CONTROL TECHNOLOGY AND EXPOSURE ASSESSMENT FOR OCCUPATIONAL EXPOSURE TO BERYLLIUM: BERYLLIUM FACILITY #3 – ALUMINUM/BERYLLIUM FOUNDRY, and COPPER/BERYLLIUM FOUNDRY AND MACHINE SHOP

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SITES SURVEYED:	Beryllium Facility #3 Aluminum Beryllium Foundry, Copper/Beryllium Foundry and Machine Shop South-Eastern USA
NAICS:	331521
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DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention.

The findings and conclusions in this report are those of the author(s) and do not necessarily reflect the views of the National Institute for Occupational Safety and Health.

EXECUTIVE SUMMARY

On September 26 - 27, 2007, the National Institute for Occupational Safety and Health (NIOSH) conducted an in-depth industrial hygiene survey at a facility with two foundries: an ingot foundry which manufactured aluminum/beryllium and copper/beryllium ingots; and a greensand foundry with a cutting and grinding operation which manufactured a variety of copper/beryllium products including non-sparking hand tools. The company employed a total of 20 employees in the two foundry operations and the cutting and grinding shop. The ingot foundry produces both aluminum/beryllium alloy and copper/beryllium alloy ingots containing 1.0 % to 5% beryllium. The greensand foundry and associated cutting and grinding operations produce a variety of copper/beryllium products containing a maximum of 4% beryllium, 0.25% up to 2.5% cobalt, 0% up to 1.8% nickel, with the balance being copper.

The facility employed several control technology and administrative controls to reduce the potential for worker exposures to beryllium. The ingot foundry, green sand foundry and the cutting and grinding shop are beryllium designated areas with access limited to employees who have been trained and cleared to work in those areas. Employees entering beryllium designated areas are required to wear respiratory protection, protective clothing, safety glasses and safety shoes. Additionally, employees working in the cutting and grinding shop are required to use ear plugs or ear muffs for hearing protection. Employees must enter and exit the plant through a series of clean side locker room, shower room and beryllium side (dirty) change rooms. At the end of their shift, employees exiting the beryllium designated areas must enter the dirty side locker room, remove company provided work clothing, shower, and change to street clothing in the clean side locker room before leaving the worksite. The employee lunch room in the building is physically divided to separate the beryllium side of the building from the clean side (see plant diagram), and the two lunch rooms are on separate HVAC systems.

The beryllium ingot foundry, the greensand foundry and the cutting and grinding operations were equipped with local exhaust ventilation (canopy hoods, side draft, slot, etc.) to reduce process emissions. All workers wore half-face MSA Comfo air purifying respirators equipped with P-100 cartridges or 3M 8293 P-100 disposable filtering face masks in beryllium designated areas including the two foundry areas, greensand molding operation, melt shop, shake out, cut off, and grinding areas. Additionally, when pouring molten metal and certain other operations, workers wore protective jackets, gloves, leg protection and face shields.

Air sampling results indicate that three samples exceeded the NIOSH REL for beryllium (0.5 $\mu g/m^3$) while none exceeded the OSHA PEL (2 $\mu g/m^3$). The three samples that exceeded the NIOSH beryllium REL were personal samples: one sample collected on the copper/beryllium foundry supervisor showed a concentration of 0.58 $\mu g/m^3$; one collected on the aluminum/beryllium furnace operator showed a concentration of 0.55 $\mu g/m^3$; and one collected on a grinding room employee showed a concentration of 1.07 $\mu g/m^3$. The highest copper metal dust concentration detected was less than 5% of the NIOSH and OSHA criteria (1000 $\mu g/m^3$); the highest copper metal fume concentration detected was less than 6% of the NIOSH and OSHA criteria (100 $\mu g/m^3$); and the highest aluminum concentration detected was less than 5% of the NIOSH and OSHA criteria (5000 $\mu g/m^3$).

Surface wipe sample results indicated measurable quantities of beryllium ranging from 0.2 $\mu g/100\ cm^2$ up to 180 $\mu g/100\ cm^2$. The lowest beryllium surface concentrations detected (0.2 $\mu g/100\ cm^2$) were on a table top in the clean side lunch room and a concentration of 0.7 $\mu g/100\ cm^2$ was detected on the table top in the beryllium side of the lunch room. These levels are below the DOE Guideline (3 $\mu g/100\ cm^2$) for non-operational periods. The two lunch rooms had separate entrances and separate HVAC systems. The highest beryllium surface concentration detected (180 $\mu g/100\ cm^2$) was on a wood workbench surface in the Aluminum/Beryllium ingot foundry. Another sample collected on a workbench in the copper/beryllium foundry area showed a surface concentration of 95 $\mu g/100\ cm^2$. Employees spend a lot of time at these benches where they frequently touch the surfaces as they fill-in work logs to document work orders. These levels are many times the DOE Guidelines which recommend that removable surface contamination levels be maintained at concentrations that do not exceed 3$\mu g/100\ cm^2$ during non-operational periods.

The results of size-selective sampling show beryllium was detected on six of the 11 personal samples collected; two of these six samples indicate measurable quantities of beryllium particles in stage B (size range 1.0 to 2.5 μm). This tends to suggest that some airborne beryllium is present in concentrations that may potentially reach lower portions of the respiratory tract.

Recommendations to further reduce airborne beryllium concentrations and controlling worker exposures to beryllium-containing dust and fume at this facility are included in the body of this report.

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), working under an interagency agreement with the Office of Regulatory Analysis of the Occupational Safety and Health Administration (OSHA), conducted a study of occupational exposures in secondary beryllium processing facilities to document engineering controls and work practices affecting those exposures. The performance of a thorough industrial hygiene survey for a variety of individual employers provides valuable and useful information to the public and employers in the industries included in the work. The principal objectives of this study were:

1. To measure full-shift, personal breathing zone exposures to metals including beryllium, copper and other toxic metals.

2. To evaluate contamination of surfaces in the work areas that could create dermal exposures or allow re-suspension of metals into the air.

3. To identify and describe the control technology and work practices in use in operations associated with occupational exposures to beryllium, as well as to determine additional controls, work practices, substitute materials, or technology that can further reduce occupational beryllium exposures.

4. To evaluate the use of personal protective equipment in these facilities.

5. To determine the size distribution of airborne particles.

An in-depth evaluation was conducted September 26 - 27, 2007. During this evaluation, two full shifts of environmental monitoring were conducted for the duration of normal plant operations.

II. PROCESS DESCRIPTION

On September 26 - 27, 2007, NIOSH conducted an in-depth industrial hygiene survey at a facility with two foundries: an ingot foundry which manufactured aluminum/beryllium ingots and copper/beryllium ingots; and a greensand foundry which manufactured a variety of copper/beryllium products including hand tools and a cut-off and grinding operation. This was the third of three facilities selected to investigate worker exposures to beryllium where secondary processing of beryllium products takes place. The purpose of the study was to measure airborne beryllium and heavy metal concentrations in the machining and foundry operations, and to identify and describe the control technology and work practices being used in this facility.

The company employed a total workforce of 20 employees in the two foundry operations. At the time of the NIOSH survey the two foundries were operated on one shift from 5:00 am to 1:00 pm, and the cut-off and grinding operation operated one shift from 7:00 am to

3:00 pm. The ingot foundry was approximately 9,800 square feet (ft^2) with a total of four employees; the greensand foundry was approximately 10,500 ft^2 with a total of 10 employees; and the cut-off and grinding operation was approximately 3250 ft^2 with six workers.

The ingot foundry produces both aluminum/beryllium and copper/beryllium ingots, but was only producing aluminum/beryllium ingots on the days of sampling. The greensand foundry and associated cutting and grinding operations produce a variety of copper/beryllium products including hand tools. The aluminum/beryllium ingots contain 1.0 % to 5% beryllium with the remaining balance being aluminum. The copper/beryllium greensand foundry and cutting operations manufactures copper/beryllium products containing a maximum of 4% beryllium, 0.25% up to 2.5% cobalt, 0% up to 1.8% nickel, with the balance being copper.

Process Description and Work Practices

Greensand Foundry

Operations in the copper/beryllium greensand foundry involved the production of a mold with associated core(s), the melting and pouring of copper/beryllium alloy into that mold, and the subsequent shake-out operations where the solid metal casting is released by removing the refractory material of the mold. A number of potential health hazards are associated with each stage of this operation. The focus of our evaluation was processes where workers had potential exposures to beryllium and other metals. The main products manufactured in the greensand foundry were various types of copper/beryllium alloy tools (wrenches, shovel blades, hammer heads, etc.).

The principle exposures typically associated with mold and core production are silica sand and binders such as isocyanates, urea, phenol and formaldehyde. When sand from the shake-out is re-used in the production of molds, there is the potential for metals from previous castings to be carried into this step of the operation, and for that reason testing for metals was conducted in the mold and core making operations.

The operations believed to pose the greatest potential for exposure to beryllium and other metals in the foundries are the melting and pouring processes. The furnace operators, pourers, and foundry supervisors are present in the foundry areas of the facility during the entire work shift. Specific tasks involved in melting and pouring, include weigh-out of proper ingredients to produce copper/beryllium products containing approximately 0.5% up to 4% beryllium, charging the furnace, temperature testing, and the pouring of molten metal into the molds. Each of the tasks has potential for exposure to beryllium and other metals in various forms and particle sizes, as well as associated safety hazards. All workers involved in the furnace operations wore half-face MSA Comfo air purifying respirators equipped with P-100 cartridges or 3M 8293 P-100 disposable filtering face masks safety boots, safety glasses, and leather gloves. During pouring operations the workers wore face shields and fire-proof over coats.

Weighed quantities of copper and beryllium were placed in a furnace and melted. Ceramic molds and the crucible were preheated. The furnace was mechanically tilted forward to pour molten copper/beryllium alloy into a crucible which is transported by overhead crane from the furnace to the pouring area (see photo 1). A slotted hood LEV fitting with flexible hoses connected to the Hawley Trav-L-Vent system was placed over the crucible to remove fume during pouring and transport. Workers used two long metal arms to position the crucible, tilted it forward and poured molten copper/beryllium into molds. This operation required one furnace operator, two workers to operate the crane to move and position the crucible, and one mold worker. Two other workers in the near vicinity of the pouring operation worked preparing molds. All workers in the greensand foundry wore half-face MSA Comfo air purifying respirators equipped with P-100 cartridges or 3M 8293 P-100 disposable filtering face masks.

The shake-out operation has the potential for exposures to beryllium and other metals in the form of small particles when the solidified (but still hot) castings are freed from the molds, as well as potential exposure to the sand, which may contain metals, from contact with the molten alloy. Removal of spurs and similar finishing processes using cut-off wheels or grinders also pose the potential for creating airborne particles of metals. All of these operations were monitored for metals, especially beryllium, in the air and on surfaces where skin contact could occur.

Ingot Foundry

The ingot foundry produces both aluminum/beryllium and copper/beryllium ingots, but only aluminum/beryllium ingots were produced on the days of the NIOSH survey. The ingot furnace and pouring operations used a permanent mold system which eliminated the need for sand molds. The furnace was equipped with a canopy hood with canvas extensions and a slotted hood over the furnace pot. In this operation weighed amounts of aluminum and beryllium are placed in the furnace and melted. When the molten metal is ready to pour, the furnace is mechanically tilted forward to allow the molten metal to flow into a trough positioned over a continuous loop conveyor system containing ingot molds. The bottom of the trough has slots which allow the molten metal to flow into the ingot molds as they slowly rotate under the trough. The ingot molds move slowly down the conveyor toward a shoot where the ingots drop out of the molds into the shoot where they are collected. Four workers were involved in this process, two furnace operators that monitored the pouring of molten aluminum/beryllium alloy into the ingot molds, a worker that removed dross, and a worker that monitored the cooling process and conveyor to ensured that ingots were released from the molds and dropped into the shoot. All workers in the ingot foundry wore half-face MSA Comfo air purifying respirators equipped with P-100 cartridges or 3M 8293 P-100 disposable filtering face masks.

The aluminum/beryllium alloy ingots being produced during our sampling contained approximately 2.5% beryllium with the remaining balance being aluminum. The ingot furnaces were equipped with canopy hoods over the furnace and troughs (see Photo 2).

Measurements of breathing zone concentrations of metals and determination of area concentrations of metals were conducted in the furnace rooms of both the greensand foundry and ingot foundry. In addition, particle size distribution was also evaluated in these areas. While there are other potential hazards associated with foundries such as heat stress, infrared radiation, and a variety of safety hazards, this evaluation focused primarily on worker exposures to beryllium and toxic metals.

Cut-off and Grinding Shop
In the cutting and grinding room four workers operated saws and grinders to remove (cleaning and de-burring) excess metal from the copper/beryllium alloy castings produced in the greensand foundry. All cutting and grinding operations were conducted in enclosed booths equipped with LEV (see photo 3) to exhaust airborne metals created during these processes. All workers in the cutting and grinding shop wore half-face MSA Comfo air purifying respirators equipped with P-100 cartridges or 3M 8293 P-100 disposable filtering face masks.

Cutting tools generally remove metal in relatively large chips, and tend to produce little respirable particulate. The use of LEV and enclosure of these operations reduces this potential. The potential for dermal exposure, however, is significant in cutting and grinding operations with beryllium metal. Area and personal samples were collected in the cutting and grinding operations for airborne metals.

Grinding, polishing and buffing all involve the removal of metals from the surface of a casting in increasingly smaller amounts. The decrease in mass, however, may be offset by a corresponding decrease in particle size that may carry with it an increase in toxicity. Therefore, particle size information was collected in the cutting and grinding room as well as the two foundry operations.

Control Technology and Administrative Controls
The ingot foundry, green sand foundry and the cutting and grinding shop are beryllium designated areas. Access to the foundries and the cutting and grinding shop is limited to employees that have been cleared to work in beryllium designated areas. Employees entering beryllium designated areas are required to wear the appropriate personal protective clothing and equipment (see personal protective equipment section for additional detail).

Employees working in beryllium designated areas (i.e., ingot foundry, green sand foundry, and the cutting and grinding shop) must enter and exit the plant through a clean side change room. The clean side change room is equipped with lockers for employees to store their personal clothing and shoes during their work shift. After changing from street clothing to clean work clothing, which is provided by the company, the workers pass through a corridor adjacent to the shower area to the beryllium side change room which is equipped with lockers for storage of work boots and equipment. At the end of their work shift, employees enter the beryllium side change room, store their work boots and equipment in the lockers, leave their work clothing to be laundered by the company, enter the shower room to shower prior to entering the clean side change room to change into their street clothing prior to exiting the plant (see plant diagram).

Employees enter beryllium designated areas through one of two air showers. The employee lunch room in the building is physically divided to separate the beryllium side of the building from the clean side (see plant diagram). Each of the two lunch rooms are on separate HVAC systems.

Most of the beryllium foundry and the cutting and grinding operations described above were equipped with some type of local exhaust ventilation (canopy hoods, side draft, slot, etc.) system with fixed or flexible ducting to reduce process emissions. Some of the process operations (e.g. ingot furnace and pouring stations) were equipped with a hydraulic system which enabled the furnace to be lifted and reoriented to allow for pouring of the molten metal. Workers are present and remain in the production areas during all the operations described above, and interact with the processes. Visual observations indicated that smoke and dust from these operations moved toward the local exhaust ventilation openings. Air velocity measurements were made to document the magnitude and direction of air movement at selected processes.

All copper/beryllium cutting and grinding operations in this facility are equipped with local exhaust ventilation. The exhaust air is filtered before exhausting outdoors to contain and control the release of metal particles containing beryllium.

Current Housekeeping Practices

Current housekeeping practices include the use of HEPA vacuums to clean equipment and remove dirt and dust from work surfaces. Portable HEPA vacuums are used in the greensand foundry and in the cutting and grinding shop while a stationary central HEPA vacuum system is used in the ingot foundry. Each worker is responsible for cleaning and maintaining their work areas throughout the day and at the end of their work shift. Additionally, workers must enter/exit the plant through change/shower rooms described earlier and must enter/exit beryllium designated areas (i.e., the foundries and the cutting and grinding shop) through an air shower.

Personal Protective Equipment

Entry to and exit from designated beryllium areas (ingot foundry, greensand foundry, and the cutting and grinding shop) was limited to employees who are cleared to work in those areas. Employees entering beryllium designated areas are required to wear respiratory protection, protective clothing, safety glasses and safety shoes. Workers are required to wear their respiratory equipment before entering the air shower leading to the beryllium designated areas. Additionally, employees working in the cutting and grinding shop are required to use ear plugs or ear muffs for hearing protection.

All workers wore half-face MSA Comfo air purifying respirators equipped with P-100 cartridges or 3M 8293 P-100 disposable filtering face masks in beryllium designated areas including the two foundry areas, greensand molding operation, melt shop, shake out, cut off, and grinding areas. Additionally, when pouring molten metal and certain other operations, workers wore protective jackets, gloves, leg protection and face shields.

III. SAMPLING AND ANALYTICAL METHODS

This field study was conducted in accordance with regulations governing NIOSH investigations of places of employment.[1] Methods used to assess worker exposures in this workplace evaluation included: personal breathing zone and area sampling for metals; particle size sampling; and surface wipe sampling to assess surface contamination. The methods used in this evaluation are described in more detail in the following section and the resulting data is presented in Section V (RESULTS AND DISCUSSION).

A. Workplace Observations

Information pertinent to process operation and control effectiveness (e.g. control methods, ventilation rates, work practices, use of personal protective equipment, etc.) was collected and recorded. Information was obtained from conversations with the workers and management to determine if the sampling day was a typical workday and to help place the sampling results in proper perspective. In addition, engineering control information including ventilation flow rates were collected.

B. Particulate Sampling and Analysis

Personal breathing zone and general area airborne particulate samples were collected and analyzed using inductively coupled plasma spectroscopy (ICP) according to NIOSH Method 7300[2] (with modifications) for 31 metals/elements. Samples were collected for as much of the work shift as possible, at a nominal flow rate of 3 liters/minute using a calibrated battery-powered sampling pump (model 224, SKC Inc., Eighty Four, PA) connected via flexible tubing to a 37-mm diameter filter (0.8 µm pore-size mixed cellulose ester filter) in a 3-piece, clear plastic cassette sealed with a cellulose shrink band.

C. Particulate Size Sampling - Measurement of Size/Mass Distribution of Airborne Particles

One of the objectives of this study was to determine the particle size and mass concentration of airborne beryllium particles generated during the manufacturing process. There is substantial evidence that the presence of an ultrafine component increases the toxicity for chronic beryllium disease and possibly other toxic effects.[3,4,5] The potential hazard for chemical substances present in inhaled air, as suspensions of solid particles or droplets, depends on particle size and the mass concentration because of 1) the effects of particle size on the deposition site within the respiratory tract, and 2) the tendency for many occupational diseases to be associated with material deposited in particular regions of the respiratory tract.[6] For example, the ACGIH recommends particle size-selective TLVs for crystalline silica because of the well established association between silicosis and respirable mass concentrations.[6] Because of this association, size-selective sampling was conducted to collect information on the aerosol size distribution to assist in evaluation of the health hazard. Additionally, the measurement and characterization of airborne particle size and mass distribution in workplace environments can provide useful information about the emission and exposure routes of air contaminants generated; the data collected can be used to identify appropriate control methods to reduce or eliminate contaminant sources to protect workers.

The measurement of particle size and mass distribution was accomplished using three different instruments and methods. Personal breathing zone and general area air samples were collected using Sioutas cascade impactors to determine particle size distribution. Additionally, a Micro-Orifice Uniform Deposit Impactor (MOUDI) and an Aerodynamic Particle Sizer (APS) spectrometer were used to measure the particle size and respirable mass concentrations in the general workplace air.

1. Sioutas Cascade Impactor Samples

Personal breathing zone and general area aerosol size distributions were determined using four-stage Sioutas Cascade Impactors (SKC, Inc., Eighty Four, PA), having nominal 50% cut points of 0.25 µm, 0.5 µm, 1 µm, and 2.5 µm aerodynamic diameter. The smaller the particle size the more likely it is to reach deep into the lungs.

50% cut-point of each stage at 9 lpm		
Stage A	2.5 to 10 µm	
Stage B	1.0 to 2.5 µm	Course particulate matter
Stage C	0.5 to 1.0 µm	Course to fine particulate matter
Stage D	0.25 to 0.5 µm	Ultrafine particles

The sampling flow rate for these impactors was 9 liters per minute (lpm), provided by a calibrated Leland Legacy™ sampling pump (SKC, Inc., Eighty Four, PA). A 25-mm diameter, 0.8 µm pore size PVC filter was used on each stage of the impactor to collect particles. A 37-mm diameter, 5 µm pore size PVC filter was used as a backup to collect all particles that were not impacted on the previous four stages. The impactor filters were analyzed for 31 metals/elements by ICP in accordance with NIOSH Method 7300 modified for microwave digestion.[2]

2. Micro-Orifice Uniform Deposit Impactor (MOUDI) Samples

The MOUDIs (Model 110, MSP Corp., Minneapolis, MN) were used to determine aerosol size distributions in the greensand foundry near the furnace copper/beryllium pouring areas and in the ingot foundry near the melting furnace during the production and pouring of aluminum/beryllium ingots. The MOUDIs were connected via tubing to a high volume pump operating at a flow rate of 30 lpm. The MOUDI consists of a pre-filter to collect particles larger than 18 µm, ten filter stages in series with nominal cut points of 10 µm, 5.6 µm, 3.2 µm, 1.8 µm, 1.0 µm, 0.56 µm, 0.32 µm, 0.18 µm, 0.10 µm, and 0.056µm and a post-filter to collect all remaining particles smaller than 0.056µm. The smaller the particle size the more likely it is to reach deep into the lungs. At each filter stage particles larger than the cut size are collected by a 47-mm diameter substrate on the impaction plate due to inertial impaction while particles smaller than the cut size follow the airflow streamlines and proceed to the next stage until the final stage filter (37-mm diameter, PTFE, SKC Inc.).

Two different substrates were used in the MOUDIs to collect airborne particulate: PTFE membrane filters with a 0.5-µm-pore-size manufactured by SKC Inc., and PTFE membrane filters with a 2.0-µm-pore-size manufactured by Pall Corp. The two different PTFE membrane filters with different pore sizes and manufacturers were used to eliminate sampling bias from collecting materials. All the sample filters remained in the balance room for 24 hours before pre-weighing on an electric balance (Model AT20, Mettler-Toledo, Switzerland) to 2 µg resolution, stored and transported in Petri dishes before and after sampling.

Three MOUDIs were used in this study to measure the mass distribution of airborne particles at the locations near the furnaces where high particle concentrations were expected. Usually 8-hour sampling is necessary to obtain adequate mass for the following gravimetric analysis. Similar to the preparation steps mentioned above, the filter samples were kept in the Petri dishes after MOUDI sampling, and the post-weighing was conducted in the NIOSH laboratory after 24-hour conditioning in the balance room. After post-weighing, the PTFE filters were sent to a contract laboratory for the metal analysis.

3. Aerodynamic Particle Sizer (APS) Samples

An APS spectrometer (Model 3321, TSI, Shoreview, MN) was used to collect real time particle number measurements at the same locations where the MOUDI samples were collected: the greensand foundry near the copper/beryllium pouring area and in the ingot foundry near the melting furnace during the production of aluminum/beryllium ingots. All the APS sampling data were collected by Aerosol Instrument Manager Software for APS Sensors. This instrument is capable of measuring particles ranging from 0.5 µm to 20 µm at 5.0 lpm total sampling flow rate including 1.0 lpm aerosol flow and 4.0 lpm sheath flow. A minimum of 10 samples were collected at each sample location with the APS set to run in a one-minute sampling mode.

D. Surface Sampling Procedures and Analysis

Surface sampling is not as useful as airborne contaminant measurements for evaluating exposed dose since there are few criteria for reference, but some comparisons and professional judgments can be made based on the data collected, as discussed below. Surface sampling is useful for evaluating process control and cleanliness and for determining suitability for release of equipment.

Surface wipe samples were collected using Ghost™ Wipes (Environmental Express, Mt. Pleasant, SC) and Palintest® Dust Wipes (Gateshead, United Kingdom) to evaluate surface contamination. These wipe samples were collected in accordance with ASTM

Method D 6966-03,[7] except the cardboard template, with a 10-cm by 10-cm square hole was held in place by hand to prevent movement during sampling. Wipes were placed in sealable test tube containers for storage until analysis.

Ghost Wipes™ were sent to the laboratory to be analyzed for metals according to NIOSH Method 7303.[8] Palintest wipes were analyzed for beryllium using the Quantech Fluorometer (Model FM109515, Barnstead International, Dubuque, Iowa) for spectrofluorometric analysis.[9]

E. Other Measurements

Ventilation airflow measurements were collected at the ingot furnace slot hood and canopy hood; the greensand foundry slot hood and pour pot; and in the cutting and grinding shop at the cut-off saw and belt sander using a TSI VelociCalc Plus Air Velocity Meter Model 8360. Each of these hoods was connected to a central exhaust ventilation system for their respective areas.

IV. OCCUPATIONAL EXPOSURE LIMITS AND HEALTH EFFECTS

In evaluating the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended occupational exposure limits (OELs) for specific chemical, physical, and biological agents. Generally, OELs 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 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 exposure limit. Combined effects are often not considered in the OEL. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, thus contributing to the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday.[‡] Some chemical

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[†] On March 20, 1991, the Supreme Court decided the case of International Union, United Automobile, Aerospace & Agricultural Implement Workers of America, UAW v. Johnson Controls, Inc., 111 S. Ct. 1196, 55 EPD 40,605. It held that Title VII forbids sex-specific fetal protection policies. Both men and women must be protected equally by the employer.

[‡] OSHA PELs, unless otherwise noted, are TWA concentrations that must not be exceeded during any 8-hour workshift of a 40-hour work-week [NIOSH 1997]. NIOSH RELs, unless otherwise noted, are TWA concentrations for up to a 10-hour workday during a 40-hour workweek [NIOSH 1997]. ACGIH® TLVs®,

substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values where there are health effects from higher exposures over the short-term. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time, even instantaneously.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are mandatory, legal limits; others are recommendations. The U.S. Department of Labor Occupational Safety and Health Administration (OHSA) Permissible Exposure Limits (PELs) [29 CFR 1910 (general industry); 29 CFR 1926 (construction industry); and 29 CFR 1915, 1917 and 1918 (maritime industry)] are legal limits that are enforceable in workplaces covered under the Occupational Safety and Health Act[10] and in Federal workplaces under Executive Order 12196.[11] NIOSH recommended exposure limits (RELs) are recommendations that are made based on a critical review of the scientific and technical information available on the prevalence of hazards, health effects data, and the adequacy of methods to identify and control the hazards. Recommendations made through 1992 are available in a single compendium;[12] more recent recommendations are available on the NIOSH Web site (http://www.cdc.gov/niosh). NIOSH also recommends preventive measures (e.g., engineering controls, safe work practices, personal protective equipment, and environmental and medical monitoring) for reducing or eliminating the adverse health effects of these hazards. The NIOSH Recommendations have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the threshold limit values (TLVs)® recommended by the American Conference of Governmental Industrial Hygienists (ACGIH)®, a professional organization.[6] ACGIH-TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace environmental exposure levels (WEELs) are recommended OELs developed by AIHA, another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist."[13]

Employers should understand that not all hazardous chemicals have specific OSHA-PELs and for many agents, the legal and recommended limits mentioned above may not reflect the most current health-based information. However, an employer is still required by OSHA to protect their employees from hazards even in the absence of a specific OSHA-PEL. In particular, OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified

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unless otherwise noted, are TWA concentrations for a conventional 8-hour workday and 40-hour workweek [ACGIH 2008] workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

Both the ACGIH® TLVs® and OSHA PELs address the issue of combined effects of airborne exposures to multiple substances.[6,10] ACGIH® states:

> When two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, different substances should be considered as additive where the health effect and target organ or system is the same. That is, if the sum of

$$\frac{C_1}{T_1}+\frac{C_2}{T_2}+\dots\frac{C_n}{T_n} \qquad \text{Eqn. 1}$$

exceeds unity, the threshold limit of the mixture should be considered as being exceeded (where C_1 indicates the observed atmospheric concentration and T_1 is the corresponding threshold limit...).

A. Inhalation Exposures

Metals found in the workplace under investigation range from slightly toxic to extremely toxic by inhalation. While a subset of five primary contaminants have been selected for consideration through the body of this report because of their high toxicity or other special interest, the occupational exposure limits of all 31 metals/elements quantified in this work are listed in Table 1.

Occupational Exposure Criteria for Beryllium

The current OSHA PELs for beryllium are 2 micrograms per cubic meter ($\mu g/m^3$) as an 8-hour TWA, 5 $\mu g/m^3$ as a ceiling not to be exceeded for more than 30 minutes at a time, and 25 $\mu g/m^3$ as a peak exposure never to be exceeded.[10] The current NIOSH Recommended Exposure Limit (REL) for beryllium is 0.5 $\mu g/m^3$ for up to a 10-hour workday, during a 40-hour workweek.[14] The current American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®)[6] is an 8-hr TWA of 2 $\mu g/m^3$, and a Short Term Exposure Limit (STEL) of 10 $\mu g/m^3$.

Beryllium has been designated a Group1, known human carcinogen, by the International Agency for Research on Cancer (IARC 1993). In 2006 the ACGIH published a Notice of Intended Change (NIC) to reduce the TLV® for beryllium from 0.002 milligrams per cubic meter (mg/m^3) to 0.00005 mg/m^3 or 0.05 $\mu g/m^3$ based upon studies investigating both chronic beryllium disease (CBD) and beryllium sensitization (BeS).[3]

Occupational Exposure Criteria for Copper
In this facility copper metal is present in two physical states, copper fume and copper dust, and each has a separate environmental criteria. The NIOSH-REL[14] and OSHA-PEL[10] for copper fume are 0.1 mg/m^3 (100 µg/m^3), while the ACGIH-TLV is 0.2 mg/m^3 (200 µg/m^3) as an eight-hour TWA.[6] Inhalation of copper fume has resulted in irritation of the upper respiratory tract, metallic taste in the mouth, and nausea. Exposure has been also associated with the development of metal fume fever.[12,15]

The NIOSH-REL for copper dust is 1 mg/m^3 (1000 µg/m^3) measured as an 8-10 hour TWA.[14] The ACGIH-TLV and OSHA-PEL are also 1 mg/m^3 (1000 µg/m^3) measured as an 8-hour TWA.[6,10]

Occupational Exposure Criteria for Aluminum
There are several occupational exposure criteria for aluminum, all of which are primarily intended to minimize the potential for irritation of the respiratory tract.[16] The NIOSH-REL[14] and ACGIH-TLV[6] for welding fume is 5 mg/m^3 (5000 µg/m^3) as an eight-hour TWA; there is no OSHA-PEL[10] for aluminum fume.

B. Surface Contamination Criteria

Occupational exposure criteria have been discussed above for airborne concentrations of several metals. Surface wipe samples can provide useful information in two circumstances; first, when settled dust on a surface can contaminate the hands and then be ingested when transferred from hand to mouth; and second, if the surface contaminant can be absorbed through the skin and the skin is in frequent contact with the surface.[17] Although some OSHA standards (e.g. asbestos, lead, cadmium, shipyards, longshoring, grain handling facilities, etc.) contain housekeeping provisions which address the issue of surface contamination by mandating that surfaces be maintained as free as practicable of accumulations of the regulated substances, there are currently no quantitative surface contamination criteria included in OSHA standards.[18] For example, under the lead standard (29 CFR 1910.1025); employers need to establish a housekeeping program sufficient to maintain all surfaces as free as practicable of accumulations of lead dust. Vacuuming is the preferred method of meeting this requirement, and the use of compressed air to clean floors and other surfaces is absolutely prohibited. Dry or wet sweeping, shoveling, or brushing may not be used except where vacuuming or other equally effective methods have been tried and do not work. Vacuums must be used and emptied in a manner which minimizes the reentry of lead into the workplace. The health hazard from these regulated substances results principally from their inhalation and to a smaller extent from their ingestion; those substances are by and large "negligibly" absorbed through the skin.[17] NIOSH RELs do not address surface contamination either, nor do ACGIH TLVs or AIHA WEELs. Caplan stated, "There is no general quantitative relationship between surface contamination and air concentrations..." and that "Wipe samples can serve a purpose in determining if surfaces are as 'clean as practicable'. Ordinary cleanliness would represent totally insignificant inhalation dose; criteria should be based on surface contamination remaining after ordinarily thorough cleaning appropriate for the contaminant and the surface."[17] With those caveats in mind, the following paragraphs present guidelines that help to place the results of the surface sampling conducted at this facility in perspective.

Surface Contamination Criteria for Beryllium

A useful guideline to address the issues of beryllium surface contamination is provided by the U.S. Department of Energy (DOE), where DOE and its contractors are required to conduct routine surface sampling to determine housekeeping conditions wherever beryllium is present in operational areas of DOE/NNSA facilities.[3] Those facilities must maintain removable surface contamination levels that do not exceed 3μg/100 cm^2 during non-operational periods. The DOE also has release criteria that must be met before beryllium-contaminated equipment or other items can be released to the general public or released for use in a non-beryllium area of a DOE facility. These criteria state that the removable contamination level of equipment or item surfaces does not exceed the higher of 0.2 μg/100 cm^2, or the level of beryllium in the soil in the area of release. Removable contamination is defined as "beryllium contamination that can be removed from surfaces by nondestructive means, such as casual contact, wiping, brushing, or washing." Additionally, the ACGIH has added a skin sensitization notation in their Notice of Intended Changes.[6]

Surface Contamination Criteria for Copper and Aluminum

NIOSH, OSHA, AIHA and ACGIH® have not established occupational exposure limits for copper or aluminum on surfaces.

V. RESULTS AND DISCUSSION

On September 26 - 27, 2007, air, surface wipe, and particle size samples were collected in the greensand foundry, ingot foundry and cutting and grinding shop of this facility. These samples were analyzed for thirty-one metals/elements (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lanthanum, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, strontium, tellurium, thallium, tin, titanium, vanadium, yttrium, zinc, and zirconium) in accordance with NIOSH Method 7300 with modifications.[8] Because this foundry manufactured aluminum/beryllium ingots and copper/beryllium metal products the focus of this evaluation was beryllium, aluminum, and copper with a primary emphasis on beryllium. The results of sampling aluminum, beryllium and copper are presented in Tables 2 – 6 and in the following text. The entire set of sample data for the air, surface wipe, Sioutas impactor and MOUDI particle size samples for all thirty-one elements are listed in Appendices A, B, C and D, respectively.

A. Air Sample Results

Samples were collected on a typical production day with the ventilation systems operating. During sampling employees were wearing respirators and other personal protective equipment previously described in Section II. Personal breathing zone and area air sampling results for aluminum, beryllium and copper are contained in Table 2; while the entire sample data set of 31 elements/metals analyses is presented in Appendix

A. A total of 23 full-shift samples were collected on two consecutive days (17 personal breathing zone samples and 6 general area air samples) for elements/metals. The sample time (in minutes) is listed along with the calculated airborne aluminum, beryllium and copper concentrations in Table 2. Exposure concentrations were calculated from the analytical results after correcting for the results of field blanks.

The results of personal and area air sampling for beryllium are contained in Table 2. The data show that three of 23 samples collected exceeded the NIOSH REL for beryllium (0.5 $\mu g/m^3$) and none exceeded the OSHA PEL (2 $\mu g/m^3$). All three samples that exceeded the NIOSH beryllium REL were personal samples: one sample collected on the copper/beryllium foundry supervisor showed a concentration of 0.58 $\mu g/m^3$; one collected on the aluminum/beryllium furnace operator showed a concentration of 0.55 $\mu g/m^3$; and one collected on a grinding room employee showed a concentration of 1.07 $\mu g/m^3$.

Because this facility has both a beryllium/copper foundry and a cutting and grinding shop, the airborne copper generated in the operation would be expected to be in the form of metal fume in the foundry, and as metal dust in the cutting and grinding shop. Therefore, the measured copper concentrations in the foundry are compared to the copper fume evaluation criteria and the measured copper concentrations in cutting and grinding operations are compared to the copper dust evaluation criteria.

Copper metal was detected on all six samples analyzed for copper metal with concentrations ranging from 3.4 $\mu g/m^3$ to 42 $\mu g/m^3$; the highest concentration was less than 5% of the NIOSH and OSHA criteria (1000 $\mu g/m^3$). Copper metal fume was detected on all 17 personal samples collected with concentrations ranging from 0.9 $\mu g/m^3$ to 5.7 $\mu g/m^3$; the highest concentration detected was less than 6% of the NIOSH and OSHA criteria (100 $\mu g/m^3$).

Aluminum was detected on 14 of 17 personal samples with concentrations ranging from 3.4 $\mu g/m^3$ to 42 $\mu g/m^3$; the highest concentration was less that 5% of the NIOSH and OSHA criteria (5000 $\mu g/m^3$). The results of all other metals included in the analyses were all less than 6% of their applicable criteria (see Appendix A).

B. Surface Wipe Sample Results

The results of surface wipe sampling for beryllium, copper, and lead are presented in Table 3. These metals are presented because of their potential toxicity, or in the case of copper because it is one of the primary metals expected to be present in this workplace environment. The entire surface wipe sample data set for 31 elements/metals is presented in Appendix B. A total of 16 surface wipe samples were collected on September 26 and 27, 2007; eight using Ghost Wipes™ which were analyzed for the 31 metals/elements; and 8 using Palintest® Dust Wipes which were analyzed for beryllium only.

Ghost Wipes™ indicated measurable quantities of beryllium on 8 of 8 samples collected (see Table 3). Detectable surface concentrations ranged from 0.2 $\mu g/100\ cm^2$ to 180 μg/100 cm^2. The lowest beryllium surface concentrations detected (0.2) were detected on the table top in the clean side of the lunch room and a concentration of 0.7 μg/100 cm^2 was detected on the table top in the beryllium side of the lunch room. These levels are below the DOE Guideline (3 μg/100 cm^2) for non-operational periods. The two lunch rooms had separate entrances and separate HVAC systems.

The highest beryllium surface concentration detected (180 μg/100 cm^2) was on a wood workbench surface in the Aluminum/Beryllium ingot foundry. Another sample collected on a workbench in the copper/beryllium foundry area showed a surface concentration of 95 μg/100 cm^2. Wood is a porous material and may have retained more of the beryllium-containing dirt and grime. Employees spend a lot of time at these benches where they frequently touch the surfaces as they fill-in work logs to document work orders. The DOE Guidelines recommend that removable surface contamination levels be maintained at concentrations that do not exceed 3μg/100 cm^2 during non-operational periods.[3]

The sample collected on a workbench in the ingot foundry indicated a lead concentration of 170 μg/100 cm^2; all other wipe samples indicated lead surface concentrations of 8.8 μg/100cm^2 or less. No lead was detected in the lunch room areas.

In most instances, the beryllium surface concentration detected on the Palintest® Dust Wipes agreed with the Ghost Wipes™.

C. Particulate Size/Mass Distribution Results

One of the objectives of this study was to determine the particle size and mass concentration of airborne beryllium particles generated during the manufacturing process because there is substantial evidence that the presence of an ultrafine component increases the toxicity for chronic beryllium disease and possibly other toxic effects.

The results of particle size measurements collected using the Sioutas cascade impactors are summarized below and presented in Table 4. The MOUDI and APS data are summarized below and presented in Tables 5 and 6; the entire Sioutas cascade impactor data set is contained in Appendix C and the entire MOUDI data set is presented in Appendix D. The term particle size refers to the aerodynamic size which is defined as the diameter of a unit density (1g/cm^3) sphere which has the same settling velocity as the particle in question.[19]

a. Sioutas Cascade Size-Selective Impactor Results

The results of size-selective sampling for aluminum, beryllium and copper using the Sioutas Cascade Impactors are presented in Table 4, while the entire data set for the 31 metals/elements included in the laboratory analyses is presented in Appendix C. A mass analysis of the beryllium data collected with the Sioutas Cascade Impators is not appropriate because a large percentage (approximately 85%) of the data was non-detectable, however, a summary of the data follows. A total of 11 personal size-selective impactor samples were collected during the two days of air sampling. The results presented in Table 4 show the aluminum, beryllium and copper concentrations measured on each of the five impactor stages and the sum total of all five stages for each sample collected. Beryllium was detected on six of the 11 personal samples collected; two of these six samples indicate measurable quantities of beryllium particles in stage B (size range 1.0 to 2.5 µm). This tends to suggest that some airborne beryllium is present in concentrations that may potentially reach lower portions of the respiratory tract. Copper and aluminum were detected on all 11 samples collected.

b. *MOUDI Size-Selective Impactor and APS Results*

The MOUDI size-selective impactor sample results for total particulate are presented in Table 5. MOUDI samples in both foundry areas were collected over two working days and sampling locations were as close as possible to the furnaces. The MOUDI data showed low mass concentrations of airborne particles in the greensand foundry and the ingot foundry (0.342 and 0.060 mg/cm^3, respectively). Beryllium was not detected in any of the samples, and copper and aluminum were detected at very low concentrations.

The APS was used to check the number concentrations of airborne particles at the sampling locations where the MOUDI samples were collected. The APS data for the ingot foundry and greensand foundry are summarized numerically and graphically in Table 6. The APS data are consistent with the MOUDI data indicating that the manufacturing processes in the greensand foundry generated higher airborne particle concentrations than in the process in the ingot foundry.

D. Ventilation Measurement Observations/Results

Ventilation measurements were collected in the greensand foundry, ingot foundry and in the cutting and grinding shop. Smoke tube traces indicated that all the ventilation systems described below were capturing the released smoke.

Velocity measurements in the greensand foundry showed face velocities at the furnace slot hood (24 inches by 6 inches, or one square foot) of 700 to 1100 feet per minute (fpm),.a flow rate of 900 cubic feet per minute (cfm) (see photo 1); velocity measurements above the center of the furnace were 150 to 200 fpm. Face velocities at the slot (12 inches by 4 inches, or 0.33 ft^2) above the crucible measured 150 to 200 fpm, a flow rate of 58 cfm.

Measurements in the ingot foundry showed face velocities at the furnace slot hood of 350 to 450 fpm (the slot measured 24 inches by 8 inches or 1.33 ft^2), a volume of 532 cfm (see photo 2); velocities at breathing zone level at the canopy hood were approximately 250 to 350 fpm. Face velocities at the two dross barrel slots (24 inches by 6 inches or 1 ft^2) were approximately 1500 fpm, a flow rate of 1500 cfm.

Ventilation measurements in the cutting and grinding shop showed face velocities at the face of the enclosed cut-off saw booth of 100 to 150 fpm; the open face of the enclosure measured 5 feet wide by 4 feet high (20 ft^2). Face velocities at the opening (18 inches by

36 inches or 4.5 ft^2) to the enclosed down-draft belt-sander booth measured 500 to 700 fpm, a flow rate of 2700 cfm.

VI. CONCLUSIONS AND RECOMMENDATIONS

Beryllium is used in products manufactured at this facility because of its properties; more than 90% of the product line manufactured in the greensand foundry are non-sparking tools. The ingot foundry produces both aluminum/beryllium ingots and copper beryllium ingots for customers which require these alloys. The results of sampling during the September 2007, NIOSH in-depth survey indicate that three of 23 personal samples collected exceeded the NIOSH REL for beryllium of 0.5 $\mu g/m^3$ (currently the most restrictive OEL) and none exceeded the OSHA PEL (2 $\mu g/m^3$).

Surface wipe sampling results indicate that some work surfaces in the two foundry areas, with which employees are likely to have skin contact have contamination levels 30 to 90 times above the DOE recommendations for non-operational periods. The DOE guidelines recommend that removable surface contamination levels be maintained at levels that do not exceed 3μg/100 cm^2 during non-operational periods.[3]

Controlling worker exposures to beryllium dust and fume can be accomplished through the use of engineering controls, work practices, administrative actions, and personal protective equipment (PPE). Engineering controls are the preferred method for controlling worker exposure; examples include isolating the source and the use of ventilation systems. Administrative actions include such items as, limiting the worker's exposure time and providing showers. PPE includes wearing the proper respiratory protection and personal protective clothing.

Current Administrative and Engineering Controls

To control the spread of beryllium within the plant and to prevent take-home beryllium contamination several excellent administrative controls and engineering controls are currently used in this facility. Beryllium workers must enter and exit the plant through a change room and are provided work clothing that is laundered by the facility. The change room is designed with clean side and beryllium side (dirty side) locker rooms, with a shower room located between the two rooms. Workers are required to change from company provided work clothing which becomes contaminated during their work shift, shower, and change to clean street clothing prior to leaving the facility at the end of their work shift. These administrative controls are a good way to reduce the potential for post-work exposure and the possibility of carrying contamination home. The OSHA lead standard, 29 CFR 1910.1025(i)(2)(i) provides additional detail regarding the design of change rooms, to help prevent the spread of lead and a review of this standard would be helpful in determining if additional design considerations are needed to prevent take-home beryllium contamination.

To prevent the spread of beryllium contamination within the plant the two foundries and the cutting and grinding shop are beryllium designated areas. Entry to these beryllium designated areas is limited to workers that have been trained and cleared to work in these areas. Entry and exit to the beryllium designated areas (i.e., the ingot foundry, the green sand foundry and the cutting and grinding shop) is also controlled by limiting access through two air showers. Additionally, the facility has separate lunch rooms for the clean side and beryllium side with physical barriers and separate HVAC systems to isolate the beryllium side and help control the spread of beryllium.

Recommendations

Recommendations to further reduce airborne beryllium concentrations and controlling worker exposures to beryllium-containing dust and fume at this facility include:

- All work surfaces in beryllium designated areas that employees are likely to have skin contact with should be cleaned on a regular basis (e.g. at the end of each work shift or weekly) to meet the DOE guidelines. The DOE Guidelines recommend that removable surface contamination levels be maintained at concentrations that do not exceed $3\mu g/100\ cm^2$ during non-operational periods.[3]
- Only non-porous materials should be used for work bench surfaces. This would make decontamination efforts more effective and would result in reduced surface contaminant levels on surfaces with which workers are likely to have skin contact.
- Special attention should be given to cleaning and decontamination of any equipment before moving the equipment to non-beryllium areas of the facility, and before transferring or moving the equipment off-site.
- Only employees who have been cleared to work in beryllium designated areas should be allowed access to areas where beryllium-containing materials are processed.
- Employees should continue to receive regular training (e.g. yearly or more often) on the proper handling of beryllium, as well as the hazards of beryllium exposure. A review of the written Hazard Communications program should be conducted regularly (e.g. once every year or once every two years) to ensure that it meets all the OSHA requirements outlined in 29 CFR 1910.1200 (e).
- Dry sweeping techniques should not be used in beryllium designated work areas. The continued use of HEPA-filtered vacuums to remove dust from floors and work surfaces is recommended.
- The use of respirators requires the implementation of a site specific written respiratory protection program. Therefore, a review of the written respiratory protection program should be implemented to ensure compliance with OSHA Regulation 1910.134 and should include: the training of employees; the selection, maintenance, and use of respirators; and monitoring of the program to ensure its ongoing effectiveness and compliance with OSHA regulation 1910.134. The employer shall include in the program the following provisions of this section, as applicable:
  - 1910.134(c)(1)(i) - Procedures for selecting respirators for use in the workplace;
  - 1910.134(c)(1)(ii) - Medical evaluations of employees required to use respirators;
  - 1910.134(c)(1)(iii) - Fit testing procedures for tight-fitting respirators;
  - 1910.134(c)(1)(iv) - Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations;

- 1910.134(c)(1)(v) - Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;
- 1910.134(c)(1)(vi) - Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators;
- 1910.134(c)(1)(vii) - Training of employees in the respiratory hazards to which they are potentially exposed during routine and emergency situations;
- 1910.134(c)(1)(viii) - Training of employees in the proper use of respirators, including putting on and removing them, any limitations on their use, and their maintenance; and
- 1910.134(c)(1)(ix) - Procedures for regularly evaluating the effectiveness of the program.

- Preventive maintenance is a key ingredient to proper systems operation. Regularly scheduled maintenance of the ventilation systems should be conducted on weekly, monthly or other schedule to ensure proper operation of these systems. Ventilation hood design and exhaust rates for hot processes requires consideration of the significant quantities of heat that are transferred to the air above and around the processes by conduction and convection. A thermal draft is created which causes an upward air current with velocities as high as 400 fpm. The ACGIH Industrial Ventilation Manual[20] is an excellent reference for information on engineering controls for hot processes and other processes requiring ventilation.

Additional Sources of Information

Other guidelines for housekeeping in workplaces that use beryllium are available from several sources. In 1999, OSHA issued a Hazard Information Bulletin, Preventing Adverse Health Effects from Exposure to Beryllium on the Job (OSHA 1999). The web link to that document is provided below:

http://www.osha.gov/dts/hib/hib_data/hib19990902.html

Additional information on beryllium standards, hazard recognition, exposure evaluation and possible solutions can be found on the OSHA web site at:

http://www.osha.gov/SLTC/beryllium/index.html

The NIOSH website is also an excellent source of information on beryllium.

http://www.cdc.gov/niosh/topics/beryllium/

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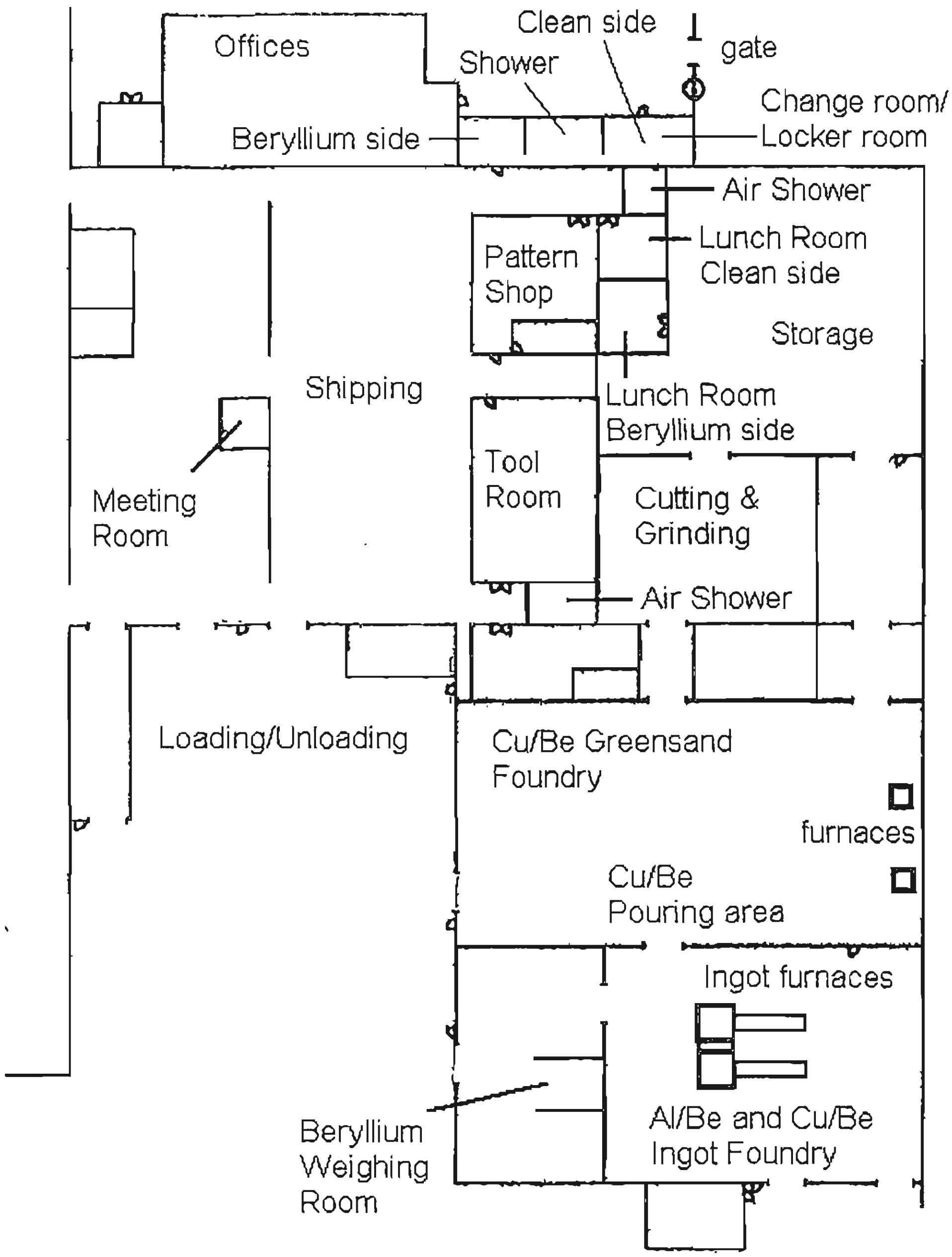
Beryllium Facility #3 – Plant Diagram
Aluminum/Beryllium Foundry and Copper/Beryllium Foundry and Machine Shop
September 2007



NOT TO SCALE

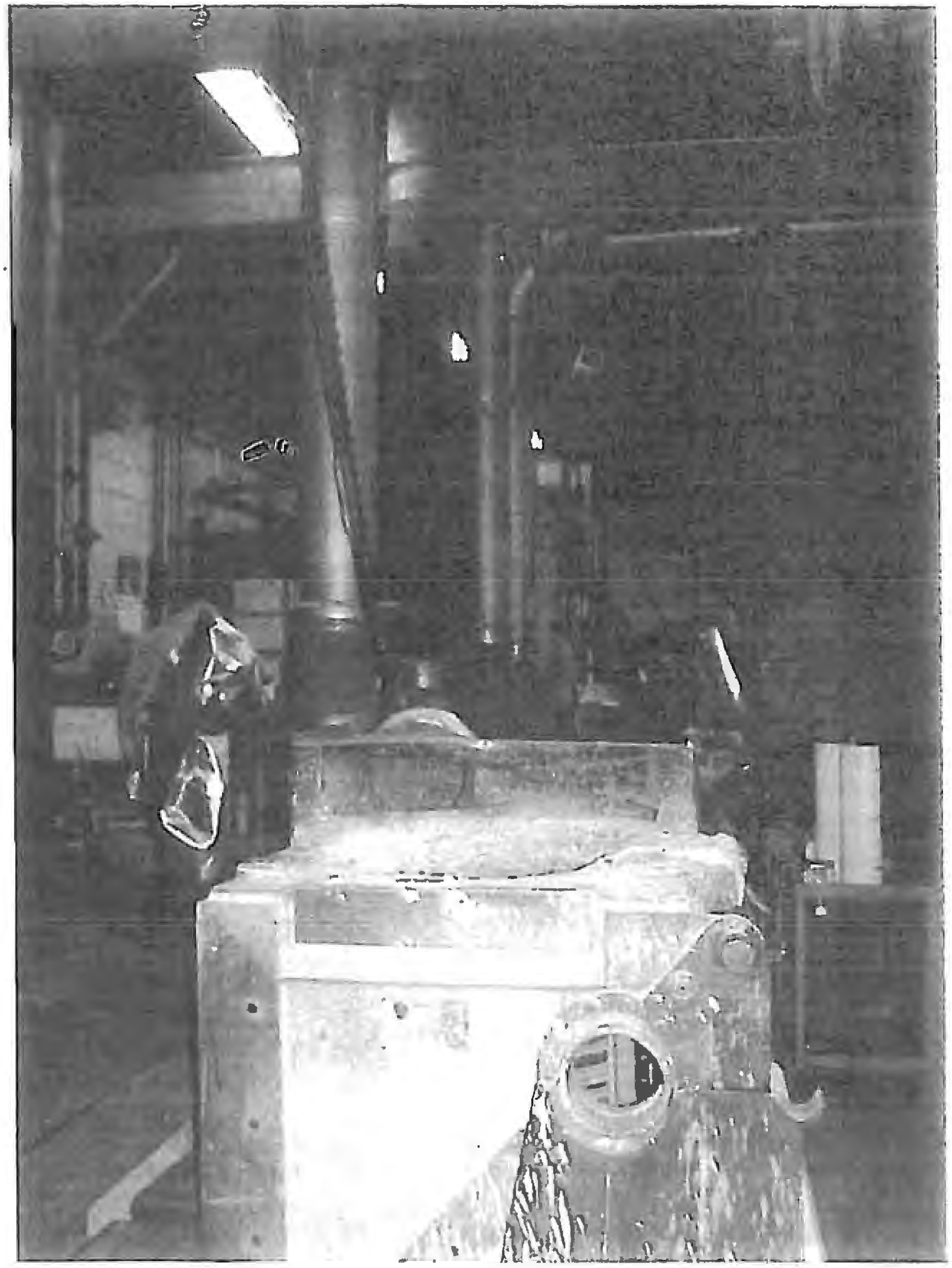


Photo #1 – This picture shows the slotted hood LEV above the greensand foundry furnace. The workers stand next to the furnace which is tilted forward via overhead crane for pouring of molten metal into molds.

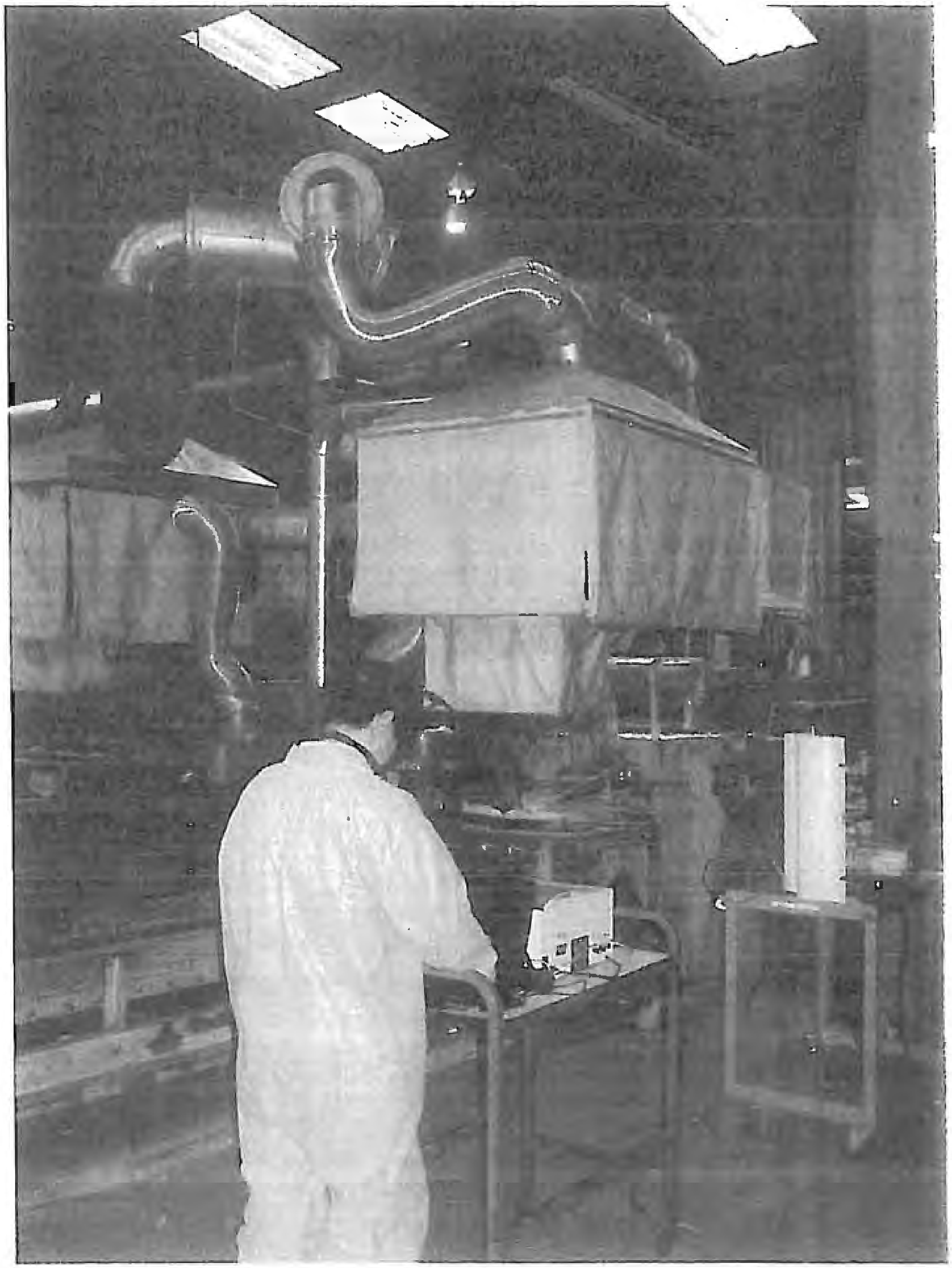


Photo #2 – This photo shows the ingot furnace with slotted hood above the furnace pot and the canopy hood with canvas extensions above the ingot furnace. The ingot furnace operators stand at the furnace area (near the canvas area shown in the photo) during pouring of molten metal into permanent metal ingot molds. The conveyor operators stand at the end of the ingot conveyor (left side of photo) to ensure that ingots are released from the ingot mold and drop into a shoot where the ingots are collected. All workers remain in the areas during the entire pouring process.

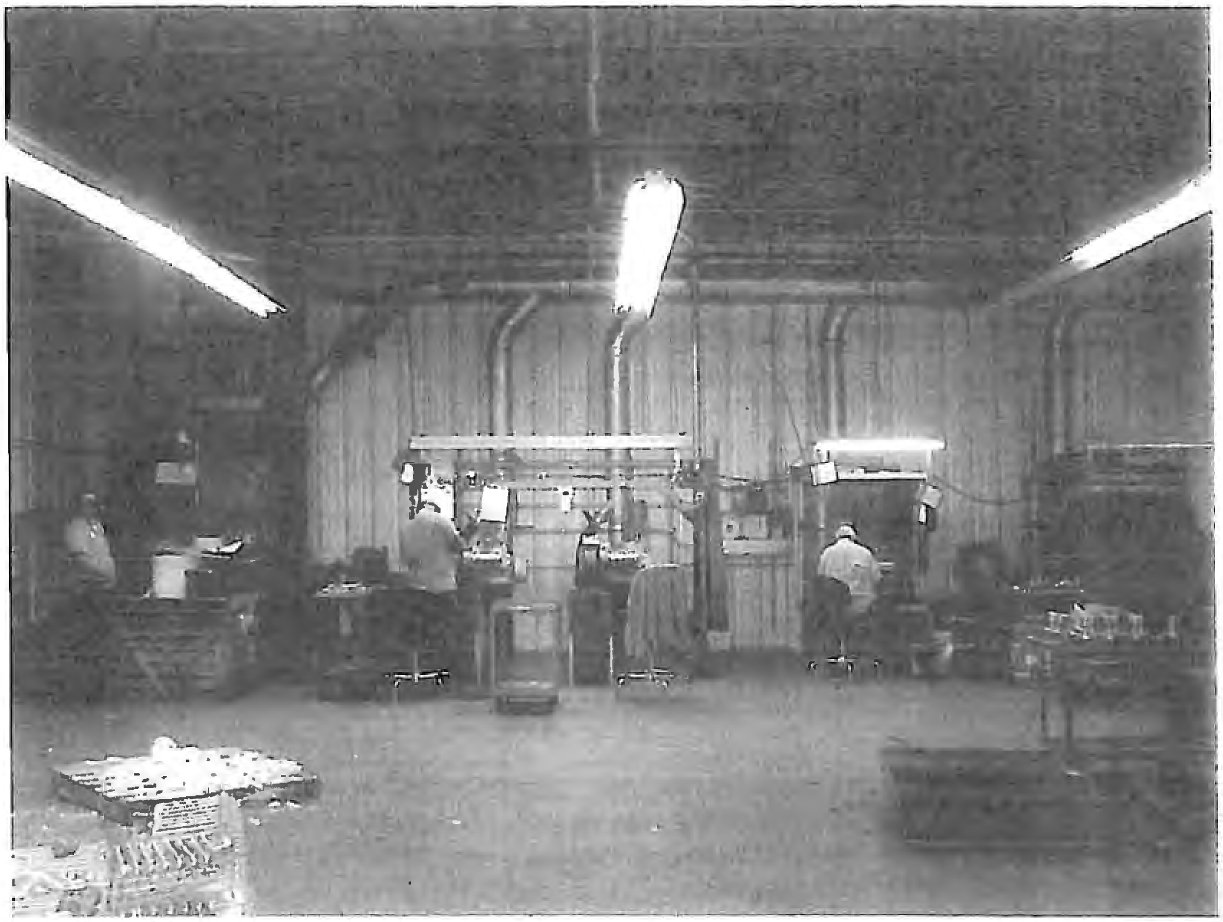


Photo #3 - This photo shows the LEV ventilation used in the cutting and grinding shop. All cutting and grinding operations are equipped with LEV and workers are required to wear respiratory protection. Three grinders are shown at their work stations.

Table 1
Occupational Exposure Criteria for Metal/Elements

TABLE 2. EXPOSURE LIMITS, CAS #, RTECS

Element (Symbol)	CAS #	RTECS	Exposure Limits, mg/m³ (Ca = carcinogen) OSHA	NIOSH	ACGIH
Silver (Ag)	7440-22-4	VW3500000	0.01 (dust, fume, metal)	0.01 (metal, soluble)	0.1 (metal) 0.01 (soluble)
Aluminum (Al)	7429-90-5	BD0330000	15 (total dust) 5 (respirable)	10 (total dust) 5 (respirable fume) 2 (salts, alkyls)	10 (dust) 5 (powders, fume) 2 (salts, alkyls)
Arsenic (As)	7440-38-2	CG0525000	varies	C 0.002, Ca	0.01, Ca
Barium (Ba)	7440-39-3	CQ8370000	0.5	0.5	0.5
Beryllium (Be)	7440-41-7	DS1750000	0.002, C 0.005	0.0005, Ca	0.002, Ca
Calcium (Ca)	7440-70-2	–	varies	varies	varies
Cadmium (Cd)	7440-43-9	EU9800000	0.005	lowest feasible, Ca	0.01 (total), Ca 0.002 (respir.), Ca
Cobalt (Co)	7440-48-4	GF8750000	0.1	0.05 (dust, fume)	0.02 (dust, fume)
Chromium (Cr)	7440-47-3	GB4200000	0.5	0.5	0.5
Copper (Cu)	7440-50-8	GL5325000	1 (dust, mists) 0.1 (fume)	1 (dust) 0.1 (fume)	1 (dust, mists) 0.2 (fume)
Iron (Fe)	7439-89-6	NO4565500	10 (dust, fume)	5 (dust, fume)	5 (fume)
Potassium (K)	7440-09-7	TS6460000	–	–	–
Lanthanum	7439-91-0	–	–	–	–
Lithium (Li)	7439-93-2	–	–	–	–
Magnesium (Mg)	7439-95-4	OM2100000	15 (dust) as oxide 5 (respirable)	10 (fume) as oxide	10 (fume) as oxide
Manganese (Mn)	7439-96-5	OO9275000	C 5	1; STEL 3	5 (dust) 1; STEL 3 (fume)
Molybdenum (Mo)	7439-98-7	QA4680000	5 (soluble) 15 (total insoluble)	5 (soluble) 10 (insoluble)	5 (soluble) 10 (insoluble)
Nickel (Ni)	7440-02-0	QR5950000	1	0.015, Ca	0.1 (soluble) 1 (insoluble metal)
Phosphorus (P)	7723-14-0	TH3500000	0.1	0.1	0.1
Lead (Pb)	7439-92-1	OF7525000	0.05	0.05	0.05
Antimony (Sb)	7440-36-0	CC4025000	0.5	0.5	0.5
Selenium (Se)	7782-49-2	VS7700000	0.2	0.2	0.2
Tin (Sn)	7440-31-5	XP7320000	2	2	2
Strontium (Sr)	7440-24-6	–	–	–	–
Tellurium (Te)	13494-80-9	WY2625000	0.1	0.1	0.1
Titanium (Ti)	7440-32-6	XR1700000	–	–	–
Thallium (Tl)	7440-28-0	XG3425000	0.1 (skin) (soluble)	0.1 (skin) (soluble)	0.1 (skin)
Vanadium (V)	7440-62-2	YW240000	–	C 0.05	–
Tungsten	7440-33-7	–	5	5 10 (STEL)	5 10 (STEL)
Yttrium (Y)	7440-65-5	ZG2980000	1	N/A	1
Zinc (Zn)	7440-66-6	ZG8600000	–	–	–
Zirconium (Zr)	7440-67-7	ZH7070000	5	5, STEL 10	5, STEL 10

Table 2
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Personal Breathing Zone and Area Air Sample Results for Total Particulate (TP), Aluminum (Al), Beryllium (Be), and Copper (Cu)

Sample Number	Job Description/Work Location	Sample Date	Time (minutes)	Sample Type	Total Particulate (µg/m³)	Al (µg/m³)	Be (µg/m³)	Cu (µg/m³)
NMWF - 1	Cu/Be foundry	9/26/2007	467	(P)ersonal	2647	9.33	0.09	1.72 (F)
NMWF - 2	Grinding room	9/26/2007	468	P	332	<0.50	0.29	4.34 (D)
NMWF - 3	Cu/Be foundry	9/26/2007	467	P	764	7.91	0.30	4.17 (F)
NMWF - 4	Cu/Be foundry	9/26/2007	460	P	1293	3.09	<0.04	0.96 (F)
NMWF - 9	Grinding room	9/26/2007	452	P	556	3.91	0.44	19.18 (D)
NMWF - 10	Cu/Be foundry supervisor	9/26/2007	465	P	2478	7.12	**0.58**	5.74 (F)
NMWF - 11	Al/Be Ingot furnace operator	9/26/2007	456	P	1493	4.13	0.21	2.73 (F)
NMWF - 13	Grinding room	9/26/2007	448	P	174	<0.52	0.10	3.44 (D)
NMWF - 15	Al/Be ingot room	9/26/2007	405	(A)rea	na	na	0.03	na
NMWF - 16	Cu/Be foundry	9/26/2007	424	A	na	na	0.11	na
NMHF - 1	Cu/Be foundry supervisor	9/27/2007	478	P	808	2.47	0.10	3.04 (F)
NMHF - 3	Cu/Be foundry	9/27/2007	481	P	2962	5.89	0.05	1.91 (F)
NMHF - 4	Al/Be Ingot furnace operator	9/27/2007	285	P	436	6.68	**0.55**	3.34 (F)
NMHF - 5	Grinding room	9/27/2007	458	P	532	1.17	0.27	10.27 (D)
NMHF - 6	Cu/Be foundry	9/27/2007	457	P	4448	14.84	0.42	2.89 (F)
NMHF - 7	Cu/Be foundry	9/27/2007	455	P	2280	4.03	0.06	1.19 (F)
NMHF - 15	Grinding room	9/27/2007	438	P	1696	1.38	**1.07**	42.16 (D)
NMHF - 16	Cu/Be foundry	9/27/2007	453	P	1468	2.40	<0.03	0.90 (F)
NMHF - 17	Grinding room	9/27/2007	448	P	465	<0.45	0.23	6.02 (D)
NMHF - 18	Al/Be ingot room	9/27/2007	411	A	na	na	0.03	na
NMHF - 19	Cu/Be foundry	9/27/2007	413	A	na	na	0.15	na
NMHF - 20	Cu/Be foundry	9/27/2007	377	A	na	na	0.14	na
NMHF - 21	Al/Be ingot room	9/27/2007	379	A	na	na	0.03	na
Evaluation Criteria		NIOSH REL NIOSH REL OSHA PEL				5000 5000	0.5 2.0	Fume (F) = 100 Dust (D) = 1000 Same as NIOSH

µg/m³ – micrograms per cubic meter of air
na – not applicable, area samples were analyzed for beryllium only

Bolded values exceed the NIOSH REL for beryllium

Table 3
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Surface Wipe Sample Results for Beryllium (Be), Copper (Cu), and Lead (Pb)

Sample Number	Sample Location	Sample Type	Be Conc. (µg/100cm²)	Cu Conc. (µg/100cm²)	Pb Conc. (µg/100cm²)
NMWW-1	Cu/Be foundry room, workbench top 15' from furnace	G	95	3000	8.8
NMWP-1	Cu/Be foundry room, workbench top 15' from furnace	P	23	na	na
NMWW-2	Cu/Be foundry room, vertical beam 40' from the furnace	G	5.9	78	2.7
NMWP-2	Cu/Be foundry room, vertical beam 40' from the furnace	P	5.0	na	na
NMWW-3	Al/Be ingot room, writing table top 20' from ingot drop	G	6.2	69	1.1
NMWP-3	Al/Be ingot room, writing table top 20' from ingot drop	P	13	na	na
NMWW-4	Al/Be ingot room, ingot drop device top	G	60	580	5.5
NMWP-4	Al/Be ingot room, ingot drop device top	P	21	na	na
NMHW-1	Al/Be ingot room, top metal computer table top 25' from furnace	G	40	440	6.8
NMHP-1	Al/Be ingot room, top metal computer table top 25' from furnace	P	37	na	na
NMHW-2	Al/Be ingot room, wood workbench top next to computer table	G	180	3400	170
NMHP-2	Al/Be ingot room, wood workbench top next to computer table	P	180	na	na
NMHW-3	Clean side lunch room table top	G	0.2	11	<0.8
NMHP-3	Clean side lunch room table top	P	0.2	na	na
NMHW-4	Dirty side lunch room table top	G	0.7	16	<0.8
NMHP-4	Dirty side lunch room table top	P	0.7	na	na
	DOE Guidelines for non-operational periods		**3.0**	---	---
	DOE Guidelines for release criteria		0.2	---	---

G = ghost wipe; P =palintest wipe; na = sample result not available, sample analyzed for beryllium only
µg/100 cm² = micrograms of compound per 100 cm² of wiped surface

Table 4
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP), Aluminum (Al), Beryllium (Be), and Copper (Cu)

Sample Number	Sample Description	Sample Type	Sample Date	Sample Time (min.)	Particle Size (µm)	TP Conc. (µg/m^3)	Al Conc. (µg/m^3)	Be Conc. (µg/m^3)	Cu Conc. (µg/m^3)
NMWF - 5A	Cu/Be foundry room	P-fume	9/26/2007	463	2.5	2422	0.82	<0.02	0.23
NMWF - 5B	Cu/Be foundry room	P-fume	9/26/2007	463	1.0	893	0.33	<0.02	0.07
NMWF - 5C	Cu/Be foundry room	P-fume	9/26/2007	463	0.50	509	<0.15	<0.02	0.03
NMWF - 5D	Cu/Be foundry room	P-fume	9/26/2007	463	0.25	204	<0.15	<0.02	0.03
NMWF - 5E	Cu/Be foundry room	P-fume	9/26/2007	463	filter	768	<0.15	<0.02	0.05
NMWF – 5 total	Cu/Be foundry room	P-fume	9/26/2007	463		4796	1.15	<0.02	0.40
NMWF - 6A	Cu/Be foundry room	P-fume	9/26/2007	466	2.5	3666	1.41	<0.02	0.47
NMWF - 6B	Cu/Be foundry room	P-fume	9/26/2007	466	1.0	1633	0.58	<0.02	0.14
NMWF - 6C	Cu/Be foundry room	P-fume	9/26/2007	466	0.50	1111	0.39	<0.02	0.07
NMWF - 6D	Cu/Be foundry room	P-fume	9/26/2007	466	0.25	1161	0.39	<0.02	0.06
NMWF - 6E	Cu/Be foundry room	P-fume	9/26/2007	466	filter	3927	2.76	<0.02	0.30
NMWF – 6 total	Cu/Be foundry room	P-fume	9/26/2007	466		11498	5.51	<0.02	1.04
NMWF - 7A	Cu/Be foundry room	P-fume	9/26/2007	455	2.5	4430	2.76	0.03	0.50
NMWF - 7B	Cu/Be foundry room	P-fume	9/26/2007	455	1.0	805	0.55	<0.02	0.09
NMWF - 7C	Cu/Be foundry room	P-fume	9/26/2007	455	0.50	660	0.58	<0.02	0.07
NMWF - 7D	Cu/Be foundry room	P-fume	9/26/2007	455	0.25	1087	1.19	<0.02	0.12
NMWF - 7E	Cu/Be foundry room	P-fume	9/26/2007	455	filter	2008	1.63	<0.02	0.11
NMWF – 7 total	Cu/Be foundry room	P-fume	9/26/2007	455		8990	6.70	0.03	0.89
NMWF - 8A	Grinding room	P-dust	9/26/2007	453	2.5	248	0.19	<0.02	0.49
NMWF - 8B	Grinding room	P-dust	9/26/2007	453	1.0	95	<0.16	<0.02	0.23
NMWF - 8C	Grinding room	P-dust	9/26/2007	453	0.50	51	<0.16	<0.02	0.04
NMWF - 8D	Grinding room	P-dust	9/26/2007	453	0.25	131	<0.16	<0.02	0.08
NMWF - 8E	Grinding room	P-dust	9/26/2007	453	filter	285	<0.16	<0.02	0.03
NMWF – 8 total	Grinding room	P-dust	9/26/2007	453		811	0.19	<0.02	0.87

Table 4 - *Continued*

Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry

Sioutas Impactor Sample Results for Total Particulate (TP), Aluminum (Al), Beryllium (Be), and Copper (Cu)

Sample Number	Sample Description	Sample Type	Sample Date	Sample Time (min.)	Particle Size (µm)	TP Conc. (µg/m³)	Al Conc. (µg/m³)	Be Conc. (µg/m³)	Cu Conc. (µg/m³)
NMWF - 12A	Al/Be ingot room	P-fume	9/26/2007	453	2.5	900	0.96	0.03	0.41
NMWF - 12B	Al/Be ingot room	P-fume	9/26/2007	453	1.0	327	0.17	<0.02	0.10
NMWF - 12C	Al/Be ingot room	P-fume	9/26/2007	453	0.50	87	<0.47	<0.02	0.02
NMWF - 12D	Al/Be ingot room	P-fume	9/26/2007	453	0.25	0	<0.47	<0.02	0.01
NMWF - 12E	Al/Be ingot room	P-fume	9/26/2007	453	filter	494	0.72	<0.02	0.12
NMWF – 12 total	Al/Be ingot room	P-fume	9/26/2007	453		2980	1.85	0.03	0.66
NMWF - 14A	Grinding room	P-dust	9/26/2007	448	2.5	344	0.33	0.06	0.79
NMWF - 14B	Grinding room	P-dust	9/26/2007	448	1.0	176	0.38	0.03	0.22
NMWF - 14C	Grinding room	P-dust	9/26/2007	448	0.50	51	0.21	<0.02	0.04
NMWF - 14D	Grinding room	P-dust	9/26/2007	448	0.25	117	<0.16	<0.02	0.03
NMWF - 14E	Grinding room	P-dust	9/26/2007	448	filter	542	<0.16	<0.02	<0.01
NMWF – 14 total	Grinding room	P-dust	9/26/2007	448		1231	0.92	0.08	1.07
NMHF - 2A	Cu/Be foundry room	P-fume	9/27/2007	474	2.5	2141	0.82	<0.02	0.22
NMHF - 2B	Cu/Be foundry room	P-fume	9/27/2007	474	1.0	0	0.28	<0.02	0.04
NMHF - 2C	Cu/Be foundry room	P-fume	9/27/2007	474	0.50	0	0.18	<0.02	<0.01
NMHF - 2D	Cu/Be foundry room	P-fume	9/27/2007	474	0.25	504	<0.15	<0.02	<0.01
NMHF - 2E	Cu/Be foundry room	P-fume	9/27/2007	474	filter	1335	0.41	<0.02	0.06
NMHF – 2 total	Cu/Be foundry room	P-fume	9/27/2007	474		3980	1.70		
NMHF - 8A	Cu/Be foundry room	P-fume	9/27/2007	470	2.5	1978	0.87	0.03	0.63
NMHF - 8B	Cu/Be foundry room	P-fume	9/27/2007	470	1.0	485	0.26	<0.02	0.15
NMHF - 8C	Cu/Be foundry room	P-fume	9/27/2007	470	0.50	318	0.25	<0.02	0.08
NMHF - 8D	Cu/Be foundry room	P-fume	9/27/2007	470	0.25	659	0.32	<0.02	0.07
NMHF - 8E	Cu/Be foundry room	P-fume	9/27/2007	470	filter	1675	0.34	<0.02	0.22
NMHF – 8 total	Cu/Be foundry room	P-fume	9/27/2007	470		5115	2.04	0.03	1.15

Table 4 - *Continued*

Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry

Sioutas Impactor Sample Results for Total Particulate (TP), Aluminum (Al), Beryllium (Be), and Copper (Cu)

Sample Number	Sample Description	Sample Type	Sample Date	Sample Time (min.)	Particle Size (µm)	TP Conc. (µg/m³)	Al Conc. (µg/m³)	Be Conc. (µg/m³)	Cu Conc. (µg/m³)
NMHF - 9A	Al/Be ingot room	P-fume	9/27/2007	469	2.5	1511	0.77	<0.02	0.23
NMHF - 9B	Al/Be ingot room	P-fume	9/27/2007	469	1.0	448	0.36	<0.02	0.04
NMHF - 9C	Al/Be ingot room	P-fume	9/27/2007	469	0.50	195	0.28	<0.02	<0.01
NMHF - 9D	Al/Be ingot room	P-fume	9/27/2007	469	0.25	253	0.22	<0.02	<0.01
NMHF - 9E	Al/Be ingot room	P-fume	9/27/2007	469	filter	1135	<0.17	<0.02	<0.01
NMHF – 9 total	Al/Be ingot room	P-fume	9/27/2007	469		3541	1.64	<0.02	0.27
NMHF - 10A	Grinding room	P-dust	9/27/2007	465	2.5	846	0.72	0.19	5.41
NMHF - 10B	Grinding room	P-dust	9/27/2007	465	1.0	287	0.26	0.04	1.06
NMHF - 10C	Grinding room	P-dust	9/27/2007	465	0.50	124	0.25	<0.02	0.22
NMHF - 10D	Grinding room	P-dust	9/27/2007	465	0.25	458	0.18	<0.02	0.28
NMHF - 10E	Grinding room	P-dust	9/27/2007	465	filter	1343	0.36	<0.02	0.16
NMHF – 10 total	Grinding room	P-dust	9/27/2007	465		3059	1.77	0.23	7.13
NMHF - 12A	Grinding room	P-dust	9/27/2007	457	2.5	837	0.34	0.04	1.30
NMHF - 12B	Grinding room	P-dust	9/27/2007	457	1.0	256	0.20	<0.02	0.40
NMHF - 12C	Grinding room	P-dust	9/27/2007	457	0.50	106	0.26	<0.02	0.08
NMHF - 12D	Grinding room	P-dust	9/27/2007	457	0.25	287	<0.16	<0.02	0.08
NMHF - 12E	Grinding room	P-dust	9/27/2007	457	filter	1109	0.20	<0.02	0.07
NMHF – 12 total	Grinding room	P-dust	9/27/2007	457		2594	1.01	0.04	1.93

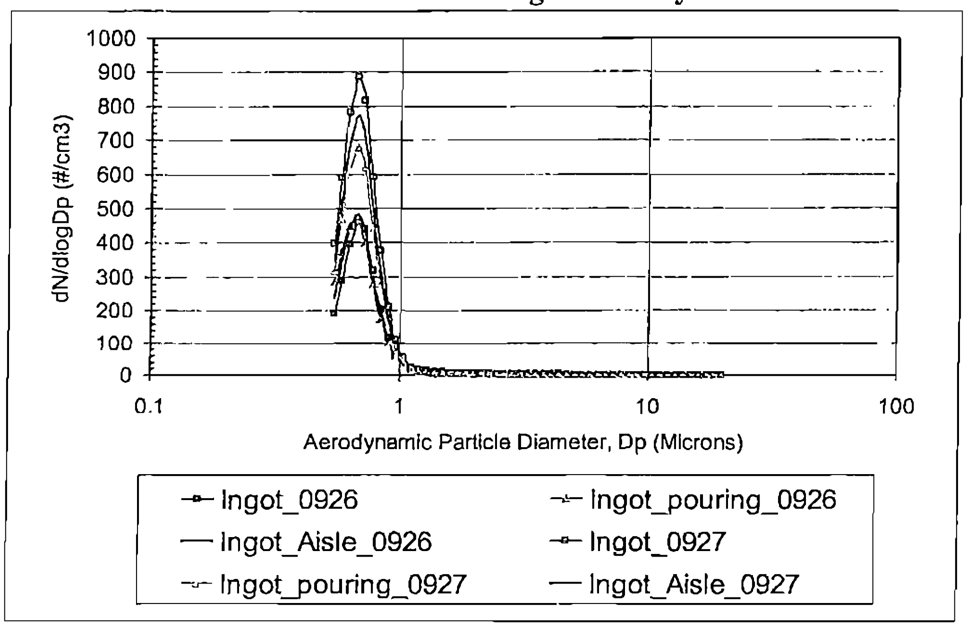
Table 5
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
MOUDI Impactor Sample Results for Total Particulate (TP), Aluminum (Al), Beryllium (Be), and Copper (Cu)

Sample Number	Sample Location	Sample Volume (m^3)	Particulate Conc. (mg/m^3)	Al Conc. ($\mu g/m^3$)	Be Conc. ($\mu g/m^3$)	Cu Conc. ($\mu g/m^3$)
A7-0	Cu/Be foundry room	25.380	0.074	0.14	<0.004	0.06
A7-1	Cu/Be foundry room	25.380	0.066	0.15	<0.004	0.03
A7-2	Cu/Be foundry room	25.380	0.047	0.17	<0.004	0.04
A7-3	Cu/Be foundry room	25.380	0.035	0.10	<0.004	0.02
A7-4	Cu/Be foundry room	25.380	0.044	0.07	<0.004	0.01
A7-5	Cu/Be foundry room	25.380	0.023	0.05	<0.004	0.01
A7-6	Cu/Be foundry room	25.380	0.001	<0.04	<0.004	<0.01
A7-7	Cu/Be foundry room	25.380	<0.001	0.06	<0.004	<0.01
A7-8	Cu/Be foundry room	25.380	0.015	0.13	<0.004	<0.01
A7-9	Cu/Be foundry room	25.380	0.019	<0.04	<0.004	<0.01
A7-10	Cu/Be foundry room	25.380	0.015	<0.04	<0.004	<0.01
A7-Final	Cu/Be foundry room	25.380	0.005	<0.04	<0.002	0.01
A7-Total	Cu/Be foundry room	25.380	0.342	0.87	<0.004	0.18
B6-0	Al/Be ingot room	24.900	0.007	0.05	<0.004	0.03
B6-1	Al/Be ingot room	24.900	0.004	0.04	<0.004	0.01
B6-2	Al/Be ingot room	24.900	0.005	0.08	<0.004	<0.01
B6-3	Al/Be ingot room	24.900	0.004	0.08	<0.004	0.02
B6-4	Al/Be ingot room	24.900	0.003	0.20	<0.004	0.02
B6-5	Al/Be ingot room	24.900	0.004	0.05	<0.004	<0.01
B6-6	Al/Be ingot room	24.900	0.005	0.08	<0.004	0.01
B6-7	Al/Be ingot room	24.900	0.008	<0.04	<0.004	<0.01
B6-8	Al/Be ingot room	24.900	0.008	0.04	<0.004	0.01
B6-9	Al/Be ingot room	24.900	0.004	0.05	<0.004	0.02
B6-10	Al/Be ingot room	24.900	0.002	0.06	<0.004	<0.01
B6-Final	Al/Be ingot room	24.900	0.006	<0.04	<0.002	0.01
B6-Total	Al/Be ingot room	24.900	0.06	0.75	<0.004	0.12

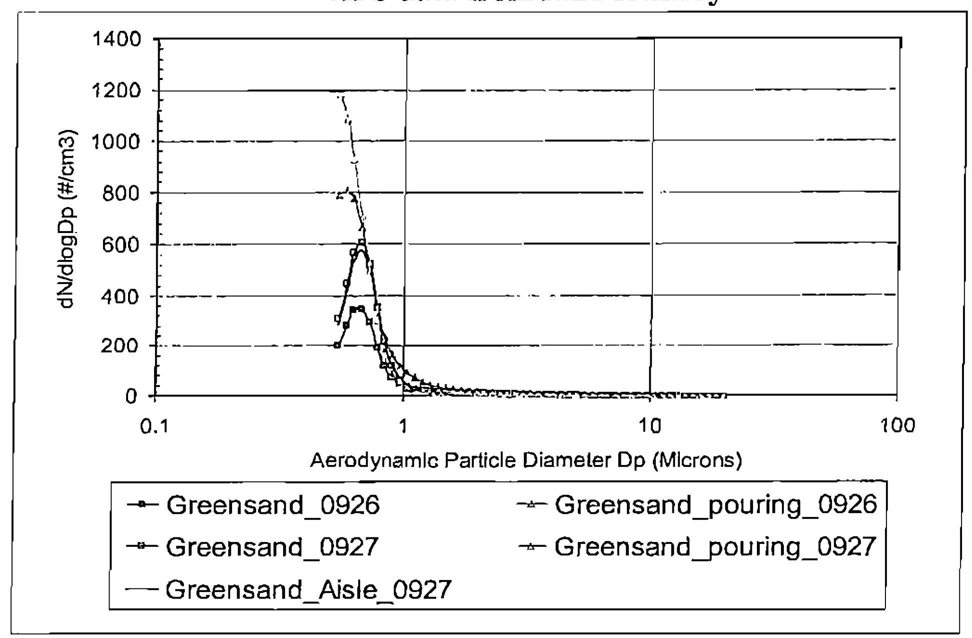
Table 6
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry Summary of APS data

Sampling location/Date	Geometric mean (μm)	Mode (μm)	Particle Concentration at mode size (#/cm^3)
Ingot_0926	0.733	0.673	459.6
Ingot_pouring_0926	0.703	0.626	449.7
Ingot_Aisle_0926	0.717	0.673	481.4
Ingot_0927	0.700	0.673	884.5
Ingot_pouring_0927	0.697	0.673	681.4
Ingot_Aisle_0927	0.699	0.673	773.0
Greensand_0926	0.762	0.673	349.8
Greensand_pouring_0926	0.718	0.583	807.9
Greensand_0927	0.723	0.673	605.7
Greensand_pouring_0927	0.655	0.542	1180.7
Greensand_Aisle_0927	0.749	0.673	577.2

APS data from ingot foundry



APS data from sand foundry



Appendix A
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Personal Breathing Zone and Area Air Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	TP Conc. (µg/m³)	Al Conc. (µg/m³)	Sb Conc. (µg/m³)	As Conc. (µg/m³)	Ba Conc. (µg/m³)	Be Conc. (µg/m³)	Cd Conc. (µg/m³)	Ca Conc. (µg/m³)	Cr Conc. (µg/m³)	Co Conc. (µg/m³)	Cu Conc. (µg/m³)
NMWF - 1	2647	9.33	<0.22	<0.36	0.18	0.09	<0.04	78.96	<0.14	<0.43	1.72
NMWF - 2	332	<0.50	<0.22	<0.36	0.05	0.29	<0.04	2.89	<0.14	0.09	4.34
NMWF - 3	764	7.91	<0.22	<0.36	0.40	0.30	<0.04	100.73	0.23	0.12	4.17
NMWF - 4	1293	3.09	<0.22	<0.37	0.09	<0.04	<0.04	132.29	<0.15	<0.44	0.96
NMWF - 9	556	3.91	<0.22	0.50	0.07	0.44	<0.04	11.81	<0.15	0.08	19.18
NMWF - 10	2478	7.12	<0.22	<0.36	0.27	0.58	<0.04	63.91	0.15	<0.44	5.74
NMWF - 11	1493	4.13	<0.22	0.44	0.13	0.21	<0.04	16.21	0.18	<0.44	2.73
NMWF - 13	174	<0.52	<0.22	<0.37	0.06	0.10	<0.04	3.14	<0.15	<0.45	3.44
NMWF - 15	na	na	na	na	na	0.03	na	na	na	na	na
NMWF - 16	na	na	na	na	na	0.11	na	na	na	na	na
NMHF - 1	808	2.47	<0.21	<0.49	0.10	0.10	<0.03	19.06	0.08	<0.02	3.04
NMHF - 3	2962	5.89	<0.21	<0.50	0.14	0.05	<0.03	233.99	0.14	<0.02	1.91
NMHF - 4	436	6.68	<0.36	<0.84	0.14	0.55	<0.05	13.12	0.24	0.04	3.34
NMHF - 5	532	1.17	<0.22	<0.51	0.04	0.27	<0.03	5.65	0.15	0.07	10.27
NMHF - 6	4448	14.84	<0.22	<0.52	0.42	0.42	<0.03	65.29	0.19	0.03	2.89
NMHF - 7	2280	4.03	<0.22	<0.52	0.09	0.06	<0.03	208.75	0.07	<0.02	1.19
NMHF - 15	1696	1.38	<0.23	<0.54	0.13	1.07	<0.03	12.26	0.37	0.28	42.16
NMHF - 16	1468	2.40	<0.22	<0.52	0.08	<0.03	<0.03	164.88	0.15	<0.02	0.90
NMHF - 17	465	<0.45	0.25	<0.53	0.03	0.23	<0.03	3.77	0.22	0.06	6.02
NMHF - 18	na	na	na	na	na	0.03	na	na	na	na	na
NMHF - 19	na	na	na	na	na	0.15	na	na	na	na	na
NMHF - 20	na	na	na	na	na	0.14	na	na	na	na	na
NMHF - 21	na	na	na	na	na	0.03	na	na	na	na	na

Appendix A - *continued*
Facility #3 – Copper/Beryllium and Aluminum/Beryllium Foundry
Personal Breathing Zone and Area Air Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Fe Conc. (µg/m^3)	La Conc. (µg/m^3)	Pb Conc. (µg/m^3)	Li Conc. (µg/m^3)	Mg Conc. (µg/m^3)	Mn Conc. (µg/m^3)	Mo Conc. (µg/m^3)	Ni Conc. (µg/m^3)	P Conc. (µg/m^3)	K Conc. (µg/m^3)	Se Conc. (µg/m^3)
NMWF - 1	9.33	<0.01	0.23	<0.02	5.38	0.17	<0.07	<0.07	<1.44	2.15	<1.44
NMWF - 2	5.13	<0.01	<0.14	<0.02	0.22	<0.06	<0.07	<0.07	<1.45	0.61	<1.45
NMWF - 3	16.55	<0.01	<0.14	<0.02	29.50	0.47	<0.07	<0.07	5.61	4.53	<1.44
NMWF - 4	6.32	<0.01	<0.15	<0.02	5.00	0.10	<0.07	<0.07	<1.47	1.10	<1.47
NMWF - 9	5.98	<0.01	<0.15	<0.02	0.96	0.08	<0.07	<0.07	<1.48	0.89	<0.55
NMWF - 10	116.21	0.04	0.28	<0.02	6.39	9.44	<0.07	0.10	<1.48	2.32	<1.45
NMWF - 11	287.34	0.15	0.15	<0.02	2.73	8.84	<0.07	<0.07	<1.48	0.96	<1.47
NMWF - 13	10.47	<0.01	0.15	<0.02	0.22	0.08	<0.07	<0.07	<1.50	1.87	<1.50
NMWF - 15	na	na	na	na	na	na	na	na	na	na	na
NMWF - 16	na	na	na	na	na	na	na	na	na	na	na
NMHF - 1	9.18	<0.01	<0.21	<0.07	1.76	0.13	<0.04	<0.14	<1.41	1.27	<1.41
NMHF - 3	12.76	<0.01	<0.21	<0.07	8.51	0.18	<0.04	<0.14	<1.42	1.70	<1.42
NMHF - 4	57.27	<0.02	<0.36	<0.12	3.34	0.67	<0.06	<0.24	<2.39	1.79	<2.39
NMHF - 5	10.27	<0.01	<0.22	<0.07	0.61	0.14	<0.04	<0.15	<1.47	2.27	<1.47
NMHF - 6	31.16	0.07	0.23	<0.07	10.39	0.41	<0.04	0.22	1.56	4.38	<1.48
NMHF - 7	8.20	<0.01	<0.22	<0.07	6.78	0.13	<0.04	<0.15	<1.49	1.27	<1.49
NMHF - 15	21.46	<0.02	<0.23	<0.08	1.15	0.22	<0.04	0.19	<1.53	2.22	<1.53
NMHF - 16	5.62	<0.01	<0.22	<0.07	4.80	0.29	0.06	0.19	<1.50	0.97	<1.50
NMHF - 17	20.33	<0.02	<0.23	<0.08	0.44	0.21	<0.15	0.23	<1.51	0.83	<1.51
NMHF - 18	na	na	na	na	na	na	na	na	na	na	na
NMHF - 19	na	na	na	na	na	na	na	na	na	na	na
NMHF - 20	na	na	na	na	na	na	na	na	na	na	na
NMHF - 21	na	na	na	na	na	na	na	na	na	na	na

Appendix A - *Continued*

Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry

Personal Breathing Zone and Area Air Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Ag Conc. (µg/m³)	Sr Conc. (µg/m³)	Te Conc. (µg/m³)	Tl Conc. (µg/m³)	Sn Conc. (µg/m³)	Ti Conc. (µg/m³)	V Conc. (µg/m³)	Y Conc. (µg/m³)	Zn Conc. (µg/m³)	Zr Conc. (µg/m³)
NMWF - 1	<0.02	0.21	<0.22	<0.51	<0.43	0.18	<0.03	0.02	0.79	<0.50
NMWF - 2	<0.02	0.21	<0.22	<0.51	<0.43	0.03	<0.03	<0.02	0.35	<0.51
NMWF - 3	<0.02	0.21	<0.22	<0.51	<0.43	0.16	<0.03	<0.02	1.15	<0.50
NMWF - 4	<0.02	0.15	<0.22	<0.51	<0.44	0.10	<0.03	<0.02	0.81	<0.51
NMWF - 9	<0.02	0.03	<0.22	<0.52	<0.44	0.07	<0.03	<0.02	0.81	<0.52
NMWF - 10	<0.02	0.14	<0.22	<0.51	<0.44	0.22	<0.03	<0.02	19.61	<0.51
NMWF - 11	<0.02	0.03	<0.22	<0.52	<0.44	0.10	<0.03	<0.02	60.41	<0.52
NMWF - 13	<0.02	<0.01	<0.22	<0.52	<0.45	0.03	<0.03	<0.02	0.16	<0.52
NMWF - 15	na	na	na	na	na	na	na	na	na	na
NMWF - 16	na	na	na	na	na	na	na	na	na	na
NMHF - 1	<0.02	0.03	<0.22	<0.50	<0.71	0.10	<0.03	<0.01	0.99	<0.28
NMHF - 3	<0.02	0.26	<0.22	<0.50	<0.71	0.13	<0.03	<0.01	0.70	<0.29
NMHF - 4	<0.04	<0.05	<0.36	<0.84	<1.19	0.09	<0.05	<0.02	0.95	<0.48
NMHF - 5	<0.02	<0.03	<0.22	<0.51	<0.73	0.03	<0.03	<0.01	0.32	<0.30
NMHF - 6	<0.02	0.47	<0.22	<0.52	<0.74	0.42	<0.03	0.03	0.89	<0.30
NMHF - 7	<0.02	0.18	<0.22	<0.52	<0.75	0.10	<0.03	<0.01	0.45	<0.30
NMHF - 15	<0.02	<0.03	<0.23	<0.54	<0.77	0.05	<0.03	<0.02	0.62	<0.30
NMHF - 16	<0.02	0.13	<0.22	<0.52	<0.75	0.05	<0.03	<0.02	0.32	<0.30
NMHF - 17	<0.02	<0.03	<0.23	<0.53	<0.75	<0.02	<0.03	<0.02	0.26	<0.30
NMHF - 18	na	na	na	na	na	na	na	na	na	na
NMHF - 19	na	na	na	na	na	na	na	na	na	na
NMHF - 20	na	na	na	na	na	na	na	na	na	na
NMHF - 21	na	na	na	na	na	na	na	na	na	na

Appendix B
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Surface Wipe Sample Results for Twenty-four Elements

Sample Number	As ($\mu g/100cm^2$)	Ba ($\mu g/100cm^2$)	Be ($\mu g/100cm^2$)	Cd ($\mu g/100cm^2$)	Cr ($\mu g/100cm^2$)	Co ($\mu g/100cm^2$)	Cu ($\mu g/100cm^2$)	Fe ($\mu g/100cm^2$)
NMWW-1	<0.8	4.3	95	<0.2	5.5	1800	3000	350
NMWP-1	na	na	23.02	na	na	na	na	na
NMWW-2	<0.8	6.5	5.9	<0.2	3.3	10	78	650
NMWP-2	na	na	4.96	na	na	na	na	na
NMWW-3	<0.8	1.9	6.2	<0.2	1.3	0.9	69	420
NMWP-3	na	na	13.12	na	na	na	na	na
NMWW-4	<0.8	12	60	0.71	6.2	7.1	580	3000
NMWP-4	na	na	20.52	na	na	na	na	na
NMHW-1	<0.8	7.8	40	0.32	3.3	8.5	440	1300
NMHP-1	na	na	36.88	na	na	na	na	na
NMHW-2	<0.8	29	180	0.46	11	510	3400	2200
NMHP-2	na	na	179.74	na	na	na	na	na
NMHW-3	<0.8	0.16	0.2	<0.2	<0.2	0.32	11	<9
NMHP-3	na	na	0.18	na	na	na	na	na
NMHW-4	<0.8	0.37	0.74	<0.2	0.21	0.13	16	21
NMHP-4	na	na	0.65	na	na	na	na	na

Appendix B - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Surface Wipe Sample Results for Twenty-four Elements

Sample Number	La (µg/100cm²)	Pb (µg/100cm²)	Mg (µg/100cm²)	Mo (µg/100cm²)	Ni (µg/100cm²)	P (µg/100cm²)	Se (µg/100cm²)	Ag (µg/100cm²)
NMWW-1	0.47	8.8	5.7	6	19	<40	<7	0.63
NMWP-1	na	na	na	na	na	na	na	na
NMWW-2	0.67	2.7	7.9	1.8	5.1	<40	<7	<0.05
NMWP-2	na	na	na	na	na	na	na	na
NMWW-3	0.13	1.1	4.2	<0.4	1.8	<40	<7	<0.05
NMWP-3	na	na	na	na	na	na	na	na
NMWW-4	1.4	5.5	31	1.2	9.9	42	<7	0.14
NMWP-4	na	na	na	na	na	na	na	na
NMHW-1	0.63	6.8	13	0.65	5.1	<40	<7	0.14
NMHP-1	na	na	na	na	na	na	na	na
NMHW-2	2.2	170	56	2.1	30	<40	<7	1
NMHP-2	na	na	na	na	na	na	na	na
NMHW-3	<0.07	<0.8	0.15	<0.4	<0.3	<40	<7	<0.05
NMHP-3	na	na	na	na	na	na	na	na
NMHW-4	<0.07	<0.8	0.44	<0.4	<0.3	<40	<7	<0.05
NMHP-4	na	na	na	na	na	na	na	na

Appendix B - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Surface Wipe Sample Results for Twenty-four Elements

Sample Number	Sr (µg/100cm²)	Te (µg/100cm²)	Tl (µg/100cm²)	Sn (µg/100cm²)	V (µg/100cm²)	Y (µg/100cm²)	Zn (µg/100cm²)	Zr (µg/100cm²)
NMWW-1	3	<0.9	<3	<4	0.55	0.37	57	<70
NMWP-1	na	na	na	na	na	na	na	na
NMWW-2	6.6	<0.9	<3	<4	0.55	0.56	29	<70
NMWP-2	na	na	na	na	na	na	na	na
NMWW-3	0.74	<0.9	<3	<4	0.068	<0.09	29	<70
NMWP-3	na	na	na	na	na	na	na	na
NMWW-4	3.8	<0.9	<3	<4	0.19	0.33	79	<70
NMWP-4	na	na	na	na	na	na	na	na
NMHW-1	2.6	<0.9	<3	<4	0.26	0.26	<9	<70
NMHP-1	na	na	na	na	na	na	na	na
NMHW-2	13	<0.9	<3	<4	1.2	0.98	90	<70
NMHP-2	na	na	na	na	na	na	na	na
NMHW-3	0.49	<0.9	<3	<4	<0.06	<0.09	84	<70
NMHP-3	na	na	na	na	na	na	na	na
NMHW-4	0.81	<0.9	<3	<4	<0.06	<0.09	51	<70
NMHP-4	na	na	na	na	na	na	na	na

Appendix C
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	TP Conc. (μg/m³)	Al Conc. (μg/m³)	Sb Conc. (μg/m³)	As Conc. (μg/m³)	Ba Conc. (μg/m³)	Be Conc. (μg/m³)	Cd Conc. (μg/m³)	Ca Conc. (μg/m³)	Cr Conc. (μg/m³)	Co Conc. (μg/m³)	Cu Conc. (μg/m³)
NMWF - 5A	2422	0.82	<0.10	<0.26	0.03	<0.02	<0.01	28.07	<0.08	<0.01	0.23
NMWF - 5B	893	0.33	<0.10	<0.26	0.01	<0.02	<0.01	10.97	<0.08	<0.01	0.07
NMWF - 5C	509	<0.15	<0.10	<0.26	<0.01	<0.02	<0.01	5.10	<0.08	<0.01	0.03
NMWF - 5D	204	<0.15	<0.10	<0.26	<0.01	<0.02	<0.01	3.83	<0.08	<0.01	0.03
NMWF - 5E	768	<0.15	<0.10	<0.26	<0.01	<0.02	<0.01	2.81	<0.08	<0.01	0.05
NMWF – 5 total	4796	1.15	<0.10	<0.26	0.04	<0.02	<0.01	50.78	<0.08	<0.01	0.40
NMWF - 6A	3666	1.41	<0.11	<0.28	0.03	<0.02	<0.01	52.35	<0.08	<0.01	0.47
NMWF - 6B	1633	0.58	<0.11	<0.28	0.01	<0.02	<0.01	24.52	<0.08	<0.01	0.14
NMWF - 6C	1111	0.39	<0.11	<0.28	<0.01	<0.02	<0.01	14.33	<0.08	<0.01	0.07
NMWF - 6D	1161	0.39	<0.11	<0.28	<0.01	<0.02	<0.01	13.50	<0.08	<0.01	0.06
NMWF - 6E	3927	2.76	<0.11	<0.28	0.02	<0.02	<0.01	41.33	<0.08	<0.01	0.30
NMWF – 6 total	11498	5.51	<0.11	<0.28	0.06	<0.02	<0.01	146.03	<0.08	<0.01	1.04
NMWF - 7A	4430	2.76	<0.11	<0.28	0.06	0.03	<0.01	19.31	<0.08	<0.01	0.50
NMWF - 7B	805	0.55	<0.11	<0.28	0.01	<0.02	<0.01	4.14	<0.08	<0.01	0.09
NMWF - 7C	660	0.58	<0.11	<0.28	0.01	<0.02	<0.01	3.03	<0.08	<0.01	0.07
NMWF - 7D	1087	1.19	<0.11	<0.28	0.01	<0.02	<0.01	2.76	<0.08	<0.01	0.12
NMWF - 7E	2008	1.63	<0.11	<0.28	0.01	<0.02	<0.01	3.03	<0.08	<0.01	0.11
NMWF – 7 total	8990	6.70	<0.11	<0.28	0.10	0.03	<0.01	32.28	<0.08	<0.01	0.89
NMWF - 8A	248	0.19	<0.11	<0.27	<0.01	<0.02	<0.01	0.55	<0.08	<0.01	0.49
NMWF - 8B	95	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	0.41	<0.08	<0.01	0.23
NMWF - 8C	51	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.04
NMWF - 8D	131	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.08
NMWF - 8E	285	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.03
NMWF – 8 total	811	0.19	<0.11	<0.27	<0.01	<0.02	<0.01	0.96	<0.08	<0.01	0.87

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	TP Conc. (µg/m³)	Al Conc. (µg/m³)	Sb Conc. (µg/m³)	As Conc. (µg/m³)	Ba Conc. (µg/m³)	Be Conc. (µg/m³)	Cd Conc. (µg/m³)	Ca Conc. (µg/m³)	Cr Conc. (µg/m³)	Co Conc. (µg/m³)	Cu Conc. (µg/m³)
NMWF - 12A	900	0.96	<0.11	<0.28	0.05	0.03	<0.01	3.86	<0.08	<0.01	0.41
NMWF - 12B	327	0.17	<0.11	<0.28	<0.01	<0.02	<0.01	0.94	<0.08	<0.01	0.10
NMWF - 12C	87	<0.47	<0.11	<0.28	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.02
NMWF - 12D	0	<0.47	<0.11	<0.28	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.01
NMWF - 12E	494	0.72	<0.11	<0.28	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.12
NMWF – 12 total	2980	1.85	<0.11	<0.28	0.05	0.03	<0.01	4.80	<0.08	<0.01	0.66
NMWF - 14A	344	0.33	<0.11	<0.27	<0.01	0.06	<0.01	0.49	<0.08	0.02	0.79
NMWF - 14B	176	0.38	<0.11	<0.27	<0.01	0.03	<0.01	<0.19	<0.08	<0.01	0.22
NMWF - 14C	51	0.21	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.04
NMWF - 14D	117	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.03
NMWF - 14E	542	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	<0.01
NMWF – 14 total	1231	0.92	<0.11	<0.27	<0.01	0.08	<0.01	0.49	<0.08	<0.01	1.07
NMHF - 2A	2141	0.82	<0.10	<0.26	0.03	<0.02	<0.01	15.98	<0.08	<0.01	0.22
NMHF - 2B	0	0.28	<0.10	<0.26	<0.01	<0.02	<0.01	4.38	<0.08	<0.01	0.04
NMHF - 2C	0	0.18	<0.10	<0.26	<0.01	<0.02	<0.01	2.09	<0.08	<0.01	<0.01
NMHF - 2D	504	<0.15	<0.10	<0.26	<0.01	<0.02	<0.01	1.24	<0.08	<0.01	<0.01
NMHF - 2E	1335	0.41	<0.10	<0.26	<0.01	<0.02	<0.01	1.19	<0.08	<0.01	0.06
NMHF – 2 total	3980	1.70	<0.10	<0.26	0.03	<0.02	<0.01	24.87	<0.08	<0.01	0.31
NMHF - 8A	1978	0.87	<0.11	<0.26	0.11	0.03	<0.01	5.54	<0.08	0.02	0.63
NMHF - 8B	485	0.26	<0.11	<0.26	0.04	<0.02	<0.01	1.56	<0.08	<0.01	0.15
NMHF - 8C	318	0.25	<0.11	<0.26	0.02	<0.02	<0.01	0.55	<0.08	<0.01	0.08
NMHF - 8D	659	0.32	<0.11	<0.26	0.03	<0.02	<0.01	<0.18	<0.08	<0.01	0.07
NMHF - 8E	1675	0.34	<0.11	<0.26	0.04	<0.02	<0.01	0.53	<0.08	<0.01	0.22
NMHF – 8 total	5115	2.04	<0.11	<0.26	0.23	0.03	<0.01	8.18	<0.08	<0.01	1.15

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	TP Conc. (µg/m^3)	Al Conc. (µg/m^3)	Sb Conc. (µg/m^3)	As Conc. (µg/m^3)	Ba Conc. (µg/m^3)	Be Conc. (µg/m^3)	Cd Conc. (µg/m^3)	Ca Conc. (µg/m^3)	Cr Conc. (µg/m^3)	Co Conc. (µg/m^3)	Cu Conc. (µg/m^3)
NMHF - 9A	1511	0.77	<0.11	<0.28	0.02	<0.02	<0.01	2.44	<0.08	<0.01	0.23
NMHF - 9B	448	0.36	<0.11	<0.28	<0.01	<0.02	<0.01	0.44	<0.08	<0.01	0.04
NMHF - 9C	195	0.28	<0.11	<0.28	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	<0.01
NMHF - 9D	253	0.22	<0.11	<0.28	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	<0.01
NMHF - 9E	1135	<0.17	<0.11	<0.28	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	<0.01
NMHF – 9 total	3541	1.64	<0.11	<0.28	0.02	<0.02	<0.01	2.88	<0.08	<0.01	0.27
NMHF - 10A	846	0.72	<0.10	<0.26	0.02	0.19	<0.01	1.29	<0.08	0.04	5.41
NMHF - 10B	287	0.26	<0.10	<0.26	<0.01	0.04	<0.01	<0.18	<0.08	<0.01	1.06
NMHF - 10C	124	0.25	<0.10	<0.26	<0.01	<0.02	<0.01	<0.18	<0.08	<0.01	0.22
NMHF - 10D	458	0.18	<0.10	<0.26	<0.01	<0.02	<0.01	<0.18	<0.08	<0.01	0.28
NMHF - 10E	1343	0.36	<0.10	<0.26	<0.01	<0.02	<0.01	<0.18	<0.08	<0.01	0.16
NMHF – 10 total	3059	1.77	<0.10	<0.26	0.02	0.23	<0.01	1.29	<0.08	<0.01	7.13
NMHF - 12A	837	0.34	<0.11	<0.27	0.01	0.04	<0.01	0.50	<0.08	<0.01	1.30
NMHF - 12B	256	0.20	<0.11	<0.27	<0.01	<0.02	<0.01	0.50	<0.08	<0.01	0.40
NMHF - 12C	106	0.26	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.08
NMHF - 12D	287	<0.16	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.08
NMHF - 12E	1109	0.20	<0.11	<0.27	<0.01	<0.02	<0.01	<0.19	<0.08	<0.01	0.07
NMHF – 12 total	2594	1.01	<0.11	<0.27	0.01	0.04	<0.01	1.01	<0.08	<0.01	1.93

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Fe Conc. (µg/m^3)	La Conc. (µg/m^3)	Pb Conc. (µg/m^3)	Li Conc. (µg/m^3)	Mg Conc. (µg/m^3)	Mn Conc. (µg/m^3)	Mo Conc. (µg/m^3)	Ni Conc. (µg/m^3)	P Conc. (µg/m^3)	K Conc. (µg/m^3)	Se Conc. (µg/m^3)
NMWF - 5A	1.63	0.02	<0.05	<0.01	1.12	<0.03	<0.05	<0.05	<0.51	0.26	<0.51
NMWF - 5B	0.56	<0.01	<0.05	<0.01	0.36	<0.03	<0.05	<0.05	<0.51	<0.10	<0.51
NMWF - 5C	<0.26	<0.01	<0.05	<0.01	0.15	<0.03	<0.05	<0.05	<0.51	<0.10	<0.51
NMWF - 5D	0.33	<0.01	<0.05	<0.01	0.16	<0.03	<0.05	<0.05	<0.51	<0.10	<0.51
NMWF - 5E	0.28	<0.01	<0.05	<0.01	0.09	<0.03	<0.05	<0.05	<0.51	0.56	<0.51
NMWF – 5 total	2.81	0.02	<0.05	<0.01	1.88	<0.03	<0.05	<0.05	<0.51	0.82	<0.51
NMWF - 6A	3.58	<0.01	<0.06	<0.01	2.04	0.03	<0.06	<0.06	<0.55	0.39	<0.55
NMWF - 6B	1.41	<0.01	0.07	<0.01	0.80	<0.03	<0.06	<0.06	<0.55	0.16	<0.55
NMWF - 6C	0.91	<0.01	<0.06	<0.01	0.47	<0.03	<0.06	<0.06	<0.55	<0.11	<0.55
NMWF - 6D	0.99	<0.01	<0.06	<0.01	0.41	<0.03	<0.06	<0.06	<0.55	<0.11	<0.55
NMWF - 6E	2.76	<0.01	0.07	<0.01	1.24	0.05	<0.06	<0.06	<0.55	0.63	<0.55
NMWF – 6 total	9.64	<0.01	0.14	<0.01	4.96	0.08	<0.06	<0.06	<0.55	1.18	<0.55
NMWF - 7A	3.59	<0.01	<0.06	<0.01	1.60	0.03	<0.06	<0.06	<0.55	2.01	<0.55
NMWF - 7B	0.88	<0.01	<0.06	<0.01	0.28	<0.03	<0.06	<0.06	<0.55	0.28	<0.55
NMWF - 7C	0.61	<0.01	<0.06	<0.01	0.23	<0.03	<0.06	<0.06	<0.55	0.24	<0.55
NMWF - 7D	1.10	<0.01	<0.06	<0.01	0.20	0.04	<0.06	<0.06	<0.55	0.47	<0.55
NMWF - 7E	0.97	<0.01	<0.06	<0.01	0.26	0.04	<0.06	<0.06	<0.55	1.32	<0.55
NMWF – 7 total	7.14	<0.01	<0.06	<0.01	2.56	0.11	<0.06	<0.06	<0.55	4.32	<0.55
NMWF - 8A	1.83	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	0.47	<0.55
NMWF - 8B	0.96	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	0.15	<0.55
NMWF - 8C	0.41	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	<0.11	<0.55
NMWF - 8D	<0.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	<0.11	<0.55
NMWF - 8E	<0.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	0.44	<0.55
NMWF – 8 total	3.20	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	1.06	<0.55

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Fe Conc. (µg/m³)	La Conc. (µg/m³)	Pb Conc. (µg/m³)	Li Conc. (µg/m³)	Mg Conc. (µg/m³)	Mn Conc. (µg/m³)	Mo Conc. (µg/m³)	Ni Conc. (µg/m³)	P Conc. (µg/m³)	K Conc. (µg/m³)	Se Conc. (µg/m³)
NMWF - 12A	25.90	<0.01	<0.06	<0.01	0.30	0.16	0.06	<0.06	0.63	0.17	<0.55
NMWF - 12B	7.44	<0.01	<0.06	<0.01	<0.08	0.04	<0.06	<0.06	<0.55	<0.11	<0.55
NMWF - 12C	2.45	<0.01	<0.06	<0.01	<0.08	<0.03	<0.06	<0.06	<0.55	<0.11	<0.55
NMWF - 12D	1.79	<0.01	<0.06	<0.01	<0.08	0.05	<0.06	<0.06	<0.55	<0.11	<0.55
NMWF - 12E	2.15	<0.01	<0.06	<0.01	<0.08	0.05	<0.06	<0.06	<0.55	0.50	<0.55
NMWF – 12 total	39.75	<0.01	<0.06	<0.01	0.30	0.30	0.12	<0.06	0.63	0.66	<0.55
NMWF - 14A	3.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	0.07	<0.55	0.18	<0.55
NMWF - 14B	0.93	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	<0.11	<0.55
NMWF - 14C	<0.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.55	<0.11	<0.55
NMWF - 14D	<0.27	<0.01	0.08	<0.01	<0.08	<0.03	<0.05	<0.05	0.74	<0.11	<0.55
NMWF - 14E	<0.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	0.41	<0.11	<0.55
NMWF – 14 total	4.20	<0.01	0.08	<0.01	<0.08	<0.03	<0.05	0.07	1.15	0.18	<0.55
NMHF - 2A	1.55	<0.01	<0.05	<0.01	0.62	<0.03	<0.05	<0.05	<0.52	0.21	<0.52
NMHF - 2B	<0.26	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	<0.10	<0.52
NMHF - 2C	<0.26	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	<0.10	<0.52
NMHF - 2D	<0.26	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	<0.10	<0.52
NMHF - 2E	<0.26	<0.01	0.07	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	0.59	<0.52
NMHF – 2 total	1.55	<0.01	0.07	<0.01	0.62	<0.03	<0.05	<0.05	<0.52	0.80	<0.52
NMHF - 8A	2.45	<0.01	<0.05	<0.01	0.53	<0.03	<0.05	<0.05	0.53	0.24	<0.53
NMHF - 8B	0.61	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	<0.11	<0.53
NMHF - 8C	<0.26	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	<0.11	<0.53
NMHF - 8D	<0.26	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	0.23	<0.53
NMHF - 8E	0.40	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	1.06	<0.53
NMHF – 8 total	3.46	<0.01	<0.05	<0.01	0.53	<0.03	<0.05	<0.05	0.53	1.52	<0.53

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Fe Conc. (µg/m³)	La Conc. (µg/m³)	Pb Conc. (µg/m³)	Li Conc. (µg/m³)	Mg Conc. (µg/m³)	Mn Conc. (µg/m³)	Mo Conc. (µg/m³)	Ni Conc. (µg/m³)	P Conc. (µg/m³)	K Conc. (µg/m³)	Se Conc. (µg/m³)
NMHF - 9A	49.81	<0.01	0.07	<0.01	0.12	0.47	<0.06	<0.06	<0.55	0.18	<0.55
NMHF - 9B	13.56	<0.01	0.07	<0.01	<0.08	0.12	<0.06	<0.06	<0.55	<0.11	<0.55
NMHF - 9C	6.64	<0.01	0.06	<0.01	<0.08	0.05	<0.06	<0.06	<0.55	<0.11	<0.55
NMHF - 9D	3.32	<0.01	<0.06	<0.01	<0.08	<0.03	<0.06	<0.06	0.64	<0.11	<0.55
NMHF - 9E	0.28	<0.01	<0.06	<0.01	<0.08	<0.03	<0.06	0.13	0.66	<0.11	<0.55
NMHF – 9 total	73.33	<0.01	0.19	<0.01	0.12	0.64	<0.06	0.13	1.30	0.18	<0.55
NMHF - 10A	2.45	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	0.22	<0.52
NMHF - 10B	0.31	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	<0.10	<0.52
NMHF - 10C	<0.26	<0.01	0.05	<0.01	<0.08	<0.03	<0.05	<0.05	0.59	<0.10	<0.52
NMHF - 10D	<0.26	<0.01	0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.52	<0.10	<0.52
NMHF - 10E	<0.26	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	0.75	<0.10	<0.52
NMHF – 10 total	2.76	<0.01	0.11	<0.01	<0.08	<0.03	<0.05	<0.05	1.34	0.22	<0.52
NMHF - 12A	2.65	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	0.58	<0.53
NMHF - 12B	1.30	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	0.19	<0.53
NMHF - 12C	<0.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	<0.11	<0.53
NMHF - 12D	<0.27	<0.01	0.06	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	<0.11	<0.53
NMHF - 12E	<0.27	<0.01	<0.05	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	0.53	<0.53
NMHF – 12 total	3.95	<0.01	0.06	<0.01	<0.08	<0.03	<0.05	<0.05	<0.53	1.30	<0.53

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Ag Conc. (µg/m³)	Sr Conc. (µg/m³)	Te Conc. (µg/m³)	Tl Conc. (µg/m³)	Sn Conc. (µg/m³)	Ti Conc. (µg/m³)	V Conc. (µg/m³)	Y Conc. (µg/m³)	Zn Conc. (µg/m³)	Zr Conc. (µg/m³)
NMWF - 5A	<0.01	0.04	<0.08	<0.18	<0.13	0.02	<0.01	<0.01	0.09	<0.13
NMWF - 5B	<0.01	0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	0.03	<0.13
NMWF - 5C	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMWF - 5D	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	0.13	<0.13
NMWF - 5E	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	0.26	<0.13
NMWF – 5 total	<0.01	0.05	<0.08	<0.18	<0.13	0.02	<0.01	<0.01	0.51	<0.13
NMWF - 6A	<0.01	0.05	<0.08	<0.19	<0.14	0.03	<0.01	<0.01	0.17	<0.14
NMWF - 6B	<0.01	0.02	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	0.06	<0.14
NMWF - 6C	<0.01	0.01	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	0.04	<0.14
NMWF - 6D	<0.01	0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.16	<0.14
NMWF - 6E	<0.01	0.04	<0.08	<0.19	<0.14	0.02	<0.01	<0.01	0.52	<0.14
NMWF – 6 total	<0.01	0.13	<0.08	<0.19	<0.14	0.06	<0.01	<0.01	0.96	<0.14
NMWF - 7A	<0.01	0.06	<0.08	<0.19	<0.14	0.03	<0.01	<0.01	0.09	<0.14
NMWF - 7B	<0.01	0.01	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 7C	<0.01	0.01	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	0.03	<0.14
NMWF - 7D	<0.01	0.01	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	0.16	<0.14
NMWF - 7E	<0.01	0.01	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	0.30	<0.14
NMWF – 7 total	<0.01	0.10	<0.08	<0.19	<0.14	0.06	<0.01	<0.01	0.59	<0.14
NMWF - 8A	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.03	<0.14
NMWF - 8B	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.05	<0.14
NMWF - 8C	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.04	<0.14
NMWF - 8D	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 8E	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF – 8 total	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.12	<0.14

Appendix C - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Ag Conc. (µg/m^3)	Sr Conc. (µg/m^3)	Te Conc. (µg/m^3)	Tl Conc. (µg/m^3)	Sn Conc. (µg/m^3)	Ti Conc. (µg/m^3)	V Conc. (µg/m^3)	Y Conc. (µg/m^3)	Zn Conc. (µg/m^3)	Zr Conc. (µg/m^3)
NMWF - 12A	<0.01	0.01	<0.08	<0.19	<0.14	0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 12B	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 12C	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 12D	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 12E	<0.01	<0.01	<0.08	<0.19	0.15	<0.01	<0.01	<0.01	0.30	<0.14
NMWF – 12 total	<0.01	0.01	<0.08	<0.19	0.15	0.01	<0.01	<0.01	0.30	<0.14
NMWF - 14A	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 14B	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 14C	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 14D	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMWF - 14E	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.22	<0.14
NMWF – 14 total	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.22	<0.14
NMHF - 2A	<0.01	0.03	<0.08	<0.18	<0.13	0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 2B	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 2C	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 2D	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 2E	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF – 2 total	<0.01	0.03	<0.08	<0.18	<0.13	0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 8A	<0.01	0.01	<0.08	<0.18	<0.13	0.02	<0.01	<0.01	<0.03	<0.13
NMHF - 8B	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 8C	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 8D	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 8E	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF – 8 total	<0.01	0.01	<0.08	<0.18	<0.13	0.02	<0.01	<0.01	<0.03	<0.13

Appendix C - *Continued*

Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry

Sioutas Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Ag Conc. (μg/m³)	Sr Conc. (μg/m³)	Te Conc. (μg/m³)	Tl Conc. (μg/m³)	Sn Conc. (μg/m³)	Ti Conc. (μg/m³)	V Conc. (μg/m³)	Y Conc. (μg/m³)	Zn Conc. (μg/m³)	Zr Conc. (μg/m³)
NMHF - 9A	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.14	<0.14
NMHF - 9B	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMHF - 9C	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMHF - 9D	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMHF - 9E	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	<0.03	<0.14
NMHF – 9 total	<0.01	<0.01	<0.08	<0.19	<0.14	<0.01	<0.01	<0.01	0.14	<0.14
NMHF - 10A	<0.01	<0.01	<0.08	<0.18	<0.13	0.02	<0.01	<0.01	0.03	<0.13
NMHF - 10B	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 10C	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 10D	<0.01	<0.01	<0.08	<0.18	0.15	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 10E	<0.01	<0.01	<0.08	<0.18	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF – 10 total	<0.01	<0.01	<0.08	<0.18	0.15	0.02	<0.01	<0.01	0.03	<0.13
NMHF - 12A	<0.01	<0.01	<0.08	<0.19	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 12B	<0.01	<0.01	<0.08	<0.19	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 12C	<0.01	<0.01	<0.08	<0.19	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 12D	<0.01	<0.01	<0.08	<0.19	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF - 12E	<0.01	<0.01	<0.08	<0.19	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13
NMHF – 12 total	<0.01	<0.01	<0.08	<0.19	<0.13	<0.01	<0.01	<0.01	<0.03	<0.13

Appendix D
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
MOUDI Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Particulate Conc. (mg/m^3)	Al Conc. (µg/m^3)	Sb Conc. (µg/m^3)	As Conc. (µg/m^3)	Ba Conc. (µg/m^3)	Be Conc. (µg/m^3)	Cd Conc. (µg/m^3)	Ca Conc. (µg/m^3)	Cr Conc. (µg/m^3)	Co Conc. (µg/m^3)	Cu Conc. (µg/m^3)
A7-0	0.074	0.14	<0.02	<0.04	<0.01	<0.004	<0.04	0.99	<0.01	<0.01	0.06
A7-1	0.066	0.15	<0.02	<0.04	<0.01	<0.004	<0.04	1.18	<0.01	<0.01	0.03
A7-2	0.047	0.17	<0.02	<0.04	<0.01	<0.004	<0.04	1.73	<0.01	<0.01	0.04
A7-3	0.035	0.10	<0.02	<0.04	<0.01	<0.004	<0.04	1.22	<0.01	<0.01	0.02
A7-4	0.044	0.07	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	0.01
A7-5	0.023	0.05	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	0.01
A7-6	0.001	<0.04	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	<0.01
A7-7	<0.001	0.06	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	<0.01
A7-8	0.015	0.13	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	<0.01
A7-9	0.019	<0.04	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	<0.01
A7-10	0.015	<0.04	<0.02	<0.04	<0.01	<0.004	<0.04	<0.79	<0.01	<0.01	<0.01
A7-Final	0.005	<0.04	<0.01	<0.03	<0.003	<0.002	<0.003	<0.12	<0.01	<0.003	0.01
A7-Total	0.342	0.87	<0.02	<0.04	<0.01	<0.004	<0.04	5.12	<0.01	<0.01	0.18
B6-0	0.007	0.05	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.03
B6-1	0.004	0.04	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.01
B6-2	0.005	0.08	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	<0.01
B6-3	0.004	0.08	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.02
B6-4	0.003	0.20	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.02
B6-5	0.004	0.05	0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	<0.01
B6-6	0.005	0.08	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.01
B6-7	0.008	<0.04	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	<0.01
B6-8	0.008	0.04	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.01
B6-9	0.004	0.05	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.02
B6-10	0.016	0.06	<0.02	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	<0.01
B6-Final	0.006	<0.04	<0.01	<0.03	<0.003	<0.002	<0.003	<0.12	<0.01	<0.003	0.01
B6-Total	0.074	0.75	0.021	<0.04	<0.01	<0.004	<0.04	<0.80	<0.01	<0.01	0.12

Appendix D - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
MOUDI Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Fe Conc. (µg/m³)	La Conc. (µg/m³)	Pb Conc. (µg/m³)	Li Conc. (µg/m³)	Mg Conc. (µg/m³)	Mn Conc. (µg/m³)	Mo Conc. (µg/m³)	Ni Conc. (µg/m³)	P Conc. (µg/m³)	K Conc. (µg/m³)	Se Conc. (µg/m³)
A7-0	0.24	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-1	0.17	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-2	0.26	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-3	0.13	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-4	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-5	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-6	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	0.08	<0.16
A7-7	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-8	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-9	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-10	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
A7-Final	0.09	<0.003	<0.01	<0.01	<0.03	<0.01	<0.01	<0.01	<0.08	<0.04	<0.03
A7-Total	127	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	0.08	<0.16
B6-0	1.00	<0.004	<0.02	<0.01	<0.24	0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-1	0.48	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-2	0.26	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-3	0.34	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-4	0.22	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-5	0.22	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-6	0.22	<0.004	<0.02	<0.01	<0.24	0.02	<0.01	<0.02	<0.32	<0.08	<0.16
B6-7	0.14	<0.004	<0.02	<0.01	<0.24	0.02	<0.01	<0.02	<0.32	<0.08	<0.16
B6-8	0.25	<0.004	<0.02	<0.01	<0.24	0.04	<0.01	<0.02	<0.32	<0.08	<0.16
B6-9	0.27	<0.004	<0.02	<0.01	<0.24	0.02	<0.01	<0.02	<0.32	<0.08	<0.16
B6-10	<0.12	<0.004	<0.02	<0.01	<0.24	<0.01	<0.01	<0.02	<0.32	<0.08	<0.16
B6-Final	0.07	<0.003	<0.01	<0.01	<0.03	<0.01	<0.01	<0.01	<0.08	<0.04	0.04
B6-Total	714	<0.004	<0.02	<0.01	<0.24	0.10	<0.01	<0.02	<0.32	<0.08	0.04

Appendix D - *Continued*
Facility #3 – Copper/Beryllium and Aluminum Beryllium Foundry
MOUDI Impactor Sample Results for Total Particulate (TP) and Thirty-one Elements

Sample Number	Ag Conc. (µg/m^3)	Sr Conc. (µg/m^3)	Te Conc. (µg/m^3)	Tl Conc. (µg/m^3)	Sn Conc. (µg/m^3)	Ti Conc. (µg/m^3)	V Conc. (µg/m^3)	Y Conc. (µg/m^3)	Zn Conc. (µg/m^3)	Zr Conc. (µg/m^3)
A7-0	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-1	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-2	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-3	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-4	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-5	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.02	<0.03
A7-6	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-7	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.03	<0.03
A7-8	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.04	<0.03
A7-9	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.03	<0.03
A7-10	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
A7-Final	<0.002	<0.004	<0.01	<0.02	<0.39	<0.004	<0.004	<0.004	<0.01	<0.03
A7-Total	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.12	<0.03
B6-0	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.016064	<0.03
B6-1	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
B6-2	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
B6-3	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.02	<0.03
B6-4	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.02	<0.03
B6-5	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.03	<0.03
B6-6	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.06	<0.03
B6-7	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.12	<0.03
B6-8	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.23	<0.03
B6-9	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.23	<0.03
B6-10	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	<0.02	<0.03
B6-Final	<0.002	<0.004	<0.01	<0.02	<0.40	<0.004	<0.004	<0.004	<0.01	<0.03
B6-Total	<0.004	<0.01	<0.02	<0.04	<0.32	<0.004	<0.004	<0.004	0.72	<0.03