Control of Silica Dust in Slate Milling Operations

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ABSTRACT

The Mine Safety and Health Administration (MSHA) conducted a study to assess the present state of technology used for controlling employees' respirable silica-bearing dust exposures during dimension slate milling operations. For this study, twelve slate milling operations were visited and various measurements were taken and observations made. These measurements and observations included exhaust and room airflow, types of enclosures, water usage, and building volumes for each of the milling processes. These mills usually employed between five and twenty people. From the study, general guidelines were developed from the best practices observed and can be used at the various sawing, splitting, trimming, and drilling operations throughout the industry.

KEYWORDS

Air Changes, Slate, Strip and Block Saws, Chimney Fan, Silica, and Respirable Dust.

INTRODUCTION

The dimension slate industry started in the 1850s along the New York/Vermont border from Granville, New York and West Pawlet, Vermont and north to Fair Haven, Vermont. Welsh immigrants provided the initial manpower and expertise to get the industry started. The first boom in the industry was in the 1890s (Slate Valley Museum, Internet Page).

The mining techniques for the slate industry went unchanged for many years. Full mechanization did not come to the industry until the 1960s with the advent of powerful saws that could efficiently cut the slate stone. The industry was also slow to introduce additional mechanization for drilling and hauling stones. There are approximately 35 dimension slate operations in the United States of which around 25 are located in the Rutland, Vermont area.

Recent demand for incombustible roofing material and decorative floor tile have resulted in increased production in the industry. Because of the rather difficult process of obtaining new quarry permits and opening new mines, due to Federal and State environmental regulations, the existing operations are working year round to meet the increased demand.

Consequently, MSHA has observed an increase in the incidence of noncompliance with the respirable silica dust standard (Title 30 CFR 56.5001(a)). Especially in the cold months, when operations are confined to enclosed buildings and natural ventilation pressures cannot control the dust levels. The allowable limit for respirable silica-bearing dust exposure is defined as ten divided by the sum of the percent quartz plus two in the dust and is measured in milligrams per cubic meter (mg/m^3). Dust from slate milling operations can contain between 5-20% silica (Taylor, 1985). Although the increased incidence of noncompliance seemed to vary from mill to mill, the sawyer appeared to be the occupation most often cited for noncompliance.

To assist the dimension slate operators in reducing the incidence of noncompliance, MSHA conducted a study to assess the present state of technology used to control silica dust exposures during slate milling operations, in order to develop specific dust control guidelines that would be effective and feasible for the slate industry. Twelve slate milling operations were visited and various measurements were taken. These measurements included airflow, types of enclosures, water usage, and building volumes for each of the milling processes. These mills employed between five and 20 people and utilized milling methods which were determined to be typical for the industry.

PRODUCTION METHOD

This study focused on the production of slate roof tiles. Floor tiles are usually finished in a wet process at off-quarry mills and these operations fall outside of the Agency's jurisdiction. There are five main steps in the production of roof tiles. These steps include quarrying, sawing, splitting, trimming, and drilling of the tile.

(1) **Mining of the Slate rocks.** The slate is mined from quarries by using conventional mining techniques (drilling and blasting). Irregular slabs of rock 0.30 m (1 ft) thick by 0.90 to 1.2 m (3 to 4 ft) wide by 1.5 to 1.8 m (5 to 6 ft) long are removed from the quarry and transported to the mill.

(2) **Sawing.** The slabs of slate are cut into rectangular blocks in a two step process. In this process the blocks are first cut into strips by a strip saw and then into blocks by a block saw. In some mills two saws were used for this operation. In other mills, one saw was used and the blocks were turned 90 degrees manually or by hydraulics after the initial cut. In some operations a gang saw was used instead of a block saw. A gang saw is a multi-blade saw that can cut strips of slate into rectangular blocks for the splitters.

(3) **Splitting.** The regular sized blocks are split by splitters. Splitting involves the use of a hammer and chisel to split the block into 3 to 6 mm (1/8 to 1/4 in) thick pieces. The splitter uses the natural cleavage planes in the block to split it into the proper thickness.

(4) **Trimming.** The trimming process involves taking the coarse slate tiles and trimming them to their final rectangular shape. This process involves a rotating blade that lops off each side of the tile. This is done so that each tile will be uniform and fit closer together on a roof.

(5) **Drilling.** The final stage of the manufacturing process in which nail holes are placed in the slate tile. This is done with a manual punch or a drill press.

A slate mill can produce between 1,000 and 3,000 roof tiles in a single production shift. Typically, mills are operated on a one shift per day basis. A schematic of a typical milling process is shown in Fig. 1. All mills do not have drilling or gaging operations. However, some operations utilize two milling circuits at the same location.

SURVEY METHODOLOGY

The survey at each of the operations visited was conducted in a similar manner. At each mill, the layout of the equipment was noted and the dimensions of the mill were taken. The type and location of the dust controls for each milling operation were recorded. Dust controls included: water sprays, ventilation fans and associated duct work, enclosures, and "dust" chimneys. After all the visual inspections were complete, measurements of fan air volumes

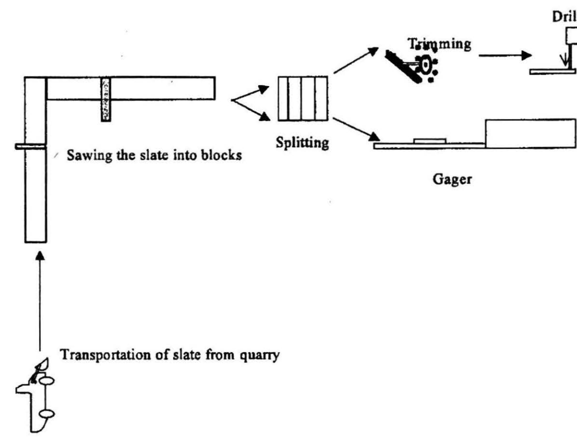


Figure 1. Production sequence for slate

were made using an anemometer or a pitot tube traverse and the air changes per hour rates were calculated for each enclosure and for the respective mill.

CONTROLS OBSERVED

The type of controls that were observed in this study consisted mainly of the use of water sprays, fans, enclosures and "dust" chimneys. The water sprays were primarily used to cool the saw blades and direct the cuttings and dust from the kerf. Also when the spray systems were properly designed, it would force the dust-laden water to the ground or to a chimney.

Generally, the saws were enclosed and, in some cases, dust chimneys were used to direct the dust-laden air and water mist from the saws out of the mill building. The momentum of the water, created by the circular motion of the saw, induced airflow through the chimney.

Saw enclosures varied in size, shape, and volume. In several mills there was either a partial enclosure or a full enclosure separating the saw from the operator. The enclosures were constructed of stainless steel, plywood, plexiglass, plastic strip curtains, or a combination of these materials. Typically a wall fan was mounted in the back of the saw enclosure. When the operators were properly isolated from the dust sources, dust was directed out of the mill and away from the operator.

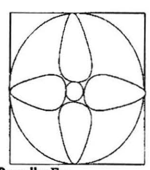
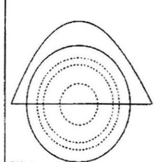
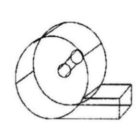
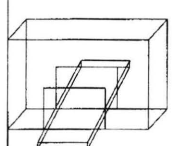
Trimming machines were also enclosed. These machines were placed against a wall with the framework covered and a scrap chute directed to the outside of the building. Wall fans were located at the rear of the trimmer to draw air away from the operator.

Fans were also used at each milling operation to exhaust air from the building. Most of the fans observed were wall-mounted propeller fans. Several of the fans were centrifugal blowers used in conjunction with exhaust duct work. A summary of the controls used is given in Table 1. The specific controls in place at each mill is given in Table 2.

RESULTS AND DISCUSSIONS OF SURVEY

The results of the survey of dust control techniques are presented in Table 2. This table shows the type of controls in place and the volume of ventilating airflow that were in place at the time of study. Enclosure or buildings ventilation exchange rates are also provided in the table.

Table 1. Table of controls.

Type of Control	# of operations Using Control	Type of Control	# of operations Using Control
 Propeller Fan	11	 Water on Saw	12
 Centrifugal Fan	4	 Enclosure	7

In this study, the operating parameters selected to be best practices were chosen from specific milling operations that were normally in compliance. These operating parameter were considered economically feasible by those operators that had implemented them.

Saws Dust Controls

All of the saws had water applied to the blade. The blade directed the water into the saw kerf and carried the cuttings and dust away from the block of slate. In four of the operations, a dust chimney was located behind the saw this allowed the dust and cuttings to be discharged outside the mill building. Additionally, enclosures were provided around the saws and a barrier was provided between the saw and the operator. This barrier was either a permanent wall or removable curtain. These enclosures ranged from 2.8 to 28 m^3 (100 to 1,000 ft^3). In most cases a fan was mounted on the outside wall of the enclosure. The fan capacities ranged from 0.23 m^3/s to 0.46 m^3/s (500 to 1,000 cfm).

Splitter Stations Dust Controls

The splitter stations were general ventilated by a wall fan. The fan was generally located on the opposite of the worker. The airflow for these wall fans ranged from 0.46 m^3/s to 3.73 m^3/s (1,000 to 8,000 cfm). In two mills, an exhaust duct was provided at the splitter work station. Placing a 15 cm (6 in) flange around the duct would improve the capture of dust at the splitting station. The airflow in the exhaust duct ranged from 0.23 m^3/s to 0.46 m^3/s (500 to 1,000 cfm).

Trimming Stations Dust Controls

Most of the trimming machines were set against an outside wall and enclosed. Generally wall fans set inside the enclosure were used to draw air and dust through the trimming machine and away from the operator. Airflow on the trimming machines ranged from 0.09 m^3/s to 0.92 m^3/s (200 to 2,000 cfm). On three operations, an exhaust duct leading to a blower was connected to the trimming enclosure.

Dust Controls for Hole Drills

One operation utilized drill presses. At each drilling station an exhaust ventilation duct was provided behind the drill bit. Placing a 5 cm (2 in.) flange around the duct would improve the capture of dust at the drill station. The exhaust air volume at the drill station ranged from 0.10 m^3/s to 0.19 m^3/s (225 to 550 cfm).

General Mill Ventilation Dust Controls

The airflow available at each of the operations also contributes to the general mill ventilation rate. The mill air flows ranged from 0.6 to 15 air changes per hour for the general work area and 15 to 321 air changes per hour for the saw rooms. The National Institute for Occupational Safety and Health (formerly the U.S. Bureau of Mines) has recommended a general mill ventilation rate of 10 air changes per hour. The general mill ventilation rate can be reduced if sufficient dust control is provided at each compartmentalized operations. The use of small well ventilated enclosures, particularly around the saws can lower the required mill ventilation rate.

Maintenance and Housekeeping

Periodic maintenance and good housekeeping enhances overall plant dust control efforts. Several good practices in these areas were observed during the survey. These include the following:

(1) Establishing periodic maintenance of dust controls to ensure optimum efficiencies.
(2) Operating dust controls at all times while dust generating processes are running.
(3) Cleaning the floor every day so that there is no build up of dust (vacuuming is preferable to sweeping).
(4) Ensuring that all equipment is always dusted and clean (vacuuming is preferable to sweeping).
(5) Washing floors at least once a week.
(6) Using respiratory protection during cleanup activities.

Training

An important, and often overlooked, facet of a good dust control program is a dynamic training program. Proper training of the workers in all aspects of dust control and the hazards of respirable dust should be a vital part of an operation's dust control strategy. A training program should include:

(1) Increase the awareness of the workers to the hazards of silica dust.
(2) Instruction on the proper use of all the dust control techniques used in the mill.
(3) When necessary, the proper fitting, care, and use of respiratory protection.

Heating of Mills in Winter

One of the reasons for increased noncompliance during winter operations is that buildings are closed and often fans are not operated to increase worker comfort. With the buildings fully enclosed, getting an adequate circulation of air at a comfortable temperature becomes more difficult.

In most cases, heating of replacement air was not a consideration in mill design. Mill volumes ranged from approximately 280 to 560 m^3 (20,000 to 100,000 ft^3). At 10 air changes per hour, the total mill airflow (and make-up air requirement) would range from, 0.18 to 8.3 m^3/s (400 to 17,000 cfm). Therefore, the smaller the mill the lower the make-up air requirement. The trend in mill design, however, is toward bigger mills to provide inside storage. This increases the make-up air requirement. The local cost of heating 4.6 m^3/s (10,000 cfm) to 19° C (70° F) of recirculating air using oil at $1.35/gallon is approximately $4,800 per year assuming 40 hours/week of operation (ACGIH., 1998).

There are several other options available to heat the air in the mill. These include space or radiant heaters, heated floor systems, and a filtered recirculating systems. All these systems have their advantages and disadvantages. It all depends on the construction or location of the building which houses the mill.

Most mills had space heaters. Space heaters can be installed near the work stations. It is preferable to use radiant heaters rather than blowing heaters to avoid entrainment of dust. The heater should be installed so that the airflow draws the heat over the worker.

One mill had a recirculating hot water system installed in the mill floor. This system reportedly provided comfort throughout the winter.

A third option would be to install a filtered recirculating airflow system. Since silica dust would need to be filtered from the recirculating air, a higher efficiency particulate air (HEPA) filter should be used, rather than a standard furnace filter.

CONCLUSIONS AND RECOMMENDATIONS

After review of all information the authors recommend the following:

(1) Water on the saw blade, and a barrier (enclosure) between the saw(s) and operator(s) with an exhaust air flow of 1.38 m^3/s (3,000 cfm),
(2) An exhaust ventilation of 0.92 m^3/s (2,000 cfm) at the splitter station,
(3) An enclosure and 0.23 m^3/s (500 cfm) of exhaust ventilation at each trimming station,
(4) A hood with 0.23 m^3/s (500 cfm) of exhaust ventilation at each hole drilling station,
(5) General mill ventilation of 10 air changes per hour,
(6) Routinely maintain dust controls and operate at all times when slate is being processed,
(7) Proper housekeeping to reduce dust exposure,
(8) Train workers in the hazards of respirable silica dust, proper work practices, and the importance of the controls installed for their protection,
(9) Provide a heating system that does not blow dust around the plant or which uses a filtered recirculating system, and
(10) When necessary, the use of proper respiratory protection for affected workers.

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Table 2. Summary of dust controls and ventilation rates for different processes at slate milling operations (cont.)

Mill Number	Product	Strip Saw	Block Saw	Splitter	Manual Trimmer	Drill/ Punch	Mill/Room Ventilation
6A	Roof Tile	Enclosure Water Chimney 0.61 m^3/s 15 change/hr	*(In same enclosure as Strip Saw)*	Exhaust Duct	Exhaust Duct		Rest of Building 631 m^3 0.50 m^3/s 3 change/hr
6B	Floor Tile	Water 0.68 m^3/s *	Water	Wall Fan			410 m^3 0.87 m^3/s 7.6 change/hr
7	Rough-cut Floor Tile	Water Enclosure 1.44 m^3/s *		---			43.m^3 1.44 m^3/s 119 change/hr *(saw only)*
8	Roof Tile	Enclosure Water 3.93 m^3/s 64 change/hr	*(In same enclosure as Strip Saw)*	---	Exhaust Fans		1882.m^3 0.22 m^3/s 0.4 change/hr *(excluding saw)*
9 A	Roof Tile	Water 0.70 m^3/s *		Wall Fan 1.84 m^3/s	Wall Fan .09 m^3/s		770.m^3 2.63 m^3/s 12 change/hr
9 B	Roof Tile	Water		—	—		Fan not operating
10 A	Roof Tile	Water 0.49 m^3/s 5 change/hr *(In same*	Water *room)*	Wall Fan 2.07 m^3/s 28 change/hr	*Fans Airflow not taken*		Each Room is Sealed off from Others
11	Roof Tile	Water Enclosure Chimney	Water Enclosure Chimney	---	---		Mill not running at Time of Study
12 A	Roof Tile	Water Enclosure 1.48 m^3/s 100 change/hr		---	Centrifugal Fan	---	---
12 B	Roof Tile	Water Enclosure 1.21 m^3/s 62 change/hr		---	Centrifugal Fan		---

Notes:
-- Indicates no controls.
Blank indicates no operation at the respective mill.
* Fan ventilated more than just saw area and the air change per hour rate is the same as the general mill ventilation.

Table 2. Summary of dust controls and ventilation rates for different processes at slate milling operations.

Mill Number	**Product**	**Strip Saw**	**Block Saw**	**Splitter**	**Manual Trimmer**	**Drill / Punch**	**Mill/Room Ventilation**
1A	Roof & Floor Tile	Enclosure Water 5 hp fan	Enclosure Water 0.16 m^3/s	Wall Fan 0.71 m^3/s	Wall Fan 0.73 m^3/s		1,636 m^3 2.63 m^3/s 6 change/hr
1B	Roof, Floor & Specialty Tile	Exhaust Duct Water					2,736 m^3 1.43 m^3/s 2 change/hr
2	Roof Tile	Exhaust Duct Water		Exhaust Duct Water	Exhaust Duct Water		467 m^3 0.37 m^3/s 3 change/hr
3	Roof Tile	Enclosure Water 2.14 m^3/s 321 change/hr		---	Wall Fans 2 fans @ 0.51 m^3/s 12 change/hr		Separate Rooms
4A	Roof Tile	Enclosure Water 8.92 m^3/s 49 change/hr *(In same*	Water 0.88 m^3/s *room)*	---		Exhaust Duct 0.26 m^3/s 1.6 change/hr	Operations in Separate Rooms
4B	Roof Tile				Enclosed Exhaust duct 0.42 m^3/s	*(Combined with Trimmer)*	2,398 m^3 0.42 m^3/s 0.6 change/hr
4C	Roof Tile				---		---
5A	Roof Tile	Water Exhaust Chimney 1.66 m^3/s 26 change/hr *(In same*	Water Exhaust Chimney 1.79 m^3/s *room)*	Wall Fan 3.08 m^3/s	Wall Fan 1.20 m^3/s		Splitter Trimmer Same Room 15 change/hr
5B	Roof Tile	Water Exhaust Chimney 1.16 m^3/s 21 change/hr *(In same*	Water Exhaust Chimney 2.09 m^3/s *room)*	Wall Fan 3.82 m^3/s	Wall Fan 0.95 m^3/s		Splitter and Trimmer in Same Room 17 change/hr