Evaluating Dust Exposure from Steel Manufacturing Electrical Arc Furnaces

by

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ABSTRACT

The purpose of this study was to identify and assess dust exposure in Electrical Arc Furnaces for steel manufacturing. The major concern of steel making processes is dust generation and accumulation. The scope of this research paper focuses on different ways to improve current controls and make recommendations. In order to achieve the purpose, various goals were developed to identify the extent of exposure. The researcher measured the level of dust concentration in Company XYZ, examined the controls of dust exposure and evaluated current controls. Problem areas were identified using pumps and filters. Eight samples were taken in order to identify the areas with the highest concentration of dust. This study consisted of topics such as EAF Electrical Arc Furnace process, standards and guidelines, health factors and fire exposure.

Workers at Company XZY are being exposed to metal dust produced from EAF during the DRI process. This study identifies problem areas, evaluates dust control processes, and presents recommendations. The results of this study will enable Company XYZ to implement changes which will reduce dust exposure to workers and decrease health and safety risks. This process at Company XYZ are exposing to metal dust that produced from EAF using DRI process. As a result, recommendations are included in the study to improve current control at Company XYZ.

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Chapter I: Introduction

There are many processes for manufacturing steel. All share a common problem: fugitive particulates emission, hereafter called dust. When oxygen is removed from iron, dust occurs. Dust also results when steel is melted. This dust is called metal dust. It is combustible and it is respirable. Excessive dust in a workplace contributes to health hazards and industrial problems such as fire explosion and equipment failure.

Company XYZ, a steel manufacturing company located in the Middle East, uses a process called Direct Reduction. A Direct Reduction process is another way of producing iron. This process has been discovered to overcome some difficulties of blast furnaces. Direct Reduction of Iron (DRI) is a manufacturing process used in various parts of the world. This process uses gas or coal based technology. Company XYZ is the world's largest Direct Reduction plant with an annual production capacity of 1.76 million tons of direct reduced iron (DRI). The operating cost of the Direct Reduction process is low compared to other steel manufacturing processes. Also, it is more useful for many developing countries where supplies of coal are limited.

This steel manufacturing company produces steel using hot transport system directly into an Electric Arc Furnace (EAF). The working mechanism of Company XYZ to make steel adds the hot transport of DRI from Direct Reduction (DR) plant to EAF via a hot transport system. By using this mechanism, the process of making steel will help to reduce electric steelmaking costs and tap-to-tap times. This facility is comprised of 4000 employees including contractors. Steel production at Company XYZ is based on the melting of scrap and DRI in a ratio of 25% scrap and 75% DRI. This melting process carries out into the EAF at temperatures exceeding 650 °C (1202 °F).

Statement of the Problem

The process of making steel creates dust. Concerns have been expressed about dust inhalation exposure which leads to lung diseases and other health problems such as: irritation to eyes, ears, nose, throat and skin. Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH) and health care professionals address dust in workplace and its consequences. Company XYZ's management is concerned about the employees' exposure to dust. The dust could contribute to health hazards and industrial explosion.

Purpose of the Study

The purpose of this study is to determine the extent of iron dust exposure produced by Electrical Arc Furnaces during the steel making process. Moreover, this study will examine the safety and health consequences associated with the dust exposure to workers.

Goals of Study

In order to evaluate the dust exposure to a specific worker in the Electrical Arc Furnaces area of the steel making process, the following steps should be taken:

- Examine the process of manufacture Company XYZ
- Measure the concentration level of total dust
- Evaluate current dust control/prevention systems in place

Limitation of the Study

1. Total dust will be measured instead of using respirable dust of inhalation dust.
2. Iron dust will be assumed to be a part of total dust collected because of the lack of laboratory tests.

Significance

The study will help Company XYZ to identify dust production and the severity of dust in the workplace. In turn, this study will help to reduce workers' injuries/illnesses due to dust. The process evaluation will help to identify the areas that contribute to dust. Measuring dust concentration will enable the researcher to categorize the severity of the dust in the workplace. Also, this study will help to improve the current control system to reduce the dust hazards for both health and safety.

Definition of Terms

Acute- In medicine, an acute disease is a disease with either or both of: a rapid onset, or a short course as opposed to a chronic course.

Alloy Steel- An iron-based mixture is considered to be an alloy steel when manganese is greater than 1.65%, silicon over 0.5%, copper above 0.6%, or other minimum quantities of alloying elements such as chromium, nickel, molybdenum, or tungsten are present. An enormous variety of distinct properties can be created for the steel by substituting these elements in the recipe (Applebaum, 2004).

Baghouse- An air pollutant control device used to trap particles by filtering gas streams through large cloth or fiberglass bags (Applebaum, 2004).

Casting- The process of pouring molten metal into a mould so that the cooled, solid metal retains the shape of the mould (Applebaum, 2004).

Chronic- A persistent and lasting disease or medical condition, or one that has developed slowly.

Direct Reduced Iron (DRI)- Processed iron ore that is iron-rich enough to be used as a scrap substitute in electric furnace steelmaking (Applebaum, 2004).

Electric Arc Furnace (EAF)- Steel-making furnace where scrap is generally 100% of the charge. Heat is supplied from electricity that arcs from the graphite electrodes to the metal bath. Furnaces may be either an alternating current (AC) or direct current (DC). DC units consume less energy and fewer electrodes, but they are more expensive (Applebaum, 2004).

Fugitive Particulate- Emissions that are not collected by the emission control systems.

Maximum Exposure Limit- Refers to the most any human being can ingest, inhale, absorb, or takeover levels of an exposure that will cause serious or permanent health damage.

Pellets- Iron ore or limestone particles rolled into little balls in a balling drum and hardened by heat.

Pneumoconiosis- an occupational lung disease caused by the inhalation of dust.

Respirable Dust- Dust particles that are small enough to travel deep into the lungs.

Short Term Exposure Limit (STEL)- The most exposure allowed for worker exposure.

SKC- the leading manufacturer and supplier of air sampling products.

Chapter II: Literature Review

Company XYZ's employees working in the Electrical Arc Furnace area of the steel manufacturing process encounter dust. This chapter will present a review of literature that relates to the production of dust by Arc Furnaces. Furthermore, this chapter will describe the significant problems of dust particles and dust control/prevention systems.

Production of Dust by Arc Furnaces.

Steel requires an arc furnace, and there are three types of arc furnaces, all based on electrodes to which the current is supplied:

- Indirect Arc Furnace
- Bottom Electrode Furnace
- Direct Arc Furnace

The Indirect Arc Furnace uses one electrode and works in much the same way as the Direct Arc Furnace. The Indirect Arc Furnace is a refractory-lined furnace in which the load is heated indirectly by the radiant heat from an electric arc. The use of this method is limited to the melting of cast irons and non-ferrous metals. These are metals which do not contain any iron. They are not magnetic and are usually more resistant to corrosion than ferrous metals (for example aluminum, copper, lead, zinc and tin). According to D'Souza (1999), it is "rarely used in steelmaking operations due to the fact that it results in severe wall refractory wear" (p. 2).

The Bottom Electrode Furnace is another steelmaking process in which an electrode is provided in the bottom of the furnace in order to produce more heat in melting steel. According to D'Souza (1999), "The main problem of Bottom Electrode Furnaces is that the power rating increases with the size of the furnace" (p. 2). The majority of steelmaking operations require the use of Direct Arc Furnaces.

The Direct Arc Furnace is used in most steelmaking countries. This uses three electrodes to heat metal. D'Souza (1999) describes the process: "A current is passed through these electrodes and an arc is sparked between each electrode and the charge" (p.2). This creates an enormous amount of heat; therefore, water jackets and other cooling devices are needed for efficient operations. The Direct Arc Furnace is graphite with a cup shape that allows forming to occur in the crucible of the molten metal. According to D'Souza (1999), "The heating process takes place mainly through radiation and convection from the arcs which can reach temperatures in excess of 20,000 C. Due to these high temperatures, the dissipation of energy and the resulting heating rate are rapid" (p. 2). Moreover, "The high temperatures attainable within the furnace coupled with a highly reducing atmosphere and a very fluid slag which can be formed result in the formation of chemical compounds which promote desulphurising and deoxidising conditions" (p. 2). The result is cost-effective: a much larger range of raw materials can be used (D'Souza, 1999, p.2).

This process of steelmaking by Direct Reduction creates dust. Dust from the steel manufacturing process can be toxic or can become explosive. As Guézennec, Huber, Patisson, Sessiecq, Bira and Ablitzer (2005) stated, "This dust contains hazardous, leachable elements such as zinc, lead or cadmium which require EAF dust to be stored in specific landfills" (p. 157). Another study was taken in Croatian steel mill company to investigate and analyze EAF dust. Monthly samples were taken at the outlet of the dust suppression system. One month (July) was excluded; the facility was out of operation. According to Sofilic, T., Rastovcan-Mioc, A., Crjan-Stefanovic, S., Novocel-Radovic, V., Jenko, M (2004), "Extraction metal dust with water caused dissolution of some components. It was observed in all samples that the pH value slightly decreased with time (1–30 days), while conductivity slightly increased" (p.65).

Dust in general consists of tiny particles carried by air currents. These particles are formed by disintegration or a fracture process. A wide range of particle sizes is produced during a dust generation process. From an occupational health point of view, dust is classified into three primary categories (OSHA, 2007):

1. Respirable Dust: This is the worst of the dusts, being able to travel past the human traffic stops such as the mucous membranes of the nose and the bronchial passageways.
2. Inhalable Dust: This is dust that is able to be inhaled through the nose or mouth but is usually stopped by these membranes.
3. Total Dust: This is everything else that is derived from the definition of dust: the respirable dust that travels past the nose and upper respiratory system.

This research will be focused on total dust generation from the Direct Reduction of Iron (DRI) process of steelmaking. DRI is most common used process to make steel.

Significant Problems of Dust Particles

The dissipation of dust particles into workplace atmosphere is undesirable. Excessive dust emission can cause both health and industrial problems, such as:

- Risk of dust explosion and fire
- Health hazard
    - Respiratory diseases
    - Irritation to eyes, ears, nose, and throat
    - Irritation to skin
- Damage to equipment
- Unpleasant odors

In order to evaluate the severity of health hazards in a workplace, the American Conference of Governmental Industrial Hygienists (ACGIH) has adopted a number of standards. These standards are known as threshold limit values (TLV's). These values are used as guides in the evaluation of health hazards. TLV's are a time-weighted concentration to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects. OSHA uses these values for health hazards evaluation and enforcement. In addition, OSHA implemented ventilation standard 29 CFR 1910.94.

The Electric Arc Furnace (EAF) in Company XYZ has been developed as a mechanical item which is capable of producing steel in an efficient manner, making the use of scrap and DRI. The furnace (EAF & Ladle Furnace LF) consists of a refractory lined bottom with bottom tapping system, a water cooled upper shell and a water cooled roof with refractory lines. Electric energy is supplied to the process via three graphite electrodes, which are helped by current conducting electrode arms connected to the transformer via cables and supported by a swivel gantry. The furnace vessel is flanged to a tilting platform, fabricated from study box type girders. The titling platform is equipped with two cocked rockers which are moved on special rails. The EAF is charged with scrap by means of scrap baskets. The roof is opened and the scrap is charged into the vessel with an overhead crane. The roof is closed and melting starts after the scrap has been melted down. Charging will be repeated. There is continuous charging once DRI is started. Once the total tapping weight has been achieved, refining will finish chemical and temperature requirements for tapping. Oxygen addition along with carbon injection will maintain foamy slag conditions and accelerate process time. After reaching tapping temperature and chemical analysis, tapping is performed through the bottom tapping system. Tapping will be into a preheated ladle and alloy additives will be added directly into the tapping process. The latest state of the art technologies will advance process times and decrease power off requirements. The furnace is designed as a full platform concept with split shell design. A single point roof lift will contribute maximum availability and accessibility to the furnace.

Dust explosions can cause a large amount of loss between life and catastrophic damage to industrial facilities. In steelmaking companies, invisible dust particles can penetrate deep into lungs to Alveoli and can remain there for a long period of time. These particles are mostly less than 5 µm in diameter. There are two types of dust concentrations (total and respirable). The total dust concentration is the collected dust mass on a filter divided by the volume of air sampled. On the other hand, the respirable dust index represents the concentration of dust that can penetrate through the nose and trachea to the alveoli. The steelmaking process can produce very small particles which can easily become airborne and settle on surfaces, dust collectors and other equipment. The US Chemical Safety Board (CSB) identified, according to Blair and Joseph (2005), "281 combustibles dust fires and explosions between 1980 and 2005 that killed 119 workers, injured 718 and extensively damaged industrial facilities. The incidents occurred in 44 states, in many different industries and involved a variety of different materials" (p.1).

In November 2006, CSB remarked there is no comprehensive OSHA standard addressing combustible dust or dust explosions. CSB issued a report in which it urged OSHA to create a new regulatory standard to prevent dust fires and explosions. In May 2008, OSHA generated a national emphasis program on combustible dust (OSHA, 2008). This program contains policies and procedures for inspecting workplaces that create combustible dusts such as Iron Dust.

The National Fire Protection Association (NFPA), a voluntary organization, developed three standards which address combustible dust explosion hazards. The standards are as follow:

- NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
- NFPA 68, Standard on Explosion Protection by Deflagration Venting
- NFPA 484, Standard for Combustible Metals, Metal Powders, and Metal Dusts

The purpose of NFPA 654, is the prevention of fire and dust explosions in the chemical, dye, pharmaceutical and plastics industries and. NFPA 654 recommends practical requirements for safety to protect life and property from fire and explosion and to minimize the resulting damage should a fire or explosion occur. Some highlights from this standard are:

1. A continuous industrial exhaust system shall be installed for processes where combustible dust is liberated in normal operations.
2. The industrial exhaust system shall incorporate a dust collector. Industrial exhaust system components, including the ductwork and dust collector, must be constructed so that dust does not leak out of the system components when the system is shut down.
3. The dust control system shall comply with the requirements of NFPA 91, Standard for Exhaust Systems for Air Conveying of Materials.
4. Dust collectors for industrial dust control shall be located outside of buildings.
5. Dust collectors may be located inside of buildings if they are located near an outside wall, are vented to the outside through straight reinforced ducts not exceeding 10 feet in length, and have explosion vents designed according to information in NFPA 68.

NFPA 68, Venting of Deflagrations, addresses how venting should be designed and maintained if it is installed. This section applies to equipment or areas needing to withstand more than 1.5 psig pressure (pound force per square inch gauge). Most dust collectors need additional reinforcement for that capability. The maximum pressure that will be reached during an explosion will always be greater than the pressure at which the vent device releases. NFPA 68 identifies pressure differential of at least 50 lbs/ft^2 or 0.35 psi (pound force per square inch) between the vent release pressure and the resistive pressure of the dust collector. This NFPA guide lists the following basic principles that are common to the venting of deflagrations:

1. The vent design must be sufficient to prevent deflagration pressure inside the dust collector from exceeding two-thirds of the ultimate strength of the weakest part of the dust collector, which must not fail. This criterion does anticipate that the dust collector may deform. Therefore expect some downtime with the dust control system after an explosion.
2. Dust vent explosion operation must not be affected by snow, ice, sticky materials or similar interferences.
3. Dust explosion vent closures must have a low mass per unit area to reduce opening time. NFPA recommends a maximum total mass divided by the area of the vent opening of 2.5 lbs./ft2.
4. Dust explosion vent closures should not become projectiles as a result of their operation. The closure should be properly restrained without affecting its function.
5. Vent closures must not be affected by the process conditions which it protects nor by conditions on the non-process side.
6. Explosion vent closures must release at overpressures close to their design release pressures. Magnetic or spring-loaded closures will satisfy this criterion when properly designed.
7. Explosion vent closures must reliably withstand fluctuating pressure differentials that are below the design release pressure.

8. Dust explosion vent closures must be inspected and properly maintained in order to ensure dependable operation. In some cases, this may mean replacing the vent closure at suitable time intervals.
9. The supporting structure for the dust collector must be strong enough to withstand any reaction forces developed as a result of operation of the dust explosion vent.

NFPA 484, Standard for Combustible Metals, Metal Powders, and Metal Dusts apply to the production, processing, finishing, handling, storage, and use of all metals and alloys that are in a form that is capable of combustion or explosion. NFPA 484 focuses on reducing the generation of dust, improving containment of dust through good housekeeping practices, inspecting frequent cleanups, designing equipment and surfaces for easy cleaning and reduced tendency for fugitive dust accumulation, and control of ignition sources. NFPA 484 has a chart of extinguishing agents. Water, foam, halogen extinguishing agents, and carbon dioxide should never be used on metal dust fires. Some highlights from this standard are:

- Machines that produce fine particles of aluminum shall be provided with hoods, capture devices, or enclosures that are connected to a dust collection system having suction and capture velocity to collect and transport all the dust produced.
- Hoods and enclosures shall be designed and maintained so that the fine particles will either fall or be projected into the hoods and enclosures in the direction of airflow.
- Special attention shall be given to the location of all the dust-producing machines with the respect to the location of the dust collection system to ensure that the connecting ducts will be as straight and as short as possible.
- Grinding operations shall not be served by the same dust collection system as buffing and polishing operations.

- Dry-type dust collectors shall be located outside of buildings.
- Dry-type collectors shall be provided with barriers or other means for protection of personnel.
- The area around the collector shall be posted with a sign that reads as follows: *Caution: This dust collector can contain explosible dust. Keep outside the marked area while equipment is operating.*
- Outer clothing shall be clean, flame retardant, and non–static generating where combustible aluminum dust is present and shall be designed to be easily removable.
- Safety shoes shall be static-dissipating, where necessary, shall have no exposed metal, and shall be appropriate for the type of operation taking place.
- Emergency procedures for handling clothing fires shall be established.

These standards recommend measurement to the location, area and depth of the dust layer. NFPA warns through these standards that more than 1/32 of an inch, which is the thickness of paper clips, is considered risky and will create a deflagration According to the International Fire Code (IRC), a deflagration is defined as "An exothermic reaction, such as the extremely rapid oxidation of a flammable dust or vapor in air, in which the reaction progresses through the unburned material at a rate less than the velocity of sound. A deflagration can have an explosive effect" (Stookey, 2006, p. 1).

Respirable Iron Dust

The term "respirable iron dust" is used to describe fugitive particles that are produced from steelmaking processes. These particles are small enough to be inhaled and stored in the deep part of the lung which may lead to health hazards. The Canadian Centre for Occupational Health & Safety (2008) stated that iron dust exposure will lead to Siderosis disease. If the particles are equal or greater in diameter 10 µm, dust particles inhaled will be retained in the upper nasal area of the respiratory system by the mucus membrane. If the particles are less than 10 µm, dust penetration will be increased as the size decreases.

The lungs are the primary organ affected by inhaling respirable Iron Dust. The lungs can be damaged by numerous injuries substances, such as dust. The lungs have a defense mechanism which clears unwanted particles. However, excessive inhalation of dust contributes to disease. Inhaled particles can be suspended in the air and eventually enter the nose; however, not all particles can reach the lungs. The nose works as an excellent filter for large particles which prevent them from entering the lungs. Smaller particles can reach the windpipe and the dividing air tubes which lead to the lungs. There are two kinds of tubes which are called bronchi and bronchioles. "Tiny hairs called cilia, covering the walls of the air tubes, move the mucus upward and out into the throat, where it is either coughed up and spat out, or swallowed" (Canadian Centre for Occupational Health & Safety, 2008, p. 2).

The greatest concern is potential health hazards to workers who are exposed to harmful dusts. Siderosis is the main disease which humans may get from breathing Iron Dust. Siderosis may lead to symptomatic and functional decline to the lungs. A number of surveys have examined respiratory function and symptoms among iron workers. These indicate the effect of iron dust on lung function can be as great as that of smoking. Iron has also been shown to cause fibrosis in some cases. In one case, a 64-year-old welder was diagnosed with Iron Dust in his lungs. The patient retired from his job after his initial evaluation and lung biopsy. His respiratory symptoms, which first appeared after about fifteen years of initial exposure to Iron Dust, resolved within a month with a supportive therapy. According to Khalid, Khalid and Jennings (2009), "Pneumosiderosis or Welder's lung is an occupational disease that occurs mainly in welders after prolonged exposure to iron dust. Avoidance of iron dust exposure and implementing strict prevention strategies are the mainstay of therapy in these patients" (p. 3). According to a case report by Khalid, Khalid and Jennings (2009), "His chest radiograph (CXR) showed a pattern of reticular-nodular opacities bilaterally, with lower lung field predominance" (p. 2).

Pneumoconiosis. Pneumoconiosis, meaning "dusty lung," forms a group of lung related diseases resulting from the inhalation of respirable dust. The most serious cases of lung diseases result from the inhalation of fibers such as silica and asbestos. However, other forms of pneumoconiosis may be produced from the inhalation of excessive amounts of the following dust: beryllium (berylliosis); kaolin (kaolinosis); barium (barytosis); tin (stannaosis) and iron oxide (siderosis).

Systemic poisoning. The respiratory system provides entry for fine particles into the body. Once inside the body they can dissolve and enter into the blood circulation and internal organs. Manganese, lead, cadmium and their compounds are examples of toxic substances that can be found in particulate form.

Cancer. An accumulation of particulate matter in the lungs can lead to cancer. Examples of particulate matter that cause cancer of the lungs after inhalation are arsenic and its compounds, chromates, particles containing polycyclic aromatic hydrocarbons, and certain nickel bearing dusts.

Irritation and inflammatory long injuries. Although the major irritants to the respiratory system are gases, particulate matter irritants can also occur. Exposure to such irritants could cause tracheittis, bronchitis, pneumonitis and pulmonary oedema. Examples of airborne particle irritants include: cadmium fumes, berylli, zinc chloride, cadmium compounds and manganese.

Allergic responses. Deposition and retention of inhaled sensitizing substances may cause allergic or other sensitivity reaction. Occupational asthma is a particular respiratory disease of an allergic type caused by exposure to particulate matter. Certain metal dusts such as nickel and chromium can lead to the onset of occupational asthma.

Dust Control/Prevention

Several organizations require the ventilation requirements for certain types of operations (such as abrasives, blasting, grinding, or buffing) which involve dusts, including combustible dusts. Additionally 29 CFR 1910.22(a)(1) requires employers to keep work places and other areas clean, which includes the removal of dust accumulations.

There are many dust control systems currently used in industry. The basic three systems used are:

- Dust Collection Systems
- Wet Dust Suppression Systems
- Airborne Dust Capture Through Water Sprays

Dust collection systems. In the simplest terms, a dust collection system is comprised of a ducting system to transport the dust from the source (table saw, planer, etc.) and a collection device (such as a bag and filter system or a cyclone), which pulls the dust through the ducting and collects it. According to Mody and Jakhete (1988), it is also known as the local exhaust ventilation system and consists of the following:

- An exhaust hood to capture dust emissions at the source
- Ductwork to transport the captured dust to a dust collector
- A dust collector to remove the dust from the air
- A fan and motor to provide the necessary exhaust volume and energy

Wet dust suppression systems. The principle behind Wet Dust Suppression Systems is the idea that dust will not even be given a chance to form and become airborne. According to Mody and Jakhete (1988), effective wetting of the material can be achieved by the following means:

- Static Spreading: The material is wetted while stationary. The diameter and contact angle of water droplets are important factors in static spreading.
- Dynamic Spreading: The material is wetted while moving. The surface tension of liquid, the droplet diameter, the material size and the droplet impact velocity are important variables in dynamic spreading.

Airborne dust capture through water sprays. Airborne dust wet suppression systems works by spraying very small water droplets into airborne dust. When the small droplets collide with the airborne dust particles, they stick to each other and fall out of the air to the ground.

Summary

A review of the literature suggests that the workers on EAF using DRI process at Company XYZ have the potential of developing lung diseases and encountering a fire explosion. Company XYZ uses the steel making DRI process and generates dust. The literature review outlines how to control and manage dust generation in order to protect workers and property. It is essential that an assessment should be conducted using air sampling devices in order to assess the extent of dust exposure on workers and the facility. In order to reduce the potential exposure, conclusions and recommendations must be drawn from the assessments.

Chapter III: Methodology

The purpose of the study was to examine, through observation and the use air sampling devices, the major areas of Company XYZ that contributed to metal dust and exposed employees to potential risk. This study will measure the total dust exposure in steel making Company XYZ that uses DRI. In addition, the scope of this research paper will focus on different ways to improve the current process (from workers' standpoint) and make recommendations. The main goals of the study were to analyze the extent of the dust level in the workplace:

- Conduct a site visit to steel making plant Company XYZ to analyze the DRI process.
- Examine the process by observation and identify any unsafe practices
- Measure, using air sampling device, different areas in order to identify most area need to improve
- Identify exposures that could potentially lead to lungs diseases or fire

The researcher will perform a systematic observation to examine the steel making process by visiting the Company XYZ. This observation will allow the researcher to categorize the risk in the workplace. Also, the researcher will measure the level of the total dust concentration created by the steelmaking process. Furthermore, evaluating the process and measuring the dust will help to make recommendations about where Company XYZ should install a dust prevention system. This chapter will outline the steelmaking EAF's DRI process and the testing area methods used to conduct the research study.

Selection of Sampling Area

A systemic observation was conducted. The goal was to identify the areas which have major accumulations of dust. Also, this observation involved searching for hidden areas which may contain accumulation of dust without cleaning activity. This observation examined workers' behavior inside (melt shop and caster area). Proper use of Personal Protective Equipment (PPE) was evaluated in order to measure the extent of dust exposure and risk to workers. Eight sampling areas were selected. The sampling areas will be based on these factors:

1. Interaction area between melting process and workers
2. Different workers with different tasks
3. Different areas selected

Data Collection Procedure

Dust sampling areas will be selected at various locations inside Company XYZ's steel plant (melt shop and caster area). The researcher will be taking dust samples for two days from three distinct melting process areas (EAF, Ladle Furnace and Caster) to measure total dust. The researcher will measure the exposure created in a specific area by the production machine; therefore, the researcher will identify the areas or machines that create most dust. Also, the researcher will examine different exposures for different tasks in workplace. The researcher will randomly choose 10 different employees to test their proper use of PPE. The researcher will be using a Shaping the Future of Air Sampling (SKC) pump at flow rate 2.0 liters per minutes (Lpm) – the OSHA exposure rate which approximates the human breathing rate. The sampler filter should be 5.0 µm polyvinyl chloride membrane and 4 field blanks per set (NIOSH, 1994). Each personal sampling pump and filter will be calibrated with a researcher sampler in line. The researcher will accurately pre-calibrate and post-calibrate the pump in order to make sure the sampler volume won't exceed the filter's loading limit.

Chapter IV: Results

Purpose of the Study

The purpose of this study was to determine the extent of iron dust exposure produced by Electrical Arc Furnaces during the steel making process at Company XYZ in the melt shop and caster area. This study examined the safety and health consequences associated with the dust exposure to workers. In order to evaluate the dust exposure to a specific worker in the Electrical Arc Furnaces area of the steel making process, the following steps should be taken:

- Examine the manufacturing process of Company XYZ
- Measure the concentration level of total dust
- Evaluate current dust control/prevention systems in place

Examine Process

During the melting of the DRI scrap and due to the addition of additives dust is generated from the Electric Arc Furnace. Dust is also generated at the time of refining the molten metal in the Ladle Furnace. A Fume Extraction Systems is required so that the furnace hot waste gas produced during operations is withdrawn from the furnace into the direct fume extraction system including the drop out box for dust and slag particles. The fumes escaping during charging and tapping as well as through the electrode ports are captured via the canopy hood located in the roof above the furnaces.

Process Steps

First. Scrap is charged by batch charging through the charging bucket. The scrap bucket is delivered by carrier directly from scrap yard to the melt shop. The charging crane will pick up the bucket and bring the bucket to the EAF ahead of time in order to avoid additional Power Off times for charging.

Second. DRI is fed through a continuous feeding system into the furnace roof directly into the area of the arc in between the electrodes.

Third. An alloy and additive system will be used for charging alloys and additives into the following areas of EAF operation with continuous feeding and tapping into the ladle.

Fourth. Carbon injection will be through sidewall injection points.

With the carbon injection unit it is possible to inject carbon through the EAF sidewall between steel and slag (inter-face) for slag foaming. The necessary carbon will be delivered by truck and unloaded in an underground hopper with grid. Storage silo filling will be done via a belt feeder pocket belt conveyor and vibrating screen. The primary chemical reactions involved in natural gas reforming are presented as follows:

$$CH4 + H20 \rightarrow 3H2 + CO$$

$$CO + H20 \rightarrow H2 + CO2$$

Fifth. Lime injection is provided in the hot spots through nozzles in the roof. The necessary dolomite and lime is delivered by truck and unloaded in an underground hopper with a grid. Storage silo filling is done via belt feeder and pocket belt conveyor.

Sixth. During the taping, bottom stirring is applied to the ladle car. Stirring is maintained until overhead crane will pick ladle for transport to LF. Stirring will be started/stopped and controlled from desk by operator.

In this process, eight areas were identified that contribute to dust. These areas are illustrated in the graph below:

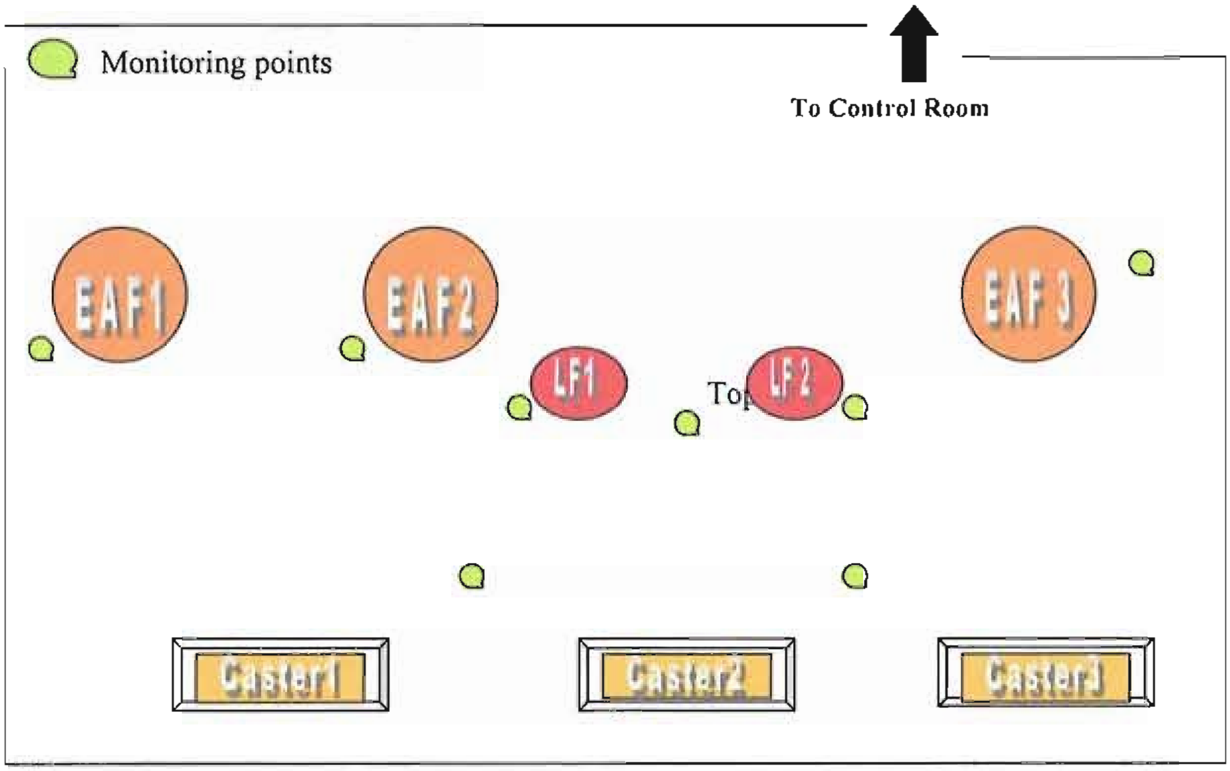

Figure 1. Diagram Representation of Monitoring Points

Monitoring Locations

The researcher located measuring points after site visit. The intention of selecting the above locations is to record the dust escaping from each dust-emitting source. The selected points are as follow:

- Electric Arc Furnace (Furnace 1, Furnace 2 and Furnace 3)
- Ladle Furnace Area (LF1, LF2 and Top of LF 1&2)
- Caster Area (2 & 3)

Measure the Concentration Level of Total Dust

The air sampling test was completed for the eight areas which were selected in the melt shop and caster. The results of these tests are presented in the tables below:

Table 1

Dust Concentration for Selected Points First Samples

Monitoring Location	Pump	Run time (min)	Sample Vol M^3	Respirable dust (mg)	Total Conc mg/M^3
Adjacent to EAF1	Running	330.3	0.6606	0.5	0.76
Adjacent to EAF2	Running	322.2	0.6444	0.6	0.93
Adjacent to EAF3	Running	317	0.634	2.8	4.42
LF1	Running	320.8	0.6416	4.2	6.55
LF2	Running	320.1	0.6402	2.7	4.22
Top of LF1&2	Running	319.7	0.6394	19.5	31.12
CASTER 1-2	Running	334.2	0.6684	0.3	0.45
CASTER 2-3	Running	331.2	0.6624	1.4	2.11

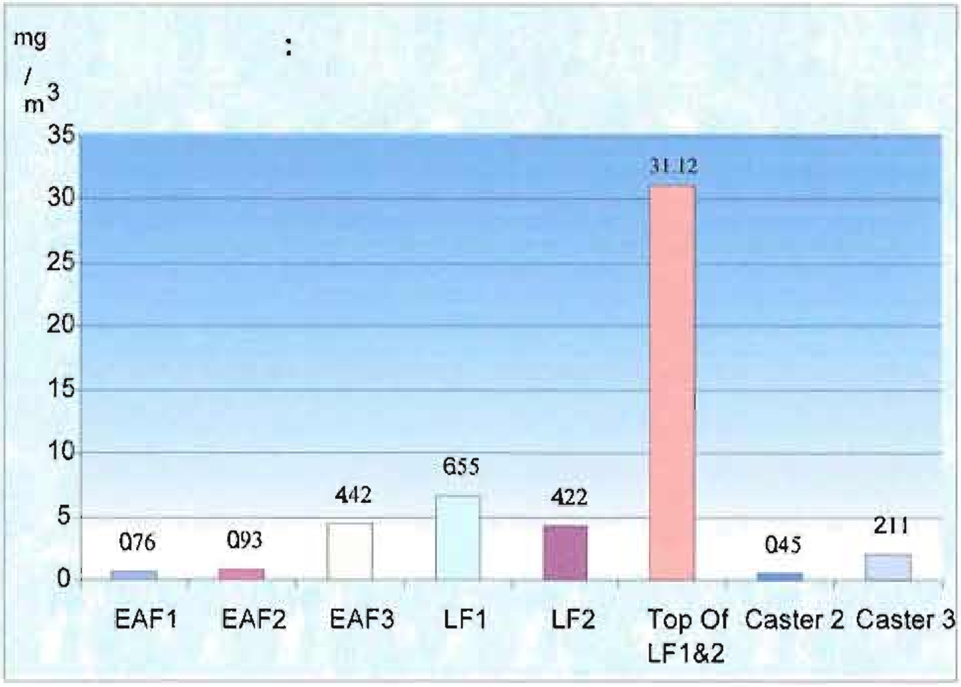

Figure 2. Dust Concentration First Samples

Table 2

Dust Concentration for Selected Points Second Samples

Monitoring Location	Pump	Run time (min)	Sample Vol M^3	Respirable dust (mg)	Total Conc mg/M^3
Adjacent to EAF1	Running	280.7	0.5614	0.6	2.10
Adjacent to EAF2	Stopped	286.7	0.5734	0.5	2.16
Adjacent to EAF3	Running	272.2	0.5444	2.1	3.65
LF1	Running	282.4	0.5648	2.4	6.65
LF2	Running	280	0.56	3.6	4.25
Top of LF1&2	Running	256	0.512	13.5	35.11
CASTER 1-2	Running	304.2	0.6084	1	2.63
CASTER 2-3	Running	303.7	0.6074	2.4	3.95

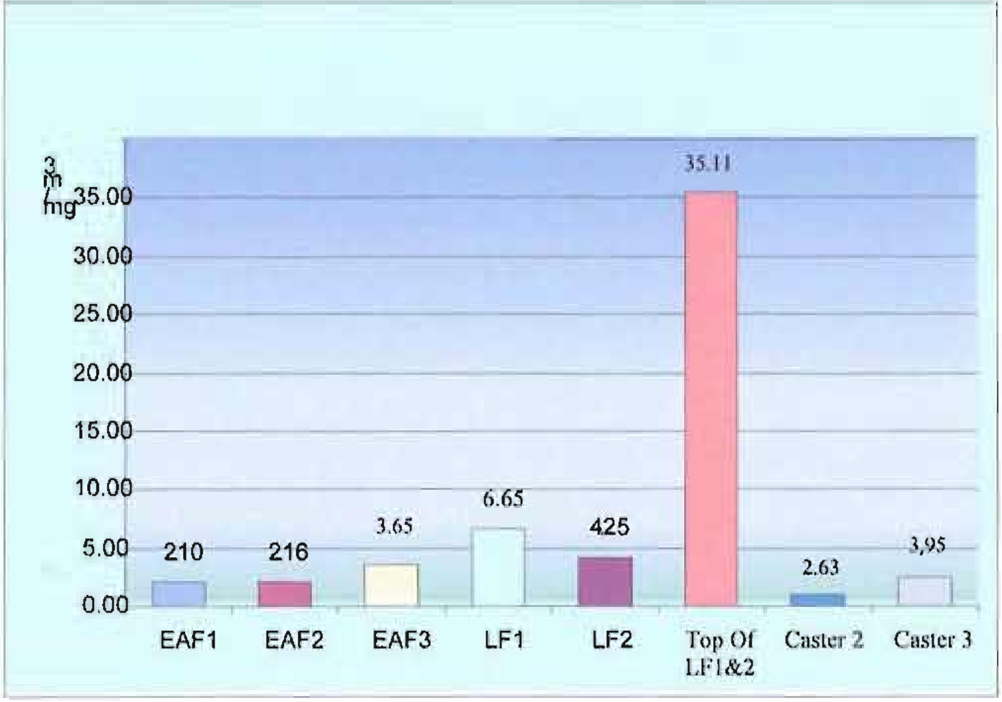

Figure 3. Dust Concentration Second Samples

Dust Concentration Analysis and Observation

All EAF furnaces are in operation with the Ladle Furnaces (LF). The monitoring results of two sets of measurements were conducted at each location (8 reading/ Set) during first samples. From the graphs it can be observed that there is a discernable trend at each location. The average dust concentration as shown in Figure 2 at Furnace 1, Furnace 2 and Furnace 3 is 1.43mg/m3 (2.6 %), 1.55 mg/m3 (2.9 %) and 4.07 mg/m3 (7.5 %), respectively. Similarly the average concentration of dust generated from LF1, LF2 and top of LF is 6.6 mg/m3 (12.2%), 4.2 mg/m3 (7.8%) and 35.11 mg/m3 (61.5%).

Upon comparing the percentage of dust at location EAF with LF, it can be noticed from Figure 3 that the percentage of dust recorded on top of LF's is 61.5% of the total dust concentration which a significant difference compared to the percentage of dust at other locations.

Calculations

The following are the calculations involved to obtain the concentration of dust:

1. Volume (M^3) of sampled air, V = (Run time x 2.0 Liters/min)/ 1000
2. Weight (mg) of empty filter = W_{dry}
3. Weight (mg) of filter + filtrate = W_{sample}
4. Respirable dust weight (mg), $W_{resp} = W_{sample} - W_{dry}$
5. Non-Respirable dust weight (mg) = W_{nresp}
6. Total dust (mg), $W_{total} = W_{resp} + W_{nresp}$
7. Total dust Concentration (mg/M^3) = (W_{total} / V)

Evaluate Current Dust Control/Prevention Systems in Place

The suction points are equipped with stationary hoods in steel plate structure and connected via a pipeline system upstream of the filter. Suction is carried out at the DRI belt conveyor delivery points. The suction points are placed over EAFs in steel plate structure and connected via a pipe line. A booster fan is provided on the upstream of the filter to avoid pressure drop in the system.

The old baghouse #2. The design of baghouse # 2 is based on reversed air flow. When Steel plant was commissioned in early 1980, one dedusting unit currently known as Baghouse #2 was built for the extracting the EAF dust. The unit is equipped with three fans upstream of the Baghouse filtration unit (compartments). The Baghouse consists of two separate parallel units, each having 10 compartments on each side.

The filter bags consist of polyester material, support rings are provided in each bag to ensure that the bags do not completely collapse during reversed air cleaning. The upper and lower ends of the bags are secured by snap-rings which are located in grooves in the bag end sleeves.

The dust first enters the hoppers, and then via the hole plate into the bags themselves. All "cake," which actually comprise the filtration medium. As the dust continues to collect, pressure drops through the bag and rises to a point where the bags must be cleaned. Differential pressure measuring gauges are installed for each compartment to check the conditions of the bags.

The switching over from "filtration" to "cleaning" and vice versa is done by disc-valves. At the inlet of each hopper a manual operated flap is situated with this and the disc-valve. Each compartment can be separated from the others manually and may be inspected during operation of the filter system.

The cleaning of the filter bags is done periodically by an automatic cycle operation which collapses the bags using a reverse air flow system. The air flows in the opposite direction through the filtration medium, i.e. from outside to inside of the bag.

The new baghouse (1 and 3). With the enhancement of the plant, there was a need to have an additional baghouse to control the emission of dust. Two baghouse were added to serve each EAF. The additional baghouse are known as baghouse No.1 & 3. The baghouse 1 & 3 to serve EAF 1 and EAF 3. With this addition each of the EAF has a dedicated fume extracting system for the fumes generated during charging, melting, tapping and melting. The design of baghouses 1 & 3 is based on pulse jet technology. Both baghouse have three fans that are located downstream of the EAFs. The cleaning of filters is done by means of vibration. The settling chamber is installed near the furnace and is fitted with a water-cooled roof. The settling chamber is designed to collect pieces of light scrap, coarse dust and slag sucked from the EAF 1 and EAF 3. The settled material is easily removed through a water-cooled door by means of a small front-end loader. Both baghouse are equipped with stacks that have continuous emission monitoring systems for particulates and CO.

Chapter V: Summary, Conclusions and Recommendations

Summary

This study was to determine the extent of Iron Dust exposure produced by Electrical Arc Furnaces during the steel making process. Company XYZ uses three EAFs and two LFs with DRI for steel making at Company XYZ has the potential risk to employees' health and life. This process creates dust which leads to health hazards such as siderosis and industries problems such as fire explosion. the purpose of. Moreover, the objective of this study was to examine the safety and health consequences associated with the dust exposure to workers. In order to achieve this purpose various goals were developed:

1) Examine the process using systemic approach and observation by site visit
2) Select the locations of the facility which expect contributing to dust
3) Select the best method to prevent/control systems

Methods

This paper focused on two machines EAFs and LFs at Company XYZ that uses DRI for steel making. The methods used for achieving these goals including conducting a literature review, conducting a task analysis of five locations (three EAFs and two LFs) and completing 16 dust samples for select locations. The literature review consisted of various focuses (process overview, dust health hazards, dust fire exposure and dust control/prevention). This research was conducted to collect information to collect information related to the problem statement.

The researcher collected dust samples from select areas. By collecting dust samples in Company XYZ (melt shop and caster area), the risks were identified that could potentially lead to the development of lung diseases and fire explosion.

Findings

Through the completion of the systematic observations and dust samples (sixteen total) it was observed that the workers at EAF in steel making at Company XYZ are exposed to Iron Dust (metal dust) which is combustible and toxic. According to literature review, this type of process (DRI) of steel making could lead to siderosis, fire explosion, impaired visibility and equipment failure. It was observed that the workers at LFs are at risk on these areas which produced a high volume of dust. The amount measured exceeded PEL (permissible exposure limit) from OSHA and TLV guidelines. It was found:

1. The wind coming from the north side of the melt shop pushes all the dust towards furnace 3 and mostly from the LFs.
2. The dust concentration increased moving from Furnace 1 towards Furnace 3, 2.10, 2.16 and 3.65 consecutively, which concludes that the LFs have the maximum contribution and dust generation in the meltshop.
3. The dust is not captured in both LFs due to opening in the LFs roofs and due to the poor suction from the canopy hoods. Also, dust is escaping due to the gap between the roof and the treated ladle (visual observation).
4. The canopy hoods are placed over the EAFs which helps to decrease the dust concentration in EAFs areas. However, LFs don't have any controls in place to suck the dust generated in their area.

The concentration of dust from LFs at exceeds the limits of 15mg/m3 recommended by environmental and occupational health regulations (American Conference for Governmental & Industrial Hygiene) and OSHA.

Conclusions

- Based on the systemic observation, air sampling and the evaluation of the current control, the literature review concluded that the EAF process at Company XYZ has the potential of exposing workers to developing health hazards.
- Air sampling concentration at the Ladle Furnaces (LF) area and the evaluation of current controls show the workers at Company XYZ encountering fire explosions.
- Current controls in the workplace show that workers are not protected against metal and dust and the job performed in the EAF plant at Company XYZ has high risks at LF areas.

Recommendations

The following is a list of recommendations the author feels will help Company XYZ control the potential of their workers from injury/illness:

Engineering Controls

- Consider installing a dust collection system to minimize dust concentration in LF area. The location of the exhaust hood must be in the top between LF 1 and LF 2. This location will allow maximizing dust capture efficiency at minimum exhaust volumes. This is the most effective way to reduce dust emissions in Company XYZ.
- Consider installing dust collection system using direct shell evacuation. this method will capture the gases and particulates en route to the baghouse.
- Consider installing a roof hood over the top of LFs. This will take care of dust emission from the most dust generation in Company XYZ. This roof hood will generally work very well with metal dust; however, this might not be great way for NOx and CO emissions.

Administration Control

- Company XYZ should evaluate whether the dust collection system is performing in accordance with the design or not. The company should measure the followings:
    - Air velocity and static pressure in each branch and main hood
    - Static and total pressure at the fan inlet and outlet
    - Differential pressure between the inlet and outlet of the dust collector
- Company XYZ should identify maintenance needs to the dust collection system.
- Company XYZ should design and evaluate an effective future installation yearly.
- For the workers near to LFs, Company XYZ should consider developing a rotation schedule and make sure that workers don't work more than half hour per hour. Therefore, each employee should work half an hour and go to a control room for half an hour. This will reduce the amount of exposure to dust.
- Company XYZ should provide a certified dust mask. This mask must be worn properly. The company should create a policy requiring the use of masks and implement procedures for the proper use of a respirator.
    - Company XYZ must provide the respirators, training, and medical evaluation.
    - Company XYZ must require:
        - Fit testing for each employee before initial use of a respirator to identify the specific make, model style, and size that is best suited for each employee.

    - Fit checking for each employee per use a respirator. Each employee must perform a positive and negative pressure seal check.
  - Company XYZ must provide an effective protection and a maintenance program for respirators.
- Company XYZ should provide a rubber glasses to workers. These will prevent the dust from entering eyes and causing impairment to workers.
- Company XYZ should provide appropriate protective clothing and equipment that must be carefully selected, used, and maintained in order to prevent skin contact with metal dust. The selection of the appropriate personal protective equipment (PPE) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the worker's potential exposure to metal dust.
- Company XYZ should evaluate the use of PPE materials with metal dust and consult the best available performance data and manufacturers' recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.
- Company XYZ should periodically evaluate clothing and gloves to determine effectiveness in preventing dermal contact.

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