IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR REMOVING LEAD-BASED PAINT
FROM STEEL STRUCTURES
ABRASIVE BLASTING INSIDE TWO VENTILATED CONTAINMENT SYSTEMS

AT

BRIDGE STREET AND SHRIBNER STREET OVERPASS
Seaway Painting Company, Inc
Grand Rapids, Michigan

REPORT WRITTEN BY
R Leroy Mickelsen
Phillip A Froehlich

REPORT DATE
December 1994

REPORT NO
ECTB 183-14a

U S DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
4676 Columbia Parkway - R5
Cincinnati, Ohio 45226
BRIDGE FACILITY SURVEYED
Bridge street and Shribner Overpass
Grand Rapids, Michigan
Seaway Painting Company, Inc
31801 Schoolcraft
Livonia, Michigan

SIC CODE
1721, 1622

SURVEY DATES
October 6 and 7, 1992

SURVEY CONDUCTED BY
R Leroy Mickelsen
Phillip A Troehlich
Donald J Murdock

CONTRACTOR REPRESENTATIVE
Steve Vlahakia, Vice-President

EMPLOYEE REPRESENTATIVE
Joseph Wohlfert
International Brotherhood of Painters and Allied Trades

FACILITY OWNER REPRESENTATIVE
Fred Weber
Wyoming Project Officer
Michigan Department of Transportation
Wyoming District
731 54th Street S W
Wyoming, Michigan 49509

ANALYTICAL WORK PERFORMED BY
Mark Millson
Division of Physical Sciences and Engineering
4676 Columbia Parkway
Cincinnati, Ohio 45226

DataChem Laboratories
950 West LeVoy Drive
Salt Lake City, Utah 84123-2547
(801) 266-7700

MANUSCRIPT PREPARED BY
Debra A Lipps
Deanna L Elfers
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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary federal organization engaged in occupational safety and health research. It is located in the Department of Health and Human Services (DHHS), Centers for Disease Control and Prevention (CDC). An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of hazard control.

Because of increased reports of lead poisoning and silicosis among workers in the steel structures painting industry, researchers from ECTB developed a project to evaluate engineering controls in this industry. A basic need for nearly all steel structures is protection from corrosion. Historically, lead-containing coating systems were used because they were low cost, aesthetically appealing, and corrosion resistant. To adequately prepare the steel surface to receive a new coating system, the old coating must be removed. The cleaning process has traditionally been achieved by abrasive blasting. Abrasive blast devices are designed to deliver a high-velocity stream of abrasive to remove the coating as well as impart an anchor pattern on the metal surface. The workers direct the blasting nozzles at the surface to be cleaned. As the paint is removed, small particles of lead paint, silica (silica from abrasives or from surface coatings), and other debris become airborne. Lead poisoning and silicosis are not uncommon among workers who remove lead-based paints from bridges and other steel structures.

Two environmental requirements have been the driving force for contractors to contain paint chips, dust, and used abrasive during paint removal processes. The Resource Conservation and Recovery Act (RCRA) requires that waste material must be collected, tested, and classified as hazardous or not hazardous. Secondly, the Clean Air Act limits levels of particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM10) to a maximum of 150 μg/m³ average concentration over a 24-hour period. The Clean Air Act also limits the amount of airborne lead to 1.5 μg/m³, evaluated as a maximum arithmetic mean averaged over a calendar quarter. The containment structures used to collect waste materials and control emissions has increased workers' risk of occupational exposure to lead and other waste materials, by concentrating these agents in and around the paint removal containment structures.

Support personnel as well as workers doing abrasive blasting are at risk of high exposures to potentially hazardous particulate mentioned above. Support personnel may also receive exposure when containment structures (which may contain or be contaminated with residual lead and silica particles) are disassembled and moved or when handling abrasive and waste materials. High exposures have been observed for auxiliary equipment operators and for those cleaning up the site after paint removal has been completed.
Two separate engineering controls were evaluated during this survey. They consisted of two separate containment, ventilation, and abrasive blasting systems.

BRIDGE SITE AND PROCESS DESCRIPTION

The first control system consisted of abrasive blasting with low silica (<1% by weight) sand, Star Blast XL (E I DuPont DeNemours and Company, Inc, Wilmington, Delaware) in a large enclosure made of interconnected canvas tarps suspended from the top of the roadway down to the ground, creating a room with a volume of 200,000 cubic feet. Within the left half of the containment the overpass was 50 feet above the ground. From the middle of the containment the ground sloped up to the right so that the far right side of the overpass was 20 feet above the ground (Figure 1). The enclosure was ventilated by two 20-inch diameter exhaust ducts which were suspended from a light pole, this placed the duct openings approximately 12 feet above the ground. There were no provisions for supply inlets, the seams of the tarp walls and other unplanned openings (most openings were at ground level where the tarps were not adequately fastened to the ground tarps) acted as supply air inlets. Figure 1 shows a top and side view of the large containment and accompanying exhaust system. The Star Blast abrasive was used one time and allowed to settle to the floor tarps along with other wastes created by the paint removal process, then it was collected for disposal.

The second system consisted of abrasive blasting with recyclable steel grit in a 3,000 ft² enclosure (8' X 8' X 48') made of an alloy piping for the frame, rigid corrugated polycarbonate panels for the sides and an aluminum grating floor. The enclosure was suspended from two adjacent I-beams under the bridge (Figure 2). The small enclosure had a supply air fan at one end and an exhaust duct with a fan at the other end. The sloping walls under the grate flooring directed the used abrasive and wastes to the bottom center of the containment where the materials were removed from the containment. The steel grit was air washed using a recycle machine (IPEC Advanced Systems, North Kingstown, RI) and reused.

In both the large and small containment, the workers donned a single-use dust respirator under a continuous-flow, loose-fitting hood respirator prior to entering the containment and did not remove the respirator inside the containment.

SAMPLING METHODS

The control techniques were evaluated by collecting and analyzing bulk samples of paint, abrasive, and waste materials, personal breathing zone (PBZ) air samples of blasters and support personnel, and area air samples. Work practices and personal hygiene practices were also observed.
Figure 2

- Exhaust duct
- Containment structure attached to the bridge I-beams
- Cross-sectional area of containment
- Dirty grit return
- Air flow
- Fan

Dimensions:
- 8' x 8' x 3'
- 48'
BULK SAMPLES

Old paint was collected from the bridge by scraping the surface with a sharp chisel. The bulk paint collection process removed all of the top and intermediate paint coatings, leaving a metal surface with only traces of the primer coating (less than 10 percent of the surface was covered by thin traces of paint). Bulk samples of unused abrasive were obtained from freshly opened packages of Star Blast. The used abrasive samples were collected by mixing abrasive from five locations within the storage bins or from the containment floor and taking one sample from the mixture for analysis. Two samples of used steel grit from the small enclosure were collected before and after the recycle cleaning process.

PERSONAL SAMPLES

Seven paired sets of PBZ samples were collected on 37-mm diameter, mixed cellulose ester membrane, 0.8-μm pore-size filters in closed-face cassettes using personal sampling pumps (Model 224-PCXR7, SKC Inc, Eighty Four, PA) each operating at 2.0 liters per minute (1 lpm). Paired PBZ samples were collected inside and outside of the respirator Tygon® tubing placed under the workers' blast-protective outer clothing, and passing beneath the respirator cape, was used to connect one pump to the inside of the respirator sample cassette. The tubing was attached to the respirator collar, so that the cassette was in the breathing zone of the worker inside the respirator. The outside respirator sample cassettes were attached to the back of the blasters' outer clothing rather than on the front lapels. This procedure was used in an attempt to reduce the likelihood of getting the cassette knocked off the workers' lapels and to reduce the likelihood of pinching the tubing between the worker and the scaffolding or bridge members.

Four PBZ samples were collected on recycle and blast pot equipment operators and one laborer who was sweeping up beneath the small containment. These sampling cassettes were attached to the workers' lapels.

AREA SAMPLES

Area samples for total lead, inhalable dust, and total dust samples were collected inside each containment, near the dust collector outlets, near the intake of the respirator compressors, and near the equipment outside of the containments. The area total lead samples were collected using the same equipment as for the PBZ samples. The total dust samples were collected on preweighed 37-mm, 0.5-μm pore size, PVC filters in a closed-face cassette, at a flow rate of 2.0 lpm. For convenience, pumps for area samples used inside the containments were placed in 5-gallon buckets and the cassettes were positioned on the periphery of the top of the buckets.

A sampler (SKC, Eighty Four, PA) designed by the Institute of Occupational Medicine (IOM), Edinburgh, was used to collect inhalable dust (particles with equivalent aerodynamic diameters of up to approximately 100 μm). Air was drawn with a personal sampling pump (Model P2500, Ametek, Largo, FL) at 2.0 lpm. The collection medium was a 25-mm diameter, 0.5-μm pore-size, PVC
filter. The IOM samples were weighed to determine the amount of inhalable dust, then analyzed to determine the amount of inhalable lead.

SAMPLE ANALYSIS

Analyses of air samples for lead and other elements were conducted using NIOSH Method 7300, which utilizes inductively coupled argon plasma atomic emission spectrometry, when the lead results were below the limit of detection (LOD), samples were reanalyzed using graphite furnace atomic absorption spectroscopy, NIOSH Method 7105. Total dust and inhalable dust analyses were performed using NIOSH Method 0500 with a limit of detection of 0.02 mg.

VENTILATION MEASUREMENTS AND OBSERVATIONS

The ventilation airflow inside both containment was evaluated using a Rosco fog machine (Rosco Laboratories, Inc, Port Chester, NY) to determine the airflow direction and a Kurz hot-wire thermal anemometer (Kurz Instruments, Inc, Monterey, CA) to measure the air velocity. Video recording was used to document the flow direction during the fog generation.

REAL-TIME (RESPIRABLE) AEROSOL MONITOR

A Real-Time Aerosol Monitor (RAM) (MIE, Inc, Billerica, MA) was used to measure the transient respirable dust concentrations inside the large containment immediately following abrasive blasting.

NOISE LEVELS AND OTHER OBSERVATIONS

A-weighted Noise Logging Dosimeters (Model M-27, Quest Electronics, Oconomowoc, WI) were included in the buckets containing the area samplers placed inside the containments. Dosimeters placed outside of the containments were also used to determine noise levels. Work practices, the use of personal protective equipment (e.g., respirators and hearing protection), and the use of personal hygiene facilities (e.g., hand washing and clothing changing) were documented.

EXPOSURE EVALUATION CRITERIA

The OSHA PEL for lead in the construction industry during this survey was 200 µg/m³ but since has been reduced to 50 µg/m³ as an 8-hour TWA. The 50 µg/m³ exposure limit is currently recommended for the construction industry by NIOSH as a more protective criteria and is used in this study as the evaluation criteria for personal exposures. The OSHA PEL for total particulate not otherwise regulated is an 8-hour TWA of 15 mg/m³.

The A-weighted decibel (dBA) is the preferred unit for measuring sound levels. It is weighted to approximate the sensory response of the human ear. The NIOSH PEL for noise specifies an exposure limit of 85 dBA for 8 hours, 5 dBA less than the OSHA PEL of 90 dBA.

The respiratory program was evaluated based on the respirator program given in the NIOSH guide to industrial respiratory protection.
include information on selecting respirators, training users, and fitting each user with the appropriate NIOSH approved respirator

RESULTS AND DISCUSSION

BULK SAMPLES

Table 1 presents results of bulk sample analyses of paint obtained from the bridge, and clean and used abrasive. Based on two samples, the deteriorated paint from the bridge contained an average of 600,000 ppm (60 percent) lead by weight. Some other components of the deteriorated paint include the following: aluminum, 17,000 ppm, zinc, 290 ppm, manganese, 230 ppm, and magnesium, 160 ppm. The large amount of iron (31,000 ppm) in the bulk paint samples is probably due to the removal of rust and steel from the substrate during the paint sample collection process.

Lead content in the new and used Star Blast abrasive was 50 and 12,000 ppm, respectively. Lead content in the steel grit prior to cleaning was 3,700 ppm by weight. After cleaning by the recycle equipment, the lead content in the steel grit was 1,700 ppm. This indicates a cleaning efficiency of approximately 50 percent. Virgin steel grit was not available for sampling. Normally, new steel grit and steel shot contains 70 to 120 ppm of lead. If abrasive is going to be reused, removing the lead from the abrasive may be an important element in the engineering control approach. The concentrated waste from the recycle machine contained 27 percent of lead by weight. The waste swept from the blacktop surface beneath the small containment system contained 2,800 ppm of lead by weight.

PERSONAL AIR SAMPLES

Table 2 presents the results of PBZ air sampling during abrasive blasting. Within the large containment, the blasters' geometric mean lead concentration outside of the respirator was 6200 μg/m³, 120 times greater than the OSHA PEL for lead in the interim final rule. Within the small containment, the blasters' geometric mean lead concentration outside of the respirator was 20,000 μg/m³, 400 times greater than the OSHA PEL for lead. Six of seven lead concentrations measured inside the continuous-flow loose-fitting hood respirators were greater than 50 μg/m³ with the highest being 150 μg/m³.

Within the small containment (as compared to the large containment) higher airborne lead concentrations (outside the respirator) may be a result of two major factors. The steel grit was not adequately cleaned prior to reblasting (just over half of the lead was removed from the grit prior to reusing) and high velocity air introduced by the fan and the blast nozzle will tend to pick up and recirculate particles inside the containment. Supply air should be introduced across the entire cross-section of the small containment to reduce turbulence that may re-entrain and recirculate particles. Nevertheless, improvements to the abrasive recycle cleaning system and ventilation system may not adequately reduce airborne lead and dust concentrations near the worker. Abrasive blasting systems currently in use require that the blaster be very close to the lead and dust generation source.
<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td>Lead</td>
<td>600,000</td>
<td>570,000</td>
<td>4</td>
<td>1,700</td>
<td>3,200</td>
<td>270,000</td>
<td>2,800</td>
<td>50</td>
<td>15,000</td>
<td>10,000</td>
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<td>Iron</td>
<td>11,000</td>
<td>51,000</td>
<td>4</td>
<td>800,000</td>
<td>830,000</td>
<td>350,000</td>
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<td>7</td>
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<td>Zinc</td>
<td>410</td>
<td>170</td>
<td>1</td>
<td>620</td>
<td>540</td>
<td>32,000</td>
<td>33</td>
<td>11</td>
<td>120</td>
<td>200</td>
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<td>Manganese</td>
<td>130</td>
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<td>4,500</td>
<td>2,400</td>
<td>4,000</td>
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<td>46</td>
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<td>Magnesium</td>
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<td>130</td>
<td>7</td>
<td>ND</td>
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<td>640</td>
<td>220</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
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<tr>
<td>Copper</td>
<td>78</td>
<td>65</td>
<td>1</td>
<td>920</td>
<td>920</td>
<td>200</td>
<td>650</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
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<td>Cobalt</td>
<td>28</td>
<td>28</td>
<td>1</td>
<td>68</td>
<td>66</td>
<td>31</td>
<td>34</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Titanium</td>
<td>19</td>
<td>13</td>
<td>1</td>
<td>ND</td>
<td>ND</td>
<td>260</td>
<td>ND</td>
<td>280</td>
<td>260</td>
<td>350</td>
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<tr>
<td>Chromium</td>
<td>12</td>
<td>10</td>
<td>1</td>
<td>730</td>
<td>830</td>
<td>260</td>
<td>270</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Nickel</td>
<td>ND</td>
<td>15</td>
<td>2</td>
<td>330</td>
<td>850</td>
<td>160</td>
<td>200</td>
<td>ND</td>
<td>ND</td>
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</table>

* ND = Below the detection level (Not Detected)
<table>
<thead>
<tr>
<th>Day</th>
<th>Worker</th>
<th>Containment Type</th>
<th>Sample Time (min)</th>
<th>Lead Concentration Inside (μg/l) TWA</th>
<th>Lead Concentration Outside (μg/l) TWA</th>
<th>Respirator Protection Factor (RPF)</th>
<th>Co (μg/l) TWA</th>
<th>TWA for sampling time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>Large</td>
<td>362</td>
<td>62</td>
<td>73</td>
<td>77**</td>
<td>73**</td>
<td>77**</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>416</td>
<td>100</td>
<td></td>
<td>240</td>
<td>62</td>
<td>62**</td>
<td>62**</td>
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<tr>
<td>2</td>
<td>A</td>
<td>Large</td>
<td>173</td>
<td>83</td>
<td>32</td>
<td>62</td>
<td>62**</td>
<td>62**</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>173</td>
<td>79</td>
<td></td>
<td>32</td>
<td>62</td>
<td>62**</td>
<td>62**</td>
</tr>
<tr>
<td>Sum</td>
<td>Mean</td>
<td>260</td>
<td>80**</td>
<td></td>
<td>6,200**</td>
<td>77**</td>
<td>20,000**</td>
<td>20,000**</td>
</tr>
</tbody>
</table>

* TWA for sampling time

** Geometric mean
effective, the hazard must be controlled before it reaches the blast operator. Dilution ventilation is not effective in this situation.\textsuperscript{15}

For this evaluation, the ratio of the lead concentration on the samples outside the respirator to inside the respirator are considered to be the program protection factor (PPF)\textsuperscript{15} The PPF is a measure of the effectiveness of the complete respirator program. As such, any element (i.e., respirator selection, fit, training, maintenance, storage) of the program which is deficient will adversely affect the PPF. The calculated geometric mean PPF for the continuous-flow loose-fitting hood respirator was 130 for the combined group of blasters in both containments during blasting. The PPF lower and upper 95 percent confidence intervals were 56 and 290, respectively. [Note that the sample cassettes were not placed in a standard location for the inside the respirator samples and the workers could not be visually observed during the blasting process.]

While additional controls are being developed, it would seem prudent that workers near the lead paint abrasive blasting process use a respirator with a higher protection factor (higher than the assigned protection factor of the loose-fitting respirator). However, to achieve an increase in the respiratory protection the respirator must be worn. A tight-fitting respirator (which is needed to obtain a higher APF) may be less comfortable to wear than the loose-fitting respirator. Substituting the loose-fitting respirator with one that is tight-fitting may result in a net increase in worker exposure if the latter is worn less than the former. Further evidence is needed before clear guidance can be given.

Table 3 presents the results of PBZ air sampling, for lead exposures of the support personnel near the large and small containment structures. The support personnel wore half-mask air-purifying respirators with HEPA filters which were supplied by their employer. All four of the lead exposures measured were greater than 50 \( \mu \)g/m\(^3\). Those working near the large containment had airborne lead concentrations over 2,000 \( \mu \)g/m\(^3\). With an assigned protection factor (APF) of 10, the half-mask respirators are not acceptable if lead levels exceed 500 \( \mu \)g/m\(^3\). The half-mask respirators are acceptable for the equipment operator and sweeper working around the small containment. [Note that worker D, the sweeper, also performed abrasive blasting during day two. His overall exposure was 35,000 \( \mu \)g/m\(^2\) which was mostly due to abrasive blasting.]

The high PBZ lead concentrations for workers near the large containment may be a result of the seams and closures of the large containment not being air-tight, allowing air and contaminants to move in or out of the containment with the gusting wind. The small containment was rigid and had tight seams and seals. Also, some of the support personnel were exposed to high levels of airborne lead upon entering the large containment immediately after the blasting process (before airborne particulate had settled), and from walking through the waste on the tarp floor of the containment which stirred up and re-entrains particulate into the air. Exposures may also come from moving equipment which is contaminated with lead dust.
Table III  Lead Exposures of Blast Site Support Personnel
Seaway Painting Company, Inc., Grand Rapids, MI

<table>
<thead>
<tr>
<th>Day</th>
<th>Worker</th>
<th>Containment Type</th>
<th>Task</th>
<th>Sample Time (min)</th>
<th>Lead Exposure (μg/m²) TWA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>Large</td>
<td>Equipment Operation</td>
<td>406</td>
<td>2,200</td>
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<tr>
<td>2</td>
<td>F</td>
<td>Large</td>
<td>Equipment Operation</td>
<td>169</td>
<td>2,500</td>
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<tr>
<td>1</td>
<td>G</td>
<td>Small</td>
<td>Equipment Operation</td>
<td>547</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>Small</td>
<td>Sweeping</td>
<td>51</td>
<td>360º</td>
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</tbody>
</table>

TWA for sampling time
Worker D total TWA exposure for Day 2 was 35,000 μg/m², see Table 2

AREA SAMPLING

Airborne lead and aerosol concentrations from area sampling are presented in Table 4. Inside the large containment the area samples were in a bucket located on the floor in the center of the containment, 50 feet below the blast operation. Inside the small containment a bucket was located on the grate floor midway between the supply inlet and exhaust outlet.

The equipment area 15 feet from the large containment had an airborne lead concentration of 210 μg/m³ and 25 feet away the concentration was 56 μg/m³. These results strongly support the practice of wearing respiratory protection near the large containment. The equipment area 40 feet below the small containment had a lead concentration of 17 μg/m³. The combination of distance and better control of the contaminant resulted in a much lower exposure concentration in the area beneath the small containment.

The inlet air to the compressors which supplied breathing air to the air-supply respirators for the workers in the large and small containment had a concentration of 6 and 20 μg/m³, respectively. Each air compressor was located 40 to 50 feet away from their respective containments. Breathing air passed through the compressor, an oil filter, a particulate filter, and a CO detector and alarm system before going to the respirator.

The outlet stacks of each dust collector used to filter the ventilation exhaust air from each containment were monitored using a personal sampling pump and filter. The airborne lead concentrations from the outlet ducts were 220 and 1 μg/m³ from the large containment dust collector and 110 μg/m³ from the small containment dust collector. This represents a 99 percent reduction in airborne lead concentration as compared to inside the containment.

The samples collected inside the large containment (Table 5) show that the IOM sampler lead results were higher than the closed-face sampler lead results.
Table IV  Area Air Samples  
Seaway Painting Company, Inc., Grand Rapids, MI

<table>
<thead>
<tr>
<th>Day</th>
<th>Containment Type</th>
<th>Location</th>
<th>Time (min)</th>
<th>Concentration (µg/m³)</th>
<th>Noise (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lead</td>
<td>Aerosol</td>
</tr>
<tr>
<td>1</td>
<td>Large</td>
<td>Inside the containment</td>
<td>453</td>
<td>15,000</td>
<td>480,000</td>
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<tr>
<td>1</td>
<td>Large</td>
<td>Dust collector outlet</td>
<td>254</td>
<td>220</td>
<td>2,000</td>
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<tr>
<td>1</td>
<td>Large</td>
<td>15' away from containment</td>
<td>497</td>
<td>210</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>Large</td>
<td>25' away from containment</td>
<td>493</td>
<td>55</td>
<td>-</td>
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<td>2</td>
<td>Large</td>
<td>Dust collector outlet</td>
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<td>-</td>
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<td>2</td>
<td>Large</td>
<td>Inlet to respirator compressor</td>
<td>216</td>
<td>6</td>
<td>-</td>
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<tr>
<td>1</td>
<td>Small</td>
<td>Inside the containment</td>
<td>538</td>
<td>10,000</td>
<td>55,000</td>
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<tr>
<td>1</td>
<td>Small</td>
<td>Equipment control panel</td>
<td>537</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Small</td>
<td>Dust collector outlet</td>
<td>288</td>
<td>110</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Small</td>
<td>Inlet to respirator compressor</td>
<td>297</td>
<td>20</td>
<td>-</td>
</tr>
</tbody>
</table>

However, the aerosol results from the ICM samplers were lower than the closed-face aerosol sampler results. Area dust levels were an order of magnitude greater than lead levels. In general, in areas where visible dust levels were high, a correspondingly high lead and dust concentration were determined by personal and area sampling.

Noise levels (Table 4) measured as area samples ranged from 110 dBA as a TWA in the small containment to 91 dBA in the support equipment area. The area noise levels indicate that noise levels are well above the NIOSH REL of 85 dBA. During the survey workers both inside and outside the containment routinely wore foam ear plugs. Hearing protection must continue to be used. When blasting was in progress, the noise level inside the containment increased by 20 dBA over the background noise level. Based on the area noise levels observed at this site, it is recommended that a hearing conservation program be implemented. Noise levels should be considered when selecting paint removal equipment.
REAL-TIME MONITORING

In addition to the integrated area samples, the RAM was used to monitor the respirable dust inside the large containment immediately following abrasive blasting. A respirable dust concentration decay curve is shown in Figure 3. The airborne dust levels decreased 60 percent in 10 minutes and 90 percent in 35 minutes once dry abrasive blasting stopped.

The small containment structure dilution ventilation system approached plug flow (as desired) but did not significantly reduce airborne lead levels. Even a well designed dilution ventilation system, such as this plug-flow ventilation system, may not be capable of reducing hazardous concentrations near the blast operator to an acceptable level.

VENTILATION MEASUREMENTS

Fog was generated to visually evaluate the airflow patterns within each containment. Fog within several feet of the exhaust duct vents flowed into the vents. But throughout the rest of the large containment there was no obvious airflow pattern (mostly stagnant air). The air velocities at the face of each exhaust vent were 5,300 feet per minute (fpm). The calculated total volumetric flow rate was 24,000 cubic feet per minute (cfm) through the two 20-inch diameter exhaust ducts.

The air velocity near the supply fan of the small containment could not be measured due to the turbulence. Structural cross members ran perpendicular to the flow of air and connected the two I-beams. The airflow was stagnant near these cross members. The air velocities measured at two separate cross-sections, upstream from the exhaust vent, were both 110 fpm as an average across the working cross-sections. At the face of the exhaust vent the air velocity was 2,800 fpm, hence, 6,000 cfm was removed through the 20-inch diameter duct. The dilution ventilation system of the small containment could be improved by introducing the supply air through a plenum across the entire cross-section of the containment. This will reduce turbulence caused by the high velocity supply air fan, reducing the reentrainment of particles. However, this may not be the total engineering control solution for lead paint removal operations.

The prevailing wind, gusting to perhaps 10 miles per hour, was generally from the west. The side tarps of the large containment reduced the flow of air through the blast area to a minimum. The winds did not affect the small containment. During the blasting process and at periodic intervals, dust was observed escaping the large containment. Abrasive and dust escaped from the small containment only rarely.

RESPIRATOR AND HYGIENE PRACTICE

The workers used personal protective equipment, including heavy cotton canvas coveralls (blasters), disposable earplugs, disposable Tyvek® coveralls, and respirators provided by the contractor. Blasters used NIOSH-certified continuous-flow loose-fitting hoods (E D Bullard Company, Cynthiana, KY), equipped with vortex-type air coolers. A paper dust mask was also worn under
Table V  Consecutive Area Sampling Results from Inside the Large Containment
Seaway Painting Company, Inc, Grand Rapids, MI

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Time (minutes)</th>
<th>Lead concentration (µg/m³)</th>
<th>Aerosol concentration (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample duration</td>
<td>Blast duration during sampling</td>
<td>Cassette (closed face) NCE filter</td>
</tr>
<tr>
<td>1</td>
<td>86</td>
<td>82</td>
<td>11,000</td>
</tr>
<tr>
<td>2</td>
<td>89</td>
<td>70</td>
<td>29,000</td>
</tr>
<tr>
<td>3</td>
<td>167</td>
<td>110</td>
<td>3,300</td>
</tr>
<tr>
<td>4</td>
<td>97</td>
<td>97</td>
<td>26,000</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>16</td>
<td>12,000</td>
</tr>
<tr>
<td>Sum TWA**</td>
<td>453</td>
<td>375</td>
<td>15,000</td>
</tr>
</tbody>
</table>

*One sample taken over both sequence 4 and 5 time intervals (total sample time = 113 min)
**Time-weighted average (TWA) concentration for the cumulative sampling period of each sampler type
Figure 3
Dust Decay From Large Containment
Seaway Painting, Inc., 10-7-92, Grand Rapids

Relative Dust Concentration vs Time (min)
the loose-fitting hood respirator. Workers exited the containment area before removing their hood respirators and removed their tyvek coveralls before removing the paper dust mask. During the lunch break the hood respirators were placed on the ground outside the containments. One blaster stopped working several times during the day to take smoking breaks. He came out of the containment, removed his respirators, and smoked adjacent to the large containment.

Workers performing jobs outside the containment were provided half-mask air purifying respirators with HEPA filters. An organic-vapor cartridge respirator was used during painting. To help with equipment, some workers who were wearing half-mask respirators with HEPA filters moved in and out of the large containment before blasting started and just after the blasting was completed.

The painting contractor provided periodic medical monitoring for lead exposure. Personal hygiene facilities were provided on site, which included portable toilets and a changing area with a hand-washing sink and clothing storage hooks inside a portable trailer. Although disposable protective coveralls were worn by the workers, many of the coveralls were torn several times by the end of the work day, thereby, worker clothing was contaminated with lead containing dust. Since workers did not change clothing at the site, the dust could be carried by the workers to their automobiles, housing, and laundry facilities. A more comprehensive respirator program providing for better training, use of respirators, storage of respirators and enforcement may also improve the PPF.

Although some hygiene facilities were provided, they were not always used as evident by the blaster who took frequent breaks to smoke without first washing his hands. Although disposable protective coveralls were worn, many of the coveralls were torn by the end of the workday. In which case the workers clothing was contaminated with lead containing dust which was worn when the worker left the site.

CONCLUSIONS AND RECOMMENDATIONS

- The large containment dilution ventilation system is almost of no value in reducing airborne lead exposures for those workers performing abrasive blasting inside the containment. The lead exposures were as high as 24,000 µg/m³ (geometric mean of 6,200 µg/m³) and smoke tube tests showed containment air movement was negligible. The small containment dilution ventilation system was effective in moving air as shown by the smoke tube tests but this air movement did not result in significantly lower lead exposures which were as high as 58,000 µg/m³ (geometric mean of 20,000 µg/m³).

- Persons working inside both large or small ventilated containment structures during dry abrasive blasting may be exposed to airborne lead concentrations in excess of 100 times the OSHA PEL for lead. The continuous-flow loose-fitting hood respirator with an APF of 25 would not be the respirator of choice for this application because of the high
Airbone lead levels. Additional engineering controls (i.e., automation, local exhaust, or dust suppressants) and work practices should be developed and used to reduce the lead concentration inside the containment systems during abrasive blasting. In the interim, as these more effective techniques and work practices are developed, a comprehensive respirator program, providing for good worker training, use and storage of respirators, and enforcement of the respirator programs could improve the PPF of the workers. Additional research is needed to evaluate the exposure effect of replacing the loose-fitting respirator with a tight-fitting respirator in this work environment.

- Environmental monitoring should be routinely performed to measure worker exposure to airborne lead and other hazardous agents (e.g., silica and solvents). Respiratory protection must be selected based on measured airborne hazards for each job type. It is recommended that the combination of distance and better control of the contaminant be applied so that equipment operators are not overexposed to lead. At this site, the equipment area near the small containment had airborne lead concentrations less than 50 µg/m³ because of adequate control and the distance from the equipment area to the containment. However, the equipment area near the large containment had airborne lead concentrations greater than 50 µg/m³. Support personal wearing only a half-mask respirator should not enter the containment during or immediately after the blasting process and must limit the time spent near the large containment where lead exposures are high. Change rooms with showers and washing facilities need to be provided and used.

- Based on the levels of airborne lead measured near the large containment and results from previous studies reporting lead contamination on workers’ hands, this practice of smoking prior to hand washing and smoking near the containment must be discontinued. Respirators should be stored in a clean area when they are not in use. It is recommended that employers re-enforce their hygiene program by routinely encouraging employees with walk-through and verbal contact during the work day. Contaminated clothing should be laundered by the employer and the laundry should be informed that the clothing is contaminated with lead dust.

- Further research is needed to verify the results of the small number of samples taken in this study and to investigate the effect of loose-fitting versus tight-fitting respirator performance, the effect of cleanliness of recycled grit, the type of filter needed to clean the ventilation exhaust air, and the effect of sampling in turbulent abrasive blasting atmospheres.

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