ABSTRACT OF PRESENTATIONS – MDEC 2004

1**. A Review of Controls Being Used to Reduce Diesel Particulate Exposures in Underground Metal and Nonmetal Mines,** Robert A. Haney (Mine Safety and Health Administration)

The Mine Safety and Health Administration conducted compliance assistance diesel particulate sampling throughout the metal and nonmetal mining industry. Based on that sampling, MSHA identified mines that were having difficulty meeting the dpm limit. To provide further assistance, MSHA then visited approximately 60 of the mines that were experiencing difficulty complying with the diesel particulate standard. As part of these visits, diesel particulate exposures were measured and controls technologies for diesel particulate were observed and assessed. Controls consisted of ventilation, clean engines, environmental cabs, alternative fuels, after-filters and work practices.

The focus of the follow up compliance assistance visits was to assess control effectiveness and to make recommendations to mines experiencing difficulty in meeting the diesel particulate standard. At each mine visited the ventilation controls were evaluated, engine emissions were determined for equipment in use, environmental cabs were examined, and operational practiced were noted. Additionally, in several mines control technologies including alternative fuels and after-filters were evaluated.

A comparison was made of mine and section airflow to equipment particulate indices Based on engine emissions, horsepower and operating time, the contribution of individual engine emissions to total mine emissions was made. Environmental cab integrity, positive pressure and air filtration systems were checked and operational practices relating to diesel particulate exposure were assessed. The paper summarizes the preference and magnitudes of controls that were typically used or needed for successful control of diesel particulate emissions. Additionally, results of the assessments of alternative fuels and after-filters are presented.

2. **DPM Reductions at Underground Metal and Nonmetal Mines Mine Using Alternative Fuels,** Mark J. Schultz, Deborah M. Tomko, Roger L. Rude (Mine Safety and Health Administration)

The Mine Safety and Health Administration (MSHA) has been assisting mine operators in meeting both current and future diesel particulate matter (DPM) regulations. To meet these requirements, mine operators can choose the controls that are best suited to their operation. Typical controls for DPM include: ventilation, clean engines, environmental cabs, alternative fuels, after-filters, and work practices. In an effort to evaluate the effectiveness of alternative fuels, MSHA, in cooperation with mine operators, has been conducting studies at underground mines to evaluate various alternative fuels encountered in the mining community. The alternative fuels tested include various blends of both recycled vegetable oil and soybean oil based bio-diesel fuels and both summer blend and winter blend water emulsified fuels. The surveys have been conducted at four separate mines with similar surveys conducted at different mines to confirm results. The results of the surveys indicate significant reductions in both DPM emissions and personal exposures at the mines.

The surveys conducted have taken place when the entire mine has switched over to the alternative fuel. To date, sixteen field trips have been made to collect field data. Sampling has been conducted both before and after the mine has switched over to the alternative fuel. DPM sampling is conducted at the mine for multiple days. Both area DPM sampling and personal DPM sampling are conducted throughout the mine. Area samples are placed in all intake and return entries of the mine. Air quantity measurements are also conducted at each of the area sample locations. The results of these samples are compared the baseline sampling conducted to determine magnitude and percentage change in DPM. This paper summarizes the results of these surveys.

3. **Ventilation Design Strategy for Trackless Deep Underground Mines**, Dr. Alex Rawlins (University of the Witwatersrand, South Africa)

The use of trackless equipment or diesel machinery in South African mines is becoming an important aspect of current and future mining practices. By utilising the advantages diesel equipment provide in underground operations, i.e. versatility, productivity, etc., it places greater emphasis on the surrounding environment and the condition thereof. Ventilation and the cooling of deep underground mines is a necessity and high on the list of current and future mine design strategies. The usage of diesel equipment, i.e. LHD's, dump trucks, etc., or in some instances hybrid type systems (combinations of conventional and trackless equipment) could place an additional burden on current and future deep mines.

Trackless equipment usage on deep underground mines does not simply mean investigating the production requirements for a specific mine or mining method and what machinery would satisfy the mine design. The selection process of utilising specific diesel type machinery must include the Ventilation Engineer's perspective. There are two reasons for the Ventilation Engineer's involvement. One reason is because the diesel machine exhaust/outlet/tailpipe air could contaminate or negatively effect the ambient air circulated through the mine. The second equally important aspect is the ingress of additional heat into the underground atmosphere and counter effects included to negate this contamination.

Diesel fuel types and methods to calculate and determine the exhaust outlet air requirements are generally know to the ventilation practitioner (including engineering modifications to machinery). This paper gives a brief overview on different tailpipe exhaust air requirement calculations and alternatives including the additional heat load imposed on an operation. Also included is a general ventilation design strategy for pure diesel/trackless orientated underground mines and combinations of diesel/conventional type machinery applicable to the South African mining industry.

4. The Effect of Valve Coating on Diesel Engine Emissions, Lionel Gillston (Diesel Engine Transformations, LLP)

The principal advance with this technology has been to obtain the needed catalytic effect by coating only the valve faces instead of the whole firedeck. The results include testing on two engines - 850HP Caterpillar 3508 and 150HP Deutz 1013. The coating of only the valves represents coating of 40% of the total head combustion surface at a significantly lower cost than the whole firedeck. This catalytic coating achieves a reduction of ignition lag, lower peak temperatures with lower NOx generation. In addition fuel economies are claimed of up to 3% for steady load and up to 8% on peak loads, both with reduction in the unwanted emissions of particulates, carbon monoxide and unburnt hydrocarbons.

5. **Sharing What We Learned – The Diesel Emissions Evaluation Program Technology Transfer Initiatives**, Michel Grenier (CANMET-MMSL)

The Diesel Emissions Evaluation Program (DEEP) was officially started in April of 1997. Originally, DEEP was intended to be a 5-year, tri-partite, research initiative to investigate available DPM sampling, analysis and control technologies and their application in a mining context.

Very early on, stakeholders and technical committee members realized the importance of transferring what was learned in DEEP to mine operations in Canada and abroad. To facilitate this process, a technology transfer sub-committee was formed to identify what was already being done and what other avenues could be identified to help share the results of the DEEP projects' research. This presentation has two objectives; first to comprehensively list the technology transfer tools used by DEEP through its mandate and also to make MDEC delegates aware of these, in order that they too can take advantage of the resources available to them in order to positively impact their workplace environment.

6. **Sampling of DPM Exposures in Metal and Nonmetal Mines in the United States: Update of Baseline Sampling and First Year Enforcement Experience**, Doris Ann Cash and William Baughman (Mine Safety and Health Administration)

The Mine Safety and Health Administration (MSHA), U.S. Department of Labor, conducted baseline sampling of miners' personal exposures at every underground metal and nonmetal mine covered by the existing regulation as part of a settlement agreement reached in response to a legal challenge to the January 19, 2001 diesel particular matter (DPM) standard. This paper updates and summarizes the analytical results of 1,194 personal DPM samples collected from 183 underground metal and nonmetal mines between October 30, 2002 and October 29, 2003. MSHA extended its period of baseline sampling especially to incorporate into its analysis those mines with a low sampling frequency or where no samples were collected as of March 26, 2003.

The customary way of determining total carbon (TC) concentrations is to add the elemental carbon (EC) and organic carbon (OC) concentrations. TC was also calculated using the formula prescribed in the DPM settlement agreement to eliminate potential OC interferences: TC Concentration = (EC) *1.3. For 93.6 % of the samples, the two methods of calculating TC resulted in the same compliance determination with respect to the 400TC µg/m3 interim DPM limit. Approximately 19.3% of the samples were above the 400 TC µg/m3 interim concentration limit when using TC=EC *1.3 and approximately 22.7% were above the concentration limit when using TC=OC+EC. At four of the mines, all samples taken during the assistance period were above 400TC µg/m3. No overexposures were found in 115 (63%) of the mines sampled. The mean and median TC values for each commodity group, using both EC x 1.3 and calculated by OC + EC, are lower than the interim compliance limit of 400 µg/m3. There are 63 occupations represented in this analysis. The most frequently sampled occupations are blaster, drill operator, front-end loader operator, truck driver, scaler (mechanical), and mechanic. Twenty-six occupations were found to have at least one sample in which the level of TC was over the interim 400TC µg/m3 concentration limit (TC=EC x 1.3).

In August 2003, MSHA published its enforcement policy for the interim concentration limit pursuant to the DPM settlement agreement. The subsequent compliance sampling results, citations issued, and the compliance experience across the six districts are summarized and discussed. Approximately 600 compliance samples were analyzed between October 30, 2003 and August 31, 2004. Nearly half of those samples were taken in stone mines. Metal mines, followed by the salt, trona, and potash mines were the next most frequently sampled commodities. About one in fifteen samples resulted in a citation for overexposure. In some cases where an overexposure was found, MSHA determined that all feasible engineering and administrative controls had been implemented, the affected miner was enrolled in an adequate respiratory protection program, and, therefore, no citation was issued. *

*The compliance sampling data will be updated and verified after 8/31/04.

7. Demonstration of Hydrogen as a Viable Fuel at an Underground Metal Mine, Chelsea Woodward (NIOSH, Spokane Research Laboratory), Richard Anderson (Stillwater Mining Co.) and Floyd Varley (NIOSH, Spokane Research Laboratory)

The Spokane Research Laboratory (SRL) of the National Institute for Occupational Safety and Health (NIOSH) in cooperation with the Stillwater Mining Company has undertaken the demonstration of a hydrogen-fueled mining vehicle to promote the safe use of hydrogen as an alternative fuel in underground mines. The 70 KW rubber tired vehicle, originally developed by the U. S. Bureau of Mines, was included as a subpart of an ongoing SRL project, "Reducing Diesel Emissions in Western Mines", due to the relatively clean emissions associated to hydrogen combustion. An improvement on the Bureau of Mines design was required to safely introduce the technology underground. This effort was begun at SRL in late 2000 and culminated MSHA review and field testing at the Stillwater Mine in Nye, MT in the summer of 2004.

The subject vehicle utilizes a hydrogen-powered spark ignited internal combustion engine for propulsion. The current design of the vehicle includes many technologies in fuel storage methods and safety systems that are applicable to other alternately fueled mining vehicles. The knowledge gained from this work and the monitoring and control systems developed can be transferred to hydrogen fuel-cell-powered vehicles currently under development.

The safety challenges of hydrogen use in an underground mine center around potential failures of the fuel storage and distribution systems. In addition, refueling of a vehicle with a flammable gas presents a hazard different than that posed by the liquid fuels miners are traditionally trained to use. The field demonstration of the NIOSH hydrogen mining vehicle in an underground mine provided regulators and industry with the opportunity to evaluate the necessary systems and controls for further advances in the use of hydrogen as an industrial fuel. Further research needs to make the transition to hydrogen fueled vehicles more attractive to industry are noted.

8. **Fuel Cell Powered Light Duty Mining Vehicle**, Hydrogenics Corporation, Krystal Williams (John Deere ePower Technologies), G. Desrivières and M.C. Bétournay (CANMET-MMSL), F. Delabbio and D. Eastick (HATCH)

The paper describes the applicability of fuel cells as a power source for a light duty mining vehicle (LDMV). A fuel cell is a device that produces electricity as a result of an electrochemical reaction between hydrogen (the fuel) and oxygen (the oxidant). It is similar to a battery in that it has an anode and a cathode. However, a battery is only capable of storing power, whereas the fuel cell can generate it as long as the fuel and the oxidant are being supplied. The elimination of diesel-powered vehicle emissions from underground vehicular applications is acknowledged as being a most pressing issue regarding health and safety / regulatory concerns. On a comparative basis, the LDMV is the highest diesel particulate matter emitting vehicle of all underground types in use.

Underground light duty mining vehicles are less stringent in terms of duty cycle and peak power needs and therefore pose less constraints on design and financial resources due to the acceptability of off the shelf components. The aim of this developmental work is the retrofitting of an existing 14kW diesel power plant in a 'worksite Gator'. Upon careful analyses of the duty cycles and the power profiles, a Hydrogenics 10kW fuel cell system along with suitable buffer storage (batteries/ultracapacitors) has been chosen as the electric power generation unit. The fuel cell will provide the baseline load while the batteries/ultracapacitors take up the transient peak requirements in addition to capturing the regenerative braking energy. The overall objectives of this developmental work are a) push fuelcell technology and electric power train components development to ensure availability for the retrofitting and market development of present and future underground light duty service vehicles, b) promote fuel cell technology amongst the mining community as a zero emission viable alternative to power underground mobile mining applications and c) demonstration and performance evaluation under real mining conditions.

9. **Current Developments and Future Opportunities of the Fuel Cell Mining Program**, Marc C. Bétournay (CANMET-MMSL), Arnold R. Miller and David L. Barnes (Fuelcell Propulsion Institute)

Over the last five years, an international initiative, championed by the Fuelcell Propulsion Institute and Natural Resources Canada, has been active in carrying out research projects to prove out the concept of applying fuelcell technology to underground mining vehicles. These have been carried out by a consortium consisting of mining companies, equipment manufacturers, technology developers, national laboratories and consultants, with the participation of Canadian and U.S. mine regulatory agencies.

This clean technology, which produces only water and electricity, would allow several advantages to be registered: in the health area (by eliminating diesel emissions and reducing noise generation), in lowering production costs (such as reducing ventilation required) and in lowering green house gas emissions.

This paper outlines the results obtained in several key areas, such as the operation of fuelcells in underground conditions, operation of the hydrogen mine production locomotive under mining conditions, design of the underground loader, and research directions required for industry to adopt fuel cell technology.

The article will also present an evaluation of the overall mining applications and advantages this technology can provide, including the facilitation of automation and computer-based tele-remote operation.

10. **Refuelling of Hydrogen Fuelcell Vehicles in Underground Mining Applications,** Fred C. Delabbio, and Doug Eastick (Mining Technology Unit, HATCH), Marc C. Bétournay and G. Desrivières CANMET-MMSL)

A number of hydrogen fuelcell applications specific to underground mining have recently been developed. Presently, there are a number of R&D projects such as utility vehicles (John Deer Gator) and other mobile equipment (Caterpillar LHD) that are in various stages of development. A major remaining hurdle to overcome with regard to underground hydrogen usage, is to determine what the best method and system is for delivery of hydrogen underground. The overall system selection process needs to be based on the associated costs of overcoming issues in the areas of technical functionality, operational requirements, and health and safety risks.

The project objective is to develop business cases for a range of hydrogen delivery concepts. These business cases will include both the capital and operating costs to address the Canadian regulatory requirements and health and safety risks identified during a risk workshop. Results from this study will be sufficient in detail to be combined with other studies such as ventilation, mobile equipment, etc for use by a mining company to develop and review the overall business case for a fuelcell system in their operations.

Given that this project will start around the date of the conference, this presentation will outline the proposed project and the different options that will be considered. In addition, previous related background information will be presented.

11. **Risk, Regulatory and Implementation Associated with Underground Mining Applications of Hydrogen Fuelcells,** Fred C. Delabbio, Doug Eastick and Chris Graves (HATCH), and Marc C. Bétournay (CANMET-MMSL)

With the development of any new technology for underground mining, the design and procedures must address the health and safety risks along with all regulatory requirements. Once the design has been completed the success of the project is dependent on the implementation process. This presentation will outline the general health and safety risk process and implementation recommendations that have been utilized on a number of new technology projects including two recent hydrogen fuelcell projects.

From the perspective of a mine owner/operator, that is required to meet regulatory safety requirements, the fuelcell technology is a new piece of equipment that represents a major alteration of mining technology. The technology being altered in this case is the source of energy supply for the equipment. With these changes, safety and regulatory requirements in test jurisdictions (e.g.: Ontario: Occupational Health and Safety Act; Nevada: MSHA) must be considered and met.

With the recent research growth in the hydrogen industry, there has been an equal amount of effort associated with the regulatory aspects. These changes will be discussed based on experiences from the first hydrogen powered mine vehicle developed in 2001-2002 (production locomotive) and also the current Caterpillar load-haul-dump (LHD) project.

12. **Fuel Cell Technology for Mining Applications**, Hydrogenics Corporation

Hydrogenics is a leading clean power generation company, dedicated to the development of hydrogen and fuel cell power products and test stations for fuel cells. A fuel cell is a device that produces electricity as a result of an electrochemical reaction between hydrogen (the fuel) and oxygen (the oxidant). It is similar to a battery in that it has an anode and a cathode. However, a battery is only capable of storing power, whereas the fuel cell can generate it as long as the fuel and the oxidant are being supplied. There are many different types of fuel cells but the one best suited for mobility applications such as mining is the PEM fuel cell. Fuel cell 'engines' operate nearly at twice the efficiencies of typical internal combustion engines. In this process of electrochemical conversion to create electricity, the only by-products of the fuel cell are water and heat, a feature particularly suited for underground mining applications wherein ventilation costs when using conventional hydrocarbon combustion technologies can be significant. Using fuel cells to provide propulsion is not only linked to fuel cell technology itself but also to others such as hydrogen generation, storage etc. Over the last few years, fuel cells have evolved towards commercially acceptable levels of power capacity, gravimetric and volumetric power density, performance, durability etc., and still continue to improve. From the year 2001 to 2004, over three design generations, Hydrogenics' fuel cell power modules have experienced approximately 50% reductions in weight and volume while at the same time, exhibiting at least a five fold increase in durability and significant improvements in system efficiencies. The automobile industry has been the main driver for this technology with almost every major automaker having its own fuel cell development program. Hydrogenics has developed certain technologies around hybrid systems using fuel cells whereby the system's performance and costs could be optimised with careful analyses of drive cycles and power usage profiles pertaining to the application. With such a commitment, the growth and the market potential for this technology is thus amply demonstrated. Niche markets such as the minig industry can just not afford not to benefit from fuel cell technology.

13. **Update on MSHA's Approval and Compliance Assistance Work,** George Saseen (Mine Safety and Health administration)

MSHA's Approval and Certification Center recently implemented the use of new altitude deration guidelines for approving engines under part 7, subpart E, of Title 30, Code of Federal Regulations. MSHA worked with the Coal Partnership group to write the new guidelines. Coal mines in the US must use MSHA part 7 engines and M/NM mines have the option. The guidelines provide specific fuel deration procedures to ensure that the gaseous and particulate emissions form the diesel engine does not increase when the engine is operated at higher altitudes.

To address electronically controlled Fuel Injected Diesel Engines for intended use in permissible equipment, MSHA has established guidelines for evaluation of these engines for permissibility.

MSHA has investigated recent ignition/kindling incidences of high temperature synthetic disposable filters. These filters are being used in both coal and metal/nonmetal mines. MSHA is developing criteria and recommendations for their use.

14. **Preliminary results from Isolated Zone testing of diesel emission control technologies**, George Schnakenberg (NIOSH-Pittsburgh)

A second series of tests (following those performed in 2003) were performed on a variety of diesel emissions control technology in an isolated zone of a metal mine in the US. The technology examined for the effects on downwind air quality were, Lubrizol's fuel water emulsion, PuriNox; twenty and fifty percent blends of soy and yellow grease biodiesel; ultra low sulfur fuel with and without a DOC, two brands of high temperature disposable exhaust filters; the Arvin-Meritor fuel burner system with platinum and palladium DOCs; Clean Air Power catalytic particle oxidizer; and the NIOSH (Spokane) Zeus hydrogen fueled spark ignition engine. Sampling included DPM as measured by TEOM, NIOSH 5040 (elemental carbon), gravimetric sampling, PAS 2000 photoelectric PAH analyzer and Scanning Mobility Particle Sizer (SMPS) and the gases CO2, CO, NO, NO2, and PAH's.

15. Evaluation of Diesel Particulate Filter Systems at INCO's Stobie Mine, George Schnakenberg (NIOSH-Pittsburgh)

Tailpipe emissions before and after control technologies being tested under the DEEP-sponsored evaluation program were conducted by NIOSH in June 2004. The tests include several DPF systems on both heavy duty and light duty vehicles. Results on the effects of DPM (opacity and smoke spot), CO, NO, and NO2 are presented.

16. The Effect of Simulated Engine Faults on the Emissions of Mechanically- and Electronically-Controlled Diesel Engines, Brent Rubeli, Mahe Gangal and David Young (CANMET-MMSL)

The gaseous and particulate emissions from two diesel engines were measured while operating under simulated fault conditions in a controlled laboratory environment. The engines were representative of those typically used in light and heavy-duty mobile underground mining equipment. Faults were applied singly and in combination. Emissions data was measured using laboratory and field instruments for comparison. The protocols for field testing of vehicles are discussed.

17. Destructive/Non-destructive Inspection and Failure Analysis of Diesel Particulate Filters and Catalytic Converters, David Young, Brent Rubeli and Mahe Gangal (CANMET-MMSL)

Various inspection techniques are used to aid emissions control device failure analysis. The advantages and limitations of visual, boroscope and x-ray inspection methods are discussed. Some common failures and their causes are discussed. The analysis of several failed and known good devices are presented.