A new method to clean dust from soiled work clothes

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ABSTRACT: Dust from worker's clothes has been shown to be a problematic source of personal dust exposure. A recently completed effort between NIOSH and the Unimin Corporation has resulted in a quick and effective way to clean worker clothing. The process involves a booth under negative pressure with an air spray manifold to supply compressed air to blow off the dust from the clothing. The overall system is designed to meet MSHA and OSHA requirements. Results of field testing indicated that the manifold cleaned the clothes 10 times faster and removed 50% more dust than cleaning methods used by workers today.

1 INTRODUCTION

New methods and techniques to lower respirable dust exposures to workers in the mining industry are constantly being investigated by health and safety specialists. One area of known worker exposure throughout all industries is from contaminated work clothing. For the mining industry, a U.S. Bureau of Mines report documented up to a 1 mg/m^3 increase in worker's dust exposures on a number of separate occasions from dusty work clothes (Cecala & Thimons, 1986). These cases indicated that respirable dust levels were elevated to the extent that workers could be over their exposure limit in less than two hours. As the individuals performed their work duties, dust was continuously emitted from their clothing. The most effective way to eliminate this dust source was to clean or change their work clothing. In the past, the only MSHA-approved method to perform clothes cleaning was to use a HEPA-filter vacuuming system which is very difficult and time-consuming task to perform. Workers will sometimes use an air hose to blow off the dust on their clothing. This method is prohibited by both MSHA and OSHA and may cause exposure to co-workers by liberating dust to the surrounding area.

A cooperative research effort between NIOSH and the Unimin Corporation has resulted in an improved method to clean the workers clothing. The new method utilizes an enclosed booth which can either be ducted to a baghouse dust collector, cleaned by a self contained HEPA filter, or ducted outside. The booth is under constant negative pressure therefore, no dust liberated by the cleaning process contaminates the surrounding area. A compressed air spray manifold system was developed to remove the product from the workers clothing. The system consists of a ball-valve actuated steel pipe manifold with flat-fan air sprays supplied by a 0.45 or 0.90 m^3 (120 or 240-gallon) air reservoir tank. The pressure to the system is regulated to 206.8 kPa (30 psi) to comply with MSHA and OSHA regulations. The new method simply requires the worker to don the required PPE, enter the booth, actuate the air valve, slowly spin in front of the air spray manifold (taking roughly 17 seconds), and exit the booth with clean clothing.

On-site testing by NIOSH researchers has shown that the new method is 10 times faster and removed 50% more dust than the currently used clothes cleaning methods. It is both simple and cost effective and has applications in the mining industry as well as other industries where particulate contamination of clothing is an issue. This new technique was recently approved by MSHA under a petition for modification.

2 CURRENT REGULATIONS AND PROCEDURES

There are two federal regulations that affect the cleaning of clothes during the work day for the United

States mining industry. The first is a mining regulation established by the Mine Safety and Health Administration (MSHA) in 30 CFR Part 56.13020, which states: "At no time shall compressed air be directed toward a person. When compressed air is used, all necessary precautions shall be taken to protect persons from injury." A second regulation is a general industry standard established by the Occupational Safety and Health Administration (OSHA) in 20 CFR 1910.242(b), stating that: "Compressed air shall not be used for cleaning purposes except where reduced to less than 206.8 kPa (30 psi) and then only with effective chip guard and personal protective equipment."

Currently, the only approved method by MSHA to perform clothes cleaning is to use a HEPA-filter vacuuming system. To perform this technique, a worker uses the vacuum hose and manually moves the nozzle over his/her soiled clothing in an attempt to remove the contamination. This is a very difficult and time-consuming task to perform. Because of this, some workers actually would prefer to use a single compressed air hose to blow dust from their work clothing, even though this is not an approved method of cleaning. Using this technique can have numerous drawbacks to include: the use of higher than OSHA approved pressures; and being performed in the open work areas which not only contaminates the worker, but co-workers as well. While investigating a new approach to perform this clothes cleaning process, it was critical to be able to meet the federal regulations and standards and come up with a process that workers would want to use.

3 A NEW CLOTHES CLEANING PROCESS

The initial step of the clothes cleaning process design was to develop a safe area to clean clothing. UNIMIN Corporation purchased an enclosed booth and installed it at their Marston facility, which provided the worker sufficient space to effectively perform the cleaning operation. Above the door was an open grate that provided an intake for the ventilation airflow. A return air plenum located on the bottom-back wall of the booth was ducted to the mill building baghouse dust collector system, which provided a constant flow of air through the enclosure. See figure 1.

The exhaust flow rate was measured at 2.17 m^3/sec (4,600 cfm). The booth had a negative differential pressure of 37.3 Pa (-0.15 inches w.g.). Since the booth is under constant negative pressure, it proved to be an effective area for clothes cleaning because it did not allow any dust leakage into the plant.

The next critical aspect was to develop an effective method to remove the product from the clothing. To do this, air nozzles were installed in a spray manifold

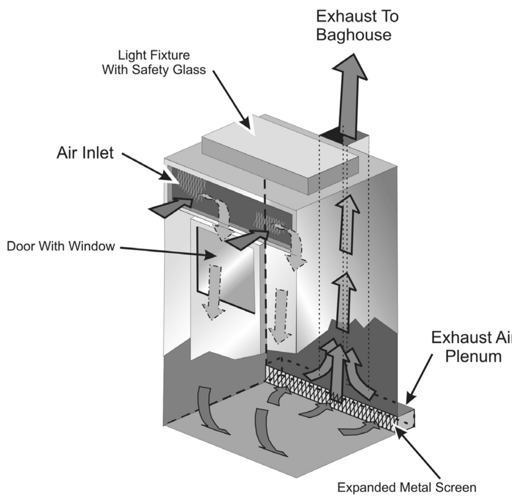

Figure 1. Cleaning booth showing airflow.

that used compressed air to remove the dust from workers' clothes. Considerable design effort went into determining the most effective spray nozzle manifold configuration and numerous laboratory tests were conducted at the NIOSH Pittsburgh Research Laboratory. Researchers also evaluated the impact of varying cleaning distances, clothing type, nozzle types, nozzle spacing, air pressure, and spraying duration to optimize the cleaning effect.

The air spray manifold was fabricated from 63.5 mm (1– $1/2$ inch) schedule 40 steel pipe that was capped at the base. The air spray manifold was actuated by the worker performing the cleaning process by operating a timer-set pneumatic valve located on the top of the manifold. The pneumatic valve had a safety interlock option which would automatically shut the air supply to the manifold if the exhaust ventilation system failed to keep the booth under sufficient negative pressure. Twenty-six (26) flat fan air nozzles were mounted along the manifold, spaced on 50.8 mm (2-inch) centers. With this spacing, the flat fan nozzles seemed to provide the most uniform cleaning. The bottom nozzle was a circular design located 152.4 mm (6 inches) from the floor. This nozzle was used in coordination with a ball-type adjustable fitting that was directed downwards to clean the individual's work shoes or boots. See figure 2.

At a pressure of 206.8 kPa (30 psi), the air spray manifold system expels 4.7 m^3 (166 cubic feet) of air for the typical cleaning period. In order to supply this compressed air volume to the air nozzles for effective cleaning, a 0.45 m^3 (120-gallon) air reservoir tank was necessary. This tank was installed at the operation and was typically pressurized to the 1,034.2 kPa

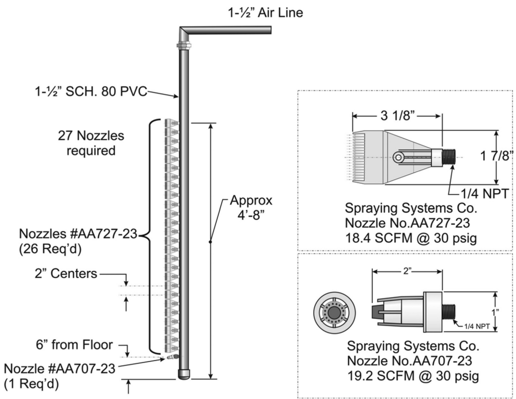

Figure 2. Air nozzle manifold design.

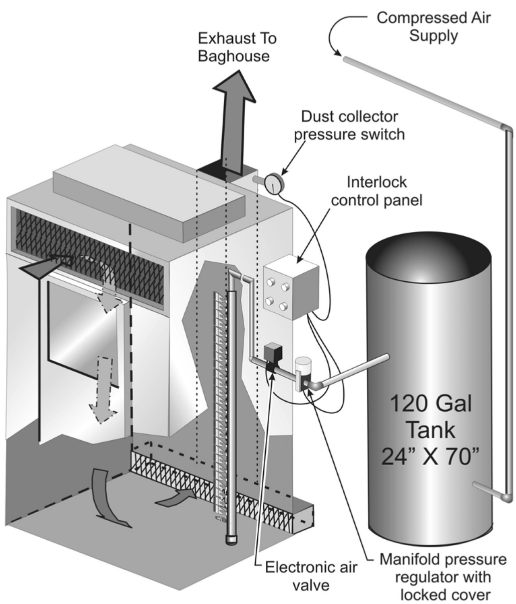

Figure 3. Booth, manifold and reservoir.

(150 psi) level. The air reservoir was located directly behind the cleaning booth and hard-piped to the air spray manifold located inside the booth. Supply air to the manifold was regulated down to 206.8 kPa (30 psi). The air regulator was located in a lock-box enclosure to prohibit anyone from tampering with the air pressure. Figure 3 shows the cleaning booth, air reservoir, and air manifold configuration.

The worker performing the cleaning process is required to wear a half-mask fit-tested respirator with an N100 filter, hearing protection, and full-seal goggles.

4 EVALUATION OF THE THREE CLEANING METHODS

Field evaluation consisted of randomly testing the three different cleaning methods. The HEPA vacuuming system, the single air nozzle regulated to 206.8 kPa (30 psi), and the air nozzle manifold system which was also regulated to 206.8 kPa (30 psi). All of these methods were performed in the booth.

Two gravimetric dust sampling racks were constructed to sample inside and outside of the booth. Each rack consisted of two pumps (calibrated to 1.7 liters/min), two 10-mm Dorr-Oliver cyclones and two 37-mm pre-weighed dust filter cassettes. One rack was hung on the inside of the booth adjacent to the spray manifold. The other rack was hung outside of the booth near the door. The weight gains on the two filters at each location were averaged to provide an average respirable dust mass for each location.

The instantaneous monitor used during this testing was the Personal Data RAM (pDR) by Thermo Electron Corporation which was set to active sampling mode. One pDR sampler was hung on the outside booth rack and one on the inside booth rack to enable a real-time dust concentration track inside the booth and monitor for outside contamination during the testing.

In order to test for possible contamination of the worker by leakage around the $1/2$-mask respirator, researchers utilized a barbed fitting which is commonly used during fit testing of respirators. This fitting was installed between the $1/2$-mask respirator and one of the filter cartridges. A piece of flexible tubing connected to $1/2$-mask respirator to an air-tight box which housed a 10-mm Dorr-Oliver cyclone. This cyclone was connected to another pDR in active mode. This set-up enabled real-time monitoring for contamination in the respirator during testing of the cleaning methods.

A matrix of tests was performed at UNIMIN's Marston plant to evaluate the effectiveness of this newly developed technique. For this field testing, the new clothes cleaning technique was compared to the vacuuming system and the single handheld compressed air nozzle. In addition, two different coverall types were tested, with one being 100 pct cotton and the other a cotton-polyester blend. Prior to each test, the coveralls were soiled with inert limestone dust to a degree that represented an extreme case of soiling.

The weighing procedure consisted of pre-weighing the clean coveralls and placing them in a pre-weighed bag. Once the coveralls were soiled, they were placed in the bag and weighed again. The researcher then removed the coveralls from the bag (which was post-weighed) and put on the coveralls while standing on a pre-weighed piece of brattice cloth. The brattice piece was then weighed to account for any dust lost while donning the coveralls. After the test method was performed, the coveralls were removed while standing on

Table 1. Amount of dust remaining on coveralls after cleaning time for cotton and polyester/cotton blend coveralls.

	Cotton	Cotton	Poly/Cot Blend	Poly/ Cot Blend
Cleaning Method	Dust on Coveralls (grams)	Clean Time (sec.)	Dust on Coveralls (grams)	Clean Time (sec.)
Vacuuming	63.1	398	45.5	346
Air Hose	68.8	183	48.4	173
Manifold	42.3	17	21.9	18

Figure 4. Effectiveness of cleaning methods.

a pre-weighed piece of brattice and placed in a pre-weighed bag. The coveralls and bag were weighed together and the brattice was weighed to account for any dust lost while removing the coveralls. This extensive weighing regimen was developed to account for all dust lost during each test.

Each test was timed by a stopwatch to determine the actual cleaning time. Results of testing indicated that the manifold cleaned the clothes 10 times faster and removed 50% more dust than the single air nozzle or vacuuming methods. Table 1 provides the average cleaning times and the remaining dust weights on the coveralls from the three different techniques evaluated.

These values represent averages calculated for two NIOSH test personnel and a total of 96 tests. Figure 4

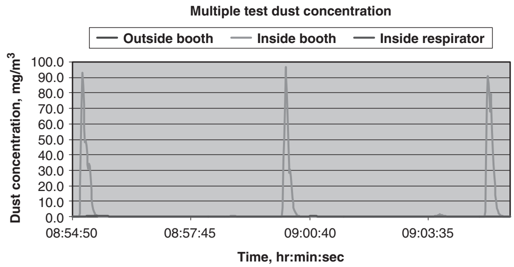

Figure 5. pDR results showing dust concentrations during tests.

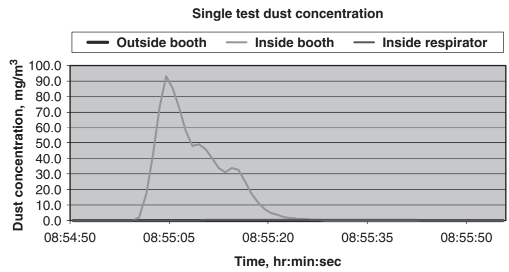

Figure 6. pDR results showing a single test.

shows the relative effectiveness of the cleaning techniques tested.

Respirable dust samples taken inside the respirator of the test personnel performing the clothes cleaning process showed minimal to no respirable dust exposure. In more than half of the 48 tests performed with the air spray manifold, the test subject's respirable dust concentration remained at 0.00 mg/m^3 inside the half-mask respirator. See figure 5.

In the remainder of the tests, the value remained very low with an overall average respirable dust concentration of 0.02 mg/m^3 for the entire test group. Figure 6 shows the effectiveness of the booth to remove the dust which is liberated from the spray manifold.

Note that there was no contamination to the outside environment during the testing. Figure 6 also shows the short time-frame to bring the inside booth concentration back to zero.

Another factor evaluated during this study was the cleaning effectiveness of the process on two different coverall fabrics. As Table 1 shows, there was a significant improvement with the cleaning effectiveness of the polyester/cotton blend coveralls when compared to the pure cotton type. This needs to be considered by operations implementing this new clothes cleaning process.

With the air spray manifold design, the flat fan nozzles extend 79.4 mm (3-1/8 inches) from the supply pipe and could easily be broken off if struck forcefully. Because of this, it is recommended that side barriers be installed to protect the air nozzles. During field testing, 25.4 mm (1-inch) wood sheeting was used along both sides of the nozzles, providing an effective barrier to minimize the potential for nozzle damage.

The air spray manifold was designed for a person 177.8 cm (5′–10″) in height, which was chosen based upon the 50-percentile height for a male worker. Taller workers will have to stoop and drop their shoulders to effectively clean their upper body. When a person is shorter, the top air nozzles can be covered with deflectors to prevent the air sprays from directly hitting the individual's face. During the final field test, the top four nozzles were modified with deflectors attached to the side barriers fabricated from 101.6 mm (4-inch) PVC pipe that was cut in half and then into 50.8 mm (2-inch) wide strips. Latches were attached on both sides of these deflectors so they could be locked in either the open or closed position.

A primary concern regarding any type of new technology is the cost of implementation. The total cost of the clothes cleaning unit should be in the \$3,000 to \$4,000 range, excluding the cost for the exhaust volume of air and ductwork cost. The clothes cleaning process utilizes compressed air as the cleaning medium. The compressed air utility available at the operation must be analyzed to ensure that critical processes are not starved due to the operation of the clothes cleaning process. A dedicated compressor to supply the necessary air may be an option in this case.

At the UNIMIN Marston Operation test site, an excess exhaust volume was available in the baghouse and thus was used for this system. Most operations will not have this luxury and this will have to be built into the cost. UNIMIN and NIOSH are in the process of testing a cleaning system for operations without available baghouse capacity which will utilize an exhaust fan to blow the dust-laden air up a stack to the outside of the facility. Since the amount of dust removed from a worker's clothing will be relatively minor in relation to the amount of air necessary to place the booth under negative pressure, the respirable dust concentration of air coming out of this stack most likely would be insignificant. Testing of this system will be performed at the UNIMIN Elco Operation located in Elco, IL, in the near future.

5 CONCLUSIONS

The new clothes cleaning process proved to be very efficient since the worker only needed to don the required PPE, enter the booth, actuate the automatic valve, slowly spin in front of the air spray manifold (taking roughly 17 seconds), and exit the booth with clean clothing. This process has been demonstrated to be a much more effective method to remove dust from a worker's clothing than methods currently used by workers. Although this process was designed for workers in the mining industry, it is applicable to any industry where contaminated work clothes are a problem.

It must be noted that this newly designed clothes cleaning technique is not currently blanket approved by MSHA for U.S. mining operations. A Petition of Modification has been granted to UNIMIN Corporation by MSHA for use of the clothes cleaning process at the Marston plant. Operations wanting to use this technique may receive MSHA approval on a case by case basis.

REFERENCE

Cecala, A.B. & Thimons, E.D. 1986. Impact of Background Sources on Dust Exposure of Bag Machine Operator. *US Bureau of Mines Information Circular*. IC 9089.