black & Decker Model 6750), Figure 16 (Milwaukee Model 750), and Figure 17 (Master Model HG501A) show the surfaces after treatment. Charred areas are obvious in all three test patches, but the Black & Decker heat gun produced the greatest amount of charring followed by the Master and Milwaukee. The appearance of the initial paint can be seen uncharred in the photographs. Overall, the heat guns are rated below in order of decreasing rates of paint removal:

1. Master Model HG501A
2. Milwaukee Model 750, Black & Decker Model 6750.

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[14] Black & Decker (U.S.) Inc., 626 Hanover Pike, Hampstead, MD 21074.

[15] MHT Products, Inc., 944 North 45th Street, Milwaukee, WI 53208.

[16] Master Appliance Corp, Racine, WI.

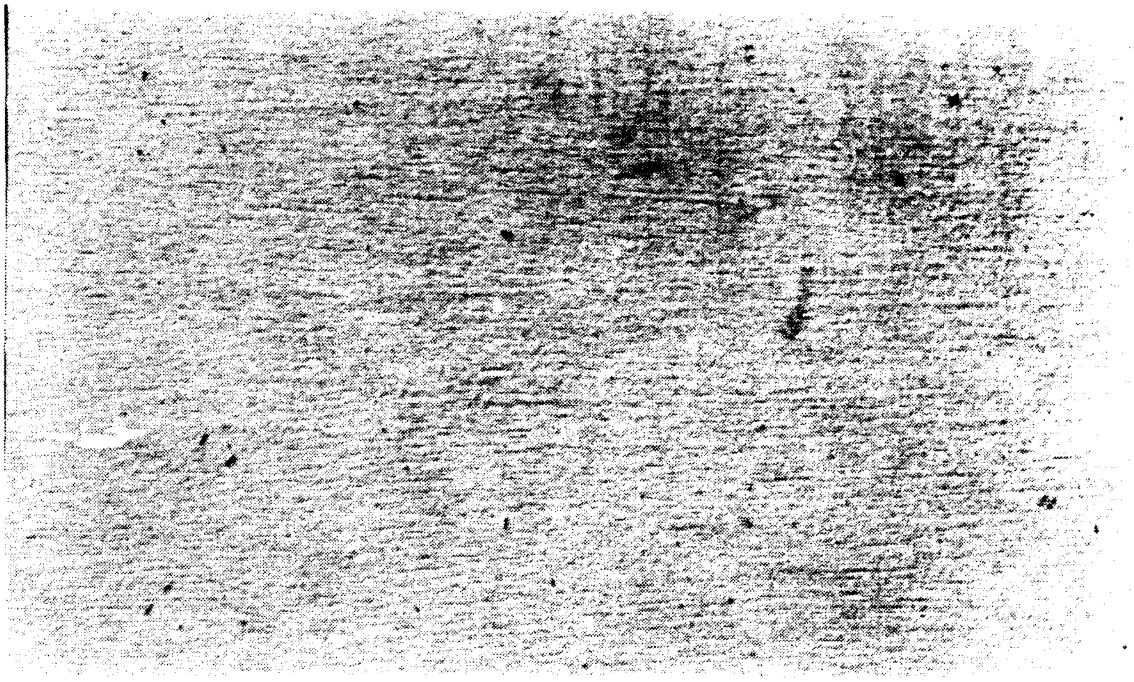

Figure 14. Untreated, Painted Particle Board.

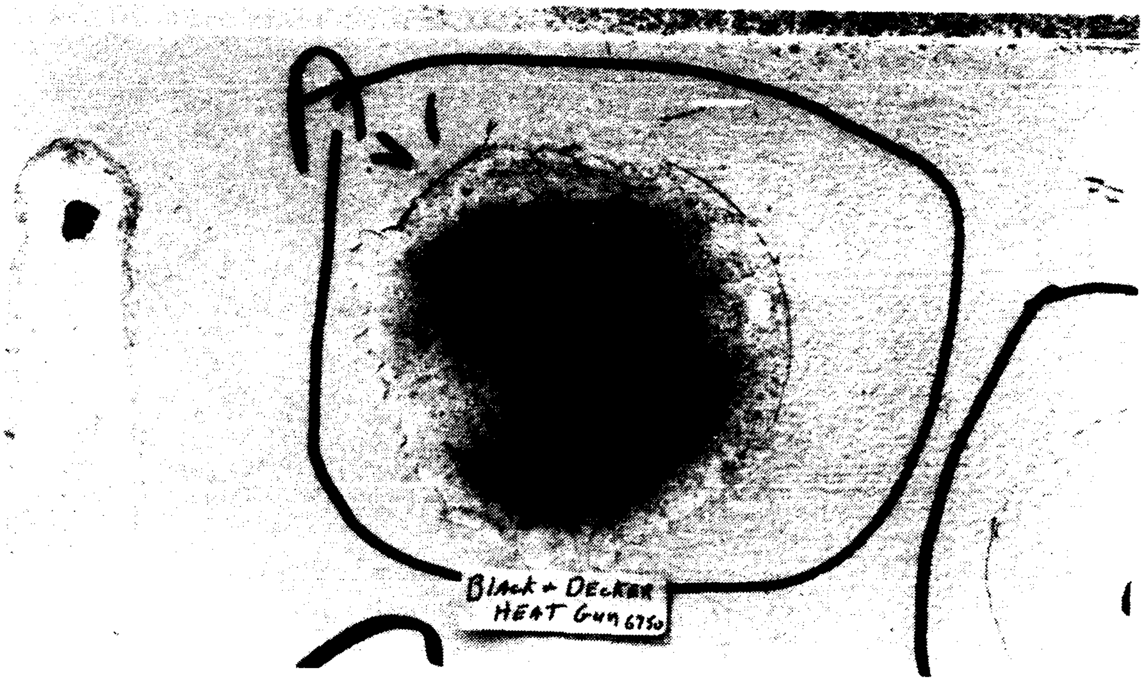

Figure 15. Black & Decker Heat Gun Blistered Particle Board.

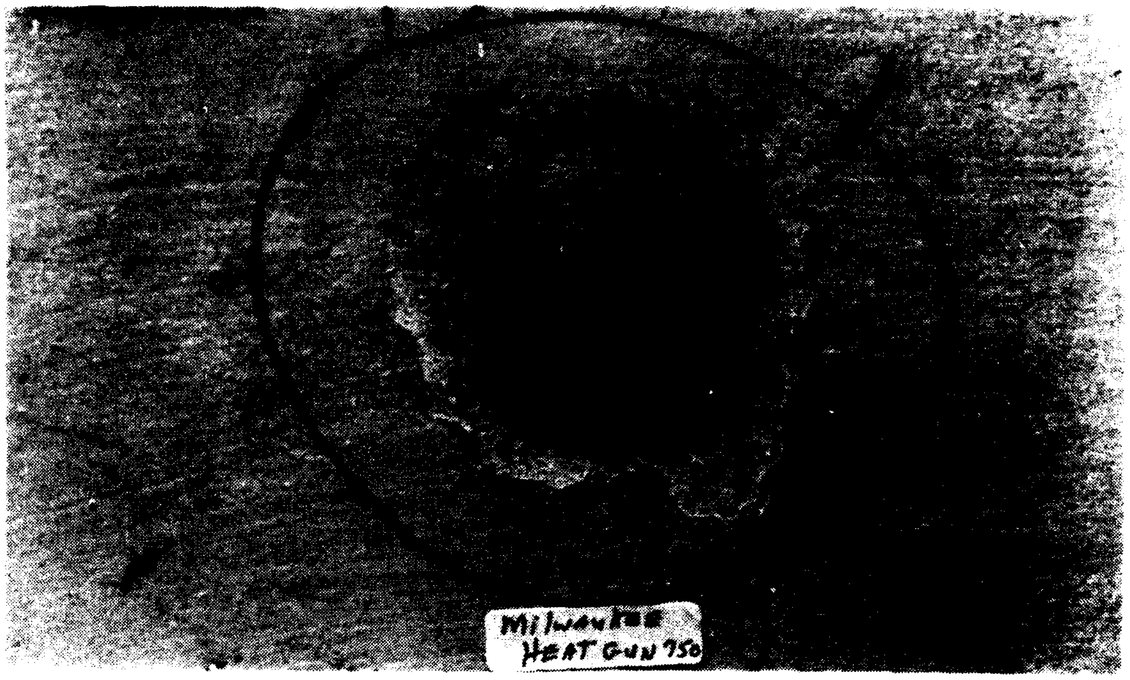

Figure 16. Milwaukee Heat Gun Blistered Particle Board.

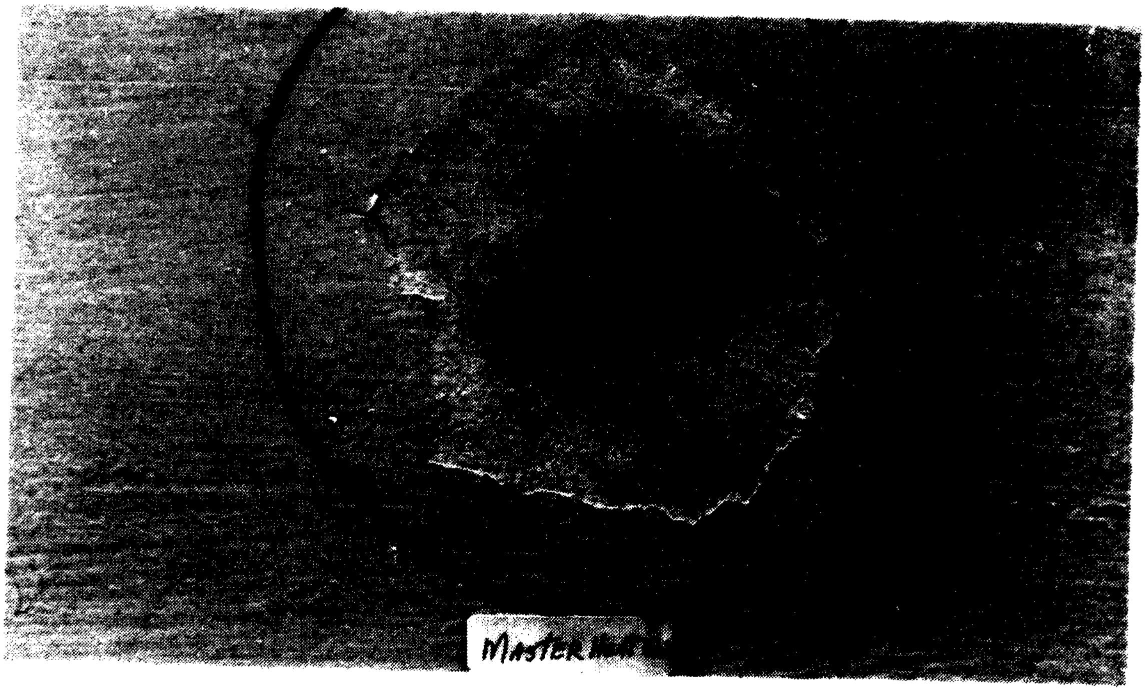

Figure 17. Master Heat Gun Blistered Particle Board.

They are rated below in order of decreasing tendency to char or burn paint:

1. Black & Decker 6750
2. Master Model HG501A
3. Milwaukee Model 750.

Heat gun cleaning is faster than vacuum abrasive cleaning of wood and slower for metal, but lead is not sufficiently removed from substrates using the heat guns (Table 5). Therefore, heat guns alone are not practical options for removing lead-based paint. Photographs of surfaces after heat gun treatment and paint removal are shown in Figures 18, 19, and 20. The method of heat gun treatment consists of blistering the paint while scrapping the surface. The scrapping tool is attached to the nozzle of the gun. A thin residual film of paint can be seen in each figure which cannot be removed without severe charring of the particle board surface. No visible smoke was observed during this process, but air monitoring near the operator revealed an averaged 0.04 mg/m^3 of lead in the air. The averaged level of lead in the air was the same for all substrates, indicating that lead enters the air during heat gun treatment. If many heat gun units were operated together in a residential structure, the accumulative effect could be unsafe for operators. In any case, caution is urged for large-scale use of heat guns.

The lead levels measured during air monitoring were acceptable as long as the working temperatures (shown above) were not significantly surpassed. Higher temperatures caused smoke and unacceptable lead particulate levels in the atmosphere. The important lessons from using heat guns are:

1. temperatures must be monitored and no smoke can be generated; proper working temperature can be maintained by selecting the proper model and electrical power.

2. metal substrates require much longer time for paint removal compared to wood substrates due to the diffusion of heat into the metal.

3. protective breathing devices should be worn by all operators to filter lead particulate and adsorb products of decomposition.

General Safety

The substrates were cleaned with extreme care not to overheat the paint. From experiments, the heat gun method of cleaning substrates is subject to the operator's skill, and the generation of some air-borne particulate is unavoidable. A dust filtering mask is mandatory for all operators and personnel in the work area. The mask must be tested to ensure it will protect the operator from lead particulate. The heat gun method is generally evaluated as "marginal" and much caution should be employed during its use.

Table 5

Results of Heat Gun Cleaning

Equipment	Electrical Consumption[1], (KWH/sq ft)	Substrate Type	Rate of Removal (sq ft/hr)	Lead Levels	
				Air (mg/m^3)	Substrate, before/after (mg/cm^2)
Black & Decker Model 6750	0.28	Exterior Wood	3.57	0.04	3.8/1.7
	0.28	Particle Board	4.00	0.04	4.4/2.8
	1.12	Aluminum	1.00	0.04	2.5/1.7
	1.12	Gavanized	1.00	0.04	2.2/1.7
	1.12	Steel		0.04	2.1/1.1
Milwaukee Model 750	0.44	Exterior Wood	4.00	0.04	4.0/1.3
	0.44	Particle Board	5.88	0.04	4.2/2.7
	1.68	Aluminum	1.00	0.04	2.5/1.5
	1.68	Galvanized	1.00	0.04	2.2/1.2
	1.68	Steel	1.00	0.04	2.4/2.2
Master Heat Gun Model HG501A	0.33	Exterior Wood	4.00	0.04	4.4/0.9
	0.33	Particle Board	5.88	0.04	4.2/2.3
	1.12	Aluminum	1.51	0.04	2.5/1.9
	1.12	Galvanized	1.51	0.04	2.2/1.5
	1.12	Steel	1.51	0.04	2.9/0.9

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[1] Residential rate of $0.07/KWH as of July 21, 1991 in Atlanta, GA.

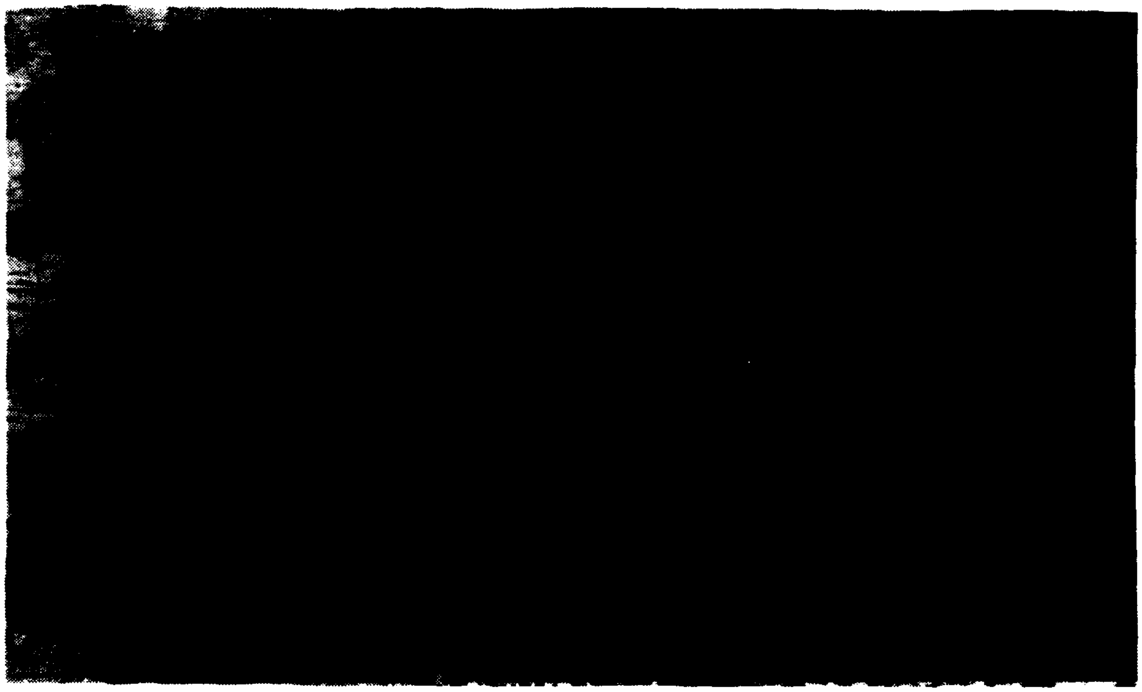

Figure 18. Black & Decker Heat Gun Cleaned Particle Board.

Figure 19. Milwaukee Heat Gun Cleaned Particle Board.

Figure 20. Master Heat Gun Cleaned Particle Board.

7 COMBINED HEAT GUN AND VACUUM ABRASIVE REMOVAL

A combination of heat gun removal of paint followed by "light" vacuum abrasive cleaning is faster than the vacuum abrasive method alone. The removal rate of the combined method is significantly higher for both wood and metal substrates. The advantage of using the composite method is faster removal of paint while rendering a lead-free substrate, which cannot be maintained consistently with heat guns alone. The efficiency of light abrasive cleaning after heat gun treatment of particle board can be seen in photographs taken after vacuum abrasive cleaning. Figures 21 (Black & Decker), 22 (Milwaukee), and 23 (Master) show the vacuum abrasive cleaned test patches of Figures 18 through 20. From these photographs, it can be seen that the surfaces are free from paint, smooth without serious roughness, and that light sanding would render them ready for painting. The slightly charred areas resulted from heat gun cleaning.

A lead-based alkyd painted steel substrate was cleaned with a heat gun and post-vacuum abrasive (LTC Model 1030) using Starblast abrasive material; the results are shown in Figures 24 through 26. In these figures, the paint (left side of photograph) is heat gun treated by Black & Decker, Milwaukee, and Master units, respectively. It can be seen that the paint is blistered, but not completely removed and is blistered to a lesser extent on steel than on the previously cleaned particle board. The effect of thermal diffusion through a metal substrate and reduction of heat gun cleaning efficiency is shown in each figure. It can also be observed that post-vacuum abrasive cleaning with Starblast abrasive material removes the paint and prepares the surface sufficiently for repainting. It was observed that the combination of heat gun and vacuum abrasive cleaning provides faster paint removal than either method alone as reported in Table 6. Table 7 contains cost estimates and comparisons.

Figure 21. Post-Abrasive Cleaning of Black & Decker Heat Gun Cleaned Particle Board.

Figure 22. Post-Abrasive Cleaning of Milwaukee Heat Gun Cleaned Particle Board.

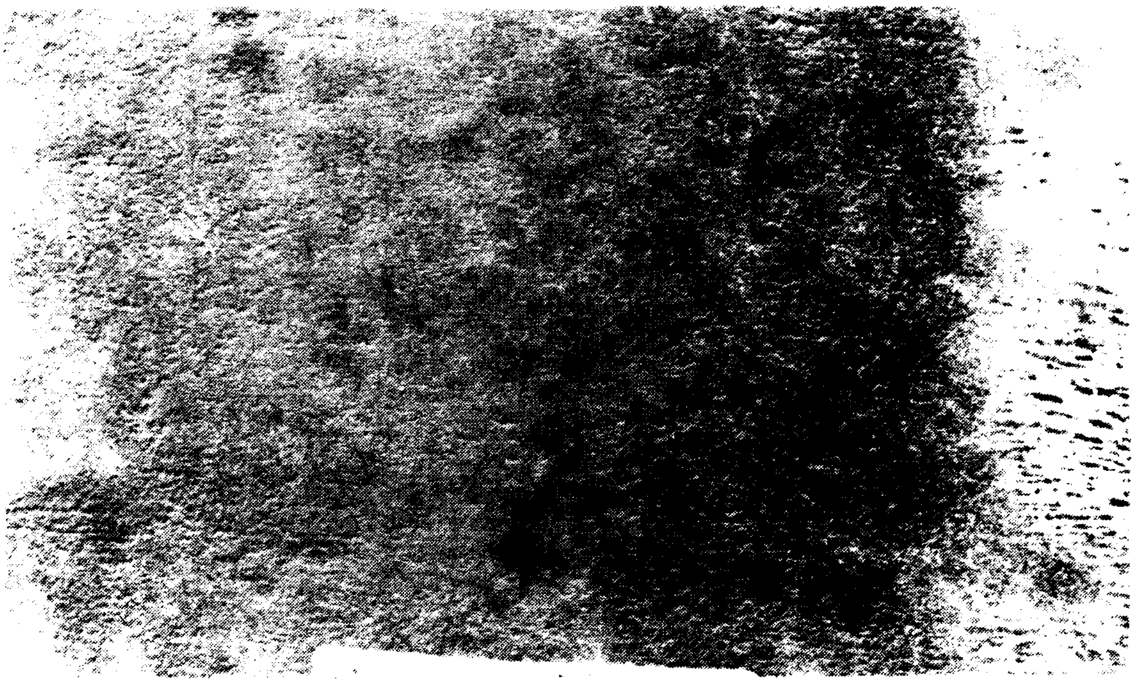

Figure 23. Post-Abrasive Cleaning of Master Heat Gun Cleaned Particle Board.

Figure 24. Post-Vacuum Abrasive Cleaning of Black & Decker Heat Gun Cleaned Steel.

Figure 25. Post-Vacuum Abrasive Cleaning of Milwaukee Heat Gun Cleaned Steel.

Figure 26. Post-Vacuum Abrasive Cleaning of Master Heat Gun Cleaned Steel.

Table 6

Results of Composite Heat Gun—Vacuum Abrasive Cleaning

Substrate Type	**Rate of Removal heat gun + vacuum cleaning hr/sq/ft**	**Total Remov Rate, sq ft/hr**
Pine Wood and Particle Board	(B&D)[1] 0.28+0.08 (LTC)[2] = 0.36	2.78
	(MIL) 0.28+0.08 (LTC) = 0.36	2.78
	(MAS) 0.25+0.08 (LTC) = 0.33	3.03
Aluminum	(B&D) 1.06+0.20 (LTC) = 1.26	0.79
	(MIL) 1.00+0.18 (LTC) = 1.18	0.85
	(MAS) 0.66+0.17 (LTC) = 0.83	1.20
Galvanized	(B&D) 1.06+0.20 (LTC) = 1.26	0.79
	(MIL) 1.00+0.18 (LTC) = 1.18	0.85
	(MAS) 0.66+0.17 (LTC) = 0.83	1.20
Steel	(B&D) 1.06+0.20 (LTC) = 1.26	0.79
	(MIL) 1.00+0.18 (LTC) = 1.18	0.85
	(MAS) 0.66+0.17 (LTC) = 0.83	1.20

Note 1 - B&D, Black & Decker Model 6750
MIL, Milwaukee Model 750
MAS, Master Model HG501A
LTC, LTC International Company Model 1030.
Note 2 - Abrasive media, Starblast.

Table 7

Cost Estimates of Vacuum Abrasive and/or Heat Gun Cleaning of Lead-Based Paint

Equipment	Substrate	Cost $/sq ft		Disposal Cost $/sq ft	Total Cost $/sq ft
		Media ($/sq ft)	Labor ($9.25/hr)		
LTC Inter-National Co. Model 1030	Aluminum	0.0183	4.62	0.005	4.64
	Galvanized	0.0183	4.62	0.005	4.64
	Steel	0.0183	4.62	0.005	4.64
	Ext. Wood	0.0183	4.62	0.005	4.64
	Part. Board	0.0183	4.62	0.005	4.64
Black & Decker, Model 6750	Aluminum		9.80	0.001	9.80
	Galvanized		9.80	0.001	9.80
	Steel		9.80	0.001	9.80
	Ext. Wood		2.59	0.001	2.59
	Part. Board		2.31	0.001	2.31
Milwaukee, Model 750	Aluminum		9.25	0.001	9.80
	Galvanized		9.25	0.001	9.80
	Steel		9.25	0.001	9.80
	Ext. Wood		2.59	0.001	2.59
	Part. Board		2.31	0.001	2.31
Master Model HG501A	Aluminum		6.10	0.001	6.10
	Galvanized		6.10	0.001	6.10
	Steel		6.10	0.001	6.10
	Ext. Wood		2.31	0.001	2.31
	Part. Board		1.57	0.001	1.57
Black & Decker LTC	Aluminum	0.0183	14.43	0.005	14.45
	Galvanized	0.0183	14.43	0.005	14.45
	Steel	0.0183	14.43	0.005	14.45
	Ext. Wood	0.0183	3.33	0.005	3.35
	Part. Board	0.0183	3.33	0.005	3.35
Milwaukee LTC	Aluminum	0.0183	10.91	0.005	10.91
	Galvanized	0.0183	10.91	0.005	10.91
	Steel	0.0183	10.91	0.005	10.91
	Ext. Wood	0.0183	3.23	0.005	3.25
	Part. Board	0.0183	3.23	0.005	3.25
Master LTC	Aluminum	0.0183	7.67	0.005	7.69
	Galvanized	0.0183	7.67	0.005	7.69
	Steel	0.0183	7.67	0.005	7.69
	Ext. Wood	0.0183	2.77	0.005	2.79
	Part. Board	0.0183	2.77	0.005	2.79

Note 1 - Disposal of lead-based paint based on $0.015/lb in Georgia July 18, 1991.

Note 2 - Electrical power costs not included, but residential for Atlanta, GA as of July 19, 1991 is $0.07/ KWH.

Note 3 - Lead monitoring is not included in this cost estimate.

8 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Although heat guns remove lead paint quickly (over 3.5 sq ft/hr on wood), they do not completely remove lead paint that has migrated into the porous structure of the wood surface. Vacuum abrasive blast cleaning is slower, about 2 sq ft/hr with proper abrasives, but leaves a lead-free surface.

It became apparent during this study that a thin layer of wood must be removed from any wood surface to assure complete removal of lead. Apparently, the lead enters the cellular structure of the wood and does not remain on the surface. Therefore, an abrasive method is necessary to completely remove lead from porous substrates.

2. A combination method, heat gun treatment followed by vacuum abrasive blast cleaning, provides the most effective method (in both labor and cost) of lead paint removal. The cost data in Table 7 shows that the vacuum abrasive cleaning is most cost effective for cleaning aluminum, galvanized steel, and steel, at $4.64/sq ft, while a combination method is more cost effective for cleaning pine wood and particle board.

3. The rate of removal of lead-based paint was not significantly affected by film thicknesses within the range of thickness encountered in this study. The diameter of the abrasive particles (3.5 mils to 39 mils), is greater than the total thickness of the coatings, and the particles quickly penetrate the coating films down to the substrate surfaces.

4. Of the six abrasive media types evaluated in the vacuum blasting study, two were judged to be generally useful: Starblast and Black Diamond. Silica sand was effective as an abrasive, but its use presents potential health hazards. Armex (bicarbonate of soda) was judged to be too soft for practical use. Solidstrip, a plastic medium, is about four times as expensive as other useful media. Steel shot was not appropriate for use in the smaller vacuum abrasive cleaning units due to its high density.

5. The zinc coating on galvanized steel was partially removed by abrasive cleaning, but the surface was not roughened. None of the other substrates were significantly roughened by abrasive cleaning.

6. The most significant cost after equipment purchase is labor. However, labor could become the largest cost for a substantive lead abatement project encompassing thousands of square feet of surface for abatement.

Recommendations

1. The heat gun method is best used to remove lead-based paint without creating a large volume of debris. However, this method should be followed with a light treatment of vacuum abrasive blasting to remove residual lead. Abrasive media would necessarily be mixed with paint only during the removal of the residual paint on surfaces. This advantage will reduce hazardous waste disposal costs by as much as 50 percent.

This study did not address the use of chemical paint strippers. However, vacuum abrasive cleaning should be considered as a final clean-up step where chemical stripping leaves residual lead on the wood.

2. If a heat gun treatment is not carefully controlled, paint will become too hot and decompose, producing hazardous lead fumes. Care must be taken to use the minimum heat required to loosen the paint from the substrate, and to avoid charring the wood or producing smoke.

3. It is recommended that vacuum abrasive blast units be equipped with a switch located at the vacuum abrasive cleaning cup/brush as a safety feature to eliminate the potential of paint chips escaping from the cup.

METRIC CONVERSION TABLE

1 in. = 2.54 cm
1 ft. = 0.305 m
1 lb. = 0.453 kg
1 cu ft = 0.028 m^3
1 sq ft = 0.093 m^2
1 gal = 3.78 L
°F = (°C + 17.78) x 1.8
°C = 0.55(°F-32)
1 oz = 28.35 g
1 cu in. = 16.39 cm^3
1 sq in. = 6.54 cm^2

APPENDIX A: Material Safety Data Sheet on Silica Sands

MATERIAL SAFETY DATA SHEET
(COMPLIES WITH 29 CFR 1910.1200)

IDENTIFICATION

NAME
Silica sands, Blast Sands, Foundry Sands, Filter Sands

SYNONYMS
Quartz sands, Crystalline Silica

CAS NAME
Crystalline Silica, Quartz

MANUFACTURER
Foster Dixiana Corporation

ADDRESS
P.O. Box 2005
Columbia, South Carolina 29202

PRODUCT INFORMATION TELEPHONE
(803) 794-7872

MEDICAL EMERGENCY TELEPHONE
(803) 784-2872

TRANSPORTATION EMERGENCY TELEPHONE
(803) 794-2872

CHEMICAL FAMILY
High purity crystalline silica.

FORMULA
Chiefly Si02 with no more than 1.6% total impurities.

CAS REGISTRY NUMBER
14808-60-7

PHYSICAL DATA

MOLECULAR WEIGHT - 60.1

MELTING POINT - 1600 degrees C (2912 degrees F)

BOILING POINT - (760 mm Hg): 2230 degrees C (4046 degrees F)

SPECIFIC GRAVITY - 2.65

PERCENT, VOLATILE BY VOLUME - Zero

EVAPORATION RATE (Butyl Acetate = 1) - Zero

VAPOR DENSITY - NOT APPLICABLE

WATER SOLUBILITY - NOT SOLUBLE

pH EFFECTS - Not applicable, not soluble

FORM - FREE FLOWING, GRANULAR SOLID

COLOR - GRAYISH WHITE

ODOR - ODORLESS

HAZARDOUS INGREDIENTS

MATERIAL - HIGH PURITY QUARTZ (Si03), 98.5% MINIMUM PURITY
Minimum quartz content - 98.5%

HAZARDOUS REACTIVITY

STABILITY - STABLE

INCOMPATIBILITY - Contact with powerful oxidizing agents such as FLUORINE, CHLORINE TRIFLUORIDE, MANGANESE TRIOXIDE, OXYGEN DIFLUORIDE, MANGANESE TRIOXIDE, OXYGEN DIFLOURIDE, etc. may cause fires.

SPECIAL PRECAUTIONS - Crystaline silica is attacked by HYDROGEN FLUORIDE (or HYDROFLUORIC ACID)

DECOMPOSITION - WILL NOT OCCUR

POLYMERIZATION - WILL NOT OCCUR

FIRE AND EXPLOSION INFORMATION

FLASH POINT - WILL NOT BURN

FLAMMABLE LIMITS IN AIR, % BY VOLUME
LOWER - NOT APPLICABLE
UPPER - NOT APPLICABLE

AUTODECOMPOSITION TEMPERATURE - NOT APPLICABLE

FIRE AND EXPLOSION HAZARDS - NONE, MAY BE USED TO EXTINGUISH FIRES.

EXTINGUISH MEDIA - USED TO EXTINGUISH FIRES NO SPECIAL FIRE FIGHTING INSTRUCTIONS

HEALTH HAZARD INFORMATION

PRINCIPAL HEALTH HAZARDS - Crystalline silica can affect the body if it is inhaled.

The product, as shipped, does not pose any inhalation health hazard because it contains essentially no particles in the respirable size range. However, during shipping, handling, or use, the sand particles may be broken down to the respiratory size range that may be inhaled. These dusts are hazardous to the respiratory system because of the presence of free quartz. Toxic effects noted in animals include, for acute exposures, alveolar damage with pulmonary edema. In Chronic exposure tests, a fibrosis was noted.

The predominant effect of overexposure to airborne respirable quartz in humans is silicosis. Silicosis is a chronic fibrotic lung disease characterized by formation of silica containing scar tissue in the lungs with symptoms of shortness of breath and/ or difficulty in breathing as well as other respiratory symptoms. Gross acute overexposure to quartz by inhalation may cause fatality. Characteristic X-ray changes are noted. People with pre-existing lung diseases may have increased susceptibility to the health effects of respirable dusts.

CARCINOGENICITY:
Silica Sands, Blast Sands, Foundry Sands and Filter Sands contain crystalline silica. Crystalline silica is not listed on the NTP or OSHA list of carcinogens, but is listed by the IARC. IARC has determined that there is sufficient evidence for the carcinogenicity of crystalline silica to experimental animals and limited evidence for the carcinogenicity of crystalline silica to humans. "Limited evidence" means that a casual relationship is possible, but that alternative explanations such as a chance, bias, or confounding factors cannot adequately be excluded.

EXPOSURE LIMITS:
NOTE, Exposure limits must be calculated form measurements of particle sizes, quantity, and percent quartz made in employee's breathing zone during work.

OSHA PEL	ACGIH TLV
.01 mg/m3	.10 mg/m3

The OSHA value is an 8 hour time weighted average.

SAFETY PRECAUTIONS - AVOID BREATHING RESPIRABLE DUSTS FROM THESE PRODUCTS.

EMERGENCY AND FIRST AID PROCEDURES -
EYE EXPOSURE: If silica dust gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper eye lids occasionally. If irritation is present after washing, get medical attention.
BREATHING: If a person breathes in large amounts of crystalline silica dust, move the exposed person to fresh air at once.

PERSONNEL PROTECTION INFORMATION:

GENERALLY APPLICABLE CONTROL MEASURES
Good general ventilation should be provided to keep the concentrations of any respirable dusts generated below the cited exposure limits.

PERSONNEL PROTECTIVE EQUIPMENT
In case exposure limits are likely to be exceeded, use an NIOSH, OSHA or MSHA permissible respirator. If this material is used in sandblasting, the use of leather gloves and a NIOSH/OSHA approved Type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode are recommended.

DISPOSAL INFORMATION

SPILLS, LEAKS, RELEASE
Sweep up spillage and dispose of properly. Avoid respiration of dust and use appropriate NIOSH/OSHA approved respirator.

WASTE DISPOSAL
If local regulations permit, sand may be disposed of in land fill operations or other suitable areas. Contact the local, state, and federal authorities in your area for specific information.

SHIPPING INFORMATION - Sand is not regulated as a hazardous material.

DATE OF LATEST REVISION/REVIEW - 10/89

The data in this Material Safety Data Sheet relates only to the specific material designated herein and does not relate to use in combination with any other material or in any process.

The information herein is given in good faith but no warrenty, express or implied is made.

MIAMI BRANCH
4101 N.W. [illegible] AVE.
MIAMI, FLORIDA [illegible]
(305) [illegible]

JACKSONVILLE BRANCH
[illegible] EAST [illegible] ST.
JACKSONVILLE, FLORIDA [illegible]
(904) [illegible]

Standard Sand & Silica Company
POST OFFICE BOX 36 • HWY. 17 & 92 NORTH
DAVENPORT, FLORIDA 33837 • (813) 422-1171

WARNING AND RECOMMENDED PROCEDURES WHEN USING SILICA PRODUCTS

Silica sand is a part of your everyday experience. The list of products or materials made with or from silica is endless, and with proper use is harmless. If not handled with caution, raw silica sand when used in sanding operations or in processes that may cause silica dust to form, could, when inhaled, cause delayed lung injury known as silicosis.

YOUR HEALTH

Silicosis is a slowly progressive disease which is caused by breathing excessive silica dust in the course of a work day, and is compounded with exposure on a frequent basis. One of the difficulties with the harmful silica dust is that the particle is so small you cannot see it. If you smoke and are exposed to silica dust on a continuing basis, you may face an increased risk of impaired health. Smoke from tobacco taken into the lungs is a health hazard. Fine silica dust places a second burden on your respiratory system. The following medical symptoms could indicate a possible health problem.

1. Shortness of breath on effort.
2. Difficulty breathing.
3. Coughing and phlegm production.
4. Getting more colds or infection than usual.

We seriously recommend the following precautions when you are involved with the dust emitted from raw silica products:

RESPIRATORS

1. Respirators should be worn when working with raw silica sand. Make sure you use the respirator according to manufacturer's instructions.
2. Respirator should fit properly. Cover the air intake area and inhale. If you form suction inside the respirator this should

indicate proper fit.

3. Many respirators are good only for a limited time. Make sure your respirator is doing the job. If it is too difficult to breathe, this may be an indication that it needs cleaning or filter replacement.

4. Inspect your respirator at least once per shift, and make sure it is in good condition. If you are using a reusable respirator, clean it before or after every shift that you use the respirator.

5. If you are self-employed, make sure the respirator you are using meets the requirement for silica dust. Contact your local safety supply or OSHA office for the best respirator suited to your work.

HOUSEKEEPING

Areas where silica sand is used should be kept as free from silica dust as possible.

1. When sweeping floors or wiping off equipment and other surfaces, it is recommended that you dampen the dust or sand with water spray to help avoid breathing silica dust.

2. If possible, a vacuum system may be used to control dust.

3. Keep an eye on equipment used with silica sand. Preventative maintenance helps in the control of dust.

Compressed air should never be used for cleaning up dust areas. This caused more dust contamination in the air you breathe.

PERSONAL HYGIENE

1. Any food, drink or chewing product should be protected from silica dust.

2. Personal cleanliness is important. Wash all exposed body areas after working in a silica dust area. When you remove work clothes, do not shake them about, just fold them up until cleaning.

3. If appropriate vacuum equipment is available it is recommended that clothing be vacuumed.

4. It is recommended that excess facial hair growth be discouraged because your hair will actually collect the dust you work around all day, and interfere with respirator fit.

Although silica dust in excessive quantity is harmful, by removing it from clothing, skin and hair, you will help to remove the possibility of inhaling the dust and the over exposure associated with it.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44-R1387

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing,
Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME: Standard Sand & Silica Company

EMERGENCY TELEPHONE NO.: 1-800-367-4378

ADDRESS (Number, Street, City, State, and ZIP Code): P. O. Box 35 Davenport, Florida 33837

CHEMICAL NAME AND SYNONYMS: Silicon Dioxide

TRADE NAME AND SYNONYMS: Silica Products

CHEMICAL FAMILY: Earth Minerals

FORMULA: SIO_2

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS		%	TLV (Units)	ALLOYS AND METALLIC COATINGS		%	TLV (Units)
PIGMENTS	None		N/A	BASE METAL	None		N/A
CATALYST	None		N/A	ALLOYS	None		N/A
VEHICLE	None		N/A	METALLIC COATINGS	None		N/A
SOLVENTS	None		N/A	FILLER METAL PLUS COATING OR CORE FLUX	None		N/A
ADDITIVES	None		N/A	OTHERS	None		
OTHERS	None		N/A				

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
* Dust-(Respirable)-at time of processing *	1	1.1Mg/M

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	N/A	SPECIFIC GRAVITY (H_2O=1)	2.65
VAPOR PRESSURE (mm Hg.)	N/A	PERCENT, VOLATILE BY ~~VOLUME~~ (%)	None
VAPOR DENSITY (AIR=1)	N/A	EVAPORATION RATE (______ =1)	none
SOLUBILITY IN WATER			

APPEARANCE AND ODOR: Sand & Gravel-No Odor

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used):

FLAMMABLE LIMITS: N/A — Lel — Uel

EXTINGUISHING MEDIA: No fire or explosive danger

SPECIAL FIRE FIGHTING PROCEDURES: None

UNUSUAL FIRE AND EXPLOSION HAZARDS: None

SECTION V · HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE As specified in OSHA Standard #1910.1000 Table Z-3

EFFECTS OF OVEREXPOSURE Prolonged exposure to respirable dust may cause delayed lung injury (silicosis)

EMERGENCY AND FIRST AID PROCEDURES None

SECTION VI · REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	

INCOMPATIBILITY *(Materials to avoid)*

HAZARDOUS DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII · SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Cleanup with use of dustless method

WASTE DISPOSAL METHOD

Any approved solid waste disposal method

SECTION VIII · SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION *(Specify type)* As specified in OSHA Standard #1910.134

VENTILATION	LOCAL EXHAUST	SPECIAL
	MECHANICAL *(General)*	OTHER

PROTECTIVE GLOVES	EYE PROTECTION

OTHER PROTECTIVE EQUIPMENT

SECTION IX · SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Use of dustless system of storage and cleanup

OTHER PRECAUTIONS

Practice good housekeeping

APPENDIX B: Fine Sieves

Sieve Designation U.S. Series Standard	Alternate	Wire Dia. (Nominal)	Tyler Screen Equiv. Desig.
5.6mm	3½	1.68mm	3½ mesh
4.75	4	1.54	4
4.00	5	1.37	5
3.35	6	1.23	6
2.80	7	1.10	7
2.36	8	1.00	8
2.00	10	0.900	9
1.70	12	0.810	10
1.40	14	0.725	12
1.18	16	0.650	14
1.00	18	0.580	16
850μm	20	0.510	20
710	25	0.450	24
600	30	0.390	28
500	35	0.340	32
425	40	0.290	35
355	45	0.247	42
300	50	0.215	48
250	60	0.180	60
212	70	0.152	65
180	80	0.131	80
150	100	0.110	100
125	120	0.091	115
106	140	0.076	150
90	170	0.064	170
75	200	0.053	200
63	230	0.044	250
53	270	0.037	270
45	325	0.030	325
38	400	0.025	400

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29th Area Support Group
ATTN: AERAS-FA 09054
100th Support Group
ATTN: AETT-EN-DPW 09114
222d Base Battalion
ATTN: AETV-BHR-E 09034
235th Base Support Battalion
ATTN: Unit 28614 Ansbach 09177
293d Base Support Battalion
ATTN: AEUSG-MA-AST-WO-E 09086
409th Support Battalion (Base)
ATTN: AETTG-DPW 09114
412th Base Support Battalion 09630
ATTN: Unit 31401
Frankfurt Base Support Battalion
ATTN: Unit 25727 09242
CMTC Hohenfels 09173
ATTN: AETTH-DPW
Mainz Germany 09185
ATTN: BSB-MZ-E
21st Support Command
ATTN: DPW (10)
US Army Berlin
ATTN: AEBA-EH 09235
ATTN: AEBA-EN 09235
SETAF
ATTN: AESE-EN-D 09613
ATTN: AESE-EN 09630
Supreme Allied Command
ATTN: ACSGEB 09703
ATTN: SHIHB/ENGR 09705

INSCOM
ATTN: IALOG-I 22060
ATTN: IAV-DPW 22186

USA TACOM 48397
ATTN: AMSTA-XE

Defense Distribution Region East
ATTN: DDRE-WI 17070

HQ XVIII Airborne Corps 28307
ATTN: AFZA-DPW-EE

4th Infantry Div (MECH)
ATTN: AFZC-FE 80913

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F
Installations:
ATTN: DPW (19)

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN
Installations:
ATTN: DPW (23)

6th Infantry Division (Light)
ATTN: APVR-DE 99505
ATTN: APVR-WF-DE 99703

National Guard Bureau 20310
ATTN: Installations Div

Fort Belvoir 22060
ATTN: CETEC-IM-T
ATTN: CECC-R 22060
ATTN: Engr Strategic Studies Ctr
ATTN: Australian Liaison Office

USA Natick RD&E Center 01760
ATTN: STRNC-DT
ATTN: DRDNA-F

TRADOC
Fort Monroe 23651
ATTN: ATBO-G
Installations:
ATTN: DPW (20)

US Army Materials Tech Lab
ATTN: SLCMT-DPW 02172

USARPAC 96858
ATTN: DPW
ATTN: APEN-A

SHAPE 09705
ATTN: Infrastructure Branch LANDA

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

HQ USEUCOM 09128
ATTN: ECJ4-LIE

AMMRC 02172
ATTN: DRXMR-AF
ATTN: DRXMR-WE

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ATTN: Facilities Engr (3) 85613

USAARMC 40121
ATTN: ATZIC-EHA

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ATTN: MT-LOF 20315
ATTN: MTE-SU-FE 28461
ATTN: MTW-IE 94626

Fort Leonard Wood 65473
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ATTN: ATZA-TE-SW
ATTN: ATSE-CFLO
ATTN: ATSE-DAC-FL

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USA Engr Activity, Capital Area
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US Army ARDEC 07806
ATTN: SMCAR-ISE

Engr Societies Library
ATTN: Acquisitions 10017

Defense Nuclear Agency
ATTN: NADS 20305

Defense Logistics Agency
ATTN: DLA-WI 22304

US Military Academy 10996
ATTN: MAEN-A
ATTN: Facilities Engineer
ATTN: Geography & Envr Engrg

416th Engineer Command 60623
ATTN: Gibson USAR Ctr

USA Japan (USARJ)
ATTN: APAJ-EN-ES 96343
ATTN: HONSHU 96343
ATTN: DPW-Okinawa 96376

Naval Facilities Engr Command
ATTN: Facilities Engr Command (8)
ATTN: Division Offices (11)
ATTN: Public Works Center (8)
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ATTN: Naval Civil Engr Service Center (3) 93043

8th US Army Korea
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Fort Sam Houston 78234
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Fitzsimons Army Medical Ctr
ATTN: HSHG-DPW 80045
Walter Reed Army Medical Ctr 20307

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