<u>PRESENTATIONS – MDEC 2002</u>

October 29 – 30, 2002

Keynote Address – Dr. Lewis Wade, Associate Director-Mining, NIOSH

1. Diesel Particulate – The Australian Experience
Brian Davies (AEHS Pty Ltd/Victoria University of Technology)

2. Tapered Element Oscillating Microbalance Technology
H. Patashnick, M. Meyer, B. Rogers and B. Anderson (Rupprecht & Patashnick Co., Inc.)

3. Diesel Emulsion Fuel Reduces Diesel Particular Matter in the Mines
Ron O. Dunfee (The Lubrizol Corporation)

4. Results of Two High Altitude Isolated Zone Studies Involving Diesel Powered Coal Mine Equipment and Exhaust Filters
G. Schnakenberg & A Bugarski (NIOSH)

5. Development of an On-Board Diesel Particulate Sampling System with Proportional Flow
B. Rubeli and K. Butler (NRCan/CANMET)

6. Light Duty Vehicle Project Update
B. Rubeli (CANMET) and W. Aldred, Falconbridge (Kidd Mining Division)

7. Evaluation of Diesel Particulate Filter Systems at INCO Stobie Mine
Aleksandar Bugarski and George Schnakenberg (NIOSH)

8. Retrofit of Mining Equipment with Diesel Particulate Filter Systems: The Challenges and the Solutions
Karen Schirmer and Beat Wälti (DCL International Inc.)

9. The Fuel Cell Mining Vehicles Development Program: An Update
Marc C. Bétournay (NRCan/CANMET)

10. Post-Field Evaluation of DEEP/Noranda Filter Traps
Mahe Gangal, Brent Rubeli, Dave Young and Vince Feres (NRCan/CANMET), Sean McGinn (Noranda)

11. Application of Non-Thermal Plasma to Diesel Particulate Control
Hannu Jääskeläinen and James S. Wallace (University of Toronto)

12. Determination of Effective Operating Diesel Engine Power on Ventilation
Kuda R. Mutama (Barrick Goldstrike Mines Inc.) and Darren Campbell (Queens University)

13. Passive and Actively Regenerated Particulate Filter Systems for Mining Applications
Kevin F. Brown (ECS)

14. Development of a Hybrid Scooptram
Sylvain Ouellette and D. A. Young (NRCan/CANMET)

15. MSHA's DPM Standard, Sampling and Compliance Strategies for Metal and Nonmetal Mines
William Pomroy (MSHA)

16. MSHA Investigation of NO_2 Generation by Platinum-based Catalyzed Ceramic Diesel Particulate Traps
Bob Setren (MSHA)

17. Impact of Low-Emission Diesel Engines on Underground Mine Air Quality: Physical Measurements
W. F. Watts (University of Minnesota), S. T. Bagley (Michigan Technological University) and D. B. Kittelson (University of Minnesota)

18. Impact of Low-Emission Diesel Engines on Underground Mine Air Quality: Chemical and Biological Measurements
S. T. Bagley (Michigan Technological University), W. F. Watts (University of Minnesota), J. J. Schauer (University of Wisconsin-Madison) and J. H. Johnson (Michigan Technological University)

19. Concluding the Field Test of Diesel Particulate Filters at Noranda Inc – Brunswick Mine
Sean McGinn (Noranda Inc. – Technology Centre), Michel Grenier and Mahe Gangal (NRCan/CANMET), Aleksandar Bugarski and George Schnakenberg (NIOSH), Dale Petrie, Ralph Johnson and Mike Kingston (Noranda Inc.– Brunswick Mine)

20. Quantitative Characterization of Diesel Particulates: Development of the Self-Calibrating Laser-Induced Incandescence Technique
W. Stuart Neill, Gregory J. Smallwood, and David R. Snelling (National Research Council, Canada), William D. Bachalo (Artium Technologies, Inc.)

21. Canyon Fuel Company's Diesel Emission Reduction Program
Steve Forbush (Canyon Fuel Company - Sufco, Skyline, and Dugout Mines)

22. Diesel Particulate Filters: Regulations and Status of Technology
W. Addy Majewski (Ecopoint Inc.)

23. Technology Transfer of the DEEP Maintenance Project
Sean McGinn (Noranda), Bob Huzij (Cambrian College), David Cisyk (IMC Potash)

24. Diesel Particulate Filter Study at INCO's Stobie Mine
Joe Stachulak (INCO)

25. Detroit Diesel Emissions Perspective
Robin Ungar (Detroit Diesel Corporation)

ABSTRACT OF PRESENTATIONS –MDEC 2002

1. Diesel Particulate – The Australian Experience
Brian Davies (AEHS Pty Ltd/Victoria University of Technology)

The Australian mining industry has had a long association with diesel equipment and its use in underground mines. The first diesel engine introduced underground was in 1941 at Mount Keira Colliery in the southern NSW coalfield (about 80 km south of Sydney). While the numbers of engines in both the metaliferrous and coal sectors were low before the mid 1960's, there has been a rapid expansion in number over the past 30 years.

The potential adverse health effects of gaseous emissions have been recognised since the introduction of diesel engines and adequately controlled through a combination of legislation, ventilation, monitoring and engineering control devices. The same cannot be said in regard to the particulate fraction and it has only been since 1988 when NIOSH published its Criteria Bulletin on the topic that the industry has focused on this aspect of diesel emissions.

Industry attention to the topic has been in two distinct segments. The underground coal mining sector has viewed the issue of diesel particulate as a threat to their viability and has reacted by funding major research projects and implementing various control technologies. The metaliferrous sector has adopted a more "wait and see" attitude but has funded some basic research.

Monitoring of the workplace environment in both sectors has highlighted the need to control employee exposures. To this end the NSW Minerals Council established a taskforce of operators, unions and government representatives to work with specialists in the field to develop an industry guideline to the control of diesel emissions. This document sets out a series of best practice guidelines however it is evident that the principles recommended have not been adopted by all sectors of the mining industry. Nevertheless, some operators have implemented significant particulate control strategies and have documented major gains in productivity due to reduced industrial action, the elimination of restrictive work practices and a happier healthier workforce.

Funding for research within the coal sector is still at a high level with a number of projects currently underway. These include a project to identify a hand held surrogate instrument for the measurement of diesel particulate in the raw exhaust of vehicles, a test rig to accurately measure the efficiency of disposable exhaust filters, a project to evaluate the new SKC sampling heads for the workplace monitoring of elemental and total carbon and a project to link elemental carbon generation in the raw exhaust of vehicles with specific maintenance parameters.

Details of the above research projects together with the results of workplace exposure monitoring will be presented. The successful programme implemented by one coal producer to control employee exposure to diesel particulate will be discussed and comments provided on the future direction of diesel emission research and control within the Australian mining sector.

2. Tapered Element Oscillating Microbalance Technology

H. Patashnick, M. Meyer, B. Rogers and B. Anderson (Rupprecht & Patashnick Co., Inc.)

For over two decades Rupprecht& Patashnick Co., Inc. (R&P) has pioneered the development and commercialization of tapered element microbalance technology. Originally designed for space related programs, instruments based on this technology have been applied to real-world particulate measurement and monitoring requirements including ambient, diesel, stack, and mining applications. The advantages of this technology include direct, NIST traceable mass measurement, near real-time, sub-microgram sensitivity in a system able to survive extremely rugged environments. It is the only filter-based mass monitoring technology which has these properties and does not depend on questionable, surrogate measurements for mass. The technology has been well established with thousands of instruments in use worldwide. In recent years, R&P has been involved in a multiphase program with MSHA and NIOSH which has resulted in miniaturized implementation of the technology in a battery operated, person-wearable dust monitoring instrument specifically designed for mining applications. Utilization of this instrument has the potential to supply all interested parties in the mining industry with timely, certifiable information on dust levels, Diesel Emissions and worker exposure.

3. Diesel Emulsion Fuel Reduces Diesel Particular Matter in the Mines

Ron O. Dunfee (The Lubrizol Corporation)

The paper reviews the results of a technology in which water is blended into diesel fuel to reduce exhaust emissions from diesel engines. The water blended diesel fuel used in this study, is co-developed by Caterpillar Inc. and The Lubrizol Corporation. It is known as PuriNOx™ Powered Fuel System and is currently under worldwide market introduction. "PuriNOx™" is a registered trademark representing a system that combines diesel fuel, water, and a proprietary additive package. A proprietary blending unit is used to produce a stable water/diesel blended emulsion fuel. The water droplets are dispersed in the diesel fuel as a macro emulsion. The water improves the distribution of the fuel/air mixture within the cylinder of the engine, slightly delays the combustion event, aids in the efficient combustion and lowers peak combustion temperature resulting in the emission benefits. The additive system keeps the emulsion stable and inhibits separation of the water from the diesel fuel. PuriNOx™ fuel when compared to commercial diesel fuel reduces NOx emissions up to 30% and particulate emissions up to 60% from a machines exhaust stream. The particulate matter reduction significantly improves the opacity (visible smoke) of the exhaust. Specific emission improvements do depend on engine type and application. In order to achieve the emission benefits of PuriNOx™ fuel no modifications to engine or fuel system are necessary. PuriNOx™ can provide emissions reductions across an existing base of diesel-powered vehicles.

Clayton Group Services, Inc. (Clayton) performed air sampling studies at a New York salt mine, located in Lansing, New York. The purpose of the study was to measure airborne diesel particulate matter concentrations prior to and subsequent to the introduction of PuriNOx™, a fuel additive intended to reduce diesel particulate matter emissions. The sampling was conducted on March 19-20, and April 24-25, 2002. A total of twenty-five personal samples and twelve long-term area samples were analyzed for diesel particulate matter. Two days of sampling were conducted prior to, and two days subsequent to, the introduction of PuriNOx™. Sampling was performed so as to duplicate pre and post operations as closely as possible. By conducting a comparison of pre and post application of PuriNOx™ in the mine, results of the laboratory data and limited statistical analysis indicate an overall area and personal reduction in diesel particulate matter concentrations after the introduction of PuriNOx™ of approximately 35%.

4. Results of Two High Altitude Isolated Zone Studies Involving Diesel Powered Coal Mine Equipment and Exhaust Filters

G. Schnakenberg & A Bugarski (NIOSH)

The diesel team at the Pittsburgh Laboratory of the National Institute for Occupational Health and Safety (NIOSH-PRL) conducted measurements of airborne concentrations of diesel particulate matter (DPM) resulting from the operation of selected diesel powered coal mine equipment under different engine fuel settings and with and without exhaust filtration. The vehicle was operated at an approximate altitude of 7600 feet in an "isolated zone" consisting of a straight section of a coal mine entry that was ventilated with air relatively free of DPM and sealed from adjacent entries for 1000 feet. The effects of derating of fuel settings, several brands of paper filters, and a ceramic filter were observed. The DPM was determined from the results of the carbon analysis by NIOSH Method 5040 of filter samples of the ventilation air taken upstream, on the vehicle, and downstream of the vehicle during an extended operating period over a strenuous duty cycle. The response of a carbon combustion particle analyzer was logged during all of the experiments and provided the relative elemental carbon particle concentrations for experiments when no filter samples could be collected. The description of the experiments and the findings are presented.

5. Development of an On-Board Diesel Particulate Sampling System with Proportional Flow

B. Rubeli and K. Butler (NRCan/CANMET)

An on-board diesel particulate sampling system has been developed to monitor vehicle emissions in an underground mine. The system receives input signals from exhaust flow transducers and can maintain compensated proportional sampling over the full range of engine operating conditions with microprocessor control. Data from system construction, calibration and field trials will be presented.

6. Light Duty Vehicle Project Update

B. Rubeli (CANMET) and W. Aldred, Falconbridge (Kidd Mining Division)

The DEEP-funded Light Duty Vehicle Project is investigating the relative contribution of light duty vehicles to the overall underground diesel particulate emissions burden. Phase I – Vehicle Characterization / Site Selection - has been completed and the report is available at www.deep.org. Phase II consists of two separate field studies measuring and comparing the particulate emissions of heavy and light-duty vehicles. Phase II – Part I (Heavy-duty vehicles) is now complete. Diesel particulate emissions were measured on-board heavy-duty vehicles during actual production work. This provides a representative picture of real-world emissions in the mine. Particulate emissions and duty-cycle data from three LHD vehicles and two haulage trucks will be reported.

7. Evaluation of Diesel Particulate Filter Systems at INCO Stobie Mine

Aleksandar Bugarski and George Schnakenberg (NIOSH)

The efficiencies of diesel particulate matter filtration systems installed on three heavy-duty and two light-duty vehicles were tested as part of long term evaluation project at INCO Stobie mine. The testing was one in the series of tests which have been staged throughout the study with objective of assessing performance of the systems throughout their service life. The various methods and instrumentation were used to measure concentrations of diesel particulate matter, carbon monoxide, nitric oxide, nitrogen dioxide, and oxygen in the exhaust of tested vehicles upstream and downstream of the filters. The results were used to assess efficiencies of the filters in the removal of elemental carbon, particle number, and in reduction of exhaust opacity. In addition, the effects of the filters on the emissions of aforementioned gases were studied. The results showed that the filters removed elemental carbon in the excess of 95 percent and particle number in excess of 93 percent. The increased concentrations of nanoparticles with geometric mean around 15 to 20 nm were observed in the exhaust of the engine supplied with fuel enriched with fuel borne catalyst. The filters were found to reduce exhaust opacity in the excess of 90 percent. The tested filters except the one with platinum coating did not offer any reductions in carbon monoxide emissions. The significant increase in concentrations of nitrogen dioxide was found only for platinum coated diesel particulate filter. In addition, the engine backpressures imposed by some filtration systems at selected test conditions were found to significantly exceed maximum backpressures recommended by engine manufacturers.

8. Retrofit of Mining Equipment with Diesel Particulate Filter Systems: The Challenges and the Solutions

Karen Schirmer and Beat Wälti (DCL International Inc.)

The acceptance of diesel particulate matter as a major source for respiratory health problems and as a potential carcinogenic substance by health organizations worldwide has driven the preparation and implementation of more stringent diesel particulate emission regulations. Until now attention was paid primarily to on-road vehicles. However, it is well known that the contribution of diesel particulate matter emission of off-road equipment to the overall pollution is significant. Furthermore, off-road equipment very often is employed in-doors and in confined space situations. Under these conditions emissions have much greater effect on the human health because dilution of the emission-polluted air as is the case outdoors, is challenged.

This is being acknowledged by the preparation and implementation of off-road equipment specific regulations as well as work place specific regulations. Whereby, MSHA (Mine Safety and Health

Administration) has been in the position of a trendsetter in North America by establishing diesel particulate matter exposure limits for underground mines effective 2002.

To comply with these regulations, the mining personnel face the challenge of retrofitting their equipment. Mining equipment very often is built or employed in a way that does not allow for retrofit with readily available standard on-road aftertreatment devices. Therefore, the mining personnel responsible of bringing the equipment up to the new emission standards is confronted with the demanding task of correctly matching the retrofit device to the application: heavy versus light duty, high or low exhaust temperatures, custom made equipment with tight packaging constraints, sulphur content, and so forth.

This paper offers some insight on retrofit systems available for mining applications. Furthermore, an application guideline on how to choose the proper retrofit technology will be given.

9. The Fuel Cell Mining Vehicles Development Program: An Update
Marc C. Bétournay (NRCan/CANMET)

Over the last four 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 lowering green house gas emissions.

This paper will outline the results obtained in several key areas, such as the operation of fuelcells in underground conditions, risk issues related to underground and surface operation of hydrogen vehicles and hydrogen production and delivery systems, and the design and mining performance of the world's first hydrogen mining vehicle, a mine production locomotive. The work to date on the fuelcell loader, designing the power plant and power transmission systems and operational requirements, will also be covered.

There will also be an evaluation of the overall mining applications and advantages this technology can bring to underground mining, including the facilitation of automation and tele-remote operation.

10. Post-Field Evaluation of DEEP/Noranda Filter Traps
Mahe Gangal, Brent Rubeli, Dave Young and Vince Feres (NRCan/CANMET), Sean McGinn (Noranda)

After about 18 months of operation at Brunswick Mine, filter traps were sent to CANMET – Diesel Emissions Laboratory for post-field emissions evaluation. Three filter traps (with platinum coating, base metal coating, and fuel additive) were tested in a controlled laboratory environment. The dynamometer testing included two types of test cycles. The first type is similar to one used at the mine during filter trap efficiency testing (full torque converter stall, full converter stall, high idle speed, low idle speed, and snap acceleration). The second type included testing at four modes (1, 3, 5 and 7) of the standard off-road test cycle (ISO 8178-C1, 8 mode). Furthermore, Various instruments such as Nanomet and Ecom as well as gas emissions test cart were used to measure both particulate as well as gas concentrations in the exhaust gas of a DDEC Series 60 engine with and without filter traps. A large amount of data was collected during transient and steady state test modes. The measurement methodology, filter efficiency in removing particles, and any changes in exhaust gas concentration due to filter traps will be presented.

11. Application of Non-Thermal Plasma to Diesel Particulate Control
Hannu Jääskeläinen and James S. Wallace (University of Toronto)

Non-thermal plasma techniques have been applied to control noxious emissions for several decades. The early applications of this technology focused mainly on reducing NOx , SOx and other regulated emissions from industrial flue gases. In addition to stationary source emissions abatement, there was some attention focused on applications for mobile source emissions from diesel engines. Although this early work achieved significant reductions in particulate matter, NOx, SOx, and CO, there wasn't sufficient motivation to develop these early units beyond the proof-of-concept stage. Due to the increasing regulatory pressures for mobile diesel sources introduced near the end of the last decade, many options have been proposed as possible candidates for meeting these tighter emissions standards. Non-thermal plasma techniques have started to receive much more attention for these applications since 1998 and some significant advances have been made. Although most of the attention in this latest round of research has been focused on their application to the very challenging issue of NOx reduction in diesel exhaust, they are also considered as a possible solution to some of the outstanding issues surrounding particulate matter abatement.

This paper examines the progress made in the application of non-thermal plasma techniques to particulate matter abatement during the last few years. Following a discussion of some relevant background material on the theory and characteristics of this type of plasma, the information that is available from the open literature will be examined and the different approaches will be discussed. The main issues that are still outstanding will then be identified.

Although there has been a lot of research activity into NOx and particulate matter aftertreatment from diesel engines, and significant progress has been made in some applications, there are still significant problems to deal with and no technology has clearly emerged as an obviously universal choice - nor is it likely that one will. Rather, the appropriate technology option for a given problem will be application specific. Thus it is worthwhile to investigate other options to determine if there might not be some better choices for the many potential applications.

12. Determination of Effective Operating Diesel Engine Power on Ventilation
Kuda R. Mutama (Barrick Goldstrike Mines Inc.) and Darren Campbell (Queens University)

An analysis was carried out to determine actual operating engine horsepower at anytime of all the diesel equipment used underground. By collecting equipment operating hours on a daily basis and estimating diesel engine idle time, part and full load, the effective engine horsepower can be calculated. Engine fuel consumption at idle and while operating was also determined. The primary data was gathered using engine hour meters, DDEC readings for Detroit Diesel engines, consultation with mechanics and operators, engine fuel consumption ratings and monthly mine diesel fuel use records. It can be shown that this effective operating horsepower is a small fraction of the nameplate engine power and its effect on ventilation can be estimated. At Barrick Goldstrike Mines Inc. there are three major mining areas which are all connected. The Rodeo area has its own fleet of diesel equipment while Meikle and Griffin share their own dedicated fleet. Rodeo has a nameplate horsepower of about 9,100 hp while Meikle and Griffin operate about 12,100 hp. Results of this study revealed that the average total horsepower of all the diesel equipment at any point in time for Meikle/Griffin was 782 hp and for Rodeo was 554 hp. Engine hours per month were 10,735 and 8,765 hrs respectively for Meikle/Griffin and Rodeo. An attempt was also made to determine the contribution of thermal energy to the ventilation air due to diesel equipment based on the actual used horsepower and a diesel engine efficiency of 40%. The Diesel engines was found to contribute 3.7 % and 2.6 % respectively for both Meikle/Griffin and Rodeo. This corresponds to 875 kW and 689 kW respectively. The total transfer of heat to the ventilation air was determined using air mass flow and the difference in enthalpy from the intake to exhaust. The total heat transfer for Meikle is 23,884 KJ/s and for Rodeo is 27,053 KJ/s. The heat contribution due to diesel equipment to the airflow is very low compared with the heat generated by the rock at Barrick Goldstrike Mines Inc. Overall airflow in Meikle/Griffin is 860,000 cfm (423 kg/s) making it 1,100 cfm/operating hp and in Rodeo it is 900 000 cfm (443 kg/s) corresponding to 1,624 cfm/ operating hp. The emission rates of the diesel engines for the mine should also be computed based on the effective or net operating horsepower of the equipment and not on a blanket number of overall engines underground.

13. Passive and Actively Regenerated Particulate Filter Systems for Mining Applications
Kevin F. Brown (ECS)

This presentation will review emissions performance results from various test cell and mining field trial programs employing base metal catalyzed and electrically regenerated diesel particulate filter systems as well as discuss the use of related maintenance equipment.

The paper will focus on the selection, proper use and maintenance of diesel particulate filters for various mining applications.

14. Development of a Hybrid Scooptram
Sylvain Ouellette and D. A. Young (NRCan/CANMET)

A proposal for the development of a Hybrid Scooptram has been made by CANMET through funding arrangements with Institut de recherché (IRSST) and corporate partners Deutz Canada and Mine Technology International (MTI). The proposed hybrid system offers several benefits over conventional diesel such as elimination of transient mode, elimination of maximum polluting emission rate during intensive work and reduction of released heat (40%-50%). The next step in the proposed hybrid scoop tram project will be emission evaluation through steady state and transient testing to be conducted at the CANMET's Bells Corners Complex, Diesel Testing Facility. The scope of the Hybrid Scooptram project is described in the presentation.

15. MSHA's DPM Standard, Sampling and Compliance Strategies for Metal and Nonmetal Mines
William Pomroy (MSHA)

In January 2001, the U.S. Dept. of Labor, Mine Safety and Health Administration published a new standard on Diesel Particulate Matter (DPM) Exposure of Underground Metal and Nonmetal Miners. Among its various provisions were the establishment of a concentration limit for DPM, and means for compliance determinations, including a DPM sampling strategy and analytic method. As a result of a partial settlement agreement relating to legal challenges to this standard, the DPM concentration limit became effective, as scheduled, on July 20, 2002. However, the terms of this agreement alter the manner in which MSHA will conduct enforcement sampling for DPM, and the steps that will be followed to make compliance determinations. This presentation will provide a brief update on the status of MSHA's DPM standard for underground metal and nonmetal mines, and discuss the procedures that will be used for DPM sampling and compliance determination.

16. MSHA Investigation of NO2 Generation by Platinum-based Catalyzed Ceramic Diesel Particulate Traps
Bob Setren (MSHA)

As a result of regulations passed in January 2001, Underground mines in the U.S. have to control the diesel particulate emissions from their engines. One diesel exhaust after-treatment method of great interest to mine operators was Platinum-based catalyzed ceramic particulate traps. These traps were reported to be a passive device which would not have to be removed or plugged into an electric source to be cleaned (regenerate). High temperature exhaust gas from the engine causes regeneration of the filter. The catalyzed substrates of these traps, lowers the temperature required for the traps to regenerate to a level, which could be produced by the duty cycle of many mining engines. In January 2002, a mine operator from Utah requested MSHA to investigate the generation of high levels of NO2 by the traps. Since that time, MSHA has conducted laboratory and field tests of many of these type traps. This presentation presents the results of this testing and discusses plans for future tests. In addition, MSHA testing and/or evaluation of other after-treatment devices will be discussed.

17. Impact of Low-Emission Diesel Engines on Underground Mine Air Quality: Physical Measurements

W. F. Watts (University of Minnesota), S. T. Bagley (Michigan Technological University) and D. B. Kittelson (University of Minnesota)

The objective of this project was to evaluate the impact of modern, electronically controlled, low-emission Diesel engine technology on air quality in an underground domal salt mine. The impact of exhaust emissions on the physical characteristics, biological activity and chemical composition of Diesel particulate matter (DPM) were evaluated. This presentation reports results from the physical measurements made in the mine.

Sampling was conducted over a two-week period at several locations within the mine. During the first week, model year1990, Caterpillar 3408C, mechanically controlled engines were used; during the second week, model year 1998, Caterpillar 3408F, electronically controlled engines were used. Low sulfur (34 ppm) Diesel fuel was used throughout the study.

DPM concentrations were estimated from elemental carbon (EC), organic carbon (OC) and total carbon (TC) measurements. The size selective (SS) sampling technique was also used to estimate DPM concentrations. Near real-time aerosol instruments were used to measure total aerosol surface area, total aerosol surface-bound polycyclic aromatic hydrocarbons and total particle number concentration. High-volume samplers collected mass samples for chemical and biological analysis.

TC and EC concentrations were reduced by at least 60 % by use of electronically controlled Diesel engines. OC levels were also reduced but to a lesser extent. The near real-time aerosol measurements also showed reductions in concentration between 50 and 60 %. The range of the decreased concentrations observed with the real-time instruments was similar to that found for EC and TC. This suggests that these parameters are related even though they measure different exhaust aerosol characteristics. There was also no evidence of increased production of nano- (or nuclei-mode) particles with use of the low-emission engines.

The use of low emission, electronically controlled Diesel engines operated with a low sulfur fuel substantially improved mine air quality with respect to DPM and its components. However, low-emission, electronically controlled engines alone cannot be relied upon to reduce concentrations below 0.15 mg/m3 in all circumstances at this mine.

18. Impact of Low-Emission Diesel Engines on Underground Mine Air Quality: Chemical and Biological Measurements

S. T. Bagley (Michigan Technological University), W. F. Watts (University of Minnesota), J. J. Schauer (University of Wisconsin-Madison) and J. H. Johnson (Michigan Technological University)

The objective of this project was to evaluate the impact of modern, electronically controlled, low-emission diesel engine technology on air quality in an underground domal salt mine. The impact of exhaust emissions on the physical characteristics, biological activity and chemical composition of diesel particulate matter (DPM) were evaluated. This presentation reports results from the chemical and biological measurements made in the mine.

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(PAHs) and nitro-PAHs, and mutagenic activity associated with the DPM-adsorbed organics. Compound quantification was conducted using gas chromatography/ mass spectrometry methods; mutagenicity was determined using a modification of the microsuspension version of the Salmonella/microsome mutagenicity assay.

As the high-volume samplers were operated only when diesel traffic occurred in the sampling areas, the detected DPM values represented potentially worst case levels in this mine. However, use of the electronically controlled diesel engines resulted in similar reductions for both DPM recovered with the high-volume samplers and the total carbon (TC, analogous to DPM) levels obtained using full-shift samplers.

The PAH levels (associated with DPM-adsorbed organics) showed large decreases with use of the electronically controlled diesel engines (by up to about 90%). Nitro-PAHs were not detected in any of the samples. Hopane levels were monitored to indicate the presence of lubricating oil in the underground mine atmosphere. While the general distribution of the hopanes did not vary between the engine types, all of the values decreased by up to about 80% with use of the electronically controlled diesel engines.

Mutagenic activity associated with the DPM (extracted organics) decreased by up to 65% with use of the electronically controlled diesel engines. As with the PAH reductions, the mutagenic activity reductions (were greater than the reductions in levels of DPM-adsorbed organics (only up to 25%). This could indicate larger changes in the chemical composition of the adsorbed organics from the electronically controlled diesel engines that resulted in less biologically active compounds (based on these assays).

Overall, the measured potentially health related components showed similar reductions to those for DPM, TC, and their components. Evidence from this study suggests that the use of electronically controlled low emission engines at this mine did not introduce new hazards into the mine from an air quality perspective.

19. Concluding the Field Test of Diesel Particulate Filters at Noranda Inc – Brunswick Mine

Sean McGinn (Noranda Inc. – Technology Centre), Michel Grenier and Mahe Gangal (NRCan/CANMET), Aleksandar Bugarski and George Schnakenberg (NIOSH), Dale Petrie, Ralph Johnson and Mike Kingston (Noranda Inc.– Brunswick Mine)

In the spring of 1999 the first steps of the field testing of Diesel Particulate Filter (DPF) technology at Brunswick Mine were launched. This began with logging of engine duty cycles to determine which technologies might possibly fit into such a project, and has recently concluded with the eventual removal of the DPF systems after more than 4000 hours of operation in some cases, and final laboratory bench tests at CANMET's diesel emissions research facility.

Of particular interest at the conclusion of this project is the overall performance comparison of the four DPF systems that were tested. Rigorous undiluted emissions testing was performed at four intervals over the 18-month field test using a combination of the most advanced measurement systems currently available, the most basic and also a measurement system newly developed through the evolution of this project. At the end of the mine field test the four systems were sent to CANMET's laboratories for detailed bench testing using parallel protocols to the testing done previously at the mine.

To summarize the results of the project the perspective from the mine operations will be discussed. The perception of the mine in terms of technology cost, additional infrastructure, maintenance costs and overall maintainability, emissions reduction performance, and acceptance is what determines where the technology moves to in the next phase.

20. Quantitative Characterization of Diesel Particulates: Development of the Self-Calibrating Laser-Induced Incandescence Technique

W. Stuart Neill, Gregory J. Smallwood, and David R. Snelling (National Research Council, Canada), William D. Bachalo (Artium Technologies, Inc.)

A self-calibrating laser-induced incandescence (SC-LII) system has been developed for the non-intrusive and real-time measurement of soot particulate concentration and primary particle size. The LII system incorporates an innovative two-color pyrometry technique for accurate measurement of soot concentration. Furthermore, the LII signal decay characteristics are used to infer the primary particle size. Besides the self-calibrating feature, the instrument also uses low laser fluence and a top-hat laser beam for improved accuracy in the measurement. The system automatically maintains constant laser fluence over a wide range of environmental conditions and also attenuates the collected incandescence signal as needed to handle a large range of soot concentration. The measurement technique, the instrumentation, and the experimental results obtained from a variety of applications to measure diesel particulate emissions are discussed.

21. Canyon Fuel Company's Diesel Emission Reduction Program

Steve Forbush (Canyon Fuel Company - Sufco, Skyline, and Dugout Mines)

With the passage of the 1996 Diesel Regulations for underground coalmines, Canyon Fuel Company was faced with weekly Carbon Monoxide tests in undiluted exhaust for all heavy-duty outby and permissible equipment. The week of November 22 1997 was the first week this fleet were tested and the results were 1597 ppm Carbon Monoxide and 997 ppm Oxides of Nitrogen. The last week's results on the same fleet were 154 ppm Carbon Monoxide and 447 ppm Oxides of Nitrogen.

The purpose of this presentation is to explain how the reductions were achieved and what benefits were gained by doing this. All of Canyon Fuel Company's are at high elevation, which by itself has been a very large obstacle. I will explain engine deration and how to compensate for lower horsepower by reconfiguring the drive train. Also I will explain how the reduced Carbon Monoxide levels have reduced the total Diesel Particulate Matter output.

I will explain how the weekly test results are taken and what steps this information goes through to be analyzed and stored. With new data gained during this last year I will be able to quantify some of the results that were brought up last year.

22. Diesel Particulate Filters: Regulations and Status of Technology

W. Addy Majewski (Ecopoint Inc.)

Adopted emission standards for new, future diesel engines and vehicles have been designed to force the use of diesel particulate filters. While wide scale use of particulate filters stimulated by these regulations will not start before 2007, increasing number of diesel car manufacturers in Europe, as well as certain heavy-duty engine manufacturers in the USA, are voluntarily introducing filters on their engines. Diesel filters are also being introduced on in-use engines through diesel retrofit programs in the USA and Japan.

23. Technology Transfer of the DEEP Maintenance Project

Sean McGinn (Noranda), Bob Huzij (Cambrian College), David Cisyk (IMC Potash)

The goal of DEEP was to transfer technical information from the DEEP Maintenance Project to the end users at mining operations. The DEEP Technical Committee decided on a pilot at the IMC Potash operations at Esterhazy, Saskatchewan. The team from Noranda Technology, and Cambrian College demonstrated the Norcat training package from the Maintenance Project over a four-day period through classroom theory sessions and hands-on demonstrations that were conducted underground. The Norcat training package is now incorporated into the Cambrian College curriculum and is available online through the college's website; this will be discussed in this paper.

Initial engine diagnostic tests at IMC proved that maintenance has a major impact on emissions, for both diesel soot and exhaust gases. Along with good training, detailed information on engine emissions is critical to sound maintenance decision-making. IMC Potash has since installed the ECOM

UGas analyzer, which was used in the maintenance and subsequent DEEP research projects, in the underground shops as a network based system to allow mechanics at the two Esterhazy mines to share data on vehicle emissions and maintenance. This project served as an example of how an operator with little exposure to the background of the project could grasp the fundamentals of the effects of maintenance on diesel emissions.