Spring 2016

EVALUATION OF PARTICULATE METAL AND NOISE EXPOSURES AT A FOUNDRY AND RECOMMENDED CONTROL STRATEGIES

Jeshua Sargetis
Montana Tech of the University of Montana

EVALUATION OF PARTICULATE METAL AND NOISE EXPOSURES AT A FOUNDRY AND RECOMMENDED CONTROL STRATEGIES

by

Jeshua Sargetis

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science in Industrial Hygiene

Montana Tech

2016

Abstract

An evaluation of current industrial hygiene practices were performed at a foundry located in the Northwestern United States. The foundry was evaluated for respirable and inhalable manganese, respirable crystalline silica and noise exposure. Personal breathing zone sampling was performed using proper safety and health practices on workers in the foundry and around the entire facility. Results showed that workers were being exposed to respirable manganese but not inhalable manganese. Bulk crystalline silica sampling was performed and personal breathing zone sampling was performed as a follow up to certain control measures which showed low concentrations. Area noise sampling was conducted in various parts of the facility and personal noise dosimetry was performed on workers in all areas of the facility. Noise exposure above the OSHA PEL was found in a few sites but most of the limits were above the OSHA Hearing Conservation criterion. Few locations were over the NIOSH and ACGIH criterions. Engineering control measures included a ventilation system being installed above the furnaces, for metal fume control, the paving of a back lot to reduce exogenous crystalline silica from the foundry. Hearing protection, along with the inclusion of a revised hearing conservation program, was also implemented for reduced worker exposure.

Keywords: Foundry, Crystalline Silica, Noise, Manganese, Exposure Testing

Dedication

I wish to thank my family for their continual support in pushing me to achieve everything that my heart desires. To a mom and dad who kept pushing me even when I was stressed beyond all belief and felt like quitting. To my neighbor Ann for all your time and effort in revising this document. To friends who made my graduate experience amazing and to someone very special and dear to my heart that keeps me pushing forward for greatness in the sight of adversity. To you all, I thank you from the bottom of my heart.

Acknowledgements

First, I would like to acknowledge Julie Hart, Terry Spear, Xufei Yang for your constant effort in supporting me throughout this project. Your time, talents and dedication have helped shape me into the Industrial Hygienist that I am today.

Second, I would like to thank The National Institute of Occupational Safety and Health (NIOSH), for providing me with the funding to accomplish this project and future endeavors. Your contribution has helped shape my future and my career, thank you.

Third, I would like to thank the foundry in which this testing was performed that allowed me to enter their facility over this past year and get to know them better. Your appreciation and love did not go unnoticed.

Lastly, I would like to thank the Montana Tech Graduate School, especially the Health, Safety and Industrial Hygiene Department, for their constant support and encouragement throughout my graduate career. Your smiling faces, constant inspiration and willingness to listen and laugh will forever be remembered.

Table of Contents

List of Tables

List of Figures

List of Equations

Glossary of Terms

Term	Definition
NIOSH	The National Institute of Occupational Safety and Health
OSHA	The United States Occupational Safety and Health Administration
ACGIH	The American Conference of Governmental Industrial Hygienists
REL	NIOSH's Recommended Exposure Limits
PEL	OSHA's Permissible Exposure Limit
TLV	ACGIH's Threshold Limit Values
OEL	Occupational Exposure Limits
PD	Parkinson's Disease
Neurotoxicity	Toxic substances that attack the Nervous System
Cytotoxicity	Toxic substances that attack cells
PNOR	Particulate not otherwise regulated
TWA	Time-Weighted Average
LOD	Limit of Detection
LOQ	Limit of Quantification
SDS	Safety Data Sheet
NRR	Noise Reduction Rating
Manganism	Chronic manganese exposure that caused poisoning
N95	Basic respirator. Synonymous to "dust masks"
NOAEL	No-Observed-Adverse-Effect-Level
SPL	Sound Pressure Level
Mn	Manganese
PBZ	Personal Breathing Zone
MCE	Mixed Cellulose Ester Filters
IOM	Institute of Occupational Medicine device
XRF	X-Ray Fluorescence Analyzer
FPM	Feet per minute
ICP	Inductively Coupled Plasma
NMAM	NIOSH Manual of Analytical Methods

1. Introduction

For centuries, human kind has found ways to make the most of and expound upon its modern technologies. It has used innovative tools and ideas to form amazing concepts and wonders. One of the greatest and most beneficial human creations is that of metal casting. Starting as early as 3200 B.C., metal was melted, molded, and formed into desired shapes and configurations (History of Metal Casting, n.d.). There are many benefits to configuring metals into various shapes and sizes. Regardless of the era, weapons of war, building materials, or even consumer goods are, were, and will be continuously made for the benefit of human kind. Just about all the metal that is commercially available today has come about as a result of foundries and smelting facilities.

The word foundry comes from the 17th century French word, *fonderie*, which means “to melt or mold” (Oxford Learner's Dictionaries, n.d.). Foundries are facilities that take metals in their raw form and reform them into the various products their buyers’ desire. Throughout the United States, there are hundreds of foundries in operation today. Many foundries mold and produce various types of products and alloys. Foundries are categorized as either ferrous or non-ferrous metal foundries.

Ferrous metals are metals and alloys that contain iron whereas nonferrous metals do not. Ferrous metals include mild steel, carbon steel, stainless steel, and cast iron. Non-ferrous metals include aluminum, brass, copper, nickel, tin, and zinc. Even though each type of foundry produces distinct products, the functional processes are very similar (Alton Materials, 2013).

As shown in Figure 1, metals are typically processed following a specific order in most foundries. The process starts with molding material which can be either sand, metal, or plaster. These molds are sized and shaped into the specifications that the buyer requests for their product. Once a worker or machine forms the mold, that mold is then sent to the casting area where it awaits the metal based compound used to form the final product.

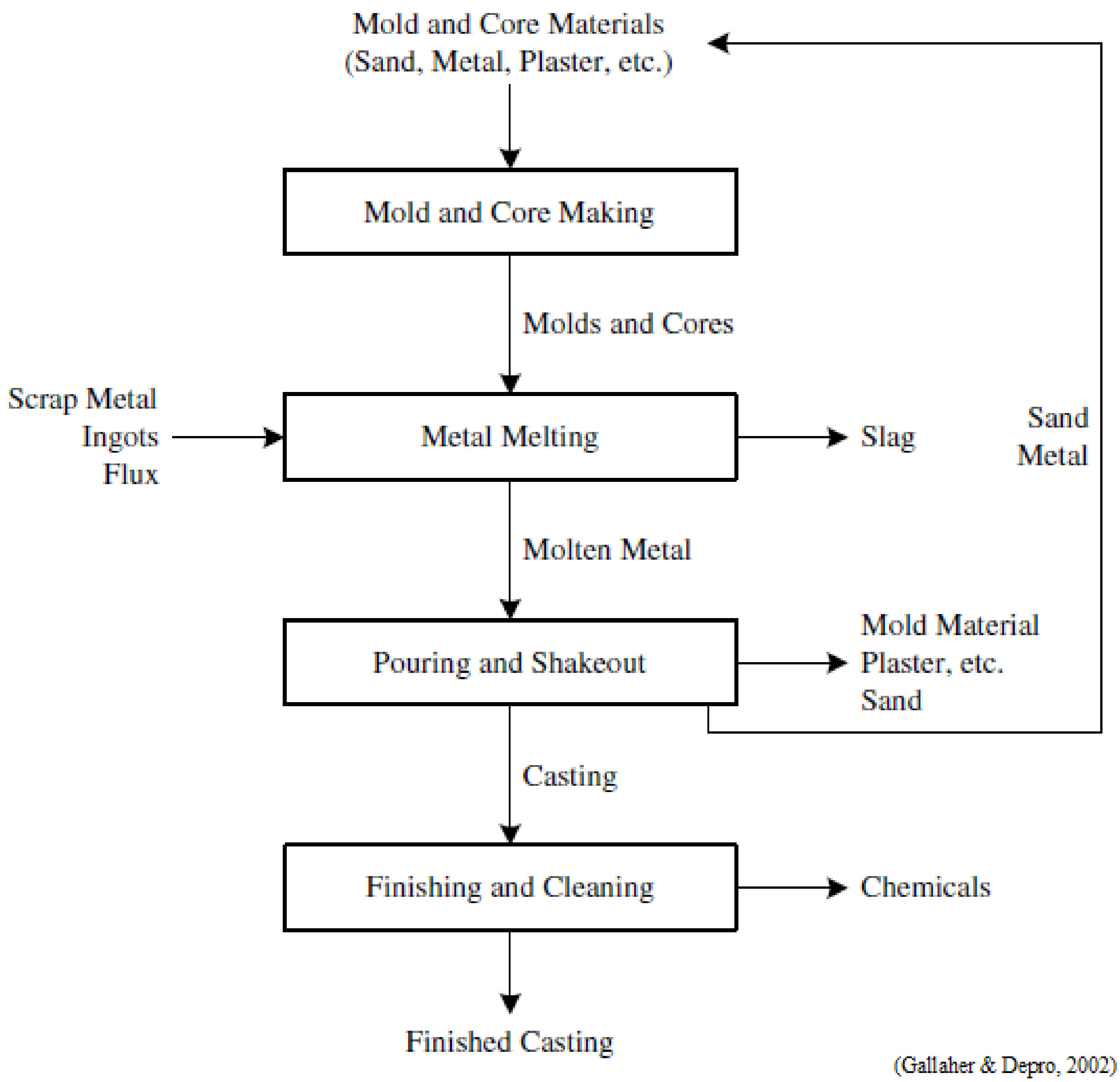


Figure 1. Foundry Process: From Start to Finish

Figure 2 shows the smelting area of the foundry examined in this study. According to D. Herbert, raw ore, scrap metal, and specific metal ores needed for various products are then put into a large smelting pot where temperatures can reach up to 3000+ degrees Fahrenheit. Increasing the temperature of the metals to 3000+ degrees Fahrenheit helps turns the metal compound to a liquid pliable material that can be poured into the molds. (Personal communication, February 9, 2016).

Figure 2: Pouring Work Area

Once the metal has reached a molten state, it is taken from the heating furnaces and transported to an area where a worker pours in an amorphous silicate compound to remove any impurities. Once the impurities are removed from the molten metal, the metal is brought to the pouring area where the compound is poured into the molds. That molten metal is then left to cool from 3-16 hours, depending on the material, until it can be transported safety to the shakeout area.

At the shakeout area, the solid metal object is put in the shakeout machine where the excess molding material separates from the metal product. After the metal is sifted from the molding material, the product is sent to a welder and grinder where it is polished and finalized to ship to the buyer. The complete process takes time and creates many opportunities for workers to be exposed to worksite hazards.

While foundry use is key to the production of many metal and nonmetal based industrial products, special attention should be given to worker health and industrial hygienic practices used to assess those potential workplace hazards. Depending on if the foundry is a ferrous or non-ferrous facility and what specific metal is being poured, a plethora of worker hazards could be present. In 1990, iron and steel accounted for 84% of all metals cast (McKinley, Jefcoat, Herz, & Frederick, 1994). Overexposure to iron can cause problems such as siderosis and lung disease (New Jersey Department of Health and Senior Services, 2007). In addition to metal exposure, other hazards such as noise and crystalline silica exposure could present problems for foundry workers

In any facility where multiple machines are running, workers have the possibility of being overexposed to noise pollution. For example, a foundry contains grinders and welders, arc welding machines, and sand blasting areas. Any one of these areas alone offers a potential noise exposure problem. Combine all of them together in a small facility and there will most likely be a high probability that worker noise exposure is above allowable and permissible limits.

Dust exposure can also present serious hazards to workers, regardless of the industry. According to the National Institute for Occupational Safety and Health (NIOSH), "[a]t least 1.7 million U.S. workers are exposed to respirable crystalline silica in a variety of industries and occupations, including construction, sandblasting, and mining" (NIOSH, 2015). Foundries are not immune to potential overexposure that crystalline silica can bring to a worksite.

In this project, an industrial hygiene assessment was performed in a foundry in the Northwestern United States. This assessment focused on potential metal, noise and crystalline silica exposures. This foundry was started in the late 19th century when copper mining in the general area needed a smelter to take the raw ore and smelt it into a variety of components that were then shipped across the world. Over the past century, the smelter has been sold and rebought out by a couple different companies and/or men. The foundry today includes a foundry area, a machine shop, an expanded fabrication shop and even a construction development group that works close with mines in the general geographical area. The environment in and outside the foundry is very old. Buildings around the production site have been around for more than a century.

Metals, crystalline silica and noise, all provide serious potential problems for the foundry workers. The objective of this research was to assess current industrial hygiene hazards, evaluate control measures associated with an operating foundry, and provide guidance to control these hazards. The primary areas of focus were manganese, crystalline silica, and noise exposures. The assessment included a review of current exposures and a remediation of the company's industrial hygiene control measures throughout the entire facility. Sampling and evaluation results were then used to make recommendations for control strategies. Control strategies included a revision to the respiratory protection and hearing conservation programs, revisions to foundry operations and the addition of a local exhaust ventilation system.

There are 6 hypothesizes have been developed for this thesis. A null hypothesis (H_o) suggests that statistically, there is not a significant difference between the two values. A research hypothesis (H_a) indicates that there is a significant difference between the first sets of hypothesizes. An alpha (α) of 0.05 was used to evaluate the following hypothesizes which are as follows.

- H_{o1} – Respirable manganese samples will be less than or equal to the threshold limit value (TLV) of 0.02mg/m^3
- H_{a1} - Respirable manganese samples will be greater than or equal to the TLV of 0.02mg/m^3
- H_{o2} – Inhalable manganese samples will be less than or equal to the TLV of 0.1mg/m^3
- H_{a2} - Inhalable manganese samples will be greater than or equal to the TLV of 0.1mg/m^3
- H_{o3} – Personal noise dosimetry will be less than or equal to the permissible exposure limit (PEL) of 90dBA

- H_{a3} - Personal noise dosimetry will be greater than or equal to the permissible exposure limit (PEL) of 90dBA
- H_{o4} - Personal noise dosimetry will be less than or equal to the OSHA Hearing Conservation limit of 85dBA
- H_{a4} - Personal noise dosimetry will be greater than or equal to the OSHA Hearing Conservation limit of 85dBA
- H_{o5} – Respirable crystalline silica samples will be less than or equal to the current calculated PEL
- H_{a5} - Respirable crystalline silica samples will be greater than or equal to the current calculated PEL
- H_{o6} - Respirable crystalline silica samples will be less than or equal to the purposed PEL of 0.05mg/m^3
- H_{a6} - Respirable crystalline silica samples will be greater than or equal to the purposed PEL 0.05mg/m^3

2. Background: Occupational Hazards of Concern

2.1. Particulate Matter

Particulate matter has the potential to enter into various parts of the respiratory tract and have a toxic affect. Many studies model particulate matter deposition in the human respiratory tract. The efficiency of particulates entering a specific region of the respiratory tract is determined by the aerodynamic diameter of the particles. According to the Environmental Protection Agency (EPA), the aerodynamic diameter of a particulate is defined as “The diameter of a sphere with unit density that has aerodynamic behavior identical to that of the particle” (Environmental Protection Agency, 2011). The aerodynamic diameter plays a role in the cut point of a particulate. The term 50% cut point is used to describe the performance of cyclones and other particulate size selective devices. The 50% cut point is the size of dust that the device collects with 50% efficiency. Particulates can be deposited into one of three regions in the respiratory tract: the inhalable, thoracic, or respirable regions.

New workplace exposure guidelines adopted by several international agencies define three particulate mass fractions; inhalable, thoracic, and respirable mass fractions. The inhalable fraction describes particulates that are hazardous when deposited anywhere in the respiratory tree including the nose and mouth, and has a 50% cut point of 100μm and includes larger and smaller diameter particles. The thoracic fraction is defined as those particulates that are hazardous when deposited anywhere within the lung airways and the gas-exchange region and has a 50% cut point of 10μm. The respirable fraction includes particulates that reach the alveolar region of the lung and has a cut point of 4μm. Figure 3 provides a visual image of the information presented here and Figure 4 provides a view of particulate mass fractions and deposition curves for further information.

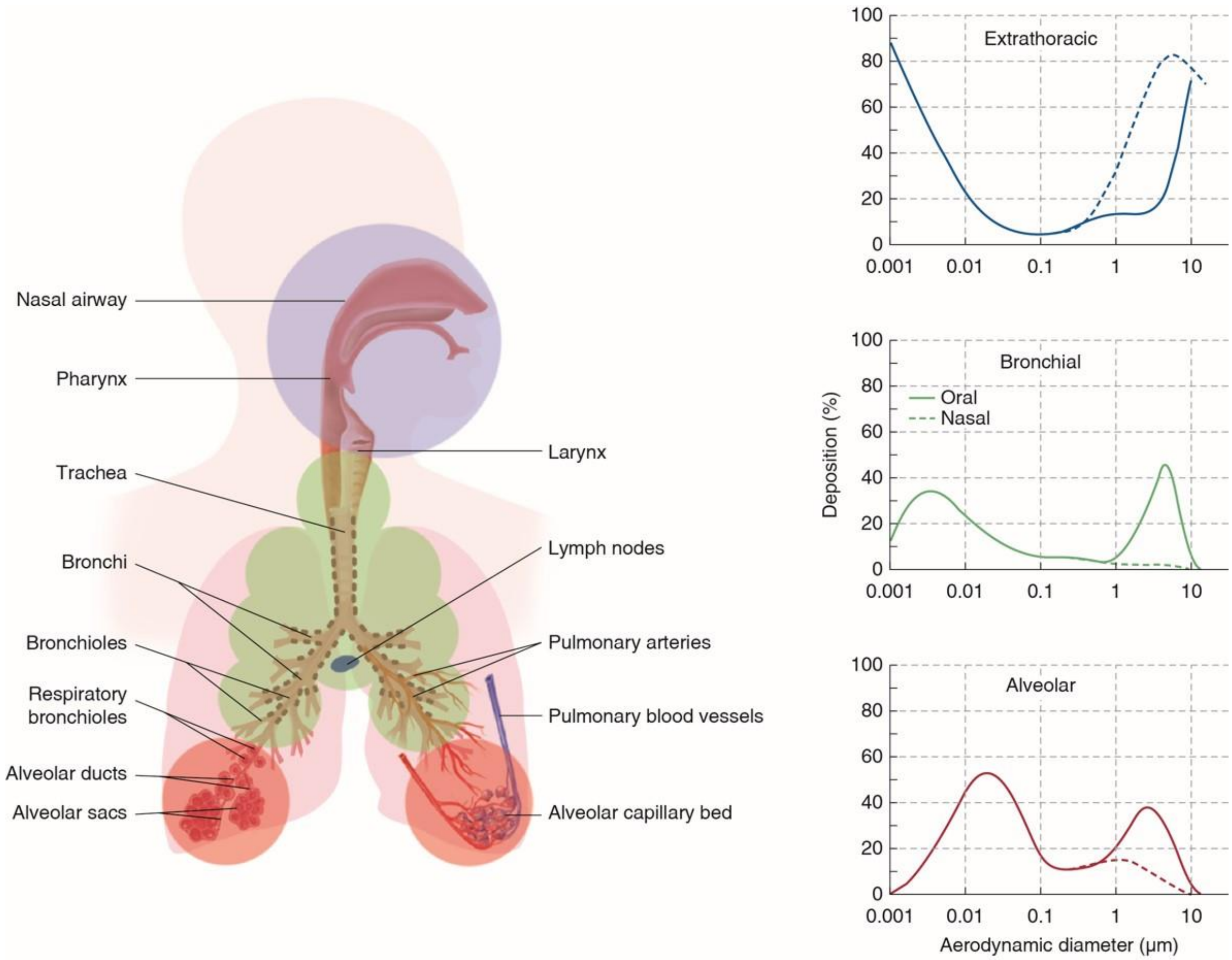
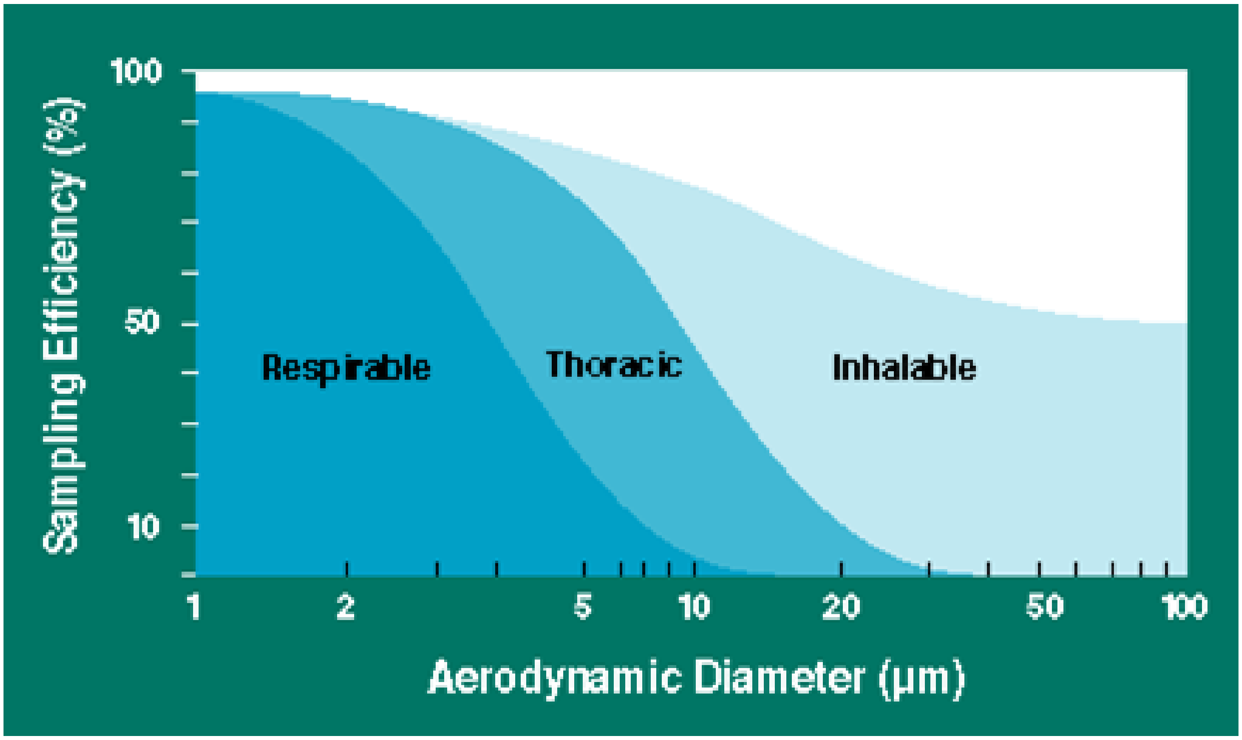


Figure 15-1. *Major regions of the respiratory tract and predicted fractional deposition of inhaled particles in the extrathoracic, bronchial, and alveolar region of the human respiratory tract during (solid line) oral or (dashed) nasal breathing.* (Adapted from Fig. 8 in Oberdörster *et al.* (2005) with drawing courtesy of J. Harkema and data from ICRP [1994].)

(Klaassen, 2013)

Figure 3: Inhalable, Thoracic and Respirable Respiratory Systems



(Robinson, 2012)

Figure 4: Particulate Mass Fractions and Deposition Curves

2.2. Manganese

Manganese (Mn) is one of the most basic atomic elements that can be found naturally throughout the world. It has the atomic number of 25 and is usually found in a solid form. While manganese byproducts were found in prehistoric cave drawings, two chemists are given the credit for first isolating the metal, Ignatius Kaim and Johan Gottlieb Gahn (Royal Society of Chemistry, 2016).

Manganese has numerous beneficial properties and is found in many industrial-based goods today. Small percentages of manganese can be found in aluminum drinking cans to improve resistance to corrosion. It can also be used as a rubber additive and can be found in steel components to increase their strength and workability (Royal Society of Chemistry, 2016). In 1816, scientists realized that adding manganese to iron produced a harder alloy without creating a more brittle metal (Manganese, 2015). Manganese, at the facility tested, has been used in alloys to provide more durable metals for their buyers. The benefits of manganese can be found in a variety of common and work related objects. It is not until manganese can either be inhaled or ingested that acute and chronic toxicological side effects occur.

2.2.1. Toxicology - Manganese

Manganese is an essential nutrient for metabolic and cellular functions. Human beings ingest daily normal levels of manganese through vegetables, grains and fruits. Daily intake levels can range from 2.0-9.0mg. Adequate intake for men is about 2.3mg/day and for women, about 1.8mg/day (Klaassen, 2013). Manganese is needed for neurologic homeostasis but in excess concentrations, it can cause toxicity. If manganese enters the body in normal, stable amounts, the liver and kidneys can remove a reasonable excess amount from the body.

There are a variety of areas in which workers can inhale or be exposed to manganese. Some of those include mines, smelters, and foundries, such as the one studied in this research. Some facilities that produce electrical coils, batteries, glass, manganese steel alloys and other manganese based products, may also cause a worker to be overexposed (Klaassen, 2013).

In the body, especially when ingested orally, manganese and iron seem to have similar interactions. Both “compete for the same binding protein in serum (transferrin) and the same transport systems (DMT1).” Manganese seems to concentrate itself in mitochondria so organs such as the pancreas, liver, kidneys, and intestines appear to have the highest concentrations of manganese in the body. Many studies have shown that manganese can easily cross the blood-brain barrier and can accumulate in specific cerebral regions. Manganese is also removed in the bile and then brought into the intestines where it is reabsorbed. The main route for excretion from the body is through feces (Klaassen, 2013).

Some possible effects of overexposure to manganese can include damage to the lungs, kidney, and Central Nervous System (CNS); fertility problems in men; and neurological and neurobehavioral issues (Center for Disease Control and Prevention, 2015).

The organ that seems to be most affected by manganese exposure is the brain. Manganese-induced neurotoxicity, manganism, affects the release of dopamine to receptive neurons. Workers who are at risk to manganism are those who are exposed to aerosols containing high amounts of manganese ranging from 0.1mg/m^3 to 5.0mg/m^3. Manganism also occurs with manganese contaminated water which has a particulate count anywhere between 1.8-14.0 ppm. Manganism is focused in the areas of the brain where high brain activity usually occurs (Klaassen, 2013).

As workers are exposed to manganese, acute and chronic effects begin to occur. Primary indicators of manganism include headaches, insomnia, memory loss, muscle cramps, and emotional instability. Continued, neurotoxic exposure to manganese may lead to decreased muscle movement, hand tremors, and speech disturbances. These manifestations are due to the impaired neurons associated with muscle movement (Klaassen, 2013).

Excess amounts of manganese in the brain can induce Parkinson's-like symptoms by producing cognitive, psychiatric, and movement irregularities within the body. Parkinson's disease (PD) is a neurological disorder that disrupts the basic motor functions of an individual. There are four main symptoms associated with PD: tremors while resting, bradykinesia, rigidity, and postural instability (Guilarte, 2010). Over time, more profound effects tend to disturb basic motor capabilities such as talking or walking. Currently, there is no cure for PD. Some medications help replenish the brain's lack of dopamine but no cure has currently been universally accepted (National Institute of Neurological Disorders and Stroke, 2016).

According to Guilarte (2010) while manganese can produce Parkinson's like effects in the brain, manganese does not directly cause PD. Guilarte (2010) found that while manganese can accumulate within the brain, it does not lead to the degradation of dopaminergic neurons in the brain. The study stated that the problem is not necessarily associated with the decreased synthesis or concentration of dopamine in presynaptic terminals, but a problem of releasing the available dopamine to the terminals (Guilarte, 2010).

In a study performed on manganese induced cytotoxicity, correlations were made between Parkinson's disease and manganism. Similarly, they both produce symptoms of gait imbalance, rigidity, tremors and bradykinesia. A big difference between the two is that manganism produces dystonia whereas Parkinson's does not. Manganese neurotoxicity can involve an imbalance of dopaminergic neurotransmissions which could result in dopamine-mediated cell death. Manganese does decrease antioxidants and could elevate reactive oxygen species (ROS) formation and decrease the total antioxidant levels in favor of cellular toxicity (Stredrick, et al., 2004). Even though differences exist between both PD and manganism, manganese does impede basic motor skills.

As previously mentioned, this article by Stredrick (2004) further explains possible effects that manganese can have on dopamine (DA) producing cells. Some of the proposed mechanisms of manganese toxicity are through dopamine levels. The study researched the effect that DA levels would have on catecholaminergic (CATH.a) and human neuroblastoma SK-N-SH cells. In general, manganese was significantly more toxic to catecholaminergic cells than to the neuroblastoma cells. Tests were performed comparing glutathione (GHS) and N-acetyl cysteine (NAC) levels, glutathione levels, internucleosomal fragmentation, and apoptosis.

It is possible that manganese can be considered to have some type of hormetic effect on the body. Protection from cell death was observed on cells treated with antioxidants NAC and GSH. ROS formation may provide a role in manganese neurotoxicity in CATH.a cells (Stredrick, et al., 2004).

Another organ in the body that is affected by manganese is the lungs. As manganese containing dust enters the lungs, an inflammatory response begins to occur. Lung irritation, cough, bronchitis, and pneumonitis can all develop as a result of manganese dust exposure. Men found to work in plants where high concentrations of manganese dust are present have been shown to be 30 times more susceptible to respiratory disease than those who are not affected (Klaassen, 2013).

Overall, manganese affects the brain, lungs, and kidney in different ways. Elevated levels, outside those normally needed for dietary intake, can produce severe and drastic side effects that can chronically last for the rest of one's life.

2.2.2. Occupational Exposure Limits – Manganese

While manganese exposure can present potential harm to a worker, limits have been set to help reduce the overall worker exposure. For the United States Occupational Safety and Health Administration (OSHA), the PEL is 5.0mg/m^3 (Permissible Exposure Limits - Annotated Table, n.d.). For the NIOSH, the recommended exposure limit (REL) is 1.0 mg/m^3 (Center for Disease Control and Prevention, 2015). For the American Conference of Governmental Industrial Hygienists (ACGIH), the TLV are 0.02mg/m^3 for respirable size fractions and 0.1mg/m^3 for inhalable size fractions. While OSHA's PELs are a regulatory standard and citable by law, ACGIH's TLVs are what is considered best practice for industrial hygienists to follow today.

2.3. Crystalline Silica

Silica (SiO_2), or silicon dioxide, is derived from the element silicon with the addition of two oxygen atoms. Silica makes up about 26% of the earth's crust and is found in most minerals, rocks, sand, and clay. Some of the most natural forms of silica that are present throughout the world which include quartz and talc. Silica can also be found in man-made products such as computer chips, glass products, and ceramics (Martin, 2007).

Besides industrial uses for silica, it has also been found in food additives, vitamins, and drugs. The dietary intake for most Western populations is between 20-50mg Si/day (Jugdaohsingh, 2007). Silicon is naturally found in beverages but most especially in water. Depending on the water source and mode of delivery, silica concentrations can be between 1.0-100mg/L. Beverages contain 55% of dietary silica intake while grain based products provide around 14% and vegetables can add about 8% (Martin, 2007). In one way or another, silica is present in many of the products used by human beings on a daily basis. Complete elimination of exposure to silica would be nearly impossible and impractical.

In nature, silica presents itself into two forms: crystalline silica and non-crystalline structured silica. Crystalline silica has three forms: quartz, cristobalite, and tridymite. Non-crystalline silica is sub-classified as amorphous, diatomaceous earth, fumed silica and silica gel. The toxicities of crystalline and non-crystalline silica are quite different from one another (American Industrial Hygiene Association, 2011).

According to OSHA, nearly two million US workers are being overexposed to crystalline silica daily. More than 100,000 of those two million workers are working in high risk jobs such as abrasive blasting, foundry work, stonecutting, rock drilling, quarry, and tunneling work.

Due to the number of workers continually being exposed to crystalline silica, OSHA has provided guidelines for what employers and employees can do to help prevent or lessen their exposure. As per the Industrial Hygiene Hierarchy of Controls, a possible engineering control would include a local exhaust ventilation system, substitution of any crystalline silica substance, and the wetting of silica based products. For administrative controls, reduced worker shifts and training on crystalline silica exposure are recommended. For personal protective equipment, NIOSH recommends that a minimum of a N95 NIOSH approved respirator, with tight seals, be used. It is always recommended to have workers constantly aware of potential exposure while on the worksite.

2.3.1. Toxicology – Crystalline Silica

The most common route of exposure to crystalline silica is through inhaling particulate matter. As fine respirable particulates of silica enter into the lungs, can deposit into the furthest region of the alveoli, or the respirable region. Once the particulate is caught in the mucosa, macrophages remove the foreign substances from the alveolar sacs. Because of the shape and size of the silica particulate, the macrophages do not fully break down the silica particulate and inflammation occurs. Over time, more alveolar sacs are congested with dead macrophages and the silica particulate produces fibrosis within the lung. Once fibrosis occurs, the lung loses its ability to fully retract after air is inhaled. The alveoli are obstructed from up taking or releasing oxygen and carbon dioxide to and from the blood stream. Once all of this occurs, the person is left with an incurable disease known as silicosis.

Silicosis is described as chronic inflammation and scarring in the upper lobes of the lung. The inflammation has been described and scarring occurs over long periods of exposure throughout the worker’s time of employment (Pollard, 2016). What makes silicosis extremely dangerous is the fact that there are no current procedures available to remove the silica from the alveoli.

Silicosis can be broken down into three different categories, as described by OSHA: chronic/classic silicosis, accelerated silicosis, and acute silicosis. Chronic silicosis is most common and usually starts presenting symptoms 15-20 years after the worker has been exposed to lower respirable silica levels. Accelerated silicosis can start occurring after 5-10 years due to high levels of silica exposure. Acute silicosis exposure can start presenting symptoms as early as a few months to a few years of extremely high exposure. Each stage presents more severe symptoms than the previous but the most common symptoms includes shortness of breath, fatigue, chest pain, weakness, and weight loss.

Many studies have been performed on the potential carcinogenic characteristics that silica may pose for an overexposed worker’s lungs. According to the International Agency for Research on Cancer (IARC) in 1997, crystalline silica had become classified as a class 1 carcinogen. This means that there is sufficient evidence in both human and animal subjects to show that crystalline silica is a carcinogenic substance.

While silica itself is a potentially hazardous substance, when combined with other known cancer producing substances, such as smoking, the effect of silica can be greatly augmented. In a cohort study done on mine workers in China, over 34,000 workers were studied to see if exposure to silica increased the probability of lung cancer later in life. After the 44-year study, it was found that 44% of the total workers, when compared to an unexposed group, had increased risk of lung cancer due to combined smoking and silica exposure. The research team involved indicated that smoking cessation could help reduce the potential for silicosis in workers (Steenland, et al., 2013).

While respirable crystalline silica is the focal point for occupational exposure, it should also be noted that exposure to crystalline silica can produce problems in the kidneys. In a review of studies done by Kallenberg, various studies involving renal disease associated with silica exposure were evaluated. One study performed by Boujemaa (1994) tested 116 workers who had been previously diagnosed with silicosis. It was found that these workers had slightly higher levels of renal excretion of albumin, retinol-binding proteins and beta-N-acetyl-D-glucosaminidase without an elevated level in their serum creatinine than workers who did not have silicosis. In another study in this same report by Saldanha (1975), a 44 year old male with extreme exposure to silicon had focal glomerulonephritis with degenerative changes of the tubuli due to his exposure. While in most cases, focus is given to respirable crystalline silica, kidney disease due to crystalline silica can also provide potential adverse health effects (Kallenberg, 1995).

While lung and kidney disease have adverse health effects due to silica exposure, ingestible silica has had less focus and attention. Although limited in the *in vivo* studies performed on the No Observed Adverse Effects Level (NOAEL), the limit for dietary silica has been determined to be about 50,000 ppm. This data was found to err on the safe side until further tests were completed and further information is obtained (Martin, 2007).

A study was performed to test the difference of gene expression and cytokine production in crystalline vs. amorphous silica in human pulmonary cells. The researchers found that when comparing cristobalite silica to amorphous silica, crystalline silica had more gene expression alterations and significant gene changes than the amorphous silica particulate did (Parkins, et al., 2012). These results are more consistent with current results as to the toxicity and carcinogenicity of crystalline silica compared to amorphous silica. For the purpose of this study, crystalline silica, and most specifically quartz, was the primary focus of evaluation.

2.3.2. Occupational Exposure Limits – Crystalline Silica

Currently, the OSHA PEL is a limit calculated based upon the respirable crystalline silica in a sample. For quartz, it is measured by taking 10mg/m^3 and dividing it by 2 + the percentage of respirable quartz found in the sample. Equation 1 provides a figure of the quartz equation as well. For both cristobalite and tridymite, the PEL is half of the value calculated from the previously mentioned formula for quartz.

$$PEL\ (crystalline\ silica, quartz) = \frac{10\ mg/m^3}{2 + \%\ respirable\ dust}$$

(U.S. Department of Labor, Occupational Safety and Health Administration)

Equation 1: OSHA PEL Crystalline Silica Formula

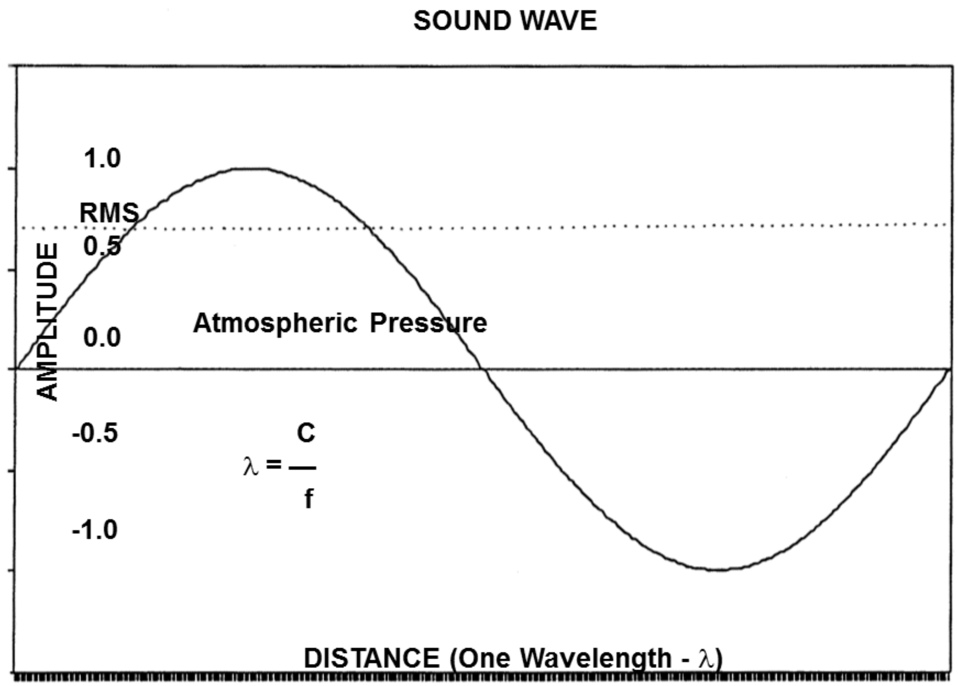
Starting as soon as June 2017, employers will have to follow a new purposed standard for crystalline silica that OSHA has outlined. This standard will not require the previous formula mentioned above based upon the sample results for silica. The new standard will set 0.05mg/m^3 as the regulatory standard for all crystalline silica subcomponents, regardless of the industry.

For the NIOSH RELs, all crystalline silica substituents, quartz, cristobalite and tridymite, have an REL set at 0.05mg/m^3 for up to a 10 hour workday during a 40 hour workweek. For the ACGIH TLVs, respirable limits for both quartz and cristobalite are set at 0.025mg/m^3 based on an 8-hour time-weighted average.

2.4. Noise

Occupational noise exposure is one of the most prevalent health concerns found in the workplace today. According to OSHA, 30 million workers every year are exposed to hazardous occupational noise. No one specific industry or occupational setting is immune from the potential effects of noise exposure.

To understand occupational noise exposure, one must understand the basic subcategories of noise. Three basic and fundamental components of noise are wavelength, frequency, and speed of sound. Wavelength, commonly expressed in units of feet or meters, is defined as the distance traveled by a sound or vibration wave during one pressure cycle. Frequency, which is commonly expressed in units of hertz (Hz), is the rate at which pressure oscillations are produced. The speed of sound is a product of both frequency and wavelength. Figure 5 provides a graph of the relationship that both frequency and wavelength have in a single sound wave. Both are closely intertwined when it comes to possible control measures one would install in an occupational environment as some materials react differently with different frequencies or wavelengths (The American Industrial Hygiene Association, 2011).



(American Industrial Hygiene Association, 2011)

Figure 5: Sound Wave

While frequency and wavelength have a direct correlation with each other, sound pressure provides a way of understanding the displacement amplitude of vibrating sounds. Sound pressure levels (SPL) indicate how potent a sound may be to a worker and how to evaluate its effects on the body. As a worker nears a source of high intensity noise pollution, the sound pressure level increases.

While sound pressure levels can vary depending upon the work environment, understanding the basic physiology of the ear helps give a more in-depth perspective about what happens on a miniature level. There are three sections of the ear: the outer or external, the middle, and the inner sections. The outer section of the ear can modify the acoustic waves so the sound that reaches the eardrum is not as potent as the sound received at the origin. The middle section of the ear is separated from the outer section of the ear by the tympanic membrane which transfers sound energy from the outer part to the inner part of the ear. The inner area of the ear is the most complex part of the ear as it contains the cochlea. The cochlea is a spiral passage way where a large number of hair cells, or cilia, are located. These cilia will bend and move with any level of sound pressure in the ear, regardless of potency. The problem lies in the dose and duration of exposure. If high sound pressure levels constantly bombard the cilia, the hairs will not be able to return to their upright, natural position and perception of sound decreases. This is what is considered hearing loss.

While the ear is constantly bombarded with low sound pressure, there are certain ranges that the human ear can hear more than others. The average human ear can hear sound pressure levels anywhere from 20 – 20,000 Hz but humans are most sensitive to sounds between 500-4000 Hz. While a human can hear in these ranges, a tone of 50 decibels can be easily heard at 1000 Hz but barely audible at 10,000 Hz. Figure 6 below provides a visual understanding of this concept (The American Industrial Hygiene Association, 2003).

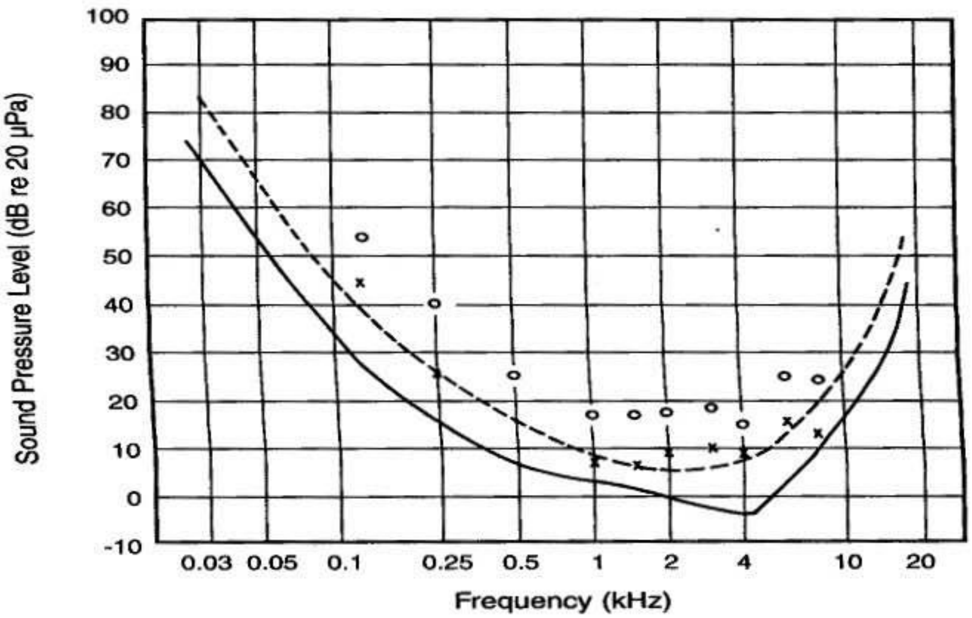


Figure 4.5 — Auditory thresholds associated with "normal" hearing. The solid curv indicates sensitivity to pure tones for young adults listening with open ears (minim audible field), the dashed curve listening with earphones (minimum audible pressure). Circles represent the SPLs that defined 0 dB HL under the old audiometric standard (ASA, 1951), and the crosses denote 0 dB HL under the present referer values (ANSI, 1969; ISO, 1964). (The American Industrial Hygiene Association, 2003)

Figure 6: Noise Threshold Graph

Hearing loss in the workplace can occur either through temporary threshold shifts or permanent threshold shifts. When a noise induced sound pressure level provides a short term hearing loss, one in which a person hears a high pressure level but then recovers over time, it is called an acute or temporary threshold shift. When a temporary threshold shift is continually repeated in a workplace over a period of time, permanent hearing loss can ensue and a chronic or permanent threshold shift can occur. Permanent threshold shifts occur most commonly in the workplace and are the focus of most noise exposure testing.

In the workplace, noise measurements may be measured as overall sound pressure levels or sound pressure levels associated within frequency weightings. Frequency weightings are commonly expressed by the center of the octave band. The octave band center frequencies at which occupational noise is most often measured include 63, 125, 250, 500, 1000, 2000, and 4000 Hz (The American Industrial Hygiene Association, 2003).

Safety and health professionals may select from a variety of noise sampling instruments. Dosimeters, for example, are personal sound pressure level meters that record the percent dose and time-weighted average for that specific worker. The dosimeter microphone is placed in the hearing zone of the worker for the total work shift to record integrated exposures. This exposure is then calculated usually by the dosimeter itself towards one of many pre-established threshold and criterion limits. These limits have been tested by one of the safety and health governing bodies shown in the next section.

Another tool used to evaluate overall sound pressure levels are the sound level meters. Sound level meters can be used if one is trying to find the specific source of noise in a workplace or used to measure real time sound pressure levels. Sound level meters fitted with octave band filters can also be used to evaluate the sound pressure levels associated with specific frequencies. Most modern sound level meters have octave band analyzers built into the device.

2.4.1. Occupational Exposure Limits – Noise

There are several published occupational exposure limits for noise given by either governmental agencies or industry organizations. These occupational exposure limits for noise are distinguished by criteria such as exchange rate, criterion, and threshold. The exchange rate is the rate at which sound pressure level is increased when the permissible noise exposure is decreased by 50%. The criterion is a continuous, 8-hour work shift exposure that constitutes 100% of the allowable noise exposure. The threshold is the lowest sound pressure level at which sound is measured based on the criterion.

There are different regulatory or recommended noise exposure standards in the industry today. OSHA has a regulatory standard which has a criterion and threshold of 90dBA and an exchange rate of 5dBA. To prevent worksites from ever reaching this level, OSHA also has the Hearing Conservation limits which sets the same criterion and exchange rate but lowers the threshold to 80dBA. NIOSH, along with the (ACGIH), have non-regulatory, recommended limits. They set their criterion at 85dBA, have a threshold of 80dBA and an exchange rate of 3dBA.

Table I below shows the noise level exchange rates, thresholds and criterions of all four governmental agencies or industry organizations who have occupational noise limits. These limits were used in comparison to the current study of noise exposure at a foundry.

Table I: Noise Levels

	Exchange Rate	**Threshold**	**Criterion**
OSHA	5 dBA	90 dBA	90 dBA
OSHA Hearing Conservation	5 dBA	80 dBA	90 dBA
NIOSH	3 dBA	80 dBA	85 dBA
ACGIH	3 dBA	80 dBA	85 dBA

3. Literature Review

3.1. Manganese (Mn) in Foundries

Many possible health concerns exist when manganese is used in any foundry or scrap metal facility. In a study performed in Funen, Denmark, from February 1996 to May 1997, 24 furnacemen and 21 scrap recycling workers were tested for their blood manganese levels and manganese in the ambient air. The scope of the study was to verify current control measures and to see if the workers were over the previous Dutch occupational exposure limit of 1.0mg/m^3. The study revealed higher blood and air manganese concentrations in two foundries with insufficient ventilation compared with a foundry and scrap metal facility with adequate ventilation. Two of the workers working in the overexposed facilities had demonstrated neurological issues associated with manganese exposure (Lander, Kristiansen, & Lauritsen, 1999).

In a study performed in Solna, Sweden, (Iregren, 1990) psychological tests were performed on 30 foundry workers exposed to low levels of manganese. On average, workers were exposed to manganese between 0.02-1.4mg/m^3 of air and had not had a significant change in their exposure for the previous 18 years.

Psychological tests, such as hand dexterity, verbal ability, and tapping speed revealed that exposure limits at the time, 2.5mg/m^3 for Sweden and 5.0mg/m^{3}in most other countries, were not suffcient to protect workers from the acute psychological effects of manganese exposure. Workers seemed to have a difficult time reactinng to the finger tapping and digit span tests. Iregren hyopthesized that these may be early signs for potential manganese exposure in a foundry setting that should be further studied (Iregren, 1990).

While respirable manganese is the main focus of this project, once manganese enters the body it has a difficult time leaving the body. In a biological monitoring study performed in the

Gansu province of China, manganese uric acid levels in human urine were analyzed (Sun, et al., 2011). A total of 94 volunteers working in a welding and foundry environment, including a control group, were tested to determine if a long term, low level occupational manganese exposure influnced urinary uric acid levels.

When compared to the control group, the foundry and welding workers exposed to low levels of manganese were found to have significantly lower levels of uric acid than those of the control group. It was deemed that low levels of long term manganese exposure did indeed induce low levels of uric acid in the body. The study found that uric acid levels in exposed men seem to be much lower than those of exposed women. Not only can manganese exposure to foundry workers entice low levels of uric acid in the body, they can potentially increase the effect of neurodegernerative disease (Sun, et al., 2011).

The rate at which manganese can exit the body is based on a vareity of factors. A study performed in Poland evaluated workers who were known to have manganese exposure and removed them from their regular work enviornment. After a year or two, a follow up study was performed to evaluate the worker's blood manganese levels and compare them to the previous test results. The study concluded that workers who were exposed to manganese and then removed from the contaminent were found to have lower blood manganese levels (Jonderko, Kujawska, & Langauer-Lewowicka, 1971).

3.2. Crystalline Silica in Foundries

Crystalline silica exposure is very common and is seen as an occupational hazard in a wide variety of foundry processeses. In an exposure assessment done in Pakdasht, Iran (Omidianidost, Ghasemkhani, Azari, & Golbabaei, 2015), 417 foundry workers in over 82 workshops were evaluated for silica exposure using total and respirable dust sampling techniques. Exposure monitoring was conducted when four different metals, e.g. cast iron, brass, aluminum, and an alloy using all three metals, were being processed.

Results showed that the aluminum processing workshops and the workshops that processed a combination of cast iron, brass, and aluminum had the highest mean respirable crystalline silica concentrations at 0.10 and 0.19mg/m^3 respectively. The aluminum casting total dust concentration seemed to be significantly higher than the rest of the metals tested at a mean of 2.30mg/m^3.

Part of their control measure was to install a fan to drive some of the lighter particulate out of the breathing zone of the worker and reduce the amount of total dust throughout the workplace. Once fans were installed and retesting was completed, samples were organized into two categories, suitable, or that with a fan system, and unsuitable, or that without any fan system. Previously, the average crystalline silica concentration was 0.07mg/m^3 but was reduced to 0.01mg/m^3 with a fan. The average total dust concentration was also reduced from 2.04mg/m^3 to 1.39mg/m^3. This fan option was deemed to be an effective control measure to reduce overall worker exposure throughout all foundries tested (Omidianidost, Ghasemkhani, Azari, & Golbabaei, 2015).

In a study performed in Iran in 2013, (Mehrizi Morteza, et al., 2013) a local exhaust ventilation system was used as a control measure to help reduce the exposure of crystalline silica and formaldehyde from the workplace environment. The local exhaust system was designed using ACGIH specifications. Crystalline silica and formaldehyde sampling was performed when the ventilation system was running and when the ventilation system was turned off. A total of 40 crystalline silica and 39 formaldehyde samples were collected.

While the ventilation system was not running, the mean exposure for crystalline silica was 0.218mg/m^3. After the local exhaust ventilation system was installed and functioning properly, the mean exposure was 0.043mg/m^3 for crystalline silica. The local exhaust ventilation system helped reduce the overall worker exposure significantly below the NIOSH REL for crystalline silica thus showing that local exhaust ventilation systems can provide a valuable and reliable way to remove most contaminants outside the breathing zone of a worker (Mehrizi Morteza, et al., 2013).

While ventilation systems may provide potential control measures throughout foundries, silica exposure can also be found after the molten metal is casted, when the grinders grind the steel down and potentially expose themselves to crystalline silica. In a study done by the American Industrial Hygiene Association (AIHA) in 1992, (O'Brien, et al., 1992), hand grinders who ground steel castings were tested for crystalline silica exposure. The study’s main focus was on the grinders and how to prevent further cases of silicosis from occurring in the workplace. Researchers employed a three step model to analyze and remove the possible contaminates from the work zone. First, personal breathing zone (PBZ) sampling was performed to assess the workers exposure. Second, real time measurements were taken with a hand held aerosol monitoring device that detected all respirable dust, not just crystalline silica. Third and last, a downdraft ventilation bench was installed to evaluate the efficiency of pulling the contaminant away from the worker’s breathing zone.

Four of the total 15 samples were over the NIOSH REL limit of 0.05mg/m^3. No worker was exposed above the OSHA PEL and the majority of the samples came back under the detectable limit. Grinder operators have the potential to be overexposed to crystalline silica (O'Brien, et al., 1992).

3.3. Noise in Foundries

As in most industries, occupational noise exposure provides a very real and serious hazard, not only workers but even the ambient environment around them. In a study performed in Nagpur, India, (Pandya & Dharmadhikari, 2002), occupational noise exposure was evaluated in and around an integrated iron and steel works facility. Worker exposure, as well as ambient environmental noise exposure, was tested and evaluated. The facility being evaluated was located in the heart of Nagpur, with ambient noise coming from constant traffic and the neighborhoods around it. Workers were evaluated based on the OSHA criterion of 90dBA for an 8-hour time-weighted average.

The areas that were found to exceed the OSHA criterion of 90dBA were the plate mill rollers and the sheet mills area, located in the handling and transportation section of the facility, and all but one area in the power house area of the facility. When workers were assessed for speech interference, they found that every frequency tested, 63-8000Hz, were over the 90dBA criterion. For speech, the 500, 1000, and 2000Hz ranges were observed most specifically and were found to have a sound pressure level of 93, 97, 93dBA respectively. This methodology provides a resource to understand the hearing loss potential that noise can produce on workers operating with metal based products, especially in a large city environment (Pandya & Dharmadhikari, 2002).

While noise induced hearing loss can occur on the worksite, what is not often studied is the potential effects noise can have on other occupational injuries and fatalities. In a study performed in a total of 1790 factories in the northern Gyeonggi Province of South Korea, a noise dose response relationship was analyzed between noise exposure and the risk of occupational injury. Workplaces were evaluated based upon noise and dust concentrations. The dust concentrations were classified as either <1.0 or $\geq 1.0 mg/m^3$, whereas the noise concentrations were categorized as either <80, 80-89, or >90dBA. The data was gathered from the South Korean Worker's Compensation and Welfare Services.

When compared to facilities that did not have high incident rates, results revealed that high occupational noise exposure had significant correlation with high incident rates in workplaces. There was no consistent correlation between noise and dust exposure on the worksite (Yoon, Hong, Roh, Kim, & Won, 2015).

In correlation with the previous study, another noise related study was performed in Quebec, Canada, (Deshaies, et al., 2015), specifically looking at work related fatality reports and their association with occupational noise exposure. This study analyzed fatal occupational work related accidents between the years of 1990 and 2005 for all that had some type of connection with noise exposure and death. The study revealed that noise is not necessarily a direct factor in work related accidents but a contributing factor that leads workers to perform or act in a way that they would not otherwise do.

In the total 788 work related accident reports involving noise, noise was explicitly mentioned in 67, or 8.5%, of the total reports. Out of those 67 cases, 17 cases concluded that noise was one of the main causes of fatality. During 2000-2005, 161 fatal accidents occurred in noisy work environments. This information provides an interesting understanding that elevated noise levels can potentially cause a significant amount of other related occupational injuries and deaths for those who are exposed. Factors such as improper communication due to loud noises, and lack of perception due to elevated noise can contribute to a large number of deaths and injuries (Deshaies, et al., 2015).

Not only does elevated occpuational noise exposure potentially cause injuries and fatalities on the worksite, it can also potentially increase the likelihood for hematomatic related injuries. Various studies have been performed on noise induced elevated blood pressure, hypertention, and a wide variety of cardiovascular diseases. In a study performed by de Souza, Périssé, & Moura, (2015) on 1,729 petrochemical workers in Rio de Janeiro, Brazil, a cross section study was done to see if there were correlations between noise exposure and hypertention. Their study confirmed that noise exposure is independently associated with hyertension. (Skogstad, et al., 2016) verified this information by reviewing and confirming that occupational noise is strongly associated with hypertention but suggested weak correlation between occupational noise exposure and other cardiovascular effects.

4. Methodology

As noted previously, the objective of this study was to evaluate metal, crystalline silica and noise exposures at a foundry in the Northwest and to provide recommendations regarding exposure control strategies. This project was prompted by manganese and crystalline silica sampling conducted at this facility the previous year which revealed increased employee Mn and crystalline silica exposures in the foundry compared with previous sampling campaigns. Inhalable and respirable size fractioned metal sampling was performed with a primary emphasis on Mn exposure. In addition, respirable crystalline silica air sampling and bulk crystalline silica sampling was performed. Personal and area noise monitoring was also performed throughout the foundry and the supporting facility structures, such as the weld shop and machine shop. Written Hearing Conservation and Respiratory Protection Program reviews were also performed with suggested revisions.

For the use of human subjects in this experiment, permission from the University of Montana Institutional Review Board (IRB), was obtained. Online training on proper ethical treatment of test subjects was completed. Permission was granted from the Board, along with approval from the company at which the testing was completed.

4.1. Respirable and Inhalable Metals Sampling

Personal breathing zone metal sampling was conducted in the pouring, shake-out and grinding area of the foundry. Since the primary emphasis of the metal sampling was Mn exposure, respirable and inhalable particulate matter size fractionating techniques were employed for best practice industrial hygiene exposure assessment techniques. As noted on page 13, the ACGIH TLV for Mn, which is based on respirable and inhalable size fractions, is considerably lower than the OSHA PEL.

Respirable metals sampling was performed using SKC aluminum cyclones fitted with 37 mm 0.8 micron mixed cellulose ester membrane (MCE) filters. Inhalable metals sampling was performed with Institute of Occupational Medicine (IOM) samplers fitted with 25 mm, 0.8 micron MCE filters. SKC Aircheck 224 sampling pumps were calibrated before and after each sampling period with a Bios® Defender 520 dry cal primary flow meter. The respirable samples were calibrated before and after sampling at 2.5 liters per minute and the inhalable samples were pre and post calibrated at 2.0 liters per minute. All calibrations were performed in the Montana Tech industrial hygiene laboratory, Science and Engineering Building, Room 206.

Throughout each period, employees wore a sampling pump with the size selective filter media placed in their breathing zone. At the conclusion of each sampling period, the MCE filter was removed from the sampling assembly and capped. Once all the samples were collected, they were submitted to ALS Laboratories in Salt Lake City, Utah, an American Industrial Hygiene Association accredited laboratory, for analysis. These samples were analyzed for metals per NIOSH analytical method 7300, elements by Inductively Coupled Plasma (ICP).

A total of 18 PBZ samples were collected along with four area samples over the three day period. Ten of the eighteen samples were respirable samples and the other eight were inhalable samples. Out of the four area samples that were taken, two of the samples were sent to the laboratory for sample analysis. The remaining two samples were reserved for later analysis using a portable Nikon x-ray fluorescence (XRF) machine. The purpose of these additional samples was to determine if a correlation exists between sample results obtained from integrated analyses and direct reading XRF analyses. In addition, 10% field blanks were submitted for analysis as per NIOSH method 7300 recommendations.

During the May 7, 2015 sampling trial, filter media for the pourer was switched out during general foundry tasks vs. pouring tasks. The purpose of this approach was to assess the pourer's metal exposure during general foundry work as well as his exposure only during pouring tasks. Currently, employees only wear respiratory protection while they are pouring.

Job tasks, sample duration, and percent Mn in the molten metal poured were recorded during each sampling period. The majority of the sampling was conducted indoors with temperate conditions comparable to that of the calibration conditions.

An internal audit was performed to evaluate current respiratory protection practices with a newly developed respiratory protection program. The audit itself was performed by surveying five workers who use respiratory protection in various parts of the facility. One worker worked in the painting and sand blasting area. Another worker worked in the grinding and welding area of the foundry. Two workers worked in the pouring area of the foundry and the last worker worked in the sand moving area, between the pouring station and the shake-out station. All workers were asked a series of questions about current workplace standards. These questions were derived directly from the company's respiratory protection program and the federal OSHA respiratory protection standard, 29 CFR 1910.134, and are provided in Appendix G.

4.2. Crystalline Silica

Crystalline silica personal breathing zone sampling was performed using SKC aluminum cyclones fitted with 37 mm 0.8 micron MCE filters. SKC Aircheck 224 sampling pumps were calibrated before and after each sampling period with a Bios® Defender 520 dry cal primary flow meter. The respirable samples were calibrated before and after sampling at 2.5 liters per minute. All calibrations were performed in the Montana Tech industrial hygiene laboratory, Science and Engineering Building, Room 206.

While performing PBZ sampling, employees wore a sampling pump with the size selective filter media placed in the breathing zone. At the conclusion of each sampling period, the MCE filter was removed from the sampling assembly and capped. Once all the samples were collected, they were submitted to ALS Laboratories in Salt Lake City, Utah for analysis per NIOSH Manual of Analytical Method 7500 and 600.

Job tasks and sample duration were recorded during the sampling period. The sampling was conducted mostly indoors with a few workers exiting the facility throughout the day. The temperate conditions were comparable to that of the calibration conditions.

4.3. Noise

One of the most noticeable industrial hygiene hazards present from the beginning of this research was the elevated levels of noise all throughout the foundry and other areas on company property. Both noise mapping of the foundry, when machines were working and when they were not, and personal noise dosimetry sampling were performed. This sampling strategy was intended to assess sound pressure levels in the foundry, machine shop, welding shop, sand blasting/paint shop, and the back fabrication/welding shop.

On April 23, 2015, two workers in the foundry shop were tested. On May 5, 2015, seven workers were tested in the foundry area, machine shop, and welding shop. On May 7, 2015, 12 workers were tested in the welding shop, machine shop, and back fabrication shop area. The personal dosimetry devices used in this study were Quest Edge dosimeters. The dosimeters were calibrated before and after sampling to 114dBA using a Quest QC-10 calibrator. On October 30, 2015, noise mapping was performed in the foundry, machine, and fabrication shops. A 3M Quest Sound Pro sound level meter, calibrated before and after sampling to 114dBA using a Quest Electronic QC-10 calibrator, were used to perform the sampling.

Job tasks and sample duration were taken during each noise dosimetry sampling period. All sampling was conducted indoors with temperate conditions comparable to that of the calibration conditions.

5. Results and Discussion

Metal sampling was performed prior to the start of this assessment. That initial report found slightly elevated levels of manganese and required further testing. The following results are given in chronological order as they were recommended or performed throughout the course of sampling.

5.1. Initial Personal Breathing Zone Sampling

Of the five PBZ respirable dust samples collected, two samples contained crystalline silica in a mass above the laboratory limit of detection: samples 44 and 76. The remaining samples reported crystalline silica, in all its forms, below the laboratory limit of detection. The concentration of quartz in sample 44 was 0.035mg/m^3 or 1.8% and the concentration of quartz in sample 76 was 0.83% (<1%). Considering the percent quartz for these samples, and the current OSH respirable crystalline silica PEL calculation, the PEL for sample 44 for an 8-hour shift is 2.6mg/m^3.

Under the current OSHA standard, samples containing < 1% crystalline silica should be compared to the OSHA PNOR PEL of 5.0mg/m^3 or the 12-hour shift modified PEL of 3.3mg/m^3. Sample 76 exceeded this value. In addition, samples 44 and 76 exceeded the ACGIH TLV for crystalline silica of 0.025mg/m^3. Therefore, samples 44 and 76 would exceed the proposed OSHA crystalline silica standard. Table II shows the results from this sampling period. Over exceeded levels are in shown in bold.

Table II: Initial Crystalline Silica Results

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Respirable Dust Concentration (mg/m^3)[A]	Crystalline Silcia: Quartz Cristobalite Tridymite (mg/m^3)[A]
12/9/14	76	Foundry – getting product ready for grinder/air arcing	431	8.3	**0.83**[B] <1.0 <1.0
12/9/14	68	Foundry- grinding	470	1.3	<0.0085 <0.017 <0.017
12/9/14	44	Foundry – making sand- shake out	465	2.0	**0.035, 1.8**[B] <0.017 <0.017
12/9/14	42	Machine shop – cleaning and changing baghouse	257	0.33	<0.015 <0.031 <0.031
12/9/14	60	Foundry - molder	278	0.96	<0.014 <0.029 <0.029

[A] Less than (<) indicates sample mass below Laboratory Limit of Detection (LOD); respirable dust: 0.02mg/sample, quartz: 0.01mg/sample, cristobalite: 0.02mg/sample, and tridymite: 0.02mg/sample. These samples are indicated with shading.
[B]Results are presented as % of the total gravimetric sample.

5.2. Manganese Personal Breathing Zone Sampling

Appendix A: Manganese Sampling Results by Worker, provides the sampling results, per each worker, for manganese sampling in detail. The sample date, number, percent manganese associated with each pour, number of pours, task performed, sample duration, metals sampled, sample results along with OSHA PEL and ACGIH TLV limits are provided in these tables.

In all of these results, both the sample weighted concentration and time-weighted concentrations were given. The sample weighted concentration reflects the concentration measured for the sampling period. Because some of the samples taken were collected for less than 480 minutes, or 8-hour time-weighted averages, the data are extrapolated to an 8-hour exposure period so that the data could be compared to the time-weighted average exposure standards.

On April 23rd, a total of four pours, equaling 4800lbs with 12-13% manganese in each pour, was melted. On that same day, there were three melts performed with 3600lbs with less than 1% manganese. On May 5th, a total of three pours, equaling 3200lbs with 12-13% manganese in each pour, were melted. On that same day, there were six melts performed with 9900lbs with less than 1% manganese. On May 7th, a total of three pours, equaling 3600lbs with 12-13% manganese in each pour, was melted. On that same day, there were three melts performed with 5100lbs with less than 1% manganese.

Out of 10 respirable manganese samples tested throughout the project, eight samples exceeded the ACGIH TLV for respirable manganese. The two samples that were below the limit were also very close to exceeding the 20 $\mu g/m^3$ limit. These samples are shaded green in Appendix A.

Out of the thirteen inhalable samples that were collected, nine samples were PBZ samples; four area samples were collected at a stationary location next to the pouring area. Two inhalable samples exceeded the ACGIH inhalable Mn TLV. On April 23, 2015, one worker who was grinding and welding revealed manganese concentrations over the inhalable TLV. In addition, a pourer was found to have an inhalable concentration over the TLV on May 7, 2015. On this date, samples were collected to distinguish pouring task concentrations from non-pouring task concentration. It is important to note that pouring tasks, with a total time of just 33 minutes a day, resulted in the highest manganese concentration. The respirable manganese concentrations during general non-pouring foundry work still exceeded the respirable TLV.

As stated previously, the first two hypothesizes stated that respirable and inhalable manganese concentrations would be less than or equal to the TLV of 0.02 mg/m^3. When comparing the statistical data, it was found that the respirable data was not normally distributed, and was not logarithmically normal, thus a t-test could not be used. A 1-sample sign non-parametric test was performed and the p-value for respirable manganese was 0.0547. Even though multiple samples came back above the TLV, the p-value was not significantly greater than the TLV, thus one would then fail to reject the null hypothesis for respirable manganese.

The inhalable data was also found to not be normally distributed but was distributed logarithmically. Even though a t-test could be used to evaluate this data, it was decided that a 1-sample sign non-parametric test would be used to keep consistency with the respirable test. The p-value for inhalable manganese was found to be 0.9998, thus not significantly greater than the TLV. One would then fail to reject the null hypothesis for inhalable manganese.

5.3. Personal Noise Dosimetry Sampling

The results of the noise dosimetry sampling are presented in Table III, Noise Dosimetry Testing in Machine and Welding Shop Table IV and Table V. The tables show the OSHA PEL and Hearing Conservation Program levels, including their respective dose percentages. ACGIH limits were tested for only a few workers, as only a few of the dosimeters used had the electronic capability of categorizing ACGIH readings. Readings that are highlighted in green are those that are overexposed to their respected criterions. Red highlighted cells are those that are over the 100% dose for that shift.

In the Foundry, out of the seven samples that were taken, three workers exceeded the OSHA criterion. Five of the seven workers were found to be above the OSHA Hearing

Conservation Program criterion of 90dBA and the one person who was sampled for ACGIH in the Foundry was above the criterion as well.

Table III: Noise Dosimetry Testing in Foundry

Sample Date	Dosimeter Number	Employee	Task Performed	Sample Duration (minutes)	OSHA PEL % Dose and TWA equivalent sound pressure level (dBA)	PEL Criterion	OSHA Hearing Conservation % Dose and TWA equivalent sound pressure level (dBA)	Hearing Conservation Criterion	ACGIH TLV % Dose and TWA equivalent sound pressure level (dBA)	TLV Criterion
Foundry										
4/23/2015	2	Employee # 1	Bit of everything	458	29.74%	100.00%	26.86%	100.00%	N/A	100.00%
					81.6	90.0	80.9	85.0	N/A	85.0
4/23/2015	3	Employee # 2	Furnace and Welding	454	11.22%	100.00%	42.54%	100.00%	N/A	100.00%
					74.6	90.0	84.2	85.0	N/A	85.0
5/5/2015	5	Employee # 3	Pouring	458	126.70%	100.00%	146.80%	100.00%	N/A	100.00%
					92.1	90.0	93.1	85.0	N/A	85.0
5/5/2015	3	Employee # 4	Welding	402	112.50%	100.00%	118.40%	100.00%	362.40%	100.00%
					92.1	90.0	92.5	85.0	96.4	85.0
5/5/2015	10	Employee # 5	Shake Out & Assistant Pourer	757	152.80%	100.00%	172.80%	100.00%	N/A	100.00%
					93.4	90.0	94.3	85.0	N/A	85.0
5/5/2015	11	Employee # 6	Molding area & Shake Out	442	74.54%	100.00%	88.87%	100.00%	N/A	100.00%
					88.5	90.0	89.8	85.0	N/A	85.0
5/5/2015	13	Employee # 7	By the welding & grinding area	402	33.89%	100.00%	48.34%	100.00%	N/A	100.00%
					83.5	90.0	86.1	85.0	N/A	85.0

Table IV shows results for the Machine Shop and the Welding Shop. In the Machine Shop, there were three samples taken and none of the samples exceeded the OSHA PEL or Hearing Conservation limit. None of the samples had the ACGIH electronic function.

In the Welding Shop, six samples were taken of four workers over two different days. Out of all six samples, none exceeded the OSHA criterion, although two samples came back with elevated levels close to the criterion. While no sample in the Welding Shop exceeded the OSHA criterion of 90dBA, all six samples were above the OSHA Hearing Conservation Program threshold and one exceeded the criterion. No ACGIH samples were taken in this sample group.

Table IV: Noise Dosimetry Testing in Machine and Welding Shop

Sample Date	Dosimeter Number	Employee	Task Performed	Sample Duration (minutes)	OSHA PEL % Dose and TWA equivalent sound pressure level (dBA)	PEL Criterion	OSHA Hearing Conservation % Dose and TWA equivalent sound pressure level (dBA)	Hearing Conservation Criterion	ACGIH TLV % Dose and TWA equivalent sound pressure level (dBA)	TLV Criterion
Machine Shop										
5/5/2015	6	Employee # 1	Rod Turning	437	12.36%	100.00%	42.70%	100.00%	N/A	100.00%
					75.6	90.0	84.6	85.0	N/A	85.0
5/7/2015	5	Employee # 2	Cleaning & Maintainence	308	13.36%	100.00%	6.49%	100.00%	N/A	100.00%
					78.4	90.0	80.2	85.0	N/A	85.0
5/7/2015	9	Employee # 3	Rod Turning	299	1.23%	100.00%	10.84%	100.00%	N/A	100.00%
					61.7	90.0	77.4	85.0	N/A	85.0
Welding Shop										
5/5/2015	4	Employee # 1	Ergonomic Welding Area	430	37.58%	100.00%	61.40%	100.00%	N/A	100.00%
					83.7	90.0	87.3	85.0	N/A	85.0
5/7/2015	6	Employee # 2	Ergonomic Welding Area	304	18.95%	100.00%	37.31%	100.00%	N/A	100.00%
					81.3	90.0	86.2	85.0	N/A	85.0
5/5/2015	12	Employee # 3	Plasma Cutting Area	458	48.79%	100.00%	61.78%	100.00%	N/A	100.00%
					85.2	90.0	86.9	85.0	N/A	85.0
5/7/2015	4	Employee # 4	Plasma Cutting Area	310	23.17%	100.00%	34.95%	100.00%	N/A	100.00%
					82.6	90.0	85.6	85.0	N/A	85.0
5/5/2015	9	Employee # 5	Grinding & Welding on large cylinder	455	88.62%	100.00%	103.90%	100.00%	N/A	100.00%
					89.5	90.0	90.7	85.0	N/A	85.0
5/7/2015	11	Employee # 6	Grinding & Welding on large cylinder	312	50.42%	100.00%	59.88%	100.00%	N/A	100.00%
					88.2	90.0	89.4	85.0	N/A	85.0

Table V provides the results for the Sand Blasting and Paint Shop area and the Back Fabrication/Welding Shop. In the Sand Blasting and Paint Shop area, one of the only workers who consistently works in that area was tested. He was below both the OSHA and the OSHA Hearing Conservation Program limit criterions. He was, although, slightly over the ACGIH criterion of 85dBA.

In the Back Fabrication/Welding Shop, four different employees were tested over during one day. No worker was over exposed per OSHA PEL and Hearing Conservation Program criterion. The same holds true for the ACGIH limit. No hearing protection is required for workers in this area.

Table V: Noise Dosimetry Testing in the Sand Blasting and Back Fab Shop Areas

Sample Date	Dosimeter Number	Employee	Task Performed	Sample Duration (minutes)	OSHA PEL % Dose and TWA equivalent sound pressure level (dBA)	PEL Criterion	OSHA Hearing Conservation % Dose and TWA equivalent sound pressure level (dBA)	Hearing Conservation Criterion	ACGIH TLV % Dose and TWA equivalent sound pressure level (dBA)	TLV Criterion
Sand Blasting Area/ Paint Shop										
5/7/2015	2	Employee # 1	Sand Blasting Area/Paint Shop	350	8.48%	100.00%	13.37%	100.00%	78.83%	100.00%
					74.5	90.0	77.8	85.0	85.3	85.0
Back Fab Shop/Welding										
5/7/2015	8	Employee # 1	Welding	331	4.33%	100.00%	9.09%	100.00%	14.93%	100.00%
					70.0	90.0	75.4	85.0	83.4	85.0
5/7/2015	10	Employee # 2	Tack Welding & Grinding	336	7.62%	100.00%	12.29%	100.00%	N/A	100.00%
					74.0	90.0	77.5	85.0	N/A	85.0
5/7/2015	12	Employee # 3	Bending and Rolling	329	3.88%	100.00%	9.73%	100.00%	N/A	100.00%
					69.3	90.0	75.9	85.0	N/A	85.0
5/7/2015	13	Employee # 4	Welding	328	9.87%	100.00%	20.70%	100.00%	N/A	100.00%
					75.3	90.0	81.4	85.0	N/A	85.0

As stated previously, the third and fourth hypothesizes stated that the personal noise dosimetry would be less than or equal to the PEL of 90dBA and the OSHA Hearing Conservation limit of 85dBA, respectively. When comparing the statistical data, it was found that both sets of data were normally distributed so a 1-sample t-test was used. Hypothesis 3, which tested the PEL, had a p-value of 1.00 while hypothesis 4 had a p-value of 0.613. It was then deemed that both p-values were not at or below the α limit of 0.05 so one would fail to reject the null hypothesis for both hypothesizes.

5.4. Noise Mapping

The results of the noise mapping are shown in Figure 7-Figure 9 below. Figure 7 and Figure 8 represent the foundry when the machines are not running and when they are. The comparison was given to show the difference of noise levels when certain equipment was running and when it was not. Figure 9 shows the machine and fabrication shop results during a normal functioning time period.

The following noise mapping figures are color coded for easy interpretation. Areas colored green are areas that are below 79.9dBA and need no immediate attention. Areas colored yellow are areas that are between 80-84.9dBA. Per the ACGIH best practice criteria, this area is recommended to have hearing protection. Per the OSHA limits, this area does not require any immediate action. It should be noted that hearing loss has been found in people who are exposed to 80dBA over an 8-hour time-weighted average. Areas that are colored red are areas that are at or above 85dBA and require immediate attention. Until engineering controls are established to lower the noise exposure below 85dBA, a Hearing Conservation Program should be implemented and monitored closely.

Figure 7 depicts when machines, such as grinders, welders, and molding area machinery, were not being operated. When the machines were not operating, the entire facility was under the 90dBA regulatory OSHA PEL. There were 14 total areas that were above 80dBA that need caution and two of those areas that were above the hearing conservation and ACGIH limit of 85dBA. These areas had elevated levels due to a forklift that was moving the sand based product around the facility while testing was being performed. While the machines were not running, no sound pressure level measurements exceeded the OSHA PEL of 90dBA.

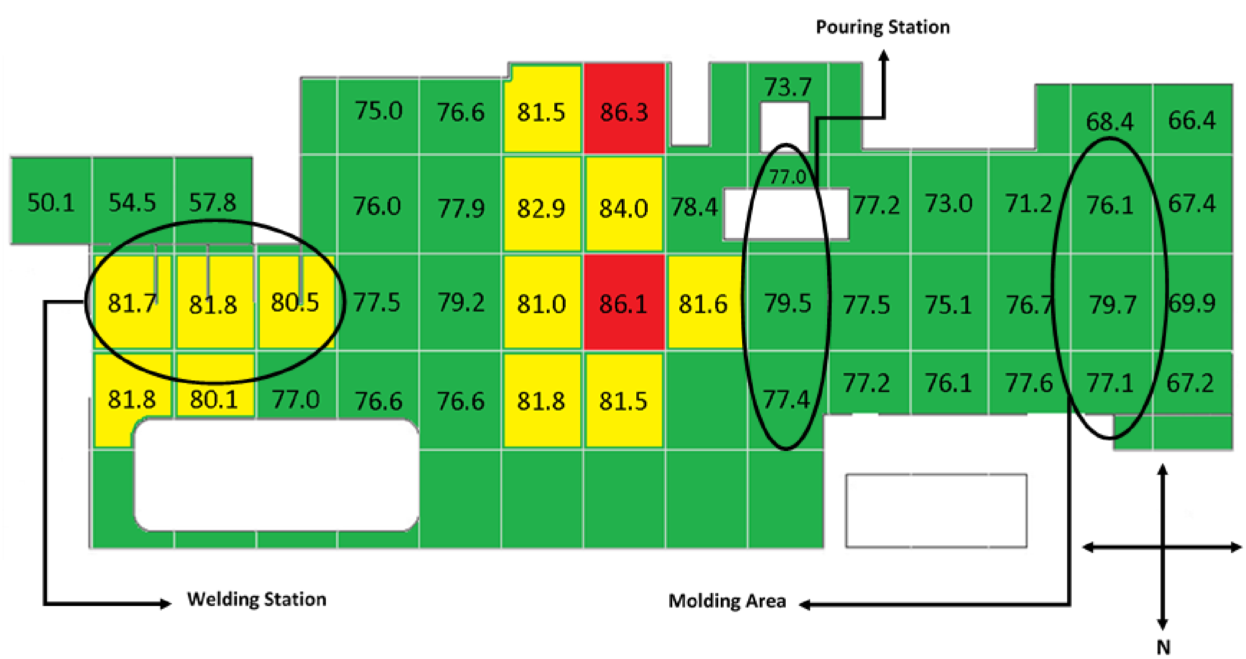


Figure 7: Foundry Map without Machines Running

In Figure 8, which depicts when machines were operating, many areas were found to be over the 85dBA best practice limit. Out of the whole facility, 26 areas were over 85dBA. Thirteen of those 26 were over the 85dBA criterion and out of those 13, four were over the 90dBA regulatory limit. The two main areas that had the highest sound pressure levels throughout the foundry were located on the east and west ends. On the west end of the facility, three areas had elevated noise levels above 85dBA which can be attributed to machines in the molding area. While none of these areas was above the 90dBA limit, two areas were very close to passing that limit. On the east end of the foundry, eight areas had elevated noise levels and four of those areas were above the 90dBA limit. This elevated level was attributed to the one arc welder who was working in that area at that time. This figure does not take into account the fact that the rest of the welders were not working when this sampling was conducted. It can only assumed that the decibel readings would increase as more machines start working.

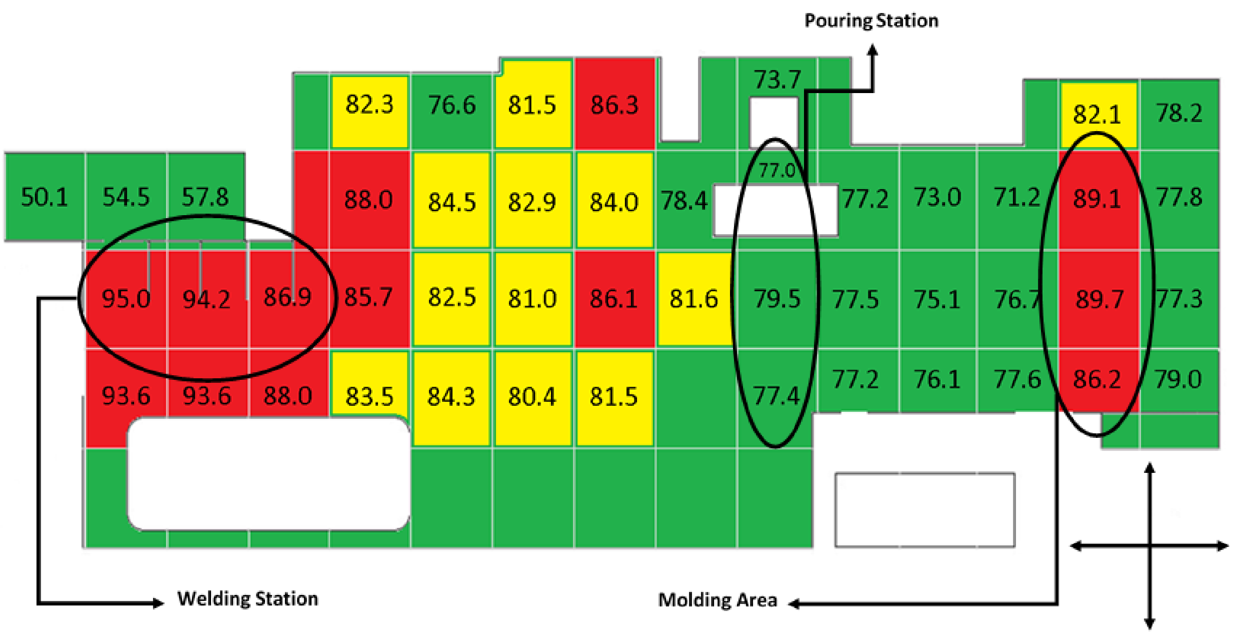


Figure 8: Foundry with Machines Running

Figure 9 represents both the Machine and Fabrication Shops. The Machine Shop, which is found on the upper area of Figure 9, had low to moderate noise levels with only two areas with readings above 80dBA. In the Fabrication Shop, there were considerably high sound pressure levels around the arc welding area. Twenty-one out of the total 32 areas were above 80dBA with 13 areas being over the 85dBA Hearing Conservation Limit. Six of the 13 elevated areas were above the 90dBA OSHA PEL. It should also be noted that the testing performed was only performed when the plasma arc welding machine was running. As per previous visits, multiple welders were welding various objects throughout the Fabrication Shop.

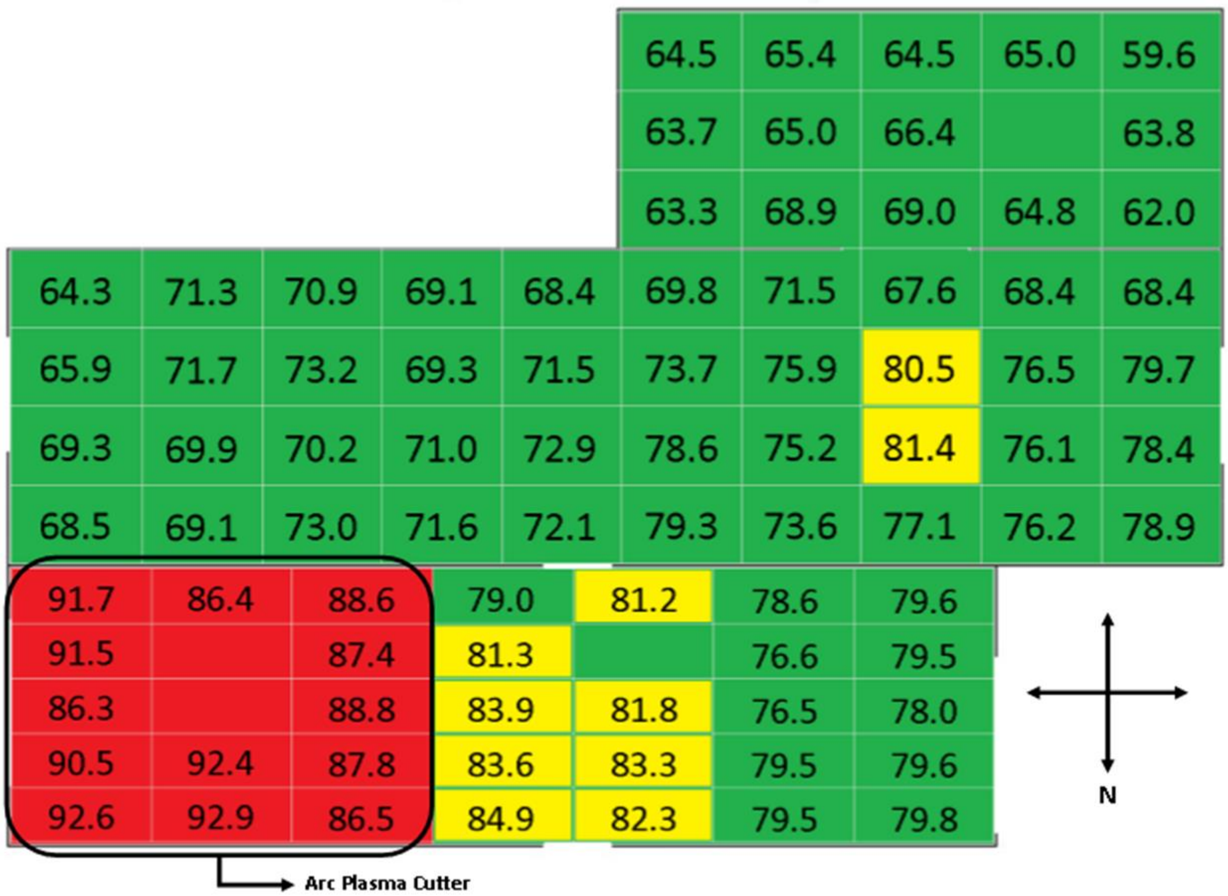


Figure 9: Machine and Fabrication Shop

5.5. Post Crystalline Silica Personal Breathing Zone Sampling Results

Table VI below shows the specific results for the personal breathing zone sampling that was performed on September 25, 2015. This information includes the sample date, number, employee sample duration, and the current and proposed OSHA crystalline silica standard. In each silica standard, the sample weighted respirable dust concentration, 8-hour shift time-weighted average respirable dust concentration and calculated permissible exposure limit are given.

Table VI: Crystalline Silica PBZ Sampling Results

				Current Standard			Proposed Standard		
Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Sample Weighted Respirable Dust Concentration (mg/m3)	8-Hour Shift Time Weighted Average (TWA) Respirable Dust Concentration (mg/m3)	OSHA PEL (mg/m3)	Sample Weighted Crystalline Silica: Quartz Cristobalite Tridymite (mg/m3)	8-Hour Shift Time Weighted Average (TWA) Crystalline Silica: Quartz Cristobalite Tridymite (mg/m3)	OSHA PEL (mg/m3)
9/25/2015	CS01	Welding outside by east door & welding inside	348	1.2	0.87	3.125	(0.014)	0.10	0.05
							<0.023	0.017	
							<0.023	0.017	
9/25/2015	CS02	Cutting and entering and exiting east end	380	3	2.375	3.46	(0.027)	0.021	0.05
							<0.021	0.017	
							<0.021	0.017	
9/25/2015	CS03	Welding, Shake out; Entering in and outside	397	3.9	3.23	4.1	(0.017)	0.014	0.05
							<0.020	0.017	
							<0.020	0.017	
9/25/2015	CS04								
9/25/2015	CS05	Molding Area, Far west end	96	0.17	0.34	PNOR PEL: 5mg/m3	<0.042	0.0084	0.05
							<0.084	0.017	
							<0.084	0.017	

Currently, the OSHA PEL is a calculated limit based upon the collected data as shown previously in Equation 1.

Out of the four samples taken, no worker exceeded the current OSHA calculated PEL. The two workers who seemed to be located outside more than inside the foundry had higher TWAs than those working inside the foundry but did not exceed the limit.

While the current OSHA PEL is considered the regulatory requirement for companies to follow, consideration was also taken for the newly proposed OSHA PEL for silica. This proposed standard is not based off of the sample's calculated equation but merely a set concentration of 0.05mg/m^3.

Out of the four samples taken, no worker exceeded the proposed OSHA PEL for crystalline silica. From the samples compared to the proposed OSHA PEL for crystalline silica, the quartz was detected in all the samples with the exception of the molding area sample and field blank. The concentrations detected were below the Limit of Detection (LOD) and above the Limit of Quantitation (LOQ). The LOD ranges from 0.0-0.01mg/m^3 and the LOQ ranges from 0.03-0.05mg/m^3.

As stated previously, the fifth and sixth hypothesizes stated that the post crystalline silica PBZ sampling would be less than or equal to the calculated PEL and newly purposed PEL of 0.05mg/m^3. While performing the statistical analysis of the data, both sets of data were not found to be normally distributed, nor logarithmically normal, so a t-test could not be used. A 1-sample sign non-parametric test was used on both sets of data and both sets of data came back with a p-value of 1.00. This value was not significantly greater than the current and newly purposed PEL so one would then fail to reject the null hypothesis for hypothesis 5.

5.6. Respiratory Protection Audit Results

The audit itself produced a wide variety of results, some of which were known to management and others which came as a surprise to both management and worker alike. Employees seemed to have a well-managed understanding of when to report damages to respirators and when to go get a new one. Management made sure that workers were provided respirators at no cost to the employee and that all those respirators were NIOSH approved. Before entering the worksite, all employees received medical evaluations by trained physicians who then deemed the employees ok to don and doff a respirator. No employee stated that they have ever altered the overall integrity of their respirator in any way and each seemed to understand how to properly use their respirator.

6. Recommended Control Strategies

Personal exposure testing was performed in a foundry in the Northwestern United States to evaluate manganese, crystalline silica and noise exposure to workers. The following control strategies are given in chronological order as they were recommended and/or implemented.

6.1. Crystalline Silica Bulk Sampling Assessment

As illustrated in Table II, initial respirable dust in the foundry revealed crystalline silica in two samples. In an effort to determine the source of crystalline silica in this area, bulk sampling was conducted. Bulk samples of particulate matter (100 grams) were collected in three locations of the foundry floor and of the bulk sand purchased for the molding process. As shown previously in Figure 2, the floor of the foundry is made of a particulate matter that has been used and recycled in the molding process for years. As of a few years ago, a new olivine based substance was purchased and eventually over time and through the molding process, ended up on the floor of the facility. Although there were two different molding substances on the floor, the ability to differentiate between the two for testing purposes is nearly impossible. A review of the Safety Data Sheets (SDS) revealed that the current bulk product is primarily comprised of amorphous silica, not crystalline silica.

For bulk samples, three from the foundry floor and one from the bulk olivine sand material were analyzed for crystalline silica for the NIOSH Manual of Analytical Methods (NMAM) 7500 by ALS Laboratories in Salt Lake City, Utah. Results of this sampling are presented in Table VII below. Results revealed that two samples had detectable amounts of quartz and two did not. Sample B and C, which had detectable amount of quartz, were the samples that were taken closest to the west end of the foundry, where a large door allowed airflow to enter the facility. These two samples, taken near the grinding area and the furnace area, were found to have 3.8% quartz and 2.2% quartz respectively.

Table VII: Crystalline Silica Bulk Sampling Results

Sample Date	Sample Number	Metals Sampled	%
4/21/2015	A	Quartz	<.75
		Cristobalite	<1.0
		Tridymite	<1.0
4/21/2015	B	Quartz	3.8
		Cristobalite	<1.0
		Tridymite	<1.0
4/21/2015	C	Quartz	2.2
		Cristobalite	<1.0
		Tridymite	<1.0
4/21/2015	D	Quartz	<.75
		Cristobalite	<1.0
		Tridymite	<1.0

It was hypothesized that quartz was most likely being transported into the facility with equipment or found in the foundry from processes performed years ago and not from the manufacturer’s bulk sand product. After speaking to management, it was then planned that the outside area next to the west side of the foundry would be paved as a control measure. Management had already had this control measure planned prior to the given recommendation. During the summer of 2015, the area next to the west entrance was paved.

On September 25, 2015, personal breathing zone sampling was performed to verify that current control measures of paving the west end of the foundry provided adequate protection for the foundry workers. A total of four personal breathing zone samples were taken. One worker worked right outside the west end door to the foundry, welding various metal products. Two other workers worked in together most of the day welding, cutting and in the shake-out area. These two workers entered and exited the foundry frequently. The last worker worked on the west end of the foundry in the molding area. One field blank was also submitted to ALS Laboratory for quality control. NIOSH method 7500 and 0600 were used to evaluate the PBZ and bulk samples.

Elevated levels of crystalline silica were noticed at the start of this survey. To mitigate worker exposure, bulk sampling was first taken to find the source of the problem, then personal breathing zone sampling was taken to assess individual worker exposure. When the results came back, elevated levels of quartz were found on the west end of the foundry and lessen the further into the foundry the samples were taken. It was presumed and hypothesized that the source of crystalline silica exposure came from the west end, the non-paved lot, when motorized vehicles entered and exited the facility. It was recommended that retesting be completed once the back lot had been paved with asphalt.

During the summer of 2015, the back lot was paved and during September 2015, follow-up PBZ respirable crystalline silica sampling was performed in the foundry following the same sampling and analytical techniques utilized in the initial sampling campaign. Although the number of samples were limited in this assessment, the data suggests that paving the west lot may have had a positive impact on reducing respirable crystalline silica exposures. Additional sampling is recommended to verify these results.

6.2. Respiratory Protection Audit

As for potential improvements, employees and management seemed to have a misunderstanding as it pertained to a few regulatory standards. Prior to this audit, the company did not have an annual fit testing regimen for its employees and some had not received a fit test in some time. Facial hair was a visible issue on all those who were audited. Each employee who was evaluated had facial hair that would impede the respirator’s tight forming seal. Seal checks seemed to be an issue for four out of the five workers tested. They either did not know how to perform the test properly or had not been trained on it in some time. Cleaning and storage was a problem for one of the workers tested. While performing the audit, it was noticed that his respirator was hanging behind him in the foundry without any protection from the dust and debris volatilizing in the area. While only the worker in the paint shop used cartridges, there was no formal change out schedule set in place for when that should be performed. The last important item was that of respiratory training. Four of the five workers stated that they could not remember when the last respiratory protection training was given. They did however state that they had received some type of training between the time they started their employment and January 19th, when the assessment was given.

There were a few items of mention noticed during and after the audit to be in compliance with current OSHA respiratory protection standards. Management and supervisors were to ensure that their workers are in proper compliance with the workplace standard. Since the workplace standard was just revised, this item could not yet be properly evaluated. While standard have the possibility of changing over time, an evaluation of the program will be completed when new standards and practices are implemented. As this program was newly revised, this has not occurred yet. Another item of mention was that of respirator cleaning after every fit test. As most employees had not performed a fit test in the past few years, this question was also difficult to effectively answer. Last, as an appendix to the respiratory protection program, a training guideline was added. Since training using this new program had not yet been implemented, this question was also difficult to evaluate.

6.3. Respiratory Protection Program

As an added control measure to all workers that work at the foundry, an update of the current written respiratory protection program was completed. The previous program completed in 1999 was updated, revised, and now provides the necessary training for this foundry's workers.

The respiratory protection program stated such things as the company's responsibility to the worker, the supervisor's responsibility to the worker, and the employee's responsibility as it pertains to respiratory protection. Selection of respirators throughout the facility was mentioned as well as stating which job task and area required which specific type of respirator.

Currently, respirators are used in four areas throughout the facility. Disposable N95 filtering face piece respirators are being used in the pouring area of the foundry and are available for any who request respirators for their specific job task. Air purifying full face elastomer respirators are currently used in the paint shop while the painter is painting. Supplied air respirators, including airline respirators, are currently being used in the sand blasting area.

As part of the recommendations and additions to the newly revised respiratory protection program, recommendations were given regarding which respirator should be used in which area. For when workers are pouring, grinding, or welding, where fine particulate matter is generated, air purifying half or full face elastomer respirators equipped with N100 filters are recommended. For any other potential particulate exposing areas, such as the sand molding area, a disposable filtering face piece respirator, N95, is recommended. The recommendations for the painting area and the sand blasting area, were the same as currently being mandated by the company.

As per all respiratory protection program guidelines set by OSHA, this respiratory program included such sections as medical evaluations, fit testing, procedures for respirator usage, inspection and cleaning, training, and program evaluation. These sections were written in accordance to 29 CFR 1910.95, the OSHA Respiratory Protection standard.

On March 31, 2016, in correlation with the newly revised respiratory protection program, training of that program was given to all company employees who use respirators on the worksite. This training was given to verify that workers knew the current OSHA and best practice standards. Training included the reason why respiratory protection is needed, what the company is doing to mitigate future hazards, which respirators are recommended for each work task, medical evaluations, fit testing, rules and procedures for wearing respirators, cleaning, inspections, and repairs. Workers were also shown how and what to look for when they inspected their respirators, and how to don and doff them.

6.4. Noise

To reduce the noise hazard in the foundry, it is recommended to have all workers be fitted with proper hearing protection to lower their exposure limits. Current basic hearing protection provided by the company was shown to have an NRR rating of 33. Equation 2 provides the formula used to properly evaluate the NRR rating.

$$Corrected\ NRR = \frac{NRR - 7}{2}$$

Equation 2: Corrected NRR Rating

After doing the NRR conversion equation listed below, the corrected NRR Rating would be 13. As per the results shown in Table II, the worker exposed to the loudest decibel rating was cited at 96.4dBA. If this hearing protection would be provided to the workers, it would essentially reduce the hearing protection down to 83.4dBA, even below the ACGIH and NIOSH criterion. While this would lower the exposure limit below all Occupational Exposure Limits (OEL), this would just put the worker barely below the limits. Special attention would need to be given to verify that workers would not exceed this limit. Further testing to verify this data is then warranted.

In the Welding Shop, it was also found that workers, although not above the OSHA PEL criterion, were above the OSHA Hearing Conservation threshold and a hearing conservation program would need to be instituted in this area. It is recommended that all employees in the Welding Shop wear hearing protection. The above mentioned ear plugs with a calculated NRR of 13 would be suitable protection, as the highest worker TWA was 90.7dBA.

In the Sand Blasting/Paint Shop area, the only consistent worker in that area was tested and was barely above the ACGIH and NIOSH criterion of 85dBA. Hearing protection is recommended to be worn as a best practice measure for this worker but is not required by OSHA standards. Current ear plugs will provide sufficient worker hearing reduction to the area.

The Back Fabrication/Welding Shop and the Machine Shop, according to the personal dosimetry testing, did not exceed any of the regulatory and recommended criterion, thus hearing protection in these areas is not required. It is up to the discretion of the worker whether or not they chose to wearing hearing protection.

As previously mentioned in the literature review section, (Jonderko, Kujawska, & Langauer-Lewowicka, 1971) provided an alternative control measure to reduce noise exposure to foundry workers. Jonderko implemented a frequent rotational shift to workers in their foundry. This control measure could also potentially be implemented in the foundry studied here by moving workers out of their work areas into quieter work areas at least once a day depending upon the overexposed location.

6.5. Hearing Conservation Program Revisions

As part of the control measures for occupational noise in the workplace, a review of the company's Hearing Conservation Program was completed. This involved taking the previous program that was completed in 1999 and updating, revising and providing the necessary training for all company workers.

The hearing conservation program stated such things as the company's responsibility to the worker, the supervisor's responsibility to the worker, and the employee's responsibility regarding hearing protection. The program gave a brief overview of which areas are most affected by high sound pressure levels. Another table that specifies job task and the potential noise pollution it can have on the worker was given to give a comparison between area and personal worker exposure based on worker task. Sections on employee notification are also included.

One section of the program goes into detail about audiometric testing and when that is to be performed. Baseline tests should be performed starting from the time that workplace noise is first evaluated. Annual audiogram testing should be performed to verify that workers are not showing signs of hearing loss that may be due to high sound pressure levels in the workplace.

The last part of the program goes into the specifics of hearing protection, training, and recordkeeping. As part of this evaluation and to verify that workers fully understood the effects of hearing loss, hearing protection training was given on April 21, 2016. The training included the effects of noise on hearing, the purpose of hearing protection, audiometric testing, and how to properly use hearing protection while on the worksite. The training was given to all company employees who were in the areas potentially affected by high sound pressure levels.

6.6. Ventilation

As part of a best practice control measure for manganese, a local exhaust ventilation system was recommended around the furnace area of the foundry, specifically when molten metal is smelted and poured. The local exhaust ventilation system would then provide a way to pull the contaminant out of the entire foundry and the breathing zone of the worker. Figure 10 provides a picture of the smelting station with no local exhaust ventilation.

Figure 10: Furnace Area before Ventilation (Picture taken by J. Sargetis)

Following the recommendation, the company decided to build two mobile ventilation systems above the furnaces. These mobile systems will allow the workers to manually move the capture hoods above the furnaces each time a manganese-based metal is being used. The ventilation system will remove the particulate and plume coming from the furnace for all workers working in the foundry.

Ever since a high manganese-based product has been added to their mixes, the company has noticed an increase in the amount of plume smoke up and around the foundry. By mid-day, the visibility throughout the foundry is reduced and workers notice the problem. Due to the age of the building the foundry is located in, proper general exhaust ventilation is not installed. The only way for particulate to leave the foundry is either through the large doors leading out of the foundry on the west and south end of the facility or through the tilted windows on the ceiling of the building. Large fans are installed on the ceiling to remove particulate but do not provide sufficient flow to remove the particulate.

Currently, the ventilation systems are in the process of being designed and built. The design of the ventilation system will have a flow rate of 6000 cfm for each furnace. As the ventilation systems will remove metal smokes away from the worker, it is recommended that a capture velocity of 2000-2500 fpm be used (ACGIH, 2013). The basic blueprints are shown in Appendix H.

Due to time constraints, retesting the proposed ventilation system is not an option. Currently, the ventilation system is still in its design phase and was not available for retesting at the time this thesis was published. Although the final testing to prove that the ventilation system functions properly is not feasible, it is recommended that future testing take place to verify that the capture velocity and flow rate of the system sufficiently provide the necessary protection from metals for the worker.

7. Conclusion

In this study, the foundry was evaluated for worker exposure to metals, crystalline silica, and noise, and control measures were recommended. Manganese exposure has been linked to a variety of neurological health issues even at low levels. In this study, manganese was tested and compared against the ACGIH TLV for inhalable and respirable limits. It was found that workers were overexposed to respirable manganese in the foundry but few workers exceeded the inhalable limit. To remediate this pollutant, a ventilation system was recommended to pull the metal away from the worker breathing zone. Although this recommendation was given, the ventilation system is still in the design phase. For the time being, an update was made to the company's respiratory protection program to provide a suitable control measure until the ventilation system is installed.

Personal breathing zone sampling was conducted at the start of this project for crystalline silica. Elevated levels of crystalline silica were found which prompted bulk sampling to be taken at multiple points in the foundry. Elevated bulk samples were found closer to the west end of the foundry and it was assumed that motorized equipment tracked in crystalline silica from the outside soil. It was recommended that the west end back lot be paved to prevent further worker exposure. After the lot was paved, personal breathing zone sampling was then retested to verify the adequacy of the purposed control measure. It was found that the paving of the back lot had provided reasonable protection from crystalline silica exposure. Further testing in the future is recommended to verify results taken in this study.

Noise testing was performed in the Foundry, Machine Shop, Fabrication Shop and other areas throughout company property. It was found that the three main areas showing elevated levels of noise pollution were in the foundry and machine shop. Due to the fact that multiple areas of the facility were now required to fall under OSHA's Hearing Conservation Program, the company's hearing conservation program was updated and revised. These revisions, along with an evaluation of the current hearing protection provided by the company, were recommended as control measures for noise exposure. Further testing is always recommended to verify that the results found in this study are accurate and true.

Beyond further testing, keeping up with current safety and health practices will provide a way for this company, and all foundry workers, to prevent and ultimately hinder the progression of future hazards found in the workplace.

Bibliography

ACGIH. (2013). *Industrial Ventilation: A Manual of Recommended Practice for Design* (28th ed.). Cincinnati, Ohio: ACGIH.

Alton Materials. (2013, March 12). *The differences between ferrous and non-ferrous scrap metal*. Retrieved February 8, 2016, from http://www.altonmaterials.com/the-differences-between-ferrous-and-non-ferrous-scrap-metal/

American Industrial Hygiene Association. (2011). *The Occupational Environment: Its Evaluation, Control and Management* (3rd ed.). (D. H. Anna, Ed.) American Industrial Hygiene Association.

Center for Disease Control and Prevention. (2015, February 13). *Manganese compounds and fume (as Mn)*. Retrieved October 11, 2015, from NIOSH Pocket Guide to Chemical Hazards: http://www.cdc.gov/niosh/npg/npgd0379.html

de Souza, T., Périssé, A., & Moura, M. (2015, April 3). Noise exposure and hypertension: investigation of a silent relationship. *BioMed Central Public Health, 15*(328).

Deshaies, P., Martin, R., Belzile, D., Fortier, P., Laroche, C., Leroux, T., et al. (2015). Noise as an explanatory factor in work-related fatality reports. *Noise & Health, 17*(78), 294-299.

Gallaher, M. P., & Depro, B. M. (2002). *Economic Impact Analysis of Proposed Iron and Steel Foundries NESHAP*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park.

Guilarte, T. (August 2010). Manganese and Parkinson's Disease: A Critical Review and New Findings. *Environmental Health Perspectives*, 1071-1080.

Iregren, A. (1990, November-December). Psychological test performance in foundry workers exposed to low levels of manganese. *Neurotoxicology and Teratology, 12*(6), 673-675.

Jonderko, G., Kujawska, A., & Langauer-Lewowicka, H. (1971, September). Problems of chronic manganese poisoning on the basis of investigations of workers at a manganese alloy foundry. *Internationales Archiv für Arbeitsmedizin, 28*(3), 250-264.

Jugdaohsingh, R. (2007, Mar-Apr). Silicon and Bone Health. *The Journal of Nutrition, Health & Aging, 11*, 99-110.

Kallenberg, C. (1995). Renal disease—another effect of silica exposure? *Nephrology Dialysis Transplantation, 10*(7), 1117-1119.

Klaassen, C. D. (2013). *Toxicology: the Basic Science of Poisons* (8th ed.). New York: Mc Graw Hill.

Lander, F., Kristiansen, J., & Lauritsen, J. (1999, November). Manganese exposure in foundry furnacemen and scrap recycling workers. *International Archives of Occupational and Environmental Health, 72*(8), 546-550.

Manganese. (2015, October 10). Retrieved from New World Encyclopedia: http://www.newworldencyclopedia.org/entry/Manganese

Martin, K. R. (2007, Mar-Apr). The chemistry of silica and its potential health benefits. *The Journal of Nutrition, Health & Aging, 11*, 94-97.

McKinley, M. D., Jefcoat, I. A., Herz, W. J., & Frederick, C. L. (1994). *Waste Management Study of Foundries Major Waste Streams: Phase II.* Champaign: Hazardous Waste Research and Information Center (HWRIC).

Mehrizi Morteza, M., Hossein, K., Amirhossein, M., Naser, H., Gholamhossein, H., & Hossein, F. (2013, March). Designing, Construction, Assessment, and Efficiency of Local Exhaust Ventilation in Controlling Crystalline Silica Dust and Particles, and Formaldehyde in a Foundry Industry Plant. *Archives of Industrial Hygiene and Toxicology, 64*(1), 123-131.

Metal Technologies. (2013). *History of Metal Casting*. Retrieved February 8, 2016, from http://www.metal-technologies.com/docs/default-source/education/historyofmetalcasting.pdf?sfvrsn=8

National Institute of Neurological Disorders and Stroke. (2016, March 21). *NINDS Parkinson's Disease Information Page*. Retrieved March 23, 2016, from http://www.ninds.nih.gov/disorders/parkinsons_disease/parkinsons_disease.htm

New Jersey Department of Health and Senior Services. (2007, May). *Iron Oxide*. Retrieved February 8, 2016, from Hazardous Substance Fact Sheet: http://nj.gov/health/eoh/rtkweb/documents/fs/1036.pdf

O'Brien, D., Froehlich, P. A., Gressel, M. G., Hall, R. M., Clark, N. J., Bost, P., et al. (1992, January). Silica Exposure in Hand Grinding Steel Castings. *American Industrial Hygiene Association Journal, 53*(1), pp. 42-48.

Omidianidost, A., Ghasemkhani, M., Azari, M. R., & Golbabaei, F. (2015, July 30). Assessment of Occupational Exposure to Dust and Crystalline Silica in Foundries. *Journal of Respiratory Disease, Thoracic Surgery, Intensive Care and Tuberculosis, 14*(3), 208-212.

Oxford Learner's Dictionaries. (2016). *Foundry*. Retrieved February 8, 2016, from http://www.oxfordlearnersdictionaries.com/us/definition/english/foundry

Pandya, G., & Dharmadhikari, D. (2002). A Comprehensive Investigation of Noise Exposure in and Around an Integrated Iron and Steel Works. *American Industrial Hygiene Association Journal*, *63*(2), 172-177.

Parkins, T. N., Shukla, A., Peeters, P. M., Steinbacher, J. L., Landry, C. C., Lathrop, S. A., et al. (2012, February 2). Differences in Gene Expression and Cytokine Production by

Crystalline vs. Amorphous Silica in Human Lung Epithelial Cells. *Particle and Fibre Toxicology*.

Pollard, K. M. (2016, March 11). Silica, Silicosis, and Autoimmunity. *frontiers in Immunology*.

Robinson, J. (2012). *AN EVALUATION OF MN EXPOSURE IN A FOUNDRY VIA INTEGRATED AND DIRECT-READING XRF METHODS.* ProQuest.

Royal Society of Chemistry. (2016). *Manganese*. Retrieved March 23, 2016, from Periodic Table: http://www.rsc.org/periodic-table/element/25/manganese

Skogstad, M., Johannessen, H., Tynes, T., Mehlum, I., Nordby, K., & Lie, A. (2016, January). Systematic review of the cardiovascular effects of occupational noise. *Occupational Medicine, 10*(6), 10-16.

Steenland, K., Rong, Y., Liu, Y., Hnizdo, E., Huang, X., Zhang, H., et al. (2013). Exposure-Response Analysis and Risk Assessment for Lung Cancer in Relationship to Silica Exposure. *American Journal of Epidemiology*, 1424-1433.

Stredrick, D. L., Stokes, A. H., Worst, T. J., Freeman, W. M., Johnson, E. A., Lash, L. H., et al. (2004, April 10). Manganese-Induced Cytotoxicity in Dopamine-Producing Cells. *NeuroToxicity*, 543-553.

Sun, X., Liu, Y., Wang, Z., Li, H., Liu, Y., & Di, D. (2011, April 25). Effect of Occupational Manganese Exposure on Uric Acid Levels in Human Urine. *Biomedical and Environmental Sciences, 24*(3), 222-227.

The American Industrial Hygiene Association. (2003). *The Noise Manual* (5th ed.). (E. Berger, I. Royster, J. Royster, D. Driscoll, & M. Layne, Eds.) AIHA.

The American Industrial Hygiene Association. (2011). *The Occupational Environment: Its Evaluation, Control and Management* (3rd ed.). (D. Anna, Ed.) AIHA.

U.S. Department of Labor, Occupational Safety & Health Administration. (2015). *Permissible Exposure Limits - Annotated Table*. (Washington, DC: Government Printing Office) Retrieved October 11, 2015, from Electronic Code of Federal Regulations (Title 29, Subtitle B, Chapter XVII, Part 1910, Subpart Z, Section 1910.1000, Table Z-1): https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992

U.S. Department of Labor, Occupational Safety and Health Administration. (n.d.). *SAMPLE CALCULATIONS FOR CRYSTALLINE SILICA.* Retrieved from Appendix J: https://www.osha.gov/dts/osta/otm/otm_ii/pdfs/otmii_chpt1_appj.pdf

WELDING AND MANGANESE: POTENTIAL NEUROLOGIC EFFECTS. (2014, May 29). Retrieved from National Institute of Occupational Safety and Health: http://www.cdc.gov/niosh/topics/welding/

Yoon, J.-H., Hong, J.-S., Roh, J., Kim, C.-N., & Won, J.-U. (2015). Dose - response relationship between noise exposure and the risk of occupational injury. *Noise & Health*, *17*(74), 43-47.

Appendix A: Manganese Sampling Results by Worker

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (μg/m3)	8 Hour Extrapolated Data (μg/m3)	OSHA PEL (μg/m3)	ACGIH TLV (μg/m3)
Worker #1									
4/23/2015	RMn1	Grinding and welding	305	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	9.40	5.97	5000	5000
					Arsenic	1.00	0.64	10	10
					Beryllium	0.02	0.01	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	7.80	4.96	5000	2
					Chromium	1.10	0.70	500	
					Copper	6.80	4.32	100	200
					Iron	490.00	311.35	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.52	0.33	50	50
					Manganese	140.00	**88.96**	15000	20
					Nickel	6.30	4.00	1000	1500
					Selenium	1.00	0.64	200	200
					Silver	0.18	0.11	10	100
					Sodium	57.00	36.22		
					Zinc	1.00	0.64	5000	5000
4/23/2015	IMn1	Grinding and welding	305	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	25.00	15.89	5000	5000
					Arsenic	1.20	0.76	10	10
					Beryllium	0.01	0.00	2	2
					Cadmium	0.04	0.02	5	10
					Calcium	26.00	16.52	5000	2
					Chromium	4.10	2.61	500	
					Copper	9.00	5.72	100	200
					Iron	1500.00	953.13	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.73	0.46	50	50
					Manganese	270.00	**171.56**	15000	100
					Nickel	12.00	7.63	1000	1500
					Selenium	1.20	0.76	200	200
					Silver	0.31	0.20	10	100
					Sodium	81.00	51.47		
					Zinc	2.00	1.27	5000	5000

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (µg/m3)	8 Hour Extrapolated Data (µg/m3)	OSHA PEL (µg/m3)	ACGIH TLV (µg/m3)
Worker #2									
4/23/2015	RMn2	Grinding and welding	408	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	33.00	28.05	5000	5000
					Arsenic	0.74	0.63	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	18.00	15.30	5000	2
					Chromium	17.00	14.45	500	
					Copper	2.10	1.79	100	200
					Iron	310.00	263.50	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.37	0.31	50	50
					Manganese	27.00	**22.95**	15000	20
					Nickel	4.20	3.57	1000	1500
					Selenium	0.74	0.63	200	200
					Silver	0.09	0.08	10	100
					Sodium	19.00	16.15		
					Zinc	0.94	0.80	5000	5000
5/5/2015	RMn8	Grinding and welding	347	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	100.00	72.29	5000	5000
					Arsenic	5.30	3.83	10	10
					Beryllium	0.02	0.02	2	2
					Cadmium	0.06	0.05	5	10
					Calcium	55.00	39.76	5000	2
					Chromium	45.00	32.53	500	
					Copper	27.00	19.52	100	200
					Iron	3300.00	2385.63	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	1.30	0.94	50	50
					Manganese	360.00	**260.25**	15000	20
					Nickel	22.00	15.90	1000	1500
					Selenium	2.10	1.52	200	200
					Silver	0.68	0.49	10	100
					Sodium	150.00	108.44		
					Zinc	3.00	2.17	5000	5000
4/23/2015	IMn3	Grinding and welding	408	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	19.00	16.15	5000	5000
					Arsenic	0.93	0.79	10	10
					Beryllium	0.00	0.00	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	18.00	15.30	5000	2
					Chromium	12.00	10.20	500	
					Copper	1.60	1.36	100	200
					Iron	300.00	255.00	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.47	0.40	50	50
					Manganese	29.00	24.65	15000	100
					Nickel	3.50	2.98	1000	1500
					Selenium	0.93	0.79	200	200
					Silver	0.09	0.08	10	100
					Sodium	12.00	10.20		
					Zinc	0.72	0.61	5000	5000

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (µg/m3)	8 Hour Extrapolated Data (µg/m3)	OSHA PEL (µg/m3)	ACGIH TLV (µg/m3)
Worker #3									
4/23/2015	RMn3	Helping pour; Drag chain	420	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	14.00	12.25	5000	5000
					Arsenic	0.72	0.63	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	15.00	13.13	5000	2
					Chromium	2.50	2.19	500	
					Copper	1.30	1.14	100	200
					Iron	79.00	69.13		5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.59	0.52	50	50
					Manganese	38.00	**33.25**	15000	20
					Nickel	1.20	1.05	1000	1500
					Selenium	0.72	0.63	200	200
					Silver	0.07	0.06	10	100
					Sodium	7.20	6.30		
					Zinc	2.80	2.45	5000	5000
5/5/2015	RMn5	Helping pour; Drag chain	405	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	13.00	10.97	5000	5000
					Arsenic	0.75	0.63	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	16.00	13.50	5000	2
					Chromium	5.00	4.22	500	
					Copper	0.90	0.76	100	200
					Iron	61.00	51.47	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	0.86	0.73	50	50
					Manganese	18.00	15.19	15000	20
					Nickel	0.68	0.57	1000	1500
					Selenium	0.75	0.63	200	200
					Silver	0.08	0.06	10	100
					Sodium	3.70	3.12		
					Zinc	1.30	1.10	5000	5000
4/23/2015	IMn4	Helping pour; Drag chain	420	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	28.00	24.50	5000	5000
					Arsenic	0.90	0.79	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	30.00	26.25	5000	2
					Chromium	2.70	2.36	500	
					Copper	1.30	1.14	100	200
					Iron	150.00	131.25	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.72	0.63	50	50
					Manganese	41.00	35.88	15000	100
					Nickel	2.70	2.36	1000	1500
					Selenium	0.90	0.79	200	200
					Silver	0.09	0.08	10	100
					Sodium	14.00	12.25		
					Zinc	2.70	2.36	5000	5000
5/5/2015	IMn6	Helped pour; Drag chain	406	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	18.00	15.23	5000	5000
					Arsenic	0.98	0.83	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	31.00	26.22	5000	2
					Chromium	4.80	4.06	500	
					Copper	1.60	1.35	100	200
					Iron	140.00	118.42	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	0.95	0.80	50	50
					Manganese	64.00	54.13	15000	100
					Nickel	1.60	1.35	1000	1500
					Selenium	0.98	0.83	200	200
					Silver	0.10	0.08	10	100
					Sodium	7.50	6.34		
					Zinc	1.80	1.52	5000	5000

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (µg/m3)	8 Hour Extrapolated Data (µg/m3)	OSHA PEL (µg/m3)	ACGIH TLV (µg/m3)
Worker #4									
5/5/2015	RMn7	Drag chain, Furnace	396	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	25.00	20.63	5000	5000
					Arsenic	0.78	0.64	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	19.00	15.68	5000	2
					Chromium	1.80	1.49	500	
					Copper	1.00	0.83	100	200
					Iron	60.00	49.50	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	1.10	0.91	50	50
					Manganese	17.00	14.03	15000	20
					Nickel	0.93	0.77	1000	1500
					Selenium	0.78	0.64	200	200
					Silver	0.08	0.06	10	100
					Sodium	6.60	5.45		
					Zinc	1.50	1.24	5000	5000

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (µg/m3)	8 Hour Extrapolated Data (µg/m3)	OSHA PEL (µg/m3)	ACGIH TLV (µg/m3)
Worker #5									
4/23/2015	RMn4	Pouring	480	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	10.00	10.00	5000	5000
					Arsenic	0.64	0.64	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	11.00	11.00	5000	2
					Chromium	1.20	1.20	500	
					Copper	0.82	0.82	100	200
					Iron	50.00	50.00	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	1.10	1.10	50	50
					Manganese	50.00	**50.00**	15000	20
					Nickel	0.47	0.47	1000	1500
					Selenium	0.64	0.64	200	200
					Silver	0.06	0.06	10	100
					Sodium	4.60	4.60		
					Zinc	2.70	2.70	5000	5000
5/5/2015	RMn6	Pouring	461	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	17.00	16.33	5000	5000
					Arsenic	0.67	0.64	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	20.00	19.21	5000	2
					Chromium	3.70	3.55	500	
					Copper	1.30	1.25	100	200
					Iron	76.00	72.99	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	1.00	0.96	50	50
					Manganese	27.00	**25.93**	15000	20
					Nickel	0.82	0.79	1000	1500
					Selenium	0.67	0.64	200	200
					Silver	0.07	0.06	10	100
					Sodium	5.40	5.19		
					Zinc	2.00	1.92	5000	5000
5/7/2015	RMn10	Not Pouring	304	3600lbs, 3 Melts, 12-13% Manganese	Aluminum	21.00	13.30	5000	5000
					Arsenic	0.99	0.63	10	10
					Beryllium	0.02	0.01	2	2
					Cadmium	0.07	0.05	5	10
					Calcium	30.00	19.00	5000	2
					Chromium	10.00	6.33	500	
					Copper	1.20	0.76	100	200
					Iron	77.00	48.77	10000	5000
				5100lbs, 3 Melts, >1% Manganese	Lead	1.70	1.08	50	50
					Manganese	76.00	**48.13**	15000	20
					Nickel	2.80	1.77	1000	1500
					Selenium	0.99	0.63	200	200
					Silver	0.11	0.07	10	100
					Sodium	6.60	4.18		
					Zinc	4.20	2.66	5000	5000
5/7/2015	RMn11	Pouring	33	3600lbs, 3 Melts, 12-13% Manganese	Aluminum	41.00	2.82	5000	5000
					Arsenic	9.10	0.63	10	10
					Beryllium	0.11	0.01	2	2
					Cadmium	0.27	0.02	5	10
					Calcium	79.00	5.43	5000	2
					Chromium	5.00	0.34	500	
					Copper	1.80	0.12	100	200
					Iron	42.00	2.89	10000	5000
				5100lbs, 3 Melts, >1% Manganese	Lead	4.60	0.32	50	50
					Manganese	330.00	**22.69**	15000	20
					Nickel	0.97	0.07	1000	1500
					Selenium	9.10	0.63	200	200
					Silver	0.91	0.06	10	100
					Sodium	19.00	1.31		
					Zinc	9.50	0.65	5000	5000

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (µg/m3)	8 Hour Extrapolated Data (µg/m3)	OSHA PEL (µg/m3)	ACGIH TLV (µg/m3)
4/23/2015	IMn2	Pouring	481	4800lbs, 4 Melts, 12-13% Manganese	Aluminum	6.10	6.11	5000	5000
					Arsenic	0.78	0.78	10	10
					Beryllium	0.00	0.00	2	2
					Cadmium	0.02	0.02	5	10
					Calcium	8.20	8.22	5000	2
					Chromium	0.91	0.91	500	
					Copper	0.18	0.18	100	200
					Iron	30.00	30.06	10000	5000
				3600lbs, 3 Melts, >1% Manganese	Lead	0.66	0.66	50	50
					Manganese	20.00	20.04	15000	100
					Nickel	0.31	0.31	1000	1500
					Selenium	0.78	0.78	200	200
					Silver	0.08	0.08	10	100
					Sodium	2.20	2.20		
					Zinc	0.83	0.83	5000	5000
5/5/2015	IMn7	Pouring	461	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	19.00	18.25	5000	5000
					Arsenic	0.87	0.84	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	26.00	24.97	5000	2
					Chromium	3.80	3.65	500	
					Copper	1.60	1.54	100	200
					Iron	110.00	105.65	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	0.94	0.90	50	50
					Manganese	43.00	41.30	15000	100
					Nickel	1.30	1.25	1000	1500
					Selenium	0.87	0.84	200	200
					Silver	0.09	0.08	10	100
					Sodium	7.70	7.40		
					Zinc	2.10	2.02	5000	5000
5/7/2015	IMn13	Not Pouring	354	3600lbs, 3 Melts, 12-13% Manganese	Aluminum	20.00	14.75	5000	5000
					Arsenic	1.00	0.74	10	10
					Beryllium	0.01	0.00	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	38.00	28.03	5000	2
					Chromium	7.90	5.83	500	
					Copper	1.20	0.89	100	200
					Iron	130.00	95.88	10000	5000
				5100lbs, 3 Melts, >1% Manganese	Lead	1.30	0.96	50	50
					Manganese	89.00	65.64	15000	100
					Nickel	3.00	2.21	1000	1500
					Selenium	1.00	0.74	200	200
					Silver	0.10	0.07	10	100
					Sodium	8.00	5.90		
					Zinc	2.70	1.99	5000	5000
5/7/2015	IMn14	Pouring	33	3600lbs, 3 Melts, 12-13% Manganese	Aluminum	110.00	7.56	5000	5000
					Arsenic	12.00	0.83	10	10
					Beryllium	0.19	0.01	2	2
					Cadmium	0.36	0.02	5	10
					Calcium	110.00	7.56	5000	2
					Chromium	6.30	0.43	500	
					Copper	2.40	0.17	100	200
					Iron	190.00	13.06	10000	5000
				5100lbs, 3 Melts, >1% Manganese	Lead	11.00	0.76	50	50
					Manganese	590.00	40.56	15000	100
					Nickel	2.80	0.19	1000	1500
					Selenium	12.00	0.83	200	200
					Silver	1.20	0.08	10	100
					Sodium	64.00	4.40		
					Zinc	17.00	1.17	5000	5000

Sample Date	Sample Number	Task Performed	Sample Duration (minutes)	Total Weight, Pours & Percentage of Manganese	Metals Samples	Metal Sample results (μg/m3)	8 Hour Extrapolated Data (μg/m3)	OSHA PEL (μg/m3)	ACGIH TLV (μg/m3)
Area Sample									
5/5/2015	IMn8	Area Sample	480	3200lbs, 3 Melts, 12-13% Manganese	Aluminum			5000	5000
					Arsenic			10	10
					Beryllium			2	2
					Cadmium			5	10
					Calcium			5000	2
					Chromium			500	
					Copper			100	200
					Iron			10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead			50	50
					Manganese			15000	100
					Nickel			1000	1500
					Selenium			200	200
					Silver			10	100
					Sodium				
					Zinc			5000	5000
5/5/2015	IMn9	Area Sample	480	3200lbs, 3 Melts, 12-13% Manganese	Aluminum	18.00	18.00	5000	5000
					Arsenic	0.82	0.82	10	10
					Beryllium	0.01	0.01	2	2
					Cadmium	0.03	0.03	5	10
					Calcium	22.00	22.00	5000	2
					Chromium	1.20	1.20	500	
					Copper	0.68	0.68	100	200
					Iron	69.00	69.00	10000	5000
				9900lbs, 6 Melts, >1% Manganese	Lead	0.68	0.68	50	50
					Manganese	19.00	19.00	15000	100
					Nickel	0.82	0.82	1000	1500
					Selenium	0.82	0.82	200	200
					Silver	0.08	0.08	10	100
					Sodium	11.00	11.00		
					Zinc	1.30	1.30	5000	5000
5/7/2015	IMn11	Area Sample	438	3600lbs, 3 Melts, 12-13% Manganese	Aluminum	5.30	4.84	5000	5000
					Arsenic	0.87	0.79	10	10
					Beryllium	0.00	0.00	2	2
					Cadmium	0.03	0.02	5	10
					Calcium	5.60	5.11	5000	2
					Chromium	0.43	0.39	500	
					Copper	0.17	0.16	100	200
					Iron	7.60	6.94	10000	5000
				5100lbs, 3 Melts, >1% Manganese	Lead	0.43	0.39	50	50
					Manganese	6.70	6.11	15000	100
					Nickel	0.41	0.37	1000	1500
					Selenium	0.87	0.79	200	200
					Silver	0.09	0.08	10	100
					Sodium	1.60	1.46		
					Zinc	0.36	0.33	5000	5000
5/7/2015	IMn12	Area Sample	438	3600lbs, 3 Melts, 12-13% Manganese	Aluminum			5000	5000
					Arsenic			10	10
					Beryllium			2	2
					Cadmium			5	10
					Calcium			5000	2
					Chromium			500	
					Copper			100	200
					Iron			10000	5000
				5100lbs, 3 Melts, >1% Manganese	Lead			50	50
					Manganese			15000	100
					Nickel			1000	1500
					Selenium			200	200
					Silver			10	100
					Sodium				
					Zinc			5000	5000

Appendix B: Calculated Flow Rates

Table VIII: Manganese Calculated Flow Rates

ID#	Pump #	Pre-Cal	Post-Cal	Average	Time (min)	Rate x time	G/1000
RMn1	17	2.50	2.41	2.46	305	748.775	0.748775
RMn2	2	2.50	2.45	2.48	408	1009.8	1.0098
RMn3	15	2.50	2.44	2.47	420	1037.4	1.0374
RMn4	3	2.50	2.40	2.45	480	1176	1.176
RMn5	1	2.50	2.44	2.47	405	1000.35	1.00035
RMn6	2	2.50	2.38	2.44	461	1124.84	1.12484
RMn7	3	2.50	2.38	2.44	396	966.24	0.96624
RMn8	6	2.50	2.41	2.46	347	851.885	0.851885
RMn9	Blank Sample						
RMn10	1	2.50	2.46	2.48	304	753.92	0.75392
RMn11	8	2.50	2.47	2.49	33	82.005	0.082005
IMn1	16	2.00	1.98	1.99	305	606.95	0.60695
IMn2	12	2.00	1.99	2.00	481	959.595	0.959595
IMn3	14	2.00	1.96	1.98	408	807.84	0.80784
IMn4	10	2.00	1.96	1.98	420	831.6	0.8316
IMn5	14	2.02	1.79	1.91	397	756.285	0.756285
IMn6	9	2.01	1.74	1.88	406	761.25	0.76125
IMn7	8	2.00	1.75	1.88	461	864.375	0.864375
IMn8	12	2.04	1.77	1.91	480	914.4	0.9144
IMn9	13	2.02	1.79	1.91	480	914.4	0.9144
IMn10	Blank Sample						
IMn11	13	2.00	1.98	1.99	438	871.62	0.87162
IMn12	12	2.01	1.98	2.00	438	873.81	0.87381
IMn13	2	2.03	2.00	2.02	354	713.31	0.71331
IMn14	9	2.00	2.00	2.00	33	66	0.066

Key	
(blue)	Taken on 4/23/2015
(peach)	Taken on 5/5/2015
(green)	Taken on 5/8/2015

Table IX: Post PBZ Crystalline Silica Flow Rate

ID#	Pump #	Pre-Cal	Post-Cal	Average	Time (min)	Rate x time (L)	G/1000 (m3)
CS01	2	2.50	2.46	2.47	348	859.56	0.860
	10	2.50	2.45				
CS02	4	2.50	2.49	2.50	380	948.10	0.948
CS03	9	2.50	2.47	2.49	397	986.55	0.987
CS04	11	Blank					0.324
CS05	14	2.50	2.46	2.48	96	238.08	0.238

Appendix C: 4/23/2015 Dosimeter Data and Results

Person	Job Duty	Dosimeter #	Pre-Cal	Post-Cal	Average	Time Start		Time Off	Total Time (min)	Comments
							Lunch Time			
Employee #1	Little of everything	2	114.0	113.9	113.95	8:00	Kept on	4:08	488	Mufflers weren't being used. On hardhat.
Employee #2	Furnace and welding	3	114.0	113.9	113.95	8:05	Kept on	3:58	473	Jacket was put on and dosimeter moved out of hearing zone. Reput back in place at 9:29

	PEL		Hearing Conservation		ACGIH	
	Original	*Extrap.*	*Original*	*Extrapolated*	*Original*	*Extrap.*
4/23/2015						
Dosimeter #	**3**					
Total Time	7:34:00				No ACGIH collected	
Las						
Lasmax	114.5					
Average	74.6		80.9			
TWA	74.2	74.62	80.5	75.92		
Dose %	11.22%	11.86%	26.86%	28.40%		
UL 115						
Dosimeter #	**2**					
Total Time	7:38:00				No ACGIH collected	
Las						
Lasmax	124.1					
Average	81.6		84.2			
TWA	81.3	81.59	83.8	79.17		
Dose %	29.74%	31.17%	42.54%	44.58%		
UL 115						

Appendix D: 5/5/2015 Dosimeter Data and Results

Person	Job Duty	Docimeter #	Average Calibration	Time Start	Lunch Time	Time Off	Total Time (hr)	Total Time (min) without Lunch taken out	Total Time (min) with Lunch taken out	Comments
Employee #1	**Tube Bundles**	2	114.00	10:25	Took off: 11:51 Returned: 12:36	15:48	5:23	323	278	Tube Bundles werent being worked on yet this day
Employee #2	**Welding in foundry**	3	114.00	8:25	Never left the site. Didn't take off	15:06	6:41	401		
Employee #3	**Welding shop; ergonomic welding area**	4	114.00	8:38	Took off: 12:00 Returned: 12:35	15:47	7:09	429	394	
Employee #4	**Pourer in foundry**	5	114.00	7:51	Never left the site. Didn't take off	15:29	7:38	458		
Employee #5	**Machine shop; Rod turning area**	6	114.00	8:34	Never left the site. Didn't take off	15:51	7:17	437		
Employee #6	**Welding shop; grinding and welding on large cylinder. Younger guy**	9	114.00	8:10	Never left the site. Didn't take off	15:45	7:35	455		
Employee #7	**Foundry; shakeout and assistant pourer**	10	114.00	7:55	Took off: 11:55 Returned: 12:50	15:32	7:37	457	402	Rubbed against docimeter at 12:38 on accident
Employee #8	**Foundry; molding area @ first then moved to shake out**	11	114.00	8:04	Never left the site. Didn't take off	15:25	7:21	441		Tapped his hand on the docimeter at 12:55. Also wears a 3M Optime 95 respirator
Employee #9	**Welding shop; plasma cutting area**	12	114.00	8:07	Never left the site. Didn't take off	15:46	7:39	459		Wears earplugs
Employee #10	**Foundry; By the welding and grinding area all day**	13	114.00	7:58	Took off: 12:00 Returned: 12:53	15:08	7:10	430	377	

	PEL		Hearing Conservation		ACGIH	
	Original	*Extrap.*	*Original*	*Extrapolated*	*Original*	*Extrap.*
5/5/2015						
Dosimeter #	**13**					
Total Time	6:41:46				No ACGIH	
Las	63.1					
Lasmax	138.6					
Average	83.5		86.1			
TWA	82.2	83.47	84.8	81.04		
Dose %	33.89%	40.47%	48.34%	57.72%		
UL 115	0:00:15					
Dosimeter #	**3**					
Total Time	6:42:27					
Las	60.1					
Lasmax	117.1					
Average	92.1		92.5		96.4	
TWA	90.9	92.1	91.2	87.5	95.6	95.6
Dose %	112.50%	134.33%	118.40%	141.37%	362.40%	432.72%
UL 115	0:00:02					
Dosimeter #	**2**					
Total Time	5:23:22					
Las	63.1					
Lasmax	106.6					
Average	69.0		80.2		83.9	
TWA	66.1	69.0	77.3		82.2	
Dose %	3.65%	5.42%	17.20%	25.58%	52.81%	
UL 115	0:00:00					
Dosimeter #	**4**					
Total Time	7:10:01				No ACGIH	
Las	63.1					
Lasmax	112.9					
Average	83.7		87.3			
TWA	83.0		86.5			
Dose %	37.58%	41.95%	61.40%			
UL 115	0:00:00					
Dosimeter #	**5**					
Total Time	7:37:44				No ACGIH	
Las	63.2					
Lasmax	139.0					
Average	92.1		93.1			
TWA	91.7		92.8			
Dose %	126.70%		146.80%			
UL 115	0:02:06					

Dosimeter #	**11**				
Total Time	7:21:49				No ACGIH
Las	63.1				
Lasmax	121.4				
Average	88.5		89.8		
TWA	87.9		89.2		
Dose %	74.54%		88.87%		
UL 115	0:04:47				
Dosimeter #	**12**				
Total Time	7:38:10				No ACGIH
Las	63.2				
Lasmax	119.2				
Average	85.2		86.9		
TWA	84.8		86.5		
Dose %	48.79%		61.78%		
UL 115	0:00:03				
Dosimeter #	**6**				
Total Time	7:16:48				No ACGIH
Las	63.1				
Lasmax	104.3				
Average	75.6		84.6		
TWA	74.9		83.9		
Dose %	12.36%		42.70%		
UL 115	0:00:00				
Dosimeter #	**9**				
Total Time	7:35:12				No ACGIH
Las	65.0				
Lasmax	116.9				
Average	89.5		90.7		
TWA	89.1		90.3		
Dose %	88.62%		103.90%		
UL 115	0:00:04				
Dosimeter #	**10**				
Total Time	7:36:53				No ACGIH
Las	63.9				
Lasmax	140.9				
Average	93.4		94.3		
TWA	93.1		94.0		
Dose %	152.80%		172.80%		
UL 115	0:02:59				

Appendix E: 5/7/2015 Dosimeter Data and Results

Person	Job Duty	Docimeter #	Pre-Cal	Post-Cal	Average	Time Start			Time Off	Total Time without Lunch taken out	Time Actually on the person
							Lunch Time	Total time without dosimeter on for lunch (min)			
Employee # 1	Sand Blasting Area/Paint Shop	2	114.0	113.8	113.90	10:04	Took off: 11:45 Returned: 12:48	63	15:53	5:49	4:46
Employee # 2	Tube Bundles	3	114.0	113.8	113.90	10:08	Took off: 11:45 Returned: 12:31	44	15:53	5:45	5:01
Employee # 3	Plasma Cutter in Welding Shop	4	114.0	114.0	114.00	10:32	Left On for Lunch	0	15:41	5:09	5:09
Employee # 4	Cleaning and a bit of everything in the Machine Shop	5	114.0	114.1	114.05	10:41	Took off: 11:55 Returned: 12:44	49	15:49	5:08	4:19
Employee # 5	Welding in Welding Shop	6	114.0	113.9	113.95	10:36	Took off: 11:55 Returned: 12:42	47	15:40	5:04	4:17
Employee # 6	Tube Bundles	7	114.0	113.8	113.90	10:09	Took off: 12:00 Returned: 12:36	36	15:54	5:45	5:09
Employee # 7	Back Fab Shop/Welding	8	114.0	113.9	113.95	10:10	Took off: 12:00 Returned: 12:40	40	15:45	5:35	4:55
Employee # 8	Rod Turning in Machine Shop	9	114.0	114.1	114.05	10:38	Left On for Lunch	0	15:37	4:59	4:59
Employee # 9	Tack Welding, Back Fab Shop, Possible Grinding	10	114.0	113.9	113.95	10:15	Left On for Lunch	0	15:50	5:35	5:35
Employee # 10	Welding Shop on Round Cylinder	11	114.0	113.9	113.95	10:30	Left On for Lunch	0	15:42	5:12	5:12
Employee # 11	Bending and Rolling; Back Fab Shop	12	114.0	114.0	114.00	10:15	Left On for Lunch	0	15:46	5:31	5:31
Employee # 12	Welding in Middle Shop by Tube Bundles	13	114.0	113.9	113.95	10:25	Left On for Lunch	0	15:53	5:28	5:28

	PEL		Hearing Conservation		ACGIH	
	Original	*Extrap.*	*Original*	*Extrapolated*	*Original*	*Extrap.*
5/7/2015						
Dosimeter #	**2**					
Total Time	5:50:30					
Las	66.0					
Lasmax	110.4					
Average	74.5		77.8		85.3	
TWA	72.2		75.5		84.0	
Dose %	8.48%		13.37%		78.83%	
UL 115	0:00:00					
Dosimeter #	**3**					
Total Time	5:45:32					
Las	64.8					
Lasmax	119.8					
Average	97.4		97.7		101.0	
TWA	95.1		95.3		99.6	
Dose %	201.80%		207.70%		907.60%	
UL 115	0:00:06					
Dosimeter #	**7**					
Total Time	5:44:32					
Las	64.8					
Lasmax	119.6					
Average	73.0		83.0		87.5	
TWA	70.6		80.6		86.0	
Dose %	6.82%		27.16%		40.16%	
UL 115	0:00:06					
Dosimeter #	**8**					
Total Time	5:31:31					
Las	66.0					
Lasmax	118.4					
Average	70.0		75.4		83.4	
TWA	67.4		72.7		81.7	
Dose %	4.33%		9.09%		14.93%	
UL 115	0:00:02					

Dosimeter #	**10**				
Total Time	5:35:41				No ACGIH
Las	67.8				
Lasmax	117.4				
Average	74.0		77.5		
TWA	71.4		74.9		
Dose %	7.62%		12.29%		
UL 115	0:00:02				
Dosimeter #	**12**				
Total Time	5:29:17				No ACGIH
Las	66.0				
Lasmax	116.2				
Average	69.3		75.9		
TWA	66.6		73.2		
Dose %	3.88%		9.73%		
UL 115	0:00:01				
Dosimeter #	**13**				
Total Time	5:27:41				No ACGIH
Las	69.7				
Lasmax	116.7				
Average	75.3		81.4		
TWA	72.5		78.7		
Dose %	9.87%		20.70%		
UL 115	0:00:01				
Dosimeter #	**11**				
Total Time	5:12:25				No ACGIH
Las	63.2				
Lasmax	127.5				
Average	88.2		89.4		
TWA	85.1		86.3		
Dose %	50.42%		59.88%		
UL 117/115	0:00:08				

Dosimeter #	**4**				
Total Time	5:09:54				No ACGIH
Las	63.9				
Lasmax	121.5				
Average	82.6		85.6		
TWA	79.5		82.4		
Dose %	23.17%		34.95%		
UL 115	0:00:06				
Dosimeter #	**6**				
Total Time	5:03:55				No ACGIH
Las	63.6				
Lasmax	119.2				
Average	81.3		86.2		
TWA	78.0		82.9		
Dose %	18.95%		37.31%		
UL 115	0:00:02				
Dosimeter #	**9**				
Total Time	4:59:27				No ACGIH
Las	68.4				
Lasmax	106.2				
Average	61.7		77.4		
TWA	58.3		74.0		
Dose %	1.23%		10.84%		
UL 115	0:00:00				
Dosimeter #	**5**				
Total Time	5:08:04				No ACGIH
Las	63.9				
Lasmax	109.7				
Average	78.4		80.2		
TWA	75.5		77.0		
Dose %	13.36%		6.49%		
UL 115	0:00:00				

Appendix F: Respiratory Audit Report Questions

Respiratory Program Audit - 1/19/2016							
#	**OSHA Standard and/or Program Details**	**Ok?**	**Worker #1**	**Worker #2**	**Worker #3**	**Worker #4**	**Worker #5**
1	Management will provide the necessary respirators to its employees who work in areas where the % oxygen content is between 19.5-23.5%.						
2	Management will provide, at no cost to the employee, medical surveillance testing to confirm that the worker is medically fit for duty.		Fit test given at hire, last one a year ago. Medical survey given at hire.	Fit test given at hire, none since. Medical survey given at hire	Fit test given at hire, none since. Medical survey given at hire	Fit test given at hire, none since. Medical survey given at hire	Fit test given at hire, last one given in 2011. Medical survey given at hire & once a year
3	Management will be responsible for updating this program as new types of respirators used in the workplace change.						
4	Management will provide proper training on all things related to respirators.		Last training was a bit ago, maybe 2-3 months	Doesn't remember training	Training was recently	Had training but has been a while	Every 6 months, don't remember last time
5	Management will be responsible for verifying that supervisors follow the following standards.						

6	Supervisors will ensure that their employees have up to date fit tests for every respirator that they use.						
7	Supervisors are responsible to verify that employees comply with the following standards.						
8	Employees are responsible to clean and maintain their individual respirator.		Cleans every now and then, maybe once a week	Cleans every now and then	Cleans every now and then, disposible respirators so gets rid of them as needed	Cleans every now and then, disposible respirators so gets rid of them as needed	Clean once a week or so
9	Each employee is responsible to understand and follow the guidelines hereafter stated in the respiratory protection program						
10	Each employee is responsible to wear the appropriate respirator that they have been assigned by management						
11	It is the responsibility of the employee to report any damage or problem with their respirator						

12	Respirators will be provided to all AFFCo employees that work in environments where work hazards to protect employees from known workplace hazard(s).						
13	The only respirators that will be used on AFFCO property will be NIOSH approved respirators.						
14	N95's will be used in certain areas and at certain times at AFFCo such as when pouring and stainless steel welding occur.						
15	When using the sandblaster, a supplied air respirator will be used to supply air to the worker inside the room.						
16	Before an employee will don any respirator or be fit tested, the employee will have do the following: 1. Completed a company medical evaluation form 2. Completed the OSHA Questionnaire 3. Visit ProMed Services for evaluation		Did at hire	Did at hire	Did at hire	Did at hire	Did at hire

17	If the employee requires a follow up examination, the company will make sure that the employee sees the medical professional for further follow up.						
18	If the employee at any time does not want to see the medical professional provided by the company, that employee will either be reassigned or terminated from the current job where a respirator is needed.						
19	After an employee has received medical clearance from the medical professional, they will then be fit tested to the specific respirator(s) that they will be using in their job.						
20	The company will fit test using the qualitative fit testing procedures						
21	The person will perform a fit test: a. Before the initial use of the respirator(s) b. Whenever a different respirator face-piece (size, style, model and/or make) is used		Fit test is not performed annually, but one was performed in the last year for him	Fit test is not performed annually	Fit test is not performed annually	Fit test is not performed annually	Fit test is not performed annually

	c. Annually						
22	If at any time that the employee's physical condition changes, ie severe facial scarring, cosmetic surgery, dental changes, the employee will then receive a new fit test regardless of when their last test was performed.						
23	No facial hair is permitted on workers who's use a respirator		Goatee	Goatee	has stubble	has stubble	has stubble
24	If an employee wears glasses of any sort, than they will need to be worn in a way that it will not interfere with the overall integrity of the respirator				Has some but are worn outside of work		
25	Alteration of any kind to the respirator is prohibited						

26	Before each and every use, employees will perform a seal check to ensure a proper seal is obtained on that respirator depending on the manufacturer's instructions.		Seal check is semi-performed	Straps are checked but I positive and negative air checks are not perfomed	Straps are tightened but not positive or negative seal checks. Gets rid of it when he can smell manganese	Straps are tightened but not positive or negative seal checks. Gets rid of it when he can smell manganese	Everytime
27	If at any time the scope of the project requires a different respirator to protect from another chemical that the current respirator cannot, the area will be reevaluated and if needed, another respirator and fit test will be given to the worker						
28	If there are any signs of damage, or the worker can detect that the respirator is not effectively performing its job, the worker will then need to leave the area and inform management for further instruction.				Throws it away and grabs a new one	Throws it away and grabs a new one	Checked weekly
29	Respirators will be cleaned and disinfected every time they are won by someone else.	Each have their own					

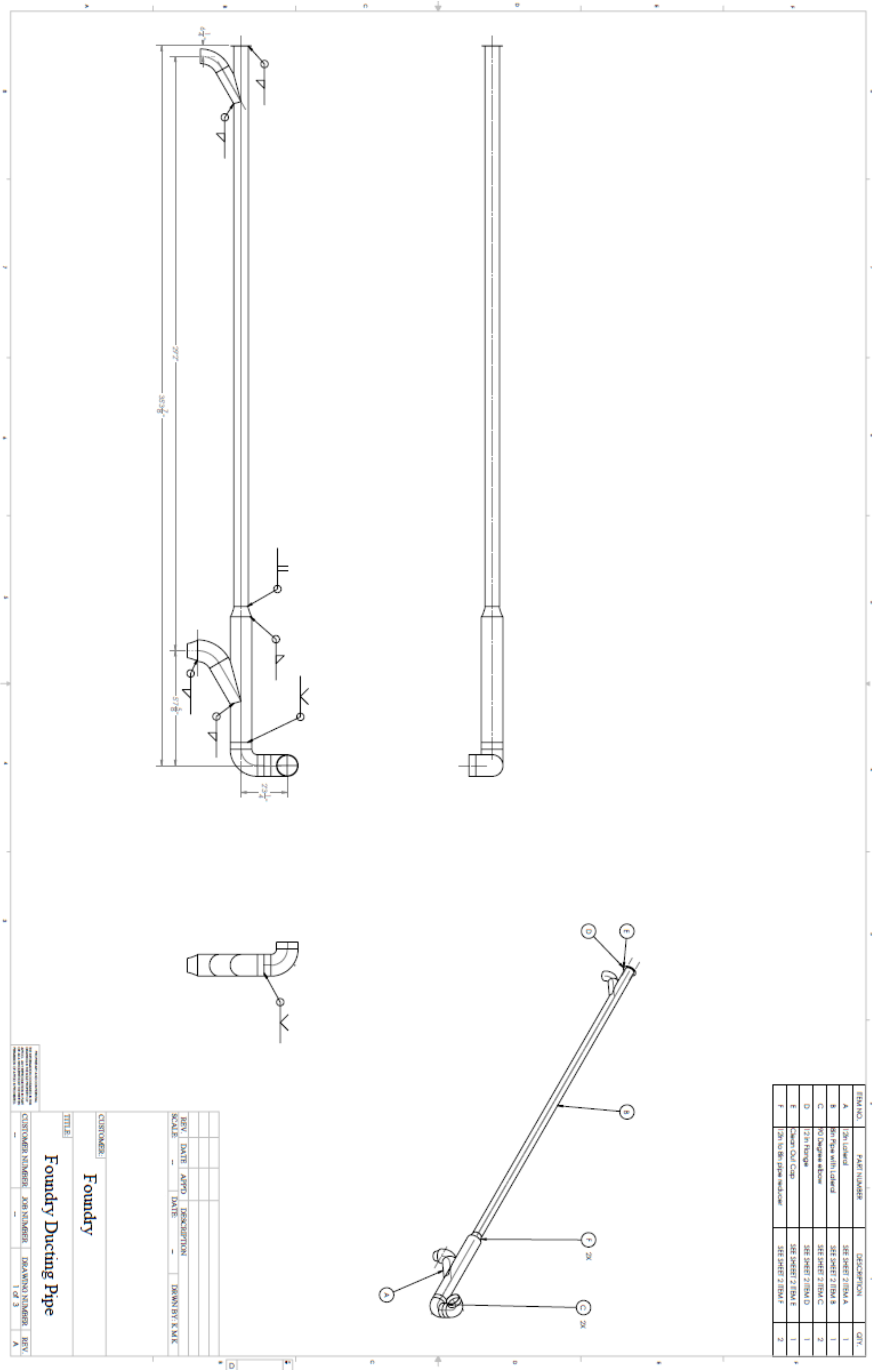
30	If a respirator is only worn by one person, then that person will clean and disinfect that respirator often enough where it can maintain a sanitary condition.	Each have their own					
31	Respirators will also be cleaned after every fit test.						
32	Respirators will be stored in a clean and neat area that is protected from sunlight or other chemicals that will deteriorate the integrity of the respirator		Stored in bag in locker	Stored in locker, left out hanging when working	Stored in bag inside pouring area shack	Stored in bag inside pouring area shack	Stored in bag inside cabinet in the paint shop
33	All respirators will be inspected before each use and after every cleaning.		bi-monthly cleaning	Never really cleans it	usually inspected prior to use	inspected sometimes	Inspected every time its put on
34	If there are problems with the respirator, that respirator will not be donned.						

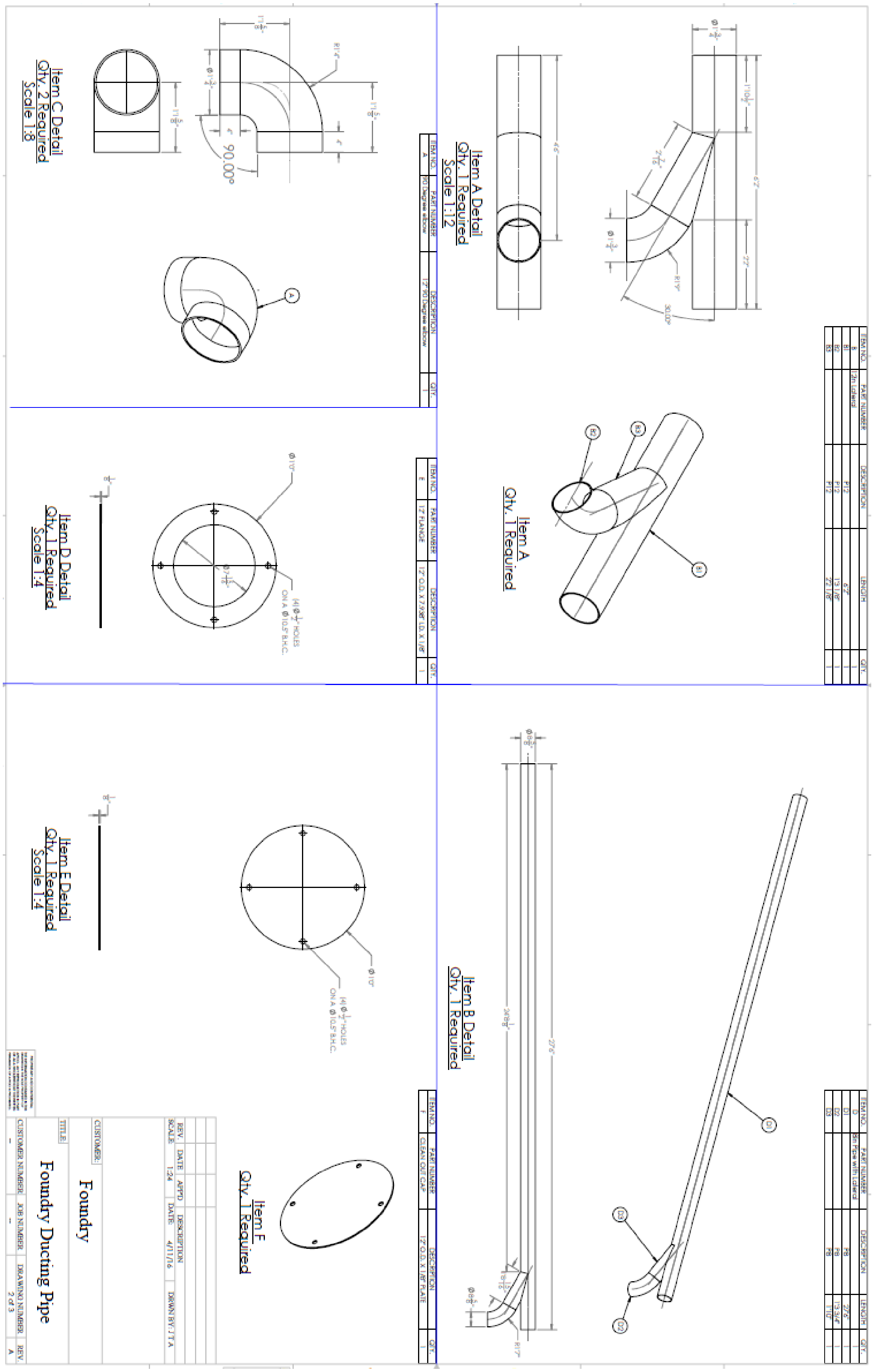
35	A visual inspection of the following should be noted for any sign of damage. i. Damage to the straps ii. If using an elastomeric respirator, the pliability of the elastomeric parts iii. Missing pieces iv. Damage to the connecting tubes and/or valves v. Are the cartridges, canisters or filters past their usage date?						
36	If there are any air canisters located on site, a monthly check of those canisters are needed to make sure air is still supplied therein.						
37	If any repairs are needed, they will be performed by a trained technician or new ones issued.						
38	Cartridge change out schedule will be per the manufacturer's recommendations, with consideration given to NIOSH for any specifics that they may have come up with.						

39	Respiratory protection training will be given before the employee first don’s a respirator. It will then occur at the minimum annually thereafter.		Given at start of employment and various times afterwards	Given at start of employment and annually	Training was not given and/or does not remember respiratory training	Given at start of employment but not afterwards	Not given at start of employment but had some since
40	Training will consist of the following:a. Why is the respirator necessaryb. How improper use can affect the overall integrity of the productc. Limitations and capabilities of the respiratord. How to use the respirator in emergency situationsi. How to manage respirator malfunctionse. How to…i. Inspectii. Put oniii. Removeiv. Usev. Check proper sealsf. Procedures for maintenance and storageg. Recognize potential medical signs and symptoms that may limit or prevent respirator effectiveness						
41	This program will be evaluated on a needs basis depending on any respiratory changes that occur in the workplace.						

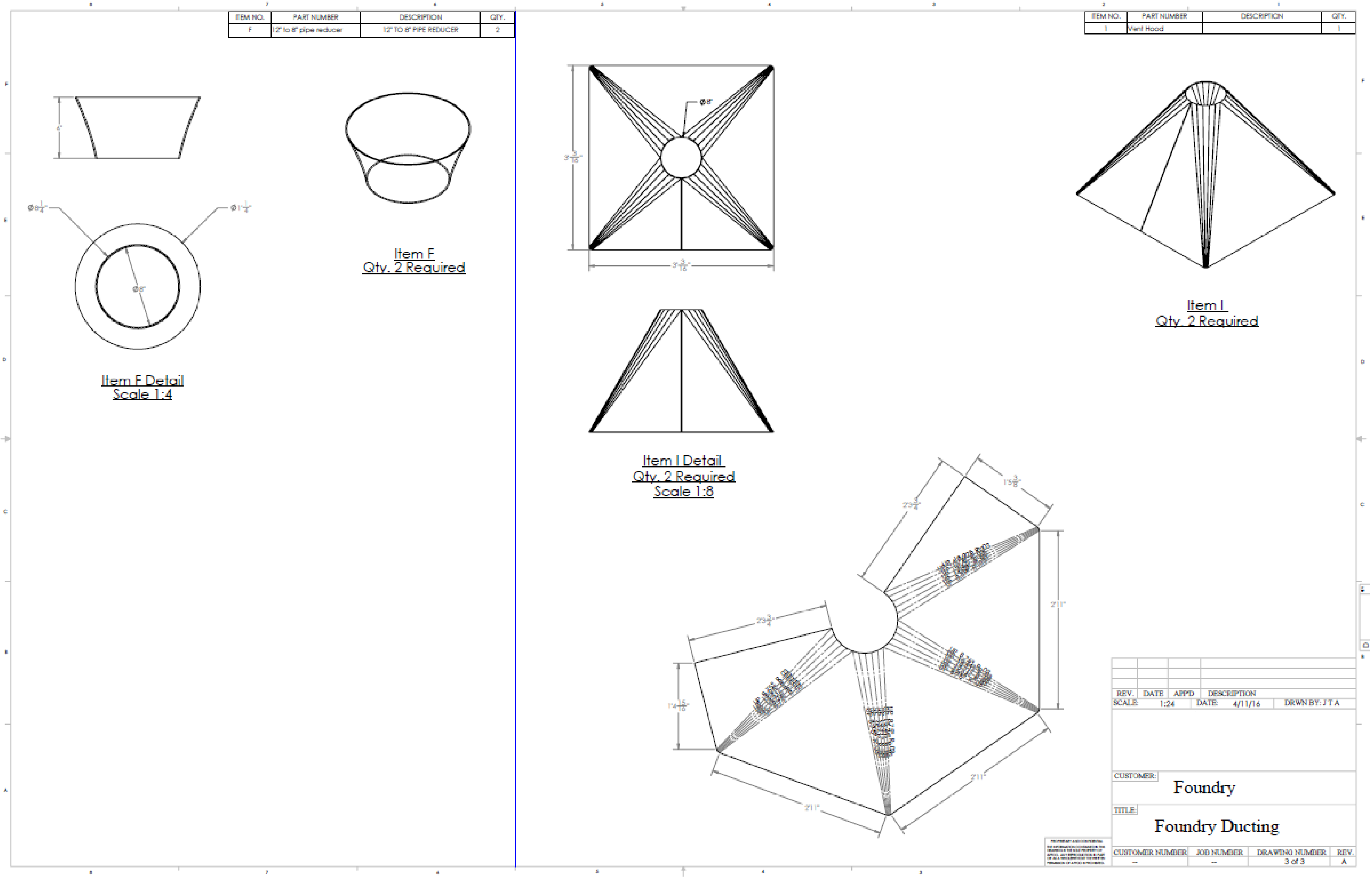
42	The following written information will be kept on file at the workplace.a. Medical evaluation will be kept for the length of employment plus 30 yearsb. Fit testing records will be kept until the next fit test is performed for each workeri. The fit test will include the following information:1. Name and/or identification of employee2. Type of fit test being performed3. Specific make, model, style and size of the respirator tested4. Date of test5. Pass or Fail notification marked on documentc. Respiratory protection program will be kept until new changes are made.						

Appendix G: Ventilation Blueprints





Item C Detail
Qty. 2 Required
Scale 1:8
90.00°
Item A Detail
Qty. 1 Required
Scale 1:12
Item A
Qty. 1 Required
Item D Detail
Qty. 1 Required
Scale 1:4
Item E Detail
Qty. 1 Required
Scale 1:4
Item B Detail
Qty. 1 Required
Item F
Qty. 1 Required
CUSTOMER:
Foundry
TITLE:
Foundry Ducting Pipe


ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
F | 12" to 8" pipe reducer | 12" TO 8" PIPE REDUCER | 2
Item F Detail
Scale 1:4
Item F
Qty. 2 Required
ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
1 | Vent Hood | | 1
Item I Detail
Qty. 2 Required
Scale 1:8
Item I
Qty. 2 Required
2'11"
REV. DATE APP'D DESCRIPTION
SCALE: 1:24 DATE: 4/11/16 DRWN BY: J T A
CUSTOMER:
Foundry
TITLE:
Foundry Ducting
CUSTOMER NUMBER -- JOB NUMBER -- DRAWING NUMBER 3 of 3 REV. A

SIGNATURE PAGE

This is to certify that the thesis prepared by Jeshua Sargetis entitled "Evaluation of Particulate Metal & Noise Exposures at a Foundry & Recommended Control Strategies" has been examined and approved for acceptance by the Department of Safety, Health, and Industrial Hygiene, Montana Tech of The University of Montana, on this 2nd day of May, 2016.

Julie Hart, CIH, PhD, Professor and Department Chair
Department of Safety, Health, and Industrial Hygiene
Chair, Examination Committee

Terry Spear, PhD, Emeritus Professor
Department of Safety, Health, and Industrial Hygiene
Member, Examination Committee

Xufei Yang, PhD, Assistant Professor
Department of Environmental Engineering
Member, Examination Committee