HETA 97–0161–2706
Bananas! Gifts, Incorporated
Clarkdale, Arizona

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PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Robert E. McCleery and Kenneth F. Martinez, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Dino A. Mattorano of the Hazard Evaluations and Technical Assistance Branch. Analytical support was provided by the Measurement Research Support Branch, NIOSH, Cincinnati, Ohio; and Data Chem Laboratories, Salt Lake City, Utah. Desktop publishing was performed by Nichole Herbert. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 97–0161–2706
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August 1998

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SUMMARY

On April 4, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Bananas! Gifts, Inc. facility in Clarkdale, Arizona. The confidential request expressed concern over possible exposure to lacquer solvents, abrasive–blasting materials, and a patina solution (brown or green layer on copper as a result of oxidation). Concern was also expressed over "homemade" heavy machinery, ventilation, and protective clothing. The employees reported symptoms of rashes, nose sores, and hyperventilation.

On November 5 and 6, 1997, NIOSH conducted a site visit at the Bananas! Gifts, Inc. facility. Area and short–term personal breathing zone (PBZ) air samples were collected on November 6, 1997. NIOSH investigators collected 6 PBZ and 6 area air samples for metals, 4 PBZ and 3 area air samples for 2–butoxyethanol, 2 PBZ and 2 area air samples for inorganic acids, 3 area air samples for respirable dust, and 2 area air samples for methylene chloride. During the sampling period, employees switched from operation to operation with a working duration ranging from a few minutes to 2–3 hours. The length of time at a specific operation depends mainly upon the customer orders received for a particular item. Therefore, full–shift PBZ air samples were not collected.

Samples collected for 2–butoxyethanol, toluene, inorganic acids, aluminum oxide (Al_2O_3), lead, and titanium dioxide (TiO_2) in various facility operations were all below relevant evaluation criteria. Methylene chloride sample concentrations were above NIOSH REL, but below ACGIH and OSHA evaluation criteria. Ventilation surveys of the lacquer and glue application areas and the abrasive–blasting room/cabinets indicated that each system was relatively effective in controlling these exposures. However, the ventilation systems for each area can be improved for increased efficiency in exposure control.

Industrial hygiene air samples indicated that there were employee exposures to 2–butoxyethanol, methylene chloride, and toluene in the two lacquer application areas; exposures to aluminum oxide, lead, and titanium dioxide in the abrasive–blasting room; and exposure to lead in the soldering area. However, other than methylene chloride, no 8–hour time–weighted average (TWA) air sample concentrations exceeded relevant evaluation criteria. Methylene chloride sample concentrations exceeded the NIOSH REL, but did not exceed the ACGIH or OSHA evaluation criteria. Real–time particulate monitoring with particle size discrimination indicated the potential for over–exposures to total and respirable dust in the abrasive–blasting room during sustained work periods. Suggestions to improve the health and safety of employees in this facility, through the use of engineering and administrative controls and personal protective equipment, are presented in the Recommendations section of this report.

Keywords: SIC 5947 (Gift, novelty and souvenir shops), copper sheets, lacquer, patina, abrasive–blasting, abrasive–blasting cabinets, soldering, torching, 2–butoxyethanol, methylene chloride, toluene, inorganic acids, aluminum oxide, acetylene/oxygen.

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INTRODUCTION

On April 4, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Bananas! Gifts, Inc. facility in Clarkdale, Arizona. The confidential request expressed concern over possible exposure to lacquer solvents, abrasive–blasting materials, and a patina solution used in the manufacture of copper–based novelty gifts. Concern was also expressed over "homemade" heavy machinery, ventilation, and protective clothing. The employees reported symptoms of rashes, nose sores, and hyperventilation.

On November 5, 1997, NIOSH representatives conducted an opening conference with management and an employee representative. Following this meeting, a walk–through inspection of the facility was conducted to identify specific work areas and job tasks of employees, leading to selection of potential air sampling sites. On November 6, 1997, personal breathing zone (PBZ) and area air samples were collected for metals, respirable dust, 2–butoxyethanol (2–BE), inorganic acids, and methylene chloride. Work practices were observed in all areas of the facility in use on November 6.

BACKGROUND

Bananas! Gifts, Inc. is a small novelty, gift manufacturing, and distribution facility that bases many of its products on the manipulation of copper sheets. Copper sheets are transformed into products ranging from toothpick and facial tissue holders to picture frames. The copper products are manufactured with a shiny, metallic exterior; an oxidized, natural blue/green likeness with the application of a patina solution; or a rustic, worn appearance when an acetylene/oxygen torch flame is applied to its surface. Two lacquer solutions consisting of 2–BE and methylene chloride/toluene are applied for the protection of exposed copper and copper/patina surfaces, respectively. The patina solution consists of copper sulfate and various inorganic acids. Workers wear 3M® 6000 series respirators with 20/20 dust/mist filters and latex gloves in the lacquer application area.

The abrasive–blasting of various materials is a significant component of most of the manufactured products. Aluminum oxide (Al_2O_3) and small, glass beads are used to engrave an impression on rocks, coffee mugs, and glassware. Abrasive–blasting is also used to roughen the surface of the copper sheets to assist in surface bonding of the 2–BE lacquer and coloring of the patina solution. Abrasive–blasting operations are performed in one of two abrasive–blasting cabinets or an enclosed, ventilated room. Workers wear Tyvek® suits, rubber gloves, an abrasive–blasting hood, and a 3M® 6000 series respirator with 20/20 dust/mist filters in the enclosed room and the same respirator and gloves while working with materials in the abrasive–blasting cabinets.

Plastic templates applied around rocks, glassware, and mugs guide the employee during the abrasive–blasting process. The plastic squares are roughly 4 x 4 inches and as flexible as paper. Each square is a template of a picture and/or words. Adherence to the blasting medium is facilitated with the application of a glue solution to each plastic square.

Employees are capable of working several manufacturing stations during the course of a day. Each work period may last from a few minutes to several hours and the employee may return to a station repeated times. The length of time spent at a station varies with the quantity of customer orders received for a particular product.

METHODS

The PBZ air samples taken during each operation were obtained for the duration of that single task. Employees do not stay at an operation (during this HHE or for normal daily jobs) for more than 2–3 hours. Employee duties throughout the day are highly variable. Therefore, an 8–hour shift with a specific task is unlikely. PBZ air samples collected during this HHE are a representation of the employee exposure to a specific hazard for a specific task, length of time, and day samples were collected. PBZ, 8–hour time–weighted average (TWA) results are based on the compilation of employees' exposure results while working in a specific area. When an employee is not working in that specific area, the exposure is considered to be zero. The area air samples collected in each operation were based upon the lack of an 8–hour shift of an employee to a specific task. Area, 8–hour TWA results are indicators of the potential exposure if an employee were to work the entire working day in a specific area.

Area and PBZ air samples were collected for metal analysis in the abrasive–blasting, soldering, and acetylene/oxygen torching areas. These samples were collected with 37–millimeter (mm) diameter, 0.8–micrometer (µm) pore size mixed cellulose ester (MCE) membrane filters at a sampling rate of 2.0 liters per minute (l/min.) for area air samples and 4.0 l/min for PBZ air samples. Area samples were collected for morning and afternoon periods. PBZ samples were collected for periods as near as possible to an entire task, changed when different materials were abrasively–blasted, and placed underneath the worker's blasting hood. The filters were analyzed by inductively coupled argon plasma (ICP) according to NIOSH Method 7300.[1] The analytical limits of detection (LOD) were 1.0, 0.5, and 0.2 micrograms per sample (µg/sample) for aluminum, lead, and titanium, respectively, which are equivalent to minimum detectable concentrations (MDCs) of 1.3, 0.6, and 0.3 micrograms per cubic meter (µg/m^3), assuming a sample volume of 776 liters. The analytical limits of quantitation (LOQ) were 4.0, 2.0, and 0.4 µg/sample for aluminum, lead, and titanium, respectively, which are equivalent to minimum quantifiable concentrations (MQCs) of 5.2, 2.6, and 0.5 µg/m^3, assuming a sample volume of 776 liters.

Area air samples were collected for respirable dust in the abrasive–blasting room and the abrasive–blasting cabinet area. The samples were collected with 37–mm diameter, 5.0–µm pore size polyvinyl chloride (PVC) filters in conjunction with a 10–mm cyclone at a sampling flow rate of 1.7 l/min. Samples were collected for periods as near as possible to an entire shift. The sample weights were determined according to NIOSH Method 0600.[1] The analytical LOD was 0.02 milligram (mg), which is equivalent to a MDC of 0.08 milligrams per cubic meter (mg/m^3), assuming a sample volume of 241 liters.

Area and PBZ samples were collected for 2–BE in the lacquer and glue application areas. Samples were collected on charcoal tubes, in 100 mg/50 mg sections, at a flow rate of 0.05 l/min. Two of the 2–BE area samples were collected with a flow rate of 0.04 l/min as an entire work shift representation. The tubes were analyzed by gas chromatography (GC) according to NIOSH Method 1403.[1] The analytical LOD was 0.003 mg, which is equivalent to a MDC of 3.0 mg/m^3, assuming a sample volume of 1.0 liter. The LOQ was 0.01 mg, which is equivalent to a MQC of 10 mg/m^3, assuming a sample volume of 1.0 liter.

Area methylene chloride air samples were collected in the lacquer application area on charcoal tubes, in 100 mg/50 mg sections, at a flow rate of 0.05 l/min, with another charcoal tube of the same type in line to detect breakthrough. Toluene was also analyzed from the same tubes. The tubes were analyzed by GC according to NIOSH Method 1005.[1] The LODs were 0.002 mg and 0.001 mg for methylene chloride and toluene, respectively, which is equivalent to MDCs of 0.22 mg/m^3 and 0.11 mg/m^3, assuming a sample volume of 9.2 liters. The LOQs were 0.006 mg and 0.003 mg for methylene chloride and toluene, respectively, which is equivalent to MQCs of 0.65 mg/m^3 and 0.33 mg/m^3, assuming a sample volume of 9.2 liters.

Area and PBZ air samples were collected for inorganic acids in the patina application areas. The patina solution consists of hydrochloric (HCl), nitric (HNO_3), and sulfuric (H_2SO_4) acids. Samples were collected on silica gel tubes, in 400 mg/200 mg sections with a glass fiber filter plug, at a flow rate of 0.5 l/min. One area sample was collected with a flow rate of 0.2 l/min. The tubes were analyzed according to NIOSH Method 7903.[1] The LOD was 0.001 mg for hydrochloric, nitric, and sulfuric acids, which is equivalent to a MDC of 0.17 mg/m^3, assuming a sample volume of 6 liters. The LOQ was 0.0034 mg for hydrochloric, nitric, and sulfuric acids, which is equivalent to a MQC of 0.57 mg/m^3, assuming a sample volume of 6 liters.

Real–time sampling for airborne particulates was conducted with the Grimm Model 1105 Dust Monitor (Labortechnik GmbH & CoKG, Ainring, Germany).[2] The Grimm Dust Monitor is a light scattering aerosol spectrometer designed for real–time particulate measurement with particle size discrimination. Eight channels collect count information for particle sizes greater than 0.75, 1, 2, 3.5, 5, 7.5, 10, and 15 µm. Data were collected to monitor the particulates generated by distinct events during abrasive–blasting operations in the enclosed room, patina spraying of copper sheets laying on a table, and acetylene/oxygen torching operations. For each operation, data were integrated for 1 second (sec) and stored sequentially on the Grimm data card over the entire time period. The collected particle count and size information was downloaded to a laptop computer following the completion of the operation. Start and stop times for significant operation events were recorded during each sample collection period.

The engineering evaluation consisted of a review of the current control systems employed to reduce potential occupational exposures to agents used in the manufacture of products. General and local ventilation exhaust systems were included in the evaluation. The rational for the design and operating parameters of these systems was determined through discussions with management. The efficacy of the exhaust systems was assessed through direct observation, the use of chemical smoke to document the movement of air streams around individual systems, and the measurement of system operating parameters (i.e., flow rate).

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre–existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[3], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®)[4] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs)[5]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA–approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH

TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A TWA exposure refers to the average airborne concentration of a substance during a normal 8–to–10–hour workday, with a maximum of 40 hours per week. Some substances have recommended short–term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short–term.

2–butoxyethanol (butyl cellosolve)

Butyl cellosolve is a common component of window and other cleaning agents. It is also used in paints, lacquers, and inks. The toxic effects of butyl cellosolve have been reported in many publications.[6] Acute (short–term) exposure to this compound can be irritating to the nose, eyes, mouth, and throat. Butyl cellosolve has the ability to permeate through the skin relatively easy. High exposure to this chemical can lead to dizziness, lightheadedness, and unconsciousness. Chronic (long–term) exposure may break down red blood cells and cause anemia, cause damage to the liver and kidneys, and may cause damage to the male reproductive system and a developing fetus. The NIOSH REL for butyl cellosolve is 24 mg/m^3 or 5 parts per million (ppm) as a 8–hour TWA, ACGIH recommends an 8–hour TWA of 121 mg/m^3 (25 ppm), and the OSHA PEL is 240 mg/m^3 (50 ppm) as an 8–hour TWA.[3,4,5] All three exposure limits have a "skin" notation, indicating that a significant portion of the overall exposure to a chemical is by the cutaneous route (skin), including the mucous membranes and eyes.

Methylene Chloride

Methylene chloride has been used as a paint remover, degreasing agent, as a process solvent in the manufacturing of pharmaceutical and food products, and as a fumigant for grain and fruits. Methylene chloride is a mild central nervous system depressant, an eye, skin, and respiratory tract irritant, and can be carcinogenic in laboratory animals.[7] Mice exposed to methylene chloride in air developed alveolar/bronchiolar cancers and tumors of the lung and hepatocellular cancers of the liver. Rats exposed to methylene chloride in air developed tumors of the mammary glands and cancer of the salivary glands.

Methylene chloride is classified by NIOSH as a substance that has the potential to cause cancer and has set an REL as the lowest feasibly possible.[3] ACGIH has classified methylene chloride as an animal carcinogen and recommends an 8–hour TWA of 174 mg/m^3 (50 ppm).[4] OSHA has an 8–hour TWA of 87 mg/m^3 (25 ppm) and a 15–minute STEL of 434 mg/m^3 (125 ppm).[5]

Toluene

Toluene is a component in gasoline, a solvent in paints and other coatings, and is used in the manufacturing of benzene and other chemicals.[8] Exposure to toluene may bring about central nervous system depression. An 8–hour human exposure in a controlled environment to 753 mg/m^3 (200 ppm) of toluene brought on symptoms of fatigue, weakness, confusion, lacrimation (tearing of the eyes), and paresthesias of the skin (sensations such as burning, tingling, itching, or prickling); exposure to 2260 mg/m^3 (600 ppm) produced euphoria, headache, dizziness, dilated pupils, and nausea; and at 3014 mg/m^3 (800 ppm) subjects showed more pronounced symptoms and aftereffects of nervousness, muscular fatigue, and insomnia.[8] ACGIH recommends an 8–hour TWA of 188 mg/m^3 with a skin designation.[4] The NIOSH REL for toluene is 375 mg/m^3 (100 ppm) and a STEL of 560 mg/m^3 (150 ppm).[3] OSHA has set an 8–hour TWA of 753 mg/m^3 (200 ppm), a ceiling concentration of 1130 mg/m^3 (300 ppm), and a 10–minute maximum peak of 1883 mg/m^3 (500 ppm).[5]

Aluminum Oxide

Aluminum oxide (Al_2O_3), also known as alumina, is used in fluxes and heat resistant fibers, abrasive and aluminum manufacturing, and in chromatographic analysis. Al_2O_3 is an eye, skin, nose, and throat irritant.[9] A study of an aluminum production facility found that 7% to 8% of the workers potentially exposed to alumina had small irregular opacities (darkened areas) in the lung, determined by chest radiographs.[10] The ACGIH recommended 8–hour TWA for Al_2O_3 is 10,000 µg/m^3 (10 mg/m^3) for particulate matter containing no asbestos and <1% crystalline silica.[4] The OSHA PEL is 15,000 µg/m^3 (15 mg/m^3) as total dust and 5000 µg/m^3 (5 mg/m^3) as the respirable fraction.[5] After reviewing available published literature, NIOSH provided comments to OSHA on August 1, 1988, regarding the "Proposed Rule on Air Contaminants" (29 CFR 1910, Docket No. H–020). In these comments, NIOSH questioned whether the proposed PEL (as an 8–hour TWA) of 10 mg/m^3 for aluminum oxide was adequate to protect workers from recognized health hazards.[3] Therefore, the NIOSH REL has not been established at this time.

Titanium dioxide

Titanium dioxide (TiO_2) is typically used as a welding rod coating and a white pigment for paints and ceramics. TiO_2 is a mild pulmonary irritant generally considered to be a nuisance dust.[8] In the lungs of workers processing TiO_2 pigment, dust deposit findings indicate that TiO_2 is a minor pulmonary irritant. Rats repeatedly exposed to concentrations of 10 to 328 million particles per cubic foot of air for up to 13 months showed small focal areas of emphysema, attributable to large deposits of dust.[8] There was no evidence that TiO_2 produced any specific lesion. A two year research study where rats were exposed to 250 mg/m^3 of TiO_2 resulted in the development of squamous cell carcinomas in 13 of 74 female rats and in 1 of 77 male rats, as well as an increase in broncho alveolar adenomas, another type of tumor. No excess tumor incidence was noted at 50 mg/m^3. The authors of that study questioned the biologic relevance of these tumors to humans, given the extremely high exposure concentrations, the unusual histology and the location of the tumors, and the absence of metastasis (spread of disease from one part of the body to another).[11] The NIOSH REL has not been established at this time. NIOSH considers TiO_2 to be a potential occupational carcinogen and recommends that exposures be reduced to the lowest feasible concentration.[3] The ACGIH TLV for TiO_2 is 10,000 µg/m^3 (10 mg/m^3) as an 8–hour TWA.[4] The OSHA PEL is 15,000 µg/m^3 (15 mg/m^3) as an 8–hour TWA.[5]

Lead

Major uses of lead include the following: batteries, ink, ceramics, and ammunition. Chronic lead exposure has resulted in nephropathy (kidney damage), gastrointestinal disturbances, anemia, and neurologic effects.[8] These effects may be felt as weakness, fatigue, irritability, high blood pressure, mental deficiency, or slowed reaction times. Exposure also has been associated with infertility in both sexes and fetal damage.[12] The OSHA PEL and ACGIH TLV for lead is 50 µg/m^3 as an 8–hour TWA.[5,4] ACGIH has designated lead as an animal carcinogen.[4] The NIOSH REL for lead is <100 µg/m^3 as an 8–hour TWA.[3] The U.S. Public Health Service (PHS) has established a national public health goal to eliminate all occupational exposures that result in blood lead levels (BLLs) greater than 25 micrograms per deciliter (µg/dL) by the year 2000.[13] NIOSH supports the PHS goal and recommends that to minimize the risk of adverse health effects, employers and workers should continually strive to reduce workplace lead exposure.

RESULTS

Work Practices and Personal Protective Equipment (PPE)

In the lacquer and patina application areas, workers wore 3M® 6000 series half–mask respirators with 20/20 dust/mist filters and latex gloves. In the past there had been reports of an organic odor in the lacquer area while wearing a respirator and working which may indicate the need to change existing engineering controls or the type of respirator filter used in this process area. Abrasive–blasting workers wore the same respirator set–up as above and rubber gloves while working with the abrasive–blasting cabinets. In the enclosed abrasive–blasting room, employees wore the same personal protective equipment (PPE) as above, with the addition of Tyvek® suits and an abrasive–blasting hood. It was noted that in some instances workers had to wipe the interior portion of the hood window because of dust build–up. Workers wore a disposable dust mask in the glue application area.

The facility did not have a respiratory protection program. Program deficiencies included inadequate respirator storage and (visible) facial hair on some of the employees that wore respirators. In some tasks, the gloves used were old and not in suitable condition for use as PPE. Also, the grinding wheel the employees use to take off rough, copper edges was inadequately guarded.

Environmental

Metals

The area and PBZ air samples for metals are presented in Tables 1 and 2, respectively. Only the results for metals with the greatest toxicological significance and found at the highest concentration are presented. Al_2O_3 concentrations in air samples taken in the abrasive–blasting areas ranged from less than 1.3 to 671 $\mu g/m^3$. The highest PBZ air sample concentration, 459 $\mu g/m^3$, was found while abrasive–blasting copper sheets inside the contained room. The area air samples (inside the contained room) had an Al_2O_3 8–hour TWA of 248 $\mu g/m^3$. The 8–hour TWA for Al_2O_3 using all PBZ air samples taken inside the contained room was 94 $\mu g/m^3$. The concentrations found were lower than the OSHA PEL of 15000 $\mu g/m^3$ and the ACGIH TLV of 10000 $\mu g/m^3$. TiO_2 concentrations ranged from less than 0.6 to the highest of 242 $\mu g/m^3$ while abrasively–blasting rock and glassware. The area air samples (inside the contained room) had an 8–hour TWA for TiO_2 of 82 $\mu g/m^3$. The 8–hour TWA for TiO_2 using all PBZ air samples taken inside the contained room was 61 $\mu g/m^3$. The concentrations found were lower than the OSHA PEL of 15000 $\mu g/m^3$ and ACGIH TLV of 10000 $\mu g/m^3$. Lead concentrations ranged from less than 3 $\mu g/m^3$ to the highest of 16.6 $\mu g/m^3$ while soldering copper pieces using an acid core, lead containing solder. The 8–hour TWA for lead using all PBZ air samples taken inside the contained room was 1.0 $\mu g/m^3$. The concentrations found were lower than the OSHA PEL and ACGIH TLV of 50 $\mu g/m^3$, and the NIOSH REL of <100 $\mu g/m^3$.

Respirable Dust

Table 3 presents the results for the respirable dust air samples. Concentrations ranged from 0.08 to the highest of 0.71 mg/m^3 while abrasively–blasting approximately 1' x 2' copper sheets. The area air samples (inside the contained room) had an 8–hour TWA for respirable dust of 0.43 mg/m^3. All concentrations are lower than the OSHA PEL of 5 mg/m^3 and the ACGIH TLV of 3 mg/m^3.

Methylene Chloride/Toluene

Table 4 presents the results of methylene chloride and toluene area air sampling performed in the lacquer application area. Methylene chloride and toluene area air samples were collected separately in the morning and afternoon. Methylene chloride morning and afternoon concentrations found were 8.02 and 7.32 mg/m^3, respectively. The area air samples had an 8–hour TWA for methylene chloride of 6.25 mg/m^3. Toluene concentrations were 7.05 and 5.46 mg/m^3 for the morning and afternoon time periods, respectively. The area air samples had an

8–hour TWA for toluene of 5.12 mg/m^3. All of these concentrations are lower than the criterion limit set by OSHA and exposure limit recommended by ACGIH for an 8–hour TWA.[5,4] The toluene 8–hour TWA concentration was below the NIOSH REL.[3] However, NIOSH classifies methylene chloride as a substance that has the potential to cause cancer and has set an exposure limit as the lowest feasibly possible.[3]

2–butoxyethanol (2–BE)

Area and PBZ air sampling results for 2–BE are described in Table 5. PBZ and area air sample concentrations of 8.2 and 5.0 mg/m^3, respectively, were collected in the lacquer application area. Other air samples taken resulted in non–detectable concentrations. The 2–BE concentration of 8.2 mg/m^3 was a PBZ sample and was the highest found. The area air samples had an 8–hour TWA for 2–BE of 2.2 mg/m^3. The PBZ air samples had an 8–hour TWA for 2–BE of 0.5 mg/m^3. Both air sample results were lower than the criterion limit set by OSHA and exposure limits recommended by ACGIH and NIOSH.[5,4,3]

Inorganic Acids

Area and PBZ air samples taken for inorganic acids all resulted in non–detectable concentrations for hydrochloric, nitric, and sulfuric acid. All air samples taken had concentrations lower than a MDC of 0.2 mg/m^3, assuming a sample volume of 6 liters.

Real–time Particulate Measurements

Figures 1 through 6 present graphical representations of the real–time data collected with the Grimm particle counter for six monitored events. The events included abrasive–blasting on glass, stone, ceramic mugs, and copper sheets in the ventilated room (Figures 1–3); abrasive–blasting on copper cutouts in the cabinets (Figure 4); the application of a torch to copper sheets (Figure 5); and the application of glue to plastic templates (Figure 6). Attempts were made to collect data over the complete time period for each event. For Figures 1–3, a correction factor was applied to the data to reflect the density of Al_2O_3 abrasives used during the sampling periods. The presented data includes all particles greater than 0.3 µm in diameter. However, estimates were made of the mass median aerodynamic diameter (MMAD) and the geometric standard deviation (GSD) based on the integrated particle size characterization provided by the instrument (Table 6).

For the event blasting large copper sheets (approximately 2 by 4 feet square) with Al_2O_3, numerous peaks above the instrument limit of 14 mg/m^3 were observed. The MMAD was graphically estimated at 7.5 µm with a GSD of 2.0. Abrasively–blasting smaller items (with Al_2O_3) in the ventilated room produced concentrations consistently below 14 mg/m^3 (Figures 2 and 3). In addition, the blasting of glass items produced lower concentrations, on average, than those produced by blasting rock and ceramic. The median particle size observed during the blasting of glass, stone, and ceramic items was smaller when compared to the blasting of large copper sheets. The MMAD during the blasting of glass and stone was 5.2 µm (GSD = 2.1); for blasting ceramic mugs the MMAD was 5.5 µm (GSD = 2.2). Abrasive–blasting in the cabinets (adjacent to the ventilated room), showed peak concentrations over the analytic limit of the instrument of 10 mg/m^3 (Figure 4). (A density correction factor was not applied because the blasting was conducted with glass beads and the Grimm is calibrated to a similar density. This directly affects the analytic limit of the instrument.) This indicates that the exhaust ventilation is ineffective in reducing the concentrations outside of the cabinet.

Real–time measurements were also collected during the application of glue to the plastic templates and during the application of a torch to copper sheets. Peak concentrations observed during the initial application of glue were above the analytical limit of the Grimm (greater than 10 mg/m^3, Figure 5). Subsequently, the concentrations decayed very slowly to background levels, which is indicative of the limited introduction of outdoor air. The dilution of generated concentrations is affected by the amount of outside air introduced. The greater the amount of outside air, the greater the dilution effect.

Particulate concentrations generated by the application of the torch to copper were low in comparison to the other monitored events (Figure 6). The peak concentrations never rose above 0.8 mg/m^3. However, the Grimm may have underestimated the concentration due to its limited ability to detect sub–micrometer (less than 1 µm) particles. The particle sizes generated by this type of activity would likely result in the generation of fumes and products of combustion which are generally in the sub–micrometer range.

Engineering

The company implemented engineering controls to (1) reduce potential occupational exposures to agents used in the manufacture of products, and (2) recover and recycle raw materials used in the abrasive–blasting process. General exhaust ventilation systems were employed at the lacquer table and in the dedicated room for abrasive–blasting. Local exhaust ventilation was used in the operation of the abrasive–blasting cabinets.

At the lacquer table, a common house fan (12 inches in diameter) was hung in the open window next to the table. Additionally, plastic curtains were hung around the spray tables to contain contaminants and minimize the effects of surrounding air currents. The fan was normally switched on during the application of lacquer on products and during the application of the patina solution onto copper sheets. After the application of the patina solution, the fan was switched off. This was reportedly done to increase the drying time. (According to management, a short drying time induced by the operation of the fan could result in an undesirable finish.) Chemical smoke disseminated around the fan during operation indicated a highly variable effectiveness (i.e., at times the smoke was observed to come back in around the fan). The limited success of the fan was primarily due to the lack of a tight seal in the window (measuring 32 by 31 inches), the effect of outside wind patterns (velocity and direction), and the status of the loading dock door (open or closed). When the loading dock door was open and the fan in the ventilated abrasive–blasting room was operating, the window fan had the least ventilation effect.

The general exhaust ventilation for the room dedicated to abrasive–blasting was achieved by the application of an exhaust fan (approximately 20 inches in diameter) located on the east wall of the room. Make–up air through a diffuser vent located above the entry door came from the adjacent room. Based on a 20–point traverse measured approximately 5 inches from the fan, the exhausted flow rate was calculated to be 2060 cubic feet per minute (cfm). A small baffle plate was angled in front of the fan to reportedly impact particles with subsequent collection on the floor for recovery and recycling. All blasting activities were observed to take place at one of two tables on the south wall adjacent to the wall with the exhaust fan.

Two abrasive–blasting cabinets were located adjacent to the ventilated room (Figure 8). Each cabinet was funneled at the base to collect the abrasive for recycling. The cabinet located next to the outside wall was hard ducted with polyvinyl chloride pipe ([PVC] 3 inch inside diameter) into the ventilated room. The other cabinet was connected with flexible duct to the PVC pipe. Close observation of the PVC pipe connection to the cabinet revealed a 2 inch length open slit. Additionally, the flexible duct was observed to sag heavily due to the deposition of abrasive particles; the duct was almost completely occluded. No connection to a fan was observed in the ventilated abrasive–blasting room. Flow rate was induced in the cabinet systems by the pressure drop created by the general exhaust ventilation fan in the ventilated room. Using the velometer to estimate the air velocity, the flow rate into the ventilated room through the PVC pipe was estimated to be 275 cfm. However, a large portion of the induced air flow was lost through the open slit in the PVC pipe connected to the cabinet. This deficiency and the occluded flexible duct are the most probable explanation for the large concentration of peaks identified by the Grimm during use of the cabinets.

DISCUSSION

The control of occupational exposures to chemical, biological, and physical agents is accomplished by the application of engineering measures, work practices, and PPE. These measures, practices, and/or equipment are applied at the source of the contaminant generation, to the general workplace environment, or at the significant exposure point of an individual. The application of engineering measures at the source provides the most effective control of both occupational and environmental contaminants. Substitution with a less hazardous material is the preferred approach to providing a safe work environment. However, as with many situations, (i.e., microbiologic agents), this option may not be available since the agents are usually not an intentional process material. Where material substitution is not feasible, process/equipment modification, isolation, or automation and the use of local exhaust ventilation (LEV) can be effective source control methods. Additionally, work practices can be modified to minimize the potential for contaminant generation and subsequent exposure. Under those circumstances where source control is not an amenable solution, modifications to the general work environment can provide the next level of control. The techniques employed include dilution ventilation, aerosol (e.g., dust) suppression, and improved housekeeping activities. The last level of control attempts to separate the exposed worker from the chemical, biological, or physical agent. Separation can be attained by the application of isolation environments (e.g., remote control rooms, isolation booths, and supplied–air cabs). Separation can also be achieved by employing PPE including chemically impervious clothing and respirators approved by NIOSH.

Area and PBZ air samples calculated as an 8–hour TWA were below the applicable evaluation criteria for Al_2O_3, TiO_2, and lead. PBZ air samples taken in the abrasive–blasting room were positioned underneath the hood the employees wore while working in this area. This may partially account for the lower air sample concentrations compared to those observed with the Grimm dust monitor. Area air samples were collected to indicate potential exposures if employees did not wear a hood. Additionally, the PBZ air samples collected were for metals and not for total dust and cannot indicate total dust exposures underneath the hood. However, the real–time instrument measured total dust peak concentrations above 10 mg/m^3 in the abrasive–blasting environment which indicates the potential for exposures above relevant evaluation criteria. The computed MMAD indicates that a majority of the mass would be deposited in the thoracic region of the respiratory system (as defined by ACGIH) including a sizable portion in the lower respiratory system. Therefore, the practice of wearing respirators should be continued with the existing abrasive–blasting system. The real–time instrument differentiates between particulate size ranges, whereas the PBZ samples do not. This allows for increased understanding of actual respirable particulates for potential exposure as discussed in the Real–time Particulate Measurements section of this report.

The exhaust fan in this area was running at approximately 2060 cfm which helped to reduce the potential for exposure to these metals. However, the position of the employee at the work station, in relation to the fan and the supply air opening (please refer to Figure 8), could lead to the possibility of an eddy (a current of air moving in a circular motion) and/or dead air spaces which could increase exposures within a normal 2–3 hour task. The most effective design is to place the worker in a straight line between the exhaust fan and the make–up air intake. This design ensures that generated aerosols are exhausted before reaching the worker's breathing zone.

The most significant potential occupational exposure to 2–BE in this facility is through skin contact. PBZ air sampling results indicated low exposures compared to the appropriate evaluation criteria. However, the lacquer containing 2–BE is contained in a bin into which the copper sheets are dipped (to maintain the shiny, metallic appearance). The skin can be a significant exposure route since the employees use their hands to maneuver the copper sheets from dipping to drying.

Area air samples collected for methylene chloride and toluene indicate there is a potential for worker exposure. The methylene chloride/toluene lacquer is a spray–on solution found in common spray aerosol cans. The house fan placed in the window directly behind the lacquer application area is designed to remove the potential for inhalation exposures. In winter, during afternoon hours where heat is not used, the loading dock door is opened. During morning hours, the loading dock door is closed and the only supply air to the facility is the exhaust fan window in the lacquer application area. When abrasive–blasting operations and the lacquer application occur at the same time when the loading dock doors are closed, the make–up air for the abrasive–blasting fan comes from the lacquer application exhaust window. In this situation, the lacquer application worker has limited exhaust from the fan and greater potential for exposures to methylene chloride and toluene vapors.

The use of engineering controls has kept the potential for exposures low as documented by the sampling results. However, during the closing conference, the NIOSH team raised concerns about the following: a general refinement of the existing engineering controls to improve the control efficiency (as discussed in the results and recommendations section), unnecessary occupational exposures to lacquer vapors when the abrasive–blasting exhaust fan is operational and the loading dock door is closed, the use of a general ventilation exhaust fan to induce flow in the abrasive–blasting cabinets, and insufficient make–up air into the facility.

CONCLUSIONS

The results from air samples indicate that occupational exposures to metals and organic compounds, except for methylene chloride, in this facility were all below the appropriate occupational evaluation criteria at the time of the site visit. Methylene chloride was above the NIOSH REL, but below ACGIH and OSHA evaluation criteria. The potential exists for increased exposure concentrations if prolonged periods (i.e., a full 8–hour workshift) are spent at a specific task by employees. The area, 8–hour TWA results reflect potential employee exposure concentrations if that employee were to work in that specific area for the entire workshift. PBZ, 8–hour TWA results are a compilation of collected samples for each task during the workshift. The current task rotation of employees during workshifts reduces the possibility of increased exposure during specific facility operations.

With modifications to the existing engineering controls, it may be possible to decrease or eliminate some PPE use during specific activities (i.e., use of respirators when using the abrasive–blasting cabinets). However, if PPE is needed, the correct choice, use, and maintenance of gloves and respirators for certain substances will be beneficial to control potential occupational exposures.

RECOMMENDATIONS

The following recommendations are based on the findings of this investigation and offered to improve the safety and health of employees working with materials used in the operations discussed in this report.

1. Although exposures in all areas, except for methylene chloride in the lacquer application area, were below appropriate evaluation criteria, modifications to the existing engineering controls should be implemented to improve the efficacy of the systems. Engineering control modifications include: creating a different source of make–up air and rearranging workstation locations in the abrasive–blasting room, installation of a dedicated exhaust fan for the two abrasive–blasting cabinets, sealing the open area around the house fan in the window space at the lacquer application table and drying area, installation of a small exhaust fan above the glue application table, and installation of a sanding belt machine guard.

2. Figure 9 shows a proposed rearrangement of the abrasive–blasting operations in the established abrasive–blasting room. Proposed changes to the

room are as follows: (1) Cover the existing hole above the doorway and create a new one across the room that opens to the outside. This will allow make–up air for the room to come from outside air instead of using air inside the building. (2) Move the existing abrasive–blasting table and worker so they face the fan. This will allow air contaminants to be pulled away from workers, rather than through their breathing zone. (3) Enclose sides from the fan to the sides of the table with wood up to the ceiling. This will keep flow of air to the fan in confined direction. (4) Install pegboard against the table front in between the table and fan. This will act as a barrier so material loss will be minimal and exposure potential from Al_2O_3 can be controlled from the fan, and create uniform pressure that ensures even air flow across the entire face. (5) The abrasive–blasting table can be reconstructed to be grated on top with a collection apparatus at the bottom (ex. abrasive–blasting cabinets) for Al_2O_3 recycling. This arrangement should reduce the eddy potential and control employee exposure to Al_2O_3 while collecting as much used material as possible. (6) Have the sides of the table enclosed with wood and a removable top for larger copper sheets or other large materials to be blasted. (7) The space between the fan and the peg board should be at least 10 in. and up to 24 in. based on a similar ventilation system recommended by ACGIH® for a Booth–type hood, (Figure 3–10 in ventilation manual).[14] The design distance between the baffle (in this case peg board) and the fan is at least D/2, where D is the diameter of the fan and is equal to 20 inches.

The purpose of this recommendation is to create a room environment for abrasive–blasting that will enhance the effectiveness of the existing system for controlling potential exposures, while improving the capture of abrasive–blasting material. Employees will need to continue respirator use in this area. Based on the real–time monitoring data, there is exposure potential to elevated levels (above 10 mg/m^3) of total dust with the current ventilation system.

3. A respiratory protection program should be implemented for the abrasive–blasting and lacquer application areas. The selection of an appropriate NIOSH–approved respirator is determined by knowledge of the suspected air contaminants. Respirators must be used in accordance with a complete respiratory protection program as specified in the OSHA Standard 29, Code of Federal Regulations 1910.134.[15] OSHA requires that respiratory protection programs include written standard operating procedures; respirator selection on the basis of hazard; user instruction and training; respirator cleaning, disinfection, storage, and inspection; surveillance of work area conditions; evaluation of the respirator protection program; medical review; and use of certified respirators. Publications developed by NIOSH can also be referenced when developing an effective respirator program including the NIOSH Respirator Decision Logic and the NIOSH Guide to Industrial Respiratory Protection.[16,17]

It is imperative that the appropriate filter cartridges are used during specific operation, i.e., the lacquer application area should use an organic vapor filter (black color), the patina area should use an acid–gas filter (white color), or a filter with a yellow color can be used for both organic vapor and acid gas. For employees working with abrasive–blasting tasks, NIOSH–approved respirators with an N95 designation (as defined by the current NIOSH certification procedures 42 CFR 84 effective July 10, 1998) would meet or exceed the CDC standard performance criteria.[18] The N95 designation indicates that the filter material has been shown to remove 95% of particles greater than 0.3 µm.

4. Use of dermal PPE should be continued in the abrasive–blasting, lacquer, and patina application areas. The lacquer and patina application areas should use nitrile gloves for short–term and butyl rubber gloves for long–term contact protection against 2–BE and nitric, sulfuric, and hydrochloric acids. Methylene chloride and toluene require the use of poly–vinyl alcohol gloves for best protection. In the abrasive–blasting areas rubber gloves are appropriate.

5. Bananas! Gifts, Inc. should conduct training for employees about the hazards involved with different operations; the PPE involved with each; and the

correct selection, donning, use and maintenance, and storage of this PPE. This training should be in accordance with the OSHA Hazard Communication Standard 29, Code of Federal Regulations 1910.1200.[19]

6. Any direct contact with the 2–butoxyethanol lacquer should be immediately washed off with soap and water. Personal hygiene practices should also be encouraged. This applies to washing hands before handling food items during the day, before using restroom facilities, and before going home at night.

7. The administrative control of employee rotation after 2–3 hours of a certain task in this facility should be continued to reduce the potential for over–exposure to harmful substances.

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Table 1
Area Air Samples for Metals
HETA 97–0161–2607
November 6, 1997

Job Task (location)	Sample Time (military)	Sample Volume (liters)	Concentrations, micrograms per cubic meter (µg/m^3)		
			Al_2O_3 *	TiO_2 *	Pb
Abrasive–blasting (on top of abrasive–blasting cabinets)	0821–1450	776	7.0	Trace	ND
Abrasive–blasting (inside contained room)	0818–1039	282	671	178	ND
Abrasive–blasting (inside contained room, entrance)	0818–1042	289	111	48	ND
Torching and soldering copper materials	0838–1451	743	Trace	Trace	0.7
Abrasive–blasting (inside contained room)	1040–1448	496	99	57	ND
Abrasive–blasting (inside contained room, entrance)	1042–1448	493	27	14	ND
** Minimum Detectable Concentration (MDC)			1.3	0.3	0.6
** Minimum Quantifiable Concentration (MQC)			5.2	0.5	2.6
Evaluation Criteria		NIOSH REL	***	LF	<100
		OSHA PEL	15000	15000	50
		ACGIH TLV	10000, A4	10000, A4	50, A3

* Assuming all reported Aluminum (Al) and Titanium (Ti) is in the form of Al_2O_3 and TiO_2.
** Reported as micrograms (µg) per sample Al and Ti.
*** See page 10, Evaluation Criteria, Aluminum oxide

Al_2O_3 = aluminum oxide
TiO_2 = titanium dioxide
Pb = lead
Trace = concentration between MDC and MQC
ND = not detected
LF = lowest feasible concentration
A3 = animal carcinogen
A4 = not classifiable as a human carcinogen

Table 2
Personal Breathing Zone Air Samples for Metals
HETA 97–0161–2607
November 6, 1997

Job Task (location)	Sample Time (military)	Sample Volume (liters)	Concentrations, micrograms per cubic meter (µg/m³)		
			Al_2O_3 *	TiO_2 *	Pb
Abrasive–blasting copper sheets (inside contained room)	0832–0901	115	459	217	8.7
Torching copper sheets	0938–1134	465	8.0	Trace	ND
Abrasive–blasting rock and glassware (inside contained room)	1059–1217	311	322	242	3.2
Soldering copper figures	1137–1152	60	ND	ND	16.6
Abrasive–blasting coffee mugs (inside contained room)	1353–1404	44	338	202	ND
Abrasive–blasting rock (inside contained room)	1419–1442	92	131	71	ND
** Minimum Detectable Concentration (MDC)			1.3	0.6	0.3
** Minimum Quantifiable Concentration (MQC)			5.2	2.6	0.5
Evaluation Criteria		NIOSH REL	***	LF	<100
		OSHA PEL	15000	15000	50
		ACGIH TLV	10000, A4	10000, A4	50, A3

* Assuming that all reported Al and Ti is in the form of Al_2O_3 and TiO_2.
** Reported as micrograms (µg) per sample Al and Ti.
*** See page 10, Evaluation Criteria, Aluminum oxide

Al_2O_3 = aluminum oxide
TiO_2 = titanium dioxide
Pb = lead
Trace = concentration between MDC and MQC
ND = not detected
LF = lowest feasible concentration
A3 = animal carcinogen
A4 = not classifiable as a human carcinogen

Table 3
Area Air Samples for Respirable Dust
HETA 97–0161–2607
November 6, 1997

Job Task (location)	Sample Time (military)	Sample Volume (liters)	Respirable Dust (mg/m^3)
AREA			
Abrasive–blasting (on top of abrasive–blasting cabinets)	0822–1450	655	0.08
Abrasive–blasting (inside contained room)	0818–1041	241	0.71
Abrasive–blasting rock, mugs, and glassware (inside contained room)	1041–1448	416	0.43
Minimum Detectable Concentration (MDC)			0.08
Evaluation Criteria		NIOSH REL	N/A
		OSHA PEL	5
		ACGIH TLV	3

N/A = not available

Table 4
Morning and Afternoon Area Air Samples for Methylene Chloride and Toluene
HETA 91–0161–2607
November 6, 1997

Job Task (lacquer type)	Sample Time (military)	Sample Volume (liters)	Concentrations, milligrams per cubic meter (mg/m^3)	
			Methylene chloride	Toluene
AREA				
Copper sheet lacquer application (spray–on can) – morning	0832–1159	10.4	8.02	7.05
Copper sheet lacquer application (spray–on can) – afternoon	1200–1503	9.2	7.32	5.46
Minimum Detectable Concentration (MDC)			0.22	0.11
Minimum Quantifiable Concentration (MQC)			0.65	0.33
Evaluation Criteria	NIOSH REL		LF	375, 560 ST
	OSHA PEL		87, 434 ST	766, 1149 C, 1915 MP
	ACGIH TLV		174, A3	188, sk, A4

LF = lowest feasible concentration
ST = short term exposure limit (15 minute)
A3 = animal carcinogen
C = ceiling
MP = 10 minute maximum peak
sk = skin designation
A4 = not classifiable as a human carcinogen

Table 5
Area and Personal Breathing Zone Air Samples for 2–butoxyethanol
HETA 97–0161–2607
November 6, 1997

Job Task (lacquer type or adhesive solution)	Sample Time (minutes)	Sample Volume (liters)	2–butoxyethanol (mg/m^3)
AREA			
Copper sheet dipping (water–based)	0825–1155	8.40	5.0
Copper sheet dipping (water–based)	1156–1502	7.44	ND
Picture template preparation (adhesive solution)	1015–1115 1322–1402	5.0	ND
PERSONAL BREATHING ZONE (PBZ)			
Copper sheet dipping (water–based)	0832–0851	0.95	ND
Copper sheet dipping (water–based)	0851–0918	1.35	8.2
Picture template preparation (adhesive solution)	1015–1045	1.5	ND
Copper sheet (spray–on lacquer)	1427–1456	1.45	ND
Minimum Detectable Concentration (MDC)			3.0
Minimum Quantifiable Concentration (MQC)			10
Evaluation Criteria		NIOSH REL	24, sk
		OSHA PEL	240, sk
		ACGIH TLV	121, sk

sk = skin designation
ND = not detected

Table 6
Estimated Particle Size Statistics for Monitored Events
HETA 97–0161–2607
November 6, 1997

Operation	MMAD (µm)	GSD
Real–time particulate measurements during blasting of copper in ventilated room	7.5	2.0
Real–time particulate measurements during blasting of glass and stone in ventilated room	5.2	2.1
Real–time particulate measurements during blasting of ceramic mugs in ventilated room	5.5	2.2
Real–time particulate measurements during blasting of copper in cabinets	7.4	2.2
Real–time particulate measurements during glue application	5.9	2.4
Real–time particulate measurements during torch application to copper	6.1	2.1

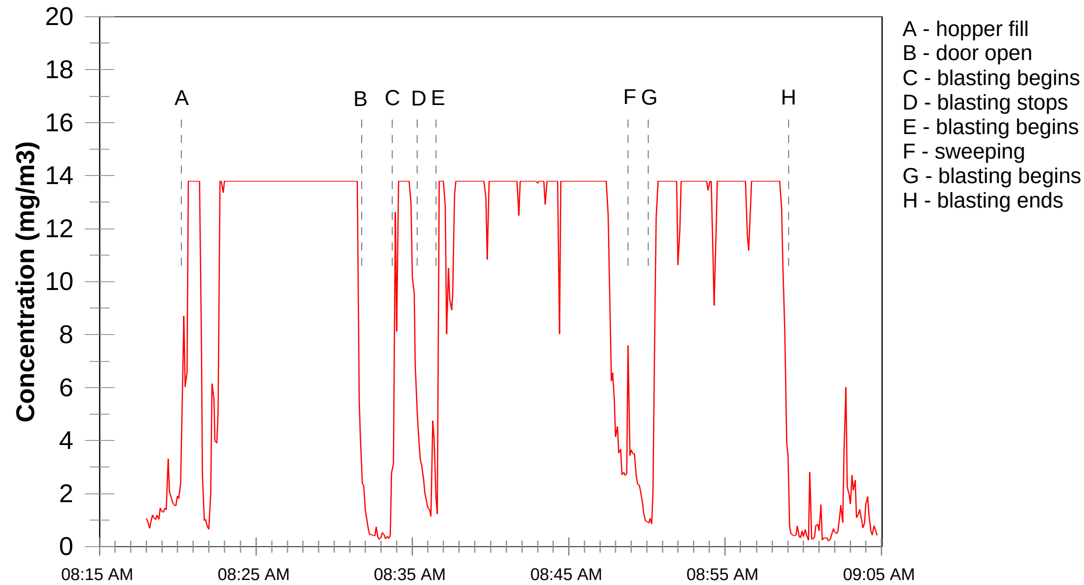

Figure 1. Real–time particulate measurements during blasting of copper in ventilated room.

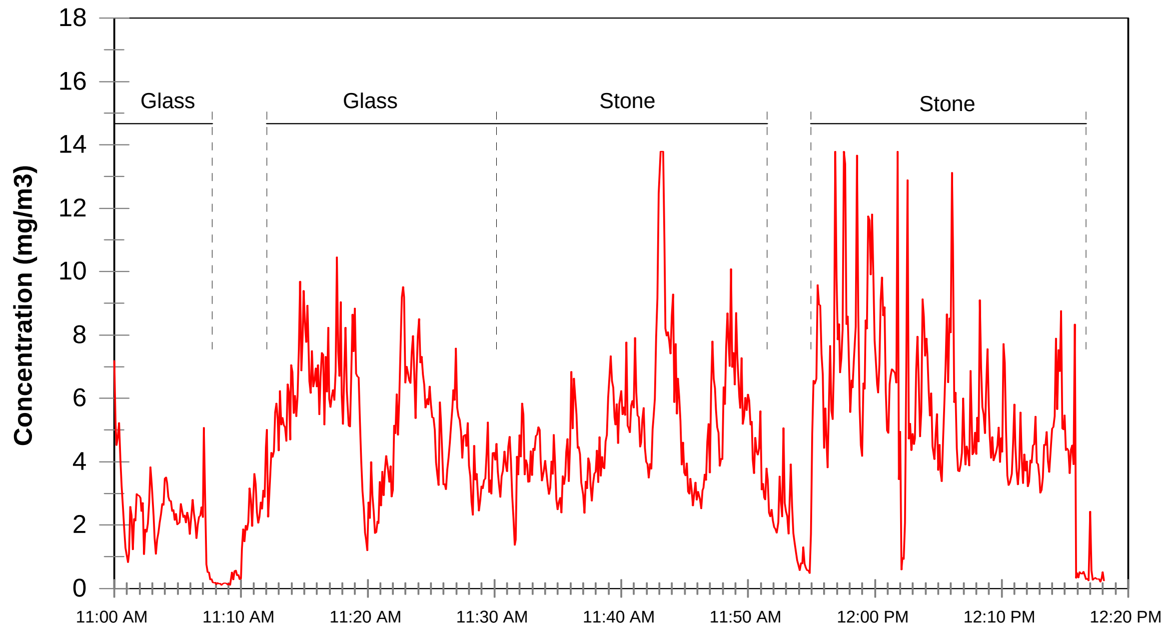

Figure 2 . Real–time particulate measurements during blasting of glass and stone in ventilated room.

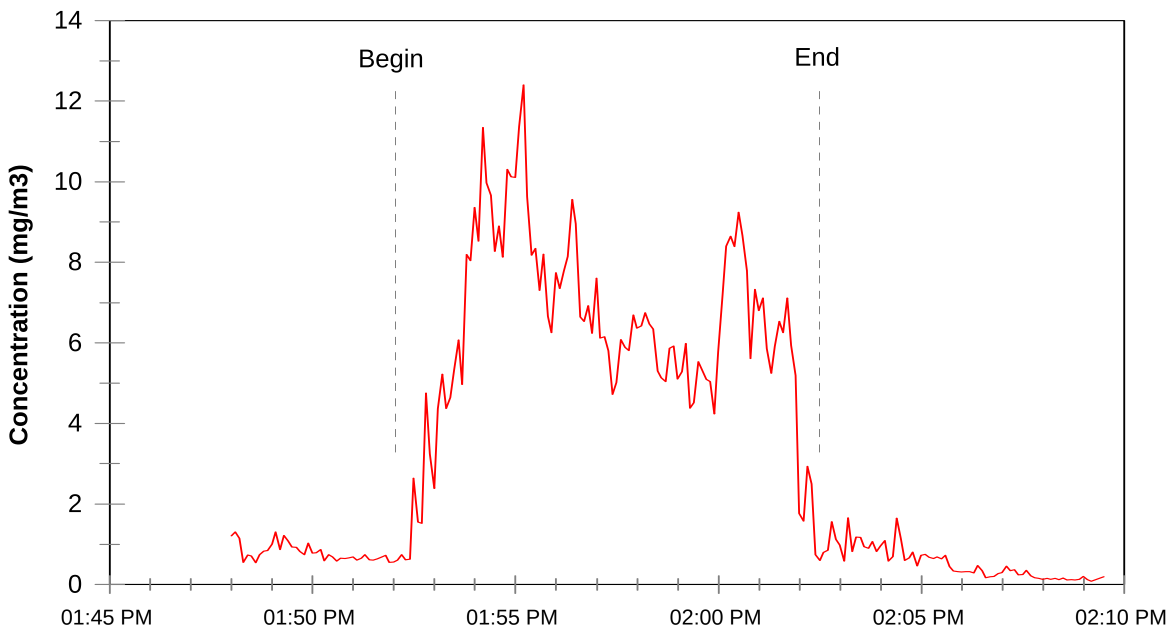

Figure 3. Real–time particulate measurements during blasting of ceramic mugs in ventilated room.

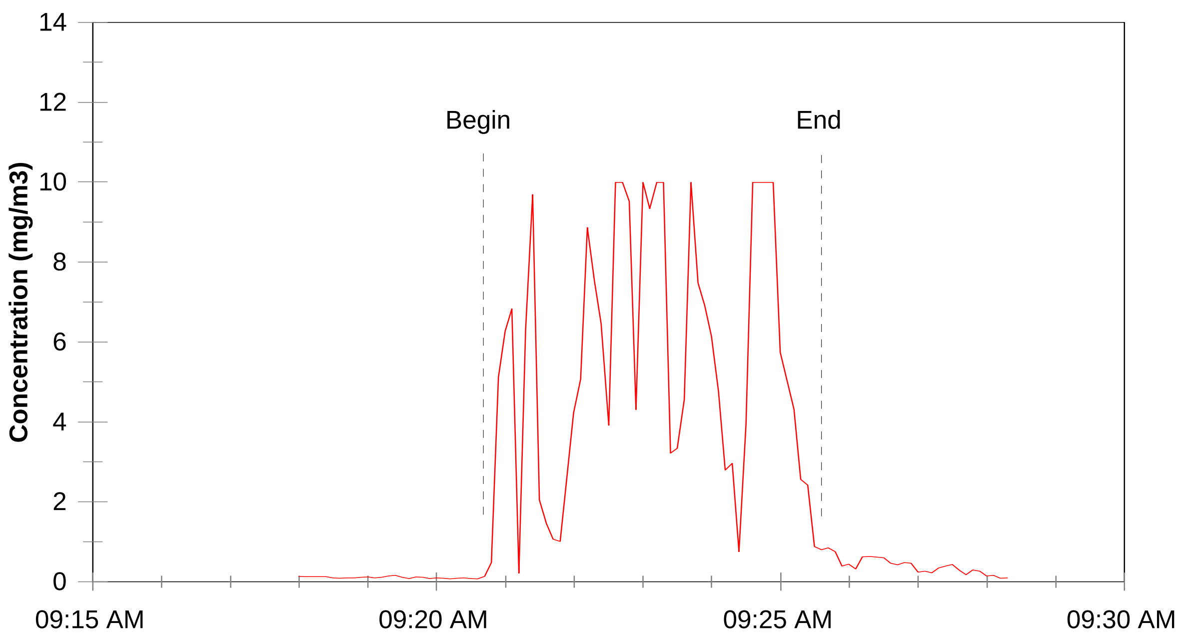

Figure 4. Real–time particulate measurements during blasting of copper in cabinets.

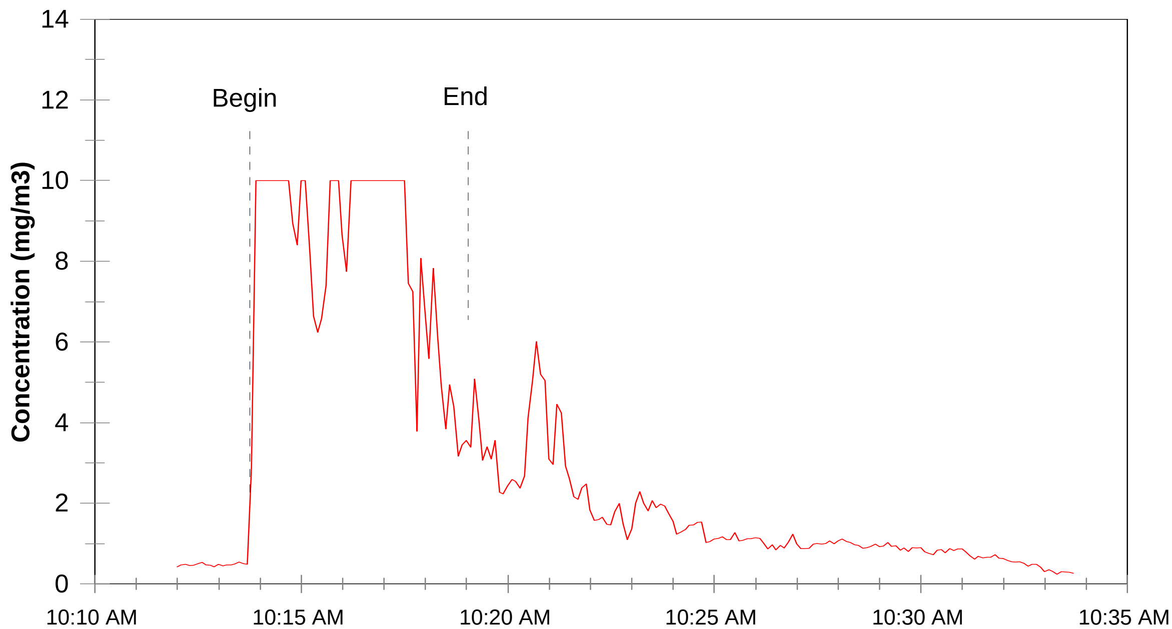

Figure 5. Real–time particulate measurements during glue application.

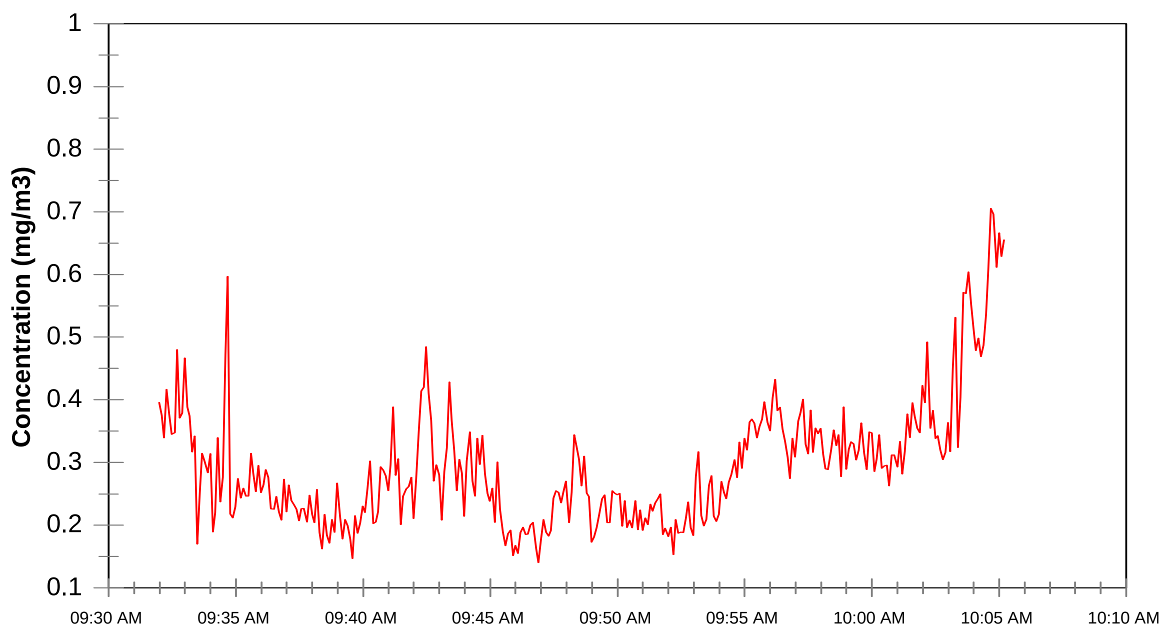

Figure 6. Real–time particulate measurements during torch application to copper.

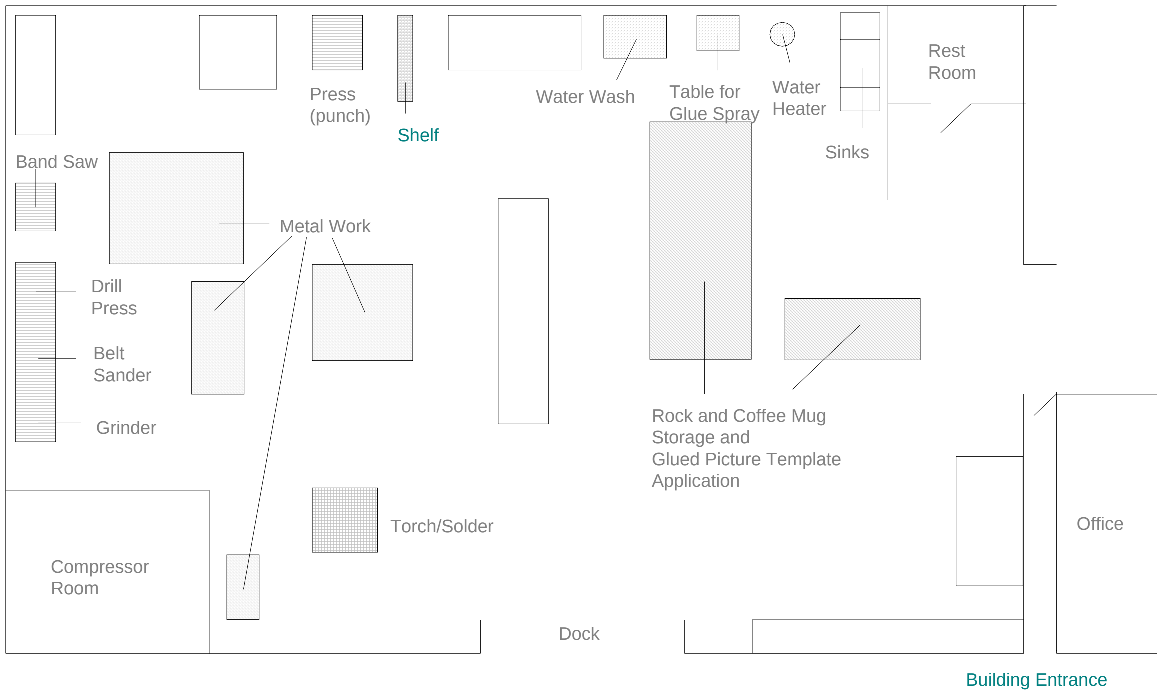

Figure 7. West Side of Facility - glue application, torching/soldering, and metal work areas

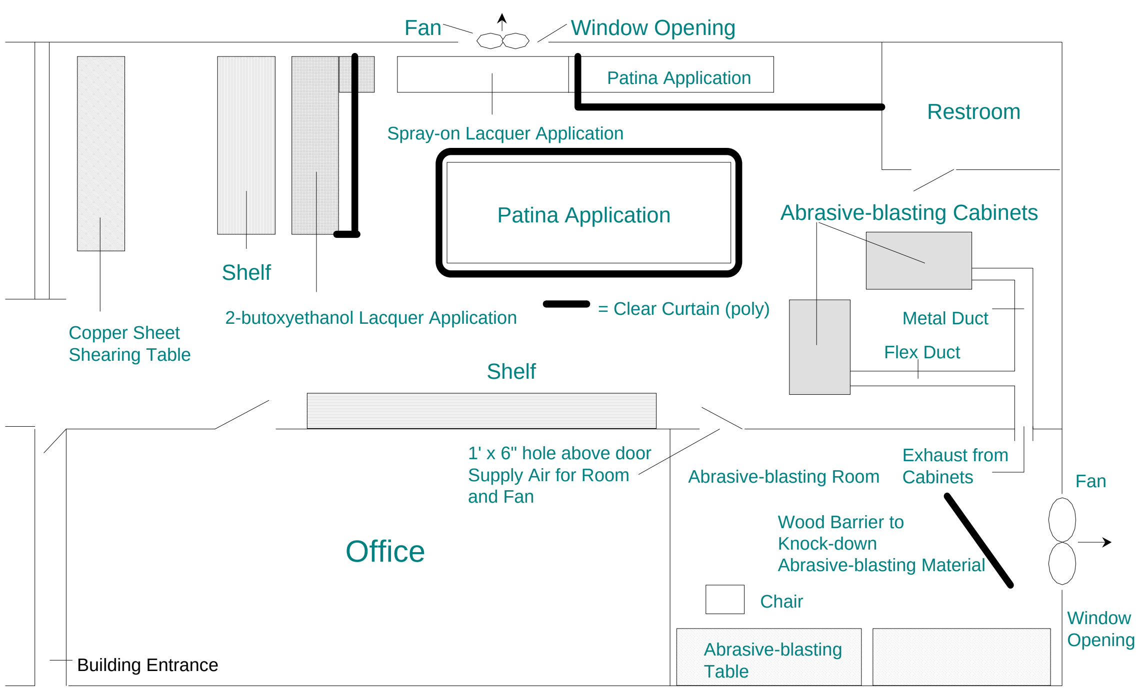

Figure 8. East Side of Facility - abrasive-blasting, lacquer and patina application areas

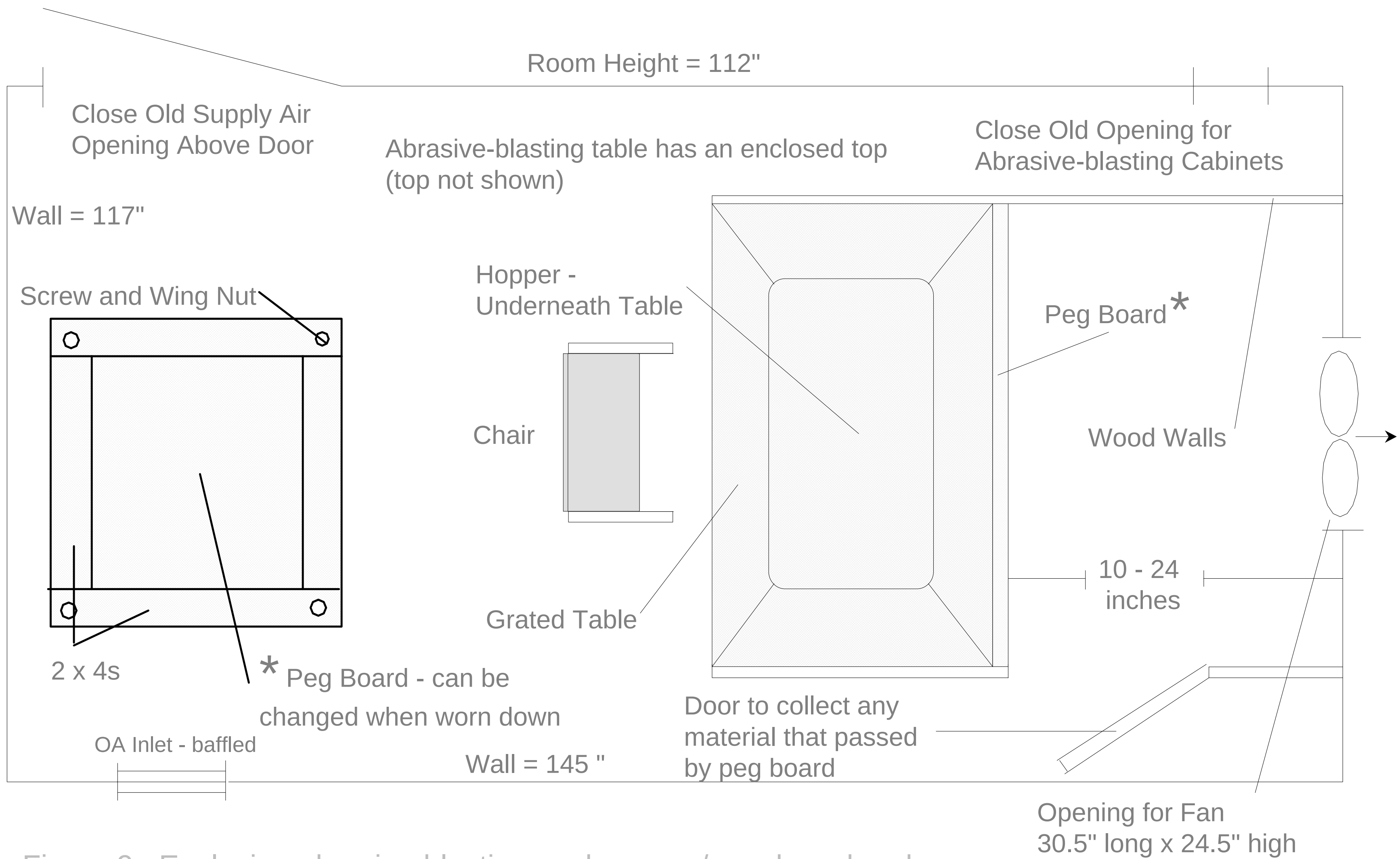

Figure 9. Enclosing abrasive-blasting work area w/ peg board and grated table to catch abrasive-blasting material for recycling purposes.

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