Controlling Silver Dust and Fumes at Mine Refinery

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ABSTRACT: As part of the refining of gold and silver molten metal, silver dust and fumes are released into the atmosphere. The Mine Safety and Health Administration (MSHA) enforces an 8-hour, equivalent Time Weighted Average concentration limit for silver dust and fumes of 10 μg/m^3.

MSHA initiated a program to assess the controls that were being used to control silver dust and fume exposure. Refineries were visited at six mines. The layout of each refinery and the controls used varied at each refinery. At each operation, personal and area silver fume and dust samples were collected to assess worker exposures and to determine sources of fume.

Primary source of silver dust and fume exposure was the pouring of molten metal from the furnace. Secondary sources of exposure included: precipitate mixing, bar cooling, and housekeeping. Guidelines were developed addressing housekeeping, exhaust ventilation, general ventilation, administrative controls, and system monitoring. In most cases, housekeeping and general ventilation were adequate; however, the exhaust ventilation systems needed to be improved.

1 INRODUCTION

Silver dust and fumes become airborne during the refining step of producing gold and silver. The dust and fumes becomes airborne when molten material is poured from the furnace into bars or buttons. Additionally, fumes that are not captured by the exhaust ventilation system can condense into dust and settle onto equipment in the refinery. This dust can then become entrained due to vibration or activities within the refinery.

The current exposure limit for silver fumes and dusts is found at 30 C.F.R. Section 56/57.5001. Those standards apply to numerous airborne contaminants including silver dusts and fumes. The Standards incorporate by reference the terms of the ACGIH's 1973 edition of "Threshold Limit Values for Chemicals Substances in Workroom Air." There, the exposure limit for silver fumes and dusts has been set at 0.01 mg/m3 (10 ug/m3) over an eight hour shift.

The one major hazard to which the silver exposure limit is directed is that of argyria. Argyria is a condition where an employee’s skin, eyes, or mucous membranes turns from slate to blue-gray in color. The color may be general or localized. Additional potential health hazards associated with exposure to silver fumes and dust include diffuse pulmonary fibrosis that could be confirmed with chest radiograms. Historically, many silver producing mines have had difficulty consistently meeting this standard.

Gold and silver ore is typically mined by open pit or underground mining methods. Both consisting of drilling, blasting, and loading via front-end loaders and truck haulage. The ore contains large amounts of impurities. To concentrate the silver ore, mining companies use cyanide leaching. The low grade silver ore is finely crushed and placed onto large piles. Beneath the pile is an impervious layer. A dilute solution of cyanide trickles through the pile, dissolves the silver and gold from the ore and is trapped by the impervious layer. The cyanide solution with the silver ore is called the pregnant leachate solution. The collected pregnant solution passes through activated coconut charcoal at the mill to be concentrated and purified. Then another volume of cyanide solution passes through the charcoal to strip the silver ore from the charcoal. Finally a zinc solution precipitates out the silver ore. The liquid is pressed from the precipitate before it is dried in an oven.

The dried precipitate along with a "flux" are loaded into a furnace and heated to over 2100 degrees Fahrenheit. Once the material has been heated, the slag and metal are poured into either buttons or bars. The buttons or bars are then moved to a cooling area. Buttons and bars typically contain 85 to 95 percent silver. Once cooled, the buttons or bars are cleaned and placed into a vault before shipping to a commercial refinery for further processing.

Silver fume and dust exposure are controlled by a number of engineering and administrative controls. Typically, these controls include:

- General refinery ventilation,
- Exhaust ventilation at the furnace,
- Material handling practices, and
- Housekeeping practices.

While the specific controls vary from refinery to refinery, there are certain consistencies among refineries. The purpose of this study was to identify and quantify those practices that gave the best results for controlling exposure to silver fumes.

2 SAMPLING AND ANALYTICAL PROCEDURES

This study included site visits to six refineries. At each operation, typically, three personal and three area silver fume samples were collected to assess worker exposures and the source of worker exposures to silver fumes. Personal samples were collected on three refiners. Area samples were collected approximately 10-feet on either side of the furnace and in the center of the refinery. Personal and area samples were collected for the full shift.

As per Metal and Nonmetal Mine Safety and Health's sampling protocol, all silver fume samples were collected using SKC Airchek® Sampler pumps (reference to specific brands of equipment is made to facilitate understanding and does not imply endorsement by the MSHA), calibrated and operated at 1.7 liters per minute (Lpm). The samples were collected on 37-millimeter diameter, MCE filters with a 5.0 micrometer pore size. The filters were mounted in two-piece Millipore filter holder. A cyclone was not used in the sample train. A control filter was utilized to verify no initial sample contamination. The samples were analyzed by Inductively Coupled Plasma (ICP), MSHA Method P-3, at the Dust Division Laboratory in Pittsburgh, Pennsylvania.

Silver fume concentrations were determined as Shift Weighted Average (SWA). The formula for calculating the SWA is:

$$\text{SWA} = \frac{\text{Weight of Contaminant (mg)}}{\text{Flow Rate (Lpm)} \times \text{Time} \times 0.001\ \text{m}^3/\text{L}}$$

As per Metal Nonmetal Safety and Health's sampling protocol, a 480-minute time is used to calculate the SWA. The PEL for silver fumes and dust, from the 1973 TLV list, is 0.01 mg/m^3.

The C/E ratio of concentration to allowable exposure (SWA/PEL) was calculated for each sample. The error factor established for silver fume determination is 1.14. When the C/E ratio exceeds 1.14, noncompliance with the silver fume standard is indicated. When the ratio is equal to or below 0.86, compliance with the standard is indicated. Ratios between 0.86 and 1.14 indicate areas of uncertainty in compliance, indicating that controls should be improved.

In addition to the personal and area samples, airflow measurements were taken with either a Pitot-static tube or a vane anemometer at exhaust hoods for the furnace. Hood and duct sizes were measured and actual air velocity and volumes were calculated.

Refinery building volume was measured and the airflow induced by wall fans was measured. Refinery air exchange rate was calculated. Other dust controls and work practices in the plant were also observed.

3 RESULTS AND DISCUSSION

In most refineries, the general mill ventilation rate exceeded 10 air changes per hour. However, in several refineries the location of exhaust fans and make-up air supply louvers caused cross drafts that overpowered the furnace exhaust ventilation system and caused silver fumes to be blown toward workers.

Several forms of administrative controls that reduce exposure to silver fumes were observed. In three of the operations, furnace controls were located more than ten feet from the furnace. In one of these three operations, a separate pouring room was established inside the refinery. The pouring room was under negative pressure and doors were closed during the pouring operation. The furnace controls were outside of the room and the pouring process was observed through a glass window. However, in the three other operations, furnace controls were close to the furnace or even inside the furnace exhaust ventilation hood.

A furnace temperature of 2200 degrees Fahrenheit was reportedly sufficient to maintain the gold and silver in a molten state for pouring. The higher temperatures produce more fumes. Furnace temperature should be monitored so that fume production is minimized.

Typically, the pouring height was two to three feet. Reducing the pouring height would reduce the amount of silver fumes emitted. Bars and buttons were generally moved with long handled carts or forklift trucks. This practice removed workers from the vicinity of molten silver bars. In one case, bars were quenched with water as soon as possible and in one case hot bars were placed under a cooling hood, to reduce the emission of fumes.

Housekeeping was generally excellent. The mills were washed down on a regular basis and floors were swept with a broom and wash several times a day. Additionally, in some operations, floors were waxed on a weekly basis. The primary housekeeping issue was dust that had settled on flat surfaces above the floor. This dust could become reentrained and contribute to worker exposure. In many cases these surfaces could not be washed down because of adjacent electrical fixtures. As a result these surfaces should be vacuumed on a regular basis to remove accumulations of settled dust. In addition to general housekeeping, heat-reflective clothing should be cleaned weekly. Wipe samples taken on the inside of heat-reflective clothing indicated that the clothing was a source of exposure.

The most noticeable deficiency at most of the refineries was the exhaust ventilation system for the furnace. In general, the hoods did not surround the furnace sufficiently and were not close enough to the pour spout to contain the fumes as molten material was poured. Additionally, the hood face velocity was below the ACGIH recommended 200 fpm velocity and insufficient to draw the fumes into the exhaust ventilation system. Duct transport velocities were below the ACGIH recommended 3600 fpm; however, because of the poor capture velocity, there was no observed dust settling or blockage of ducts observed.

System monitoring should include both monitoring of workers' exposure and monitoring of dust and fume controls. In most cases, workers' exposure were monitored on a regular basis. However, none of these operations monitored either the mill air exchange rate or the furnace exhaust ventilation system. Pressure gages were not installed on the dust collector or the exhaust ventilation fan. Periodic checks of ventilation systems should be made to assure that the systems are working properly.

Figure 1. Operation with exhaust ventilation.

Figure 1 shows an operation where hoods and enclosures, along with mill ventilation, are used to capture silver fumes. Additionally, furnace controls are positioned and trucks with long handles are used to keep workers away from silver fume exposure. In this operation a cooling station was provided for button cooling.

Figure 2. Operation with housekeeping and remote furnace controls

Figure 2 shows an operation which relied on mill ventilation, housekeeping, and administrative controls to reduce worker exposure. Additionally, furnace controls positioning and a forklift are used to keep workers away from silver fume exposure. In this operation a bar quenching station was provided for bar cooling.

Based on the measurements and observations made during these studies, a list of guidelines for controlling silver dust and fumes was developed. These guidelines are not meant as a list of best practices, but rather routine control measures that should be incorporated into all operations.

4 GUIDELINES

4.1 *Housekeeping*

- Wash refinery floor, daily and wash refinery, top to bottom, weekly.
- Buff (wax) refinery floor, weekly.
- Refiner's coveralls should be washed daily, and
- Wash heat-reflective clothing, weekly.
- Use a HEPA vacuum to clean up spills or dust.

4.2 *Administrative Controls*

- Install furnace controls at least 10 feet from furnace discharge.

- Furnace temperature should be maintained at less than 2200 degrees Fahrenheit.
- A fork lift or long-handled truck should be used to move hot bars.
- Bars or buttons should be quenched with water as-soon-as possible.
- Minimize the pouring height (distance from furnace spout to bar mold).
- Material should not be manually fed into the furnace.

4.3 *Exhaust Ventilation*

- Hoods, enclosures or booths should be provided at the:
  - Furnace and furnace discharge (booth),
  - Bar or button cooling station (hood or booth),
  - Bar or button cleaner station (enclosure),
  - Grinder (enclosure), and,
  - Mixing station (enclosure).
- Hoods and booths should surround the fume source.
- Face velocities should be greater than 200 fpm (duct airflow / hood area).
- Duct transport velocity should be greater than 3600 fpm.
- Enclosures should be under negative pressure.
- Follow design guidelines in Industrial Ventilation: A Manual of Recommended Practices,
  - Metal Melting Furnaces and Mixing (Chapter 10), and
  - Exhaust System Design Procedure (Chapter 5).

4.4 *General Ventilation*

- There should be at least 10 air changes per hour.
  - (Air changes/hour = 60 x Airflow / Building volume)
- Wall fans should be located behind or above the furnace to draw air away from workers.
- Makeup air inlets should be located to eliminate cross drafts.

4.5 *System Monitoring*

- Refinery worker exposure should be monitored quarterly.
- Air volume monitoring stations should be established for the furnace hood, bar cooling hood and dust collector fan.
- Air volumes should be measured quarterly.
- Use smoke tubes to visualize capture and cross contamination at hoods.

REFERENCES

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