The Western U.S. Mine Safety and Health Training and Translation Center's DPM Project, with a Special Emphasis on DPM Compliance Workshops

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Abstract

To help address an influx of new miners spurred by retirements and robust mining sector growth in the U.S., the Western U.S. Mining Safety and Health Training and Translation Center (MSHTTC) was established in 2004 through a grant from the National Institute for Occupational Safety and Health (NIOSH). The primary goal of the Center is to help reduce the number of injuries to miners through an integrated program of training intervention and translational research. Among the 15 education projects in its first year of operation is the "Evaluation and Control of Diesel Particulate Matter in Western Metal/Nonmetal Mines."

According to the Mine Safety and Health Administration (MSHA), there were 70 metal, 42 nonmetal, and 120 stone underground operations in the United States in 2003, all of them using diesel-powered equipment. MSHA's 2002 baseline study further showed that while most of the mines (68%) were below the 400 $_{TC}$ $\mu g/m^3$ interim limit, only 28.5% (or 49 mines) were below the 160 $\mu g/m^3$ total carbon final limit. There are still significant challenges ahead. This paper discusses the DPM project's first-year operation, including conducting workshops for large underground stone operations, participants' feedback, current control strategies, and concerns about meeting the final 160 $\mu g/m^3$ DPM standard in January 2006 or sometime later.

Introduction

Like all other industrial activities, conditions that have the potential to damage both the health and safety of miners are numerous in the field. In the United States, from 1880 to 1910, mine explosions and other accidents claimed thousands of victims. The worst year in coal mining history was 1907, when 3,242 miners lost their lives. That year also had America's worst mine explosion ever which killed 358 miners near Monongah, West Virginia. Although metal and nonmetal mines were less deadly than coal mines, records for the era show that they were highly hazardous as well with fires, explosions and cave-ins causing many deaths and injuries. The deadliest non-coal mining accident in the U.S. was also caused by a mine fire in Montana that killed 163 men in 1917. (Anon, 2005)

With each passing decade, the annual number of mining deaths and rates of injuries have declined significantly due to the involvement of the entire mining community. A combination of factors has been responsible for the dramatic safety gains in the U.S. mining industry since the turn of the last century. The major ones are (1) the creation of the U.S. Bureau of Mines which performed the primary functions of accident investigation, production and safety research, and teaching courses on safety prevention, first aid and mine rescue; (2) many subsequent federal and state laws that better advised and regulated the mining industry; (3) the creation of an enforcement agency, the Mining Enforcement and Safety Administration (MESA) in 1973 and the Mine Safety and Health Administration (MSHA) in 1977; and (4) introduction of safer and more productive mining machines and systems, mining methods, and the growing awareness of the importance of effective accident prevention programs and an increasing cooperative attitude toward safety issues by the industry, labor and government. (Anon. MSHA website)

It is also widely believed that the mandatory provisions on training and retraining of miners set forth in Part 48 of the Federal Mine Safety and Health Act of 1977 and the permanent creation of the National Mine Health and Safety Academy in Beckley, West Virginia, has also played key roles in continuously decreasing accidents and deaths rates of miners in the U.S. (Figure 1)

Figure 1. The National Mine Health and Safety Academy in Beckley, West Virginia.

Located on an 80-acre site, the Academy is responsible for training mine safety and health inspectors and technical support personnel of MSHA. Students can be trained on a variety of different disciplines that are critical to safe production in the field: roof and ground control, ventilation, electrical power, machinery, industrial hygiene, mine emergency preparedness and response, and mine rescue. Although the charge for the Academy is to provide training for all mining regions and for both coal and non-coal sectors, its proximity to the eastern U.S. major coal fields has made most people view it as dedicated to coal, and especially for the eastern U.S.

Challenges Faced in the Mining Industry in the 21st Century

Over the past half century, technological advances such as improved longwall equipment, increased use of diesel-powered equipment, better mechanical cutting of hard rock, automation, and bulk material handling have had major impacts on the mining and quarrying industries, and the nature of mining in the U.S. This has been in part driven by the need for lowering production costs, enhancing the productivity of workers and mining equipment, and meeting regulatory and stakeholder requirements in such areas as health and safety, environmental and aesthetic impacts as a result of increasing scrutiny and demand. The U.S. mining industry has been able to meet these challenges through the use of advanced technologies and improved mining methods to significantly increase mineral production and improve mine health and safety at the mine sites.

Stepping into the 21st century, the U.S. mining industry is faced with several major challenges: increased consolidation and globalization, an aging workforce, regulatory and political constraints on new development, increasing emphasis on mine health and safety, environment requirements, and until recently, low commodity prices. These trends have resulted in a mining community that is risk-averse and struggling against thin profit margins. (Peterson, *et al.* 2001) Two factors are of primary interest: The training of mine workers and meeting increasingly stringent mine health and safety standards.

An Aging U.S. Mining Workforce

For a number of years, there have been concerns about an aging mining workforce and an imminent influx of new, inexperienced miners in the mining industry. This raises some concerns in the area of health and safety as historical precedent suggests that when significant numbers of new miners entered into the workforce, job and skill training are essential. The potentially adverse impact is especially serious when new miners will work in areas where occupational safety and health problems persist and in jobs that will encounter dangerous or unhealthy conditions and work situations, e.g., encountering poor roof and ribs, methane, other gases, respirable dust, fires, and DPM. (Grayson, 2004) To help address this fast-developing problem, the Western Mining Safety and Health Training and Translation Center (MSHTTC) was formed.

Western U.S. Mining Safety and Health Training and Translation Center

Formally established on September 1, 2004, the Western Mining Safety and Health Training and Translation Center (Figure 2) was funded by the National Institute for Occupational Safety and Health (NIOSH) through a National Institute of Health (NIH) program review process. The primary specific aim of this project is to reduce the number of injuries to miners through an integrated program of training intervention and translational research. With a total funding of $4.02 million over five years, the Center is a consortium of four universities with the University of Missouri-Rolla in the lead; others include Colorado School of Mines, Montana Tech, and the University of Utah. (Grayson, 2004)

Figure 2. Logo for the Western Mining Safety and Health Training and Translation Center.

The Center is designed to specifically develop and implement a broadly collaborative western U.S. program that does the following (Grayson, 2004):

1. Identify the training needs of mining personnel, today and in the near future;
2. Develop and conduct a coordinated, systematic, targeted, and multi-faceted Western training program, which addresses prioritized mine safety and health issues;
3. Provide qualified instructors and faculty across the West to train mining personnel in thrust areas;
4. Evaluate the effectiveness and impact of the training program on reducing injuries to mining personnel;
5. Conduct limited translational projects that convert essential mining occupational health and safety research results with limited dissemination into information, resources, and tools that can achieve wider dissemination.

Other significant features include the following:

- ♦ The training provided by this program will satisfy current OSHA, MSHA, and NIOSH recommendations and guidelines.
- ♦ Through training and translational efforts, this project will also address the developing gap in experience by capturing the expert knowledge and situation-based judgments of miners in some of the industry's most persistently hazardous jobs.
- ♦ In order to ensure the effectiveness of training tools, the NIOSH critical elements of training, which hinge on the Training Intervention Effectiveness in Research (TIER) method recommended by NIOSH, will be used as a general guide for activities.
- ♦ Using this approach, the effectiveness of the tools will be demonstrated through a set of well-defined, measurable outcomes focused on attaining for miners the desired learning of knowledge via training scenarios requiring expert skills and judgments.
- ♦ Follow-up analyses to determine the impact on mine site and regional accident and injury experiences will be done.

In order to achieve the primary aim and goals to help address persistent health and safety problems, new or emerging ones, and problems specific to mining sectors, regions, and states, as well as changing regulations, jobs, accident classifications at different types of mining operations, a periodic training needs assessment will be used to prioritize issues and implement projects to effectively address identified specific training needs. Based on specific faculty expertise and background, the 15 education programs and one translation project are being conducted by university partners of the consortium (see attachment).

With the increasing use of diesel-powered mining equipment due to its power and flexibility, there have also been increasing concerns about diesel exhausts' long-term impact on miners' health. To help address this concern, the diesel evaluation and control program is one of the Center's 15 education programs (Evaluation and Control of Diesel Particulate Matter in Western Metal/Nonmetal Mines) and is conducted by the authors. The DPM education project is designed to transfer detailed knowledge to mine personnel on the nature of DPM, its health effects at high exposures, and options for combining engineering and work practice controls, largely the only means permitted to attain compliance under the new regulation, and help mine operators achieve compliance with the final permissible exposure limit.

DPM Regulations and Control Technology Options

It has been generally recognized by the medical community and, in recent years, the mining industry that long-term exposure to high concentrations of diesel exhaust emissions in a confined environment will have potential health and environmental risks. These health concerns have resulted in the issuance of government regulations governing the emission rates for diesel equipment used in U.S. coal mines (Part II - 30 CFR 72, "Diesel Particulate Matter Exposure of Underground Coal Miners; Final Rule" on January 19, 2001, with a delay in effective dates to March 15, and subsequent corrections on May 21, all in 2001.) and environmental compliance levels for U.S. metal and nonmetal mines (Part II – 30 CFR Part 57 – Diesel Particulate Matter Exposure of Underground Metal and Nonmetal Miners – Proposed Final Rule on July 5, 2001).

On June 6, 2005 MSHA released the Final Rule for DPM for metal and nonmetal mines (30 CFR Part 57 Diesel Particulate Matter Exposure of Underground Metal and Nonmetal Miners), which establishes an interim permissible exposure limit of 400 $_{TC}$ $\mu g/m^3$ for DPM at underground metal and nonmetal mines. The new Final Rule also removes 30 CFR§57.5062 (requiring a DPM control plan) and modifies §§57.5060 (interim exposure limit, use of PPE, and extensions of time to meet the final DPM limit) and 57.5075 (recordkeeping requirements). The Final Rule also reaffirmed three main conclusions from its 2001 risk assessment that exposure to DPM can materially impair miner health or functional capacity; at DPM levels currently observed underground, many miners are at significant health risk over a working lifetime; and by reducing DPM concentrations underground to the suggested level, such risks currently faced by underground miners can be reduced substantially. (Abrams, 2005)

According to MSHA, over 900 DPM samples were collected in 172 metal and nonmetal mines between November 2002 and March 2003. These averaged 5.2 samples per mine and nearly represented all underground noncoal mines. Of the mines tested, approximately 48 mines (or 27.9%) had at least one sample over the interim total carbon limit of 400 $_{TC}$ $\mu g/m^3$, 124 mines (73.8%) had values below 400 $_{TC}$ $\mu g/m^3$, and 49 mines (or 28.5%) were below 160 $_{TC}$ $\mu g/m^3$. (Pomroy, 2005) Of the mines tested, the majority (69.8%) used room-and-pillar mining methods; these included stones mines, salt mines and potash mines. Trona mines were not visited because they were in compliance with the 400 $_{TC}$ $\mu g/m^3$ limit. (Haney, *et al.*, 2005)

A Sound Ventilation System – Most Critical

A well-designed and properly maintained ventilation system should always be the primary means for control of diesel particulates underground. In fact, a sound ventilation system along with other control technologies have been known to reduce tailpiece exhaust for years, but the push in this area has been accelerated only in recent years due to MSHA regulations. This is especially necessary as the mining industry is expanding due to an increasing demand for minerals worldwide and the continuing expansion of the use of diesel engines in underground mines.

There has been much improvement in reducing DPM exposures in recent years, but more is needed, especially in providing better ventilation in underground stone mines. Many of these mines were developed in the 1980s and early 1990s and were not designed at the time to handle the large air quantity required for proper DPM dilution. What made things even more difficult is the serious lack of proper stopping lines in most of these mines to effectively deliver needed fresh air to working faces; a lack of stopping lines also are causes of air recirculation. Ventilation system upgrading for most stone mines is needed.

Other Control Options

MSHA, NIOSH and the mining industry in U.S., Canada, and Australia have identified the following additional strategies to be effective in controlling DPM underground: Clean engines, environmental cabs, proper or better work practices, alternative fuels, and after-filters. But implementing any changes in the field takes time and industry commitment. The mining industry has made much progress in this area, but more is needed. It is the goal of MSHTTC to lend a helping hand in transferring information on control options to operators by conducting training seminars and workshops, thereby helping to achieve a broader outreach to the industry.

The DPM Workshop – Des Moines, Iowa

With the assistance of MSHA's Compliance Assistance group, the first such workshop was conducted for Martin Marietta Materials personnel on August 16, 2005 in Des Moines, Iowa. There were a total 22 attendees from their regional headquarters and the surrounding mines in Iowa, Missouri, and Nebraska. (Figure 3)

Figure 3. DPM Control Workshop at Des Moines, Iowa.

Workshop content included DPM background and a legislative update; control technology options, including alternative fuel (PuriNox), DPM filters, and ventilation; MSHA's DPM estimator; case studies; and plenty of discussions during and after formal presentations. Discussions, during and after the workshop, showed that most people were concerned about the status of legislation, and more specifically, whether the January 19, 2006 effective date for the Final Rules would stand or not. If there were to be delays on the effective date, then they wanted to know what might be the phase-in criteria. The attendees seemed to feel that these issues would affect their decision-making on some of the implementation and changes.

One comment related to Mirenco retrofit computer technology at several of the mines in Iowa. The technology is designed to have considerable fuel savings, thereby reducing emissions and preventing drive-train maintenance problems, and extending the life of the vehicle. There were mixed opinions among the management: Some were pleased with the technology (at a cost between $2,500 to $3,000 per piece of equipment) and viewed it as one of the possible solutions to DPM reduction, while others felt that some of the performance gains can also be achieved by using PuriNOx.

One of Martin Marietta's mines in Iowa has used PuriNOx diesel fuel manufactured by Lubrizol since May 2004. (The mine used low sulfur #2 diesel before the switch, but switched back to ultra low sulfur #2 diesel in July 2004.) PuriNOx costs about $0.15/gal more than low sulfur #2 diesel. Although there were reductions of diesel particulates (average opacity readings were reduced from 30.8% to 7.9%), operators were not happy with the loss of power on uphill traffic. It was reported that it would take 18 to 28 seconds longer (23.16% and 34.55% longer, respectively) in an uphill drive to the crusher. One haul truck took 45 seconds (47.95%) longer when compared to using regular diesel fuel. Operational logistics and additional transportation cost were also a concern.

There were also questions regarding the experience of diesel particulate filters (DPF) at other locations. Concerns were raised on DPF costs and operational logistics.

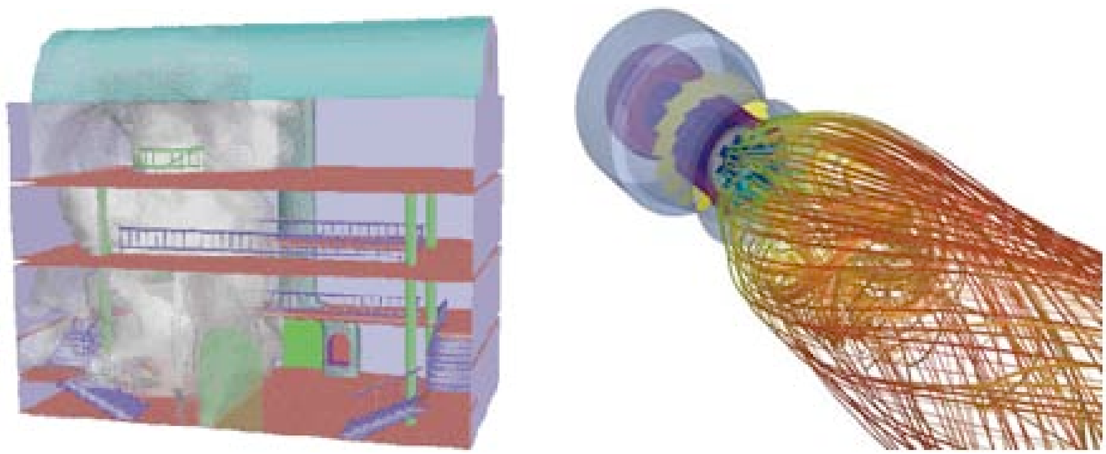
Overall, the attendees were pleased with the presentation and subsequent discussions. Some suggested that the workshop should be available to mine personnel to maximize information dissemination.

Future DPM Workshops and Ongoing DPM Simulation Research

A similar workshop has been scheduled for the Doe Run Company at Viburnum, Missouri, in mid October; between 15 and 17 attendees are expected. Two other workshops for a tunneling operation in New Mexico and stone mines in the Nebraska and Missouri area are being planned. They should be conducted in spring 2006.

An electronic DPM brainstorming session for mine operators to take advantage of modern distant-learning software and hardware at UMR has also been discussed. Through proper planning, the number of mines reached can be multiplied.

Fundamental research using FLUENT on DPM distribution in underground airways is also being studied at UMR. FLUENT is a world-leading computational fluid dynamics (CFD) code for a broad range of flow-modeling applications. Properly applied, it can model complex flows ranging from incompressible (low subsonic) to mildly compressible (transonic) to highly compressible (supersonic and hypersonic) flows, to handle Newtonian and non-Newtonian flows. It has been used in designing aircrafts and automobiles, modeling NOx distribution inside a burner (Figure 4), modeling the temperature of a flame surface, and many other applications.



(a) Surface of smoke concentration in a multi-level indoor residential space.

(b) Modeling low NO_x burner

Figure 4. FLUENT used to model complex airflows can also be used to model DPM distribution in underground airways.

This should be an ideal tool for modeling 3-D DPM distribution in underground airways, temperature distribution around exhaust pipes and other obstructions. It will enable us to better understand how DPM dissipates in an underground environment, and to better design specific applications of controls.

Summary

With an expanding use of diesel-powered equipment in the field and the already available scientific evidence of the long-term impact of diesel particulates on miners' health, MSHA determined that DPM puts miners at excess risk for diseases of the heart and lung, including lung cancer. The Agency later published *Part II – 30 CFR Part 72: Diesel Particulate Matter Exposure of Underground Coal Mines* on January 19, 2001. For metal and nonmetal mines, the Final Rule was also published in January 2001 and MSHA began compliance sampling and enforcement of 400 $_{TC}$ $\mu g/m^3$ interim DPM limit in July 2003. The Final Rule released on June 6, 2005 established the effective date for the final DPM permissible exposure limit (PEL) as January 19, 2006.

With the advent of the new MSHA regulation to control DPM exposures, the industry is still trying to comply consistently with the interim DPM concentration limit of 400 $_{TC}$ $\mu g/m^3$. Achieving the necessary reduction in DPM emissions into the mine environment at the final DPM PEL will require substantial implementation of engineering or work practice controls. A sound mine ventilation system has always been the first step towards controlling DPM. Unfortunately, many stone mines developed in the past two decades were not designed to handle the large air quantity needed for effective dilution. Upgrading an existing ventilation system, although expensive, is necessary for providing needed air quantity.

There have been DPM control technologies developed over the years that have proven effective in controlling diesel particulates underground. But to implement any changes and/or new measures requires management commitment and effort as well as the cooperation of laborers. The DPM education program discussed here will help inform mine operators and miners more broadly about issues and options for engineering and work practice controls, the only means permitted to attain compliance under the new regulations. In the end, operators want to achieve compliance with the new standards, with a comfortable margin.

References

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Attachment

Fifteen education programs (2004-2005)

1. Evaluation and Control of Diesel Particulate Matter in Western Metal/Nonmetal Mines – Tien, UMR
2. Surface Mine Haulage Safety – McGuire, CSM
3. Mine Rescue Training – Fuller, CSM
4. Basic Mine Ventilation – Pierce, CSM
5. First Responder at Mine Sites Training – Ferriter, CSM
6. Explosives and Blasting Safety – Fischer, CSM
7. Highwall Safety and Stability – Ferriter, CSM
8. Introduction to Industrial Hygiene and Dust Control – Dmytriw, CSM
9. Fundamentals of Noise – Dmytriw, CSM
10. Inspection of Embankment Dams – Dmytriw, CSM
11. Ground Control (Underground Operations) – Ferriter, CSM
12. Mine Radiation, Home Radon – Beckman, CSM
13. Hazard Identification and Risk Assessment for Small Mines in Western United States – Calizaya and Nelson, Utah
14. Jackleg Drilling and Bolting Injury Reduction – Patton, Hart, Cronoble, Jensen; Montana Tech
15. Material-Handling Injury Reduction in Western Metal/Nonmetal Mines – Patton, Montana Tech

Translation Project

Virtual Reality-Based Training of Underground Mining Roof Bolters – Grayson, Apel, Hilgers, Hall; UMR