Diesel Emissions and Control Technologies
in Underground Metal and Nonmetal Mines
March 4, 2003
Salt Lake City, Utah

Edited Notes

Disclaimer: These notes are the result of the heroic effort of Lewis Wade, NIOSH, who volunteered to capture the comments, questions and answers of the workshop. Taken in long hand, these notes are not to be construed as a verbatim transcript of the proceedings. That being the case, these notes have been extensively edited to enhance clarity and technical accuracy so as to provide a usefully accurate document for your reference. – Editors.

Welcome and Introduction **Lewis Wade, NIOSH**

We are not here to look at legal aspects, health effects, relation between OC, EC, TC, or issues of DPM sampling. We are here to look at engineering controls and the effectiveness of engineering controls, specifically diesel particulate filters (DPF).

Update on MSHA Metal/Nonmetal Rule **Bill Pomroy, MSHA**

Overview of Control Technologies Available to the Underground Mining Industry **Aleksandar Bugarski, NIOSH**

Comment:

1. Regarding slide 2 that shows up to 1500 $\mu g/m^3$: recent measurements done by MSHA (baseline survey) show a lowering of this figure. The presenter offered that the concentrations of 1500 $\mu g/m^3$ were observed in some mines a year or more ago. Current measurements show significantly lower concentrations, which confirm that mines are making an effort in reducing exposure of their employees to DPM.

Questions and Answers:

Q: People had heard that MSHA was taking away approvals on some engines.
A: The presenter had heard this as well. According to his knowledge these engines are electronically controlled turbocharged engines, and the concern is their emissions when they are operated at high elevations. MSHA regulations require that maximum fuel-air ratio for the engine is adjusted for operation at a certain elevation according to the fuel deration chart and then sealed from tampering. In addition, MSHA tolerates a certain deviation in fuel injection timing. For mechanically controlled engines, the fuel-air ratio is adjusted mechanically at the injection pump. Electronically controlled turbocharged engines compensate for elevation based upon a on-board computer program which changes fueling rate and engine timing in order to optimize DPM and gaseous,

particularly NO_x, emissions. This is done according to the information obtained from the engine map and limits imposed by the EPA, the user-selected maximum engine horsepower, the sensed barometric pressure and other internal engine parameters. He believes these are the engines that MSHA is considering taking the approval away from because they do not meet the requirement of fixed fuel-air ratio and timing. The presenter offered that, if needed, this issue could be discussed later with MSHA representatives.

Comment:
1. The presenter added that sulfur in diesel fuel poisons [reduces the activity of] catalysts, and limits the application and potential of certain control technologies.
2. Relative to his comments on synthetic diesel, he added to the slide that synthetic diesels are made from coal or natural gas using the Fischer-Tropsch process.
3. The presenter offered the opinion that DPF systems without any doubt are offering high efficiencies in the reduction of DPM, but some issues of application engineering, secondary emissions and regeneration need to be addressed.
4. With regard to slide 34, which speaks to DPF operational issues and ash accumulation, the presenter offered that it is difficult to achieve a successful application of a DPF when the engine burns lubricating oil. Burning oil adds to the DPM load in the form of both soot and more importantly ash, which hinders spontaneous regeneration and requires frequent cleaning of DPF in order to remove accumulated ash.

Diesel Particulate Filters (DPF's) in Underground Mining

DEEP-Sponsored Long-Term Evaluation Of The DPF's At Noranda's Brunswick Mining And Smelting Mine

Sean McGinn, McGinn Integration, Inc

The presenter started by saying he wanted to make two key points concerning filters:

1. Selection of a DPF for the particular application is extremely important. It is an application-engineering issue. Selection of filter media (cordierite or silicon carbide) and of the regeneration concept is only part of the complex process.
2. The other important issue is maintenance of the filter and engine.

Comments:
1. The presenter stated that the reports of the DPF evaluations are on the DEEP project website, www.deep.org. He added that the RFP [request for proposal] supplied to all DPF suppliers/manufacturers interested in participating in the New Brunswick project is also available there. This relates slide 1B. He recommends that anyone considering purchasing DPFs read the RFP.
2. In his slide 11A that shows a high NO_2 conversion for a platinum catalyzed DPF, the presenter offered that this may or may not be a problem depending upon the [ventilation] situation at particular mine. If NO_2 levels were a problem, then this high level of conversion of NO to NO_2 experienced with the DCL filter would add to that problem. If NO_2 levels are not a problem, then you do not need to be concerned.

3. In slide 12B, the presenter mentioned that the Oberland Mangold system was a deep bed filter. These types of filters are made of wound, knitted, or woven glass or ceramic fiber configured as cartridges. This DPF was found to generate lower backpressures and have somewhat lower filtration efficiencies than the ceramic filters. The presenter also pointed out that the Oberland Mangold filter is no longer available on the market.
4. In slide 15A, the presenter noted that samples were not personal samples, but ambient samples representing the worst-case concentrations, since they were taken at the exhaust end of the isolated zone downstream of all of the diesel vehicle activity. He also noted that all four systems had leaks in the exhaust system upstream of the filter. The leaking exhaust, which bypasses the filter element, increases the airborne concentration and reduces the effective filter efficiency.
5. Regarding slide 15A, the presenter made the point that with equipment using modern engines with DOCs when operated with Canadian ventilation rate of 100 cfm/hp, one might not be able to reduce ambient concentrations under 160 $\mu g/m^3$. DPF systems are capable of reducing those concentrations under aforementioned standard.
6. With regard to slide 16B, concerning the downsides of the DCL filter, the presenter stressed the fact that "it was difficult to get operators to regularly plug it in" so the system could undergo active regeneration.
7. With regard to slide 17A, one of the problems associated with the ECS Octel system was backpressure; they observed intermittently over 120 inches of water backpressure.

Questions and Answers:

Q: For the dual trap installation (relevant to ECS CatTrap) did the bottom trap tend to get more plugged than the top trap?
A: No the manifold brings the exhaust in the middle and there was no bias of one trap versus the other in terms of being more clogged.

Q: Was it 500 ppm-fuel used in the tests?
A: Yes. Actually, sulfur content was closer to 350 ppm.

Q: Is the presenter aware of tests run with ultra low sulfur fuel?
A: Yes. He would report on them this afternoon.

Q: Were operator exposures generally lower than exposures at the exhaust?
A: Yes, they were generally slightly lower.

Q: Was there any background contamination in the isozone?
A: No.

Q: Has there been any investigation on DPFs installed on light duty vehicles?
A: Yes. Joe Stachulak would discuss the results of the tests conducted at INCO's Stobie Mine.

Q: What prompted the use of dual filters as opposed to one large filter?
A: That was the manufacturer's decision. In some cases, where the larger filter elements were used, separation between the media and the enclosure is observed. [Large diameter filter elements made of cordierite are built from four pie-like sections cemented together. Those might not be perfectly circular when assembled.]

Q: What do you attribute the failure of the ECS Unikat Octel filter to?
A: In part it was the mounting orientation. The filters were mounted vertically [the other two filtration systems with ceramic media were mounted horizontally and did not have similar problems] and [it is suspected that gravity-caused] shear [forces] caused separation of the elements in the silicon carbide media. The separation of the silicon carbide blocks was shown in the presentation. The hypothesis for lack of regeneration is that the filter volume was too large making filter regeneration, which depends upon the exhaust heat to bring the filter element up to temperature, less certain.

Comment:
1. It's terribly important to do exhaust temperature profiling in order to understand specifics of your duty cycles. This is crucial for execution of the DPF selection process. It is wrong to attempt to select the filter from a matrix of DPF systems offered without knowing temperature profiles for the application.

Q: Are the units still on the system?
A: Only the ECS CatTrap system was kept after the completion of the tests. All the others systems were returned to the filter and substrate manufacturers for "post-mortem" examination.

Q: In a normal operating mode would you expect to see any changes in filter efficiency?
A: Yes, you might expect to see a bit of a drop off due to maintenance issues.

Q: Did ECS design the modified manifold system?
A: Yes.

Q: What did it cost to do the isolated zone tests?
A: Approximately $50,000. The tests were not expensive, since they were done in upper workings that were not as utilized as the lower workings. [He was pressed for the overall cost of all of the engineering work leading to and including the isolated zone tests]. The presenter said the mine kept a separate account where all items were charged and that account is now well in excess of $100,000.

Q: What is the regeneration time of the DCL system?
A: Approximately 2 hours.

Q: Why the Octel fuel additive did not work?
A: Octel has not been able to explain the phenomena. The Oberland Mangold and ECS Unikat DPF systems that were using Octel fuel additive were suppose to be

regenerating at temperatures between 325 to 350 degrees C. Unfortunately, regeneration at those temperatures was not observed.

Q: With regard to the ECS Unikat/Octel system, you remarked that they needed either more temperature or a smaller filter volume.
A: The presenter commented that you should use a process like their RFP process where you do detailed work in identifying what you are looking for and supply that to the manufacturers to bid against.

Q: Were any other styles of engines evaluated other than those reported?
A: No.

Q: What instrumentation was used for the [steady state tailpipe] mode tests?
A: A Nanomet instrument, which consists of a PAS2000 photoelectric aerosol sensor [The instrument is manufactured by Matter Engineering, Switzerland. It is sensitive to PAH attached to carbon core particles] and a LQ1 diffusion charger sensor [The instrument is manufactured by Matter Engineering, Switzerland. It is sensitive to all submicron particles]. Although the instrument contains both units, only the measurements made by the PAS2000 sensor were used.

Q: Would you talk a bit more about the isolated zone test and the regular mine test?
A: During the regular mine operation, they run a scoop/truck operation working inside the draw point. The duty cycle for the isolated zone tests was designed to emulate a normal duty cycle of the vehicles in the production. [Note, that the same cycle was used for the trucks and scooptrams. The intent was to standardize the cycles for repeatability and to have features of the vehicle's duty cycle.] Additionally, in order to ensure collection of enough sample for an accurate analysis when filters were used, the ventilation was set a bit below normal value for the engines being used. This ventilation rate resulted in an air velocity that was somewhat lower than the vehicle speed. Therefore, the vehicle was not always in the fresh air stream, [an important consideration for the vehicle operator, but of no consequence in the isozone tests, since all of the air passed the downstream sampling point].

Q: Was only one piece or were multiple pieces of equipment concurrently operated in the isolated zone test?
A: Only one piece of equipment was operated in the zone during each of the tests. The confounding effects of multiple vehicles concurrently operated in the isolated zone test would have prevented distinguishing the contribution of individual vehicles. To realize the maximum benefit from the isolated zone test you needed to look at one vehicle at a time. Dr. Bugarski added that studies such as the one conducted at BMS, provide very meaningful results and opportunities for gaining very valuable hands-on experience. If you think about it, the cost of testing is equivalent to the price of a couple of DPF systems that you can loose in process by using a trial-and-error method. As an industry, you would place yourselves at a tremendous advantage by having such experience and be able to make the right decisions in the process of selection of DPF systems for your fleets.

Q: (addressed to Sean McGinn) How many pieces of equipment are operated in your mine?
A: Generally 20 Atlas Copco ST8B scoops and 10 Atlas Copco MT 436 trucks. He was somewhat embarrassed to say that, at any one time, only 10 of the ST8Bs and only 4 or 5 of the trucks are functional and available to the operators.

Q: Do you have any results of the DPM sampling from production areas of the mine?
A: Yes, but very limited. The results appear to be favorable.

Q: Without controls, what do you realize in your mine?
A: Before the application of controls, the concentrations were about 200 $\mu g/m^3$. The concentrations were determined analyzing personal samples collected by operators using RCD method. Also note that all vehicles in the mine are equipped with diesel oxidation catalysts (DOCs). The RCD stands for respirable combustible dust method used in Canada to determine total carbon.

DEEP-Sponsored Long-Term Evaluation of the DPFs at INCO's Stobie Mine — **Jozef Stachulak, INCO, Ltd.**

Joe said that he would report upon three heavy duty and two light duty vehicles. He said given the DPM level targets that his company has set, they could not reach them through ventilation alone. They needed to consider the use of DPF's. He talked about the fact that DPF's have been used in mining in Canada for more than 20 years. Some of the early applications failed because they weren't correctly sized or maintained. He said that his company wants DPF's with at least 2000 hours of life. He mentioned on one of his slides that the Engelhard DPF was not VERT-certified at the time when it was acquired. He said that according to his best knowledge Engelhard had the intention to certify the units.

Questions and Answers:

Q: You are reporting that NIOSH found that DPFs are about 99% efficient in reducing EC [elemental carbon] while MSHA quotes 85% and 87% efficiency for the DPFs [on DPM basis]?
A: The difference is in how the efficiency results are reported. Since DPM consists of many other components beside EC, specifically sulfates and associated water, which are not removed by the DPF, one expects significantly higher efficiencies on the EC than on the DPM basis.

Q: What was the size of the Engelhard DPF?
A: It was 12" x 15". Regarding slide 31, Joe stated that the Deutz ST8 scoop with JMC (Johnson-Matthey) DPF, which uses the combination of a fuel additive (with on-board dosing system) and electrical regeneration, was hard to keep clean of ash. They had to clean it twice for ash during 1200 hours of operation. At one point Joe mentioned that they were seeing 60 to 80 inches water of exhaust backpressure.

Q: What impact this would have on the engine manufacturer's warranty?
A: This was an evaluation project and therefore exhaust backpressures could exceed those recommended for the engine. Joe later mentioned that they lease equipment and the issue of engine warranty and backpressures is an appropriate topic for discussion with the person from whom they lease the equipment.

Comment:
The ECS UNIKAT, dual Combifilter failed because the equipment operators simply failed to plug it in at the end of the shift thus skipping the regeneration cycle.

Q: When one actively regenerates a DPF, does the regeneration have to happen at one time?
A: Yes.

DPFs in U. S. Underground Coal Mines **Steve Forbush**
Canyon Fuels, Inc.

Steve Forbush (Skinner) pointed out that the coal industry, when faced with the challenge of filtering the diesel exhaust from out-by diesel equipment, conducted a nation wide filter study where several mines and companies stepped forward and evaluated individual units and then shared their findings. He suggested that the metal/nonmetal industry should follow suit.

Questions and Answers:

Q: He was asked if paper filters are as efficient as soot traps?
A: He said the jury is still out; they are waiting for information from MSHA.

Q: He was asked if all the engines he reported on were mechanical?
A: Yes

Q: Are there any electronic engines in his properties?
A: No, at this point they are working with the system to explore the use of electronically controlled engines in underground coal mines in the U.S.

Comment: Norbert Paas of Dry System Technologies, the system designer, commented that the DST system would work better with cleaner engines.

Q: What are the specific maintenance changes you referred too?
A: He said that he would report upon those changes during the afternoon presentation.

Emissions Assisted Maintenance

Maintenance of Heavy-Duty Underground Mining Diesel-Powered Equipment **Sean McGinn,**
McGinn Integration, Inc.

The speaker posed a question to the audience: What should you do first before you do anything regarding the maintenance of your diesel equipment?
The answer from the audience was: Establish benchmark.
He agreed that one needs to conduct an audit in order to recognize the status quo.

Sean made a second comment that any repair should be based upon a measurement.

Questions and Answers:

Q: What does setting your own standard for gaseous emissions mean?
A: You need to make measurements and establish your own base line [for that engine] and then seek to lower the emissions from that base line.

Maintenance Of Heavy-Duty Diesel-Powered Equipment Using Emissions Data **Steve Forbush, Canyon Fuels Co.**

Skinner made the comment, that from his perspective, it should be relatively easy for the metal/nonmetal industry to achieve a TC level of 400 $\mu g/m^3$ in their mines by just using effective maintenance, ventilation, and fine-tuning of the engines from their fleet. He believed that 160 $\mu g/m^3$ would be much tougher to achieve using the aforementioned measures [without filters].

Questions and Answers:

Q: Can you track DPM by measuring CO?
A: In his opinion CO will track DPM fairly nicely. If you have high CO you are likely to have high DPM [emissions]. On the other hand, he remarked that it would be difficult to make a precise estimate of DPM emissions using CO emissions.

Q: You said you had to sell your management on the maintenance program. Was this a hard sale?
A: Skinner said that with the MSHA coal rules going into effect in 1997, his management realized that they would have to do something. From that point on, they decided they wanted to do it right.

Q: Was additional manpower needed to perform the maintenance?
A: Performing the maintenance using his methods would not require a large increase in manpower. Skinner said that what one really needs to do is to make the maintenance program [the MSHA CO checks required weekly in coal mines] routine. CO records should be kept for each of the vehicles. For example, the CO levels should be charted and reviewed regularly with trigger levels set for the actions. Skinner said there is some initial work required in making both the engine and torque converter modifications and establishing the tracking system. Once you have the engines set and tracking process is in

the place, then one or two guys at a mine could look at 60 vehicles per week for both engine/vehicle permissibility and emissions.

Q: Do you have a device to measure DPM?
A: He is using SKC DPM cassettes and NIOSH 5040 method [ambient levels].

Q: Is the system at this point fairly mature and what does it track?
A: He said primarily CO.

A Strategy for Deployment of Diesel Particulate Filters (DPFs) -- An Overview of the NIOSH-MSHA DPF Selection Guide

George Schnakenberg, NIOSH-Pittsburgh Research Laboratory

Questions and Answers:

Q: Concerning the process of logging exhaust temperatures, George was asked how frequently temperatures should be recorded – every 10 seconds?
A: George replied that a temperature sample point taken every 15 to 30 seconds was adequate, but didn't have enough first hand experience to comment fully. The sampling rate for Omega data logger depends upon the total period sampled; for one shift of 8 to 16 hours long, the sampling rate is 1 reading per approximately every 7 seconds. Additionally, the sampling rate does not have to be any faster than the response time of the thermocouple, which for an eighth-inch diameter probe is possibly greater than this. Using a spreadsheet, George also found that an averaging time of 3 minutes on the data didn't change the resulting 30% temperature from that determined using original data points.

The following question pertains to the graph that George presented as an illustration showing the elemental carbon emissions reductions required for MSHA approved engines based on EC being 80% of TC and TC being 80% of DPM, the quantity used in the MSHA particulate index. The graph showed that many modern engines required no emissions reduction to reach 400 $\mu g/m^{3,}$ with a ventilation rate of 80 cfm.

Q: Where did you get the ventilation rate of 80 cubic feet per minute per break horsepower? There was a follow-up question asking where did the emission rate come from?
A: The 80 cfm approximates the average ventilation rate over all of the MSHA-approved engines and thus was used in the illustration. The engine PM emission rates were determined from MSHA's particulate index established for each of the certified engines. The particulate index is the ventilation rate needed to dilute the exhaust DPM concentration to 1000 $\mu g/m^3$. From this, one can calculate the DPM concentration resulting from diluting engine exhaust by the engine's ventilation rate or any other rate, such as the 80 cfm chosen in this example. For many modern engines, dilution at the 80 cfm rate results in ambient concentrations bellow 400 $\mu g/m^3$ of DPM.

Q: George was asked if there was a method for determining "raw gas particulate" concentration out of the tail pipe.
A: He replied that the method used by Sean McGinn, that of using tissue quartz in the Bacharach/Bosch smoke number apparatus and submitting it for carbon analysis by NIOSH Method 5040, was one method. Since the volume and area of the smoke spot is known, the concentration can be calculated. However, you still need to know the exhaust gas volume and the actual ventilation rate in order to determine ambient concentrations.

Q: Does the quartz filter fiber collect too small of a sample?
A: No. Although the gas volume through the sample filter is 1.69 liters, its area is quite small. Upstream of a DPF, there is no problem getting enough sample for the analysis. Downstream, it may be difficult; often the elemental carbon is not detectable. Many of the filter efficiency determinations at INCO, for example, are determined by rationing the minimum detectable limit to the upstream concentration. Thus some of our reported 99.8% efficiencies on elemental carbon are lower than the true efficiency.

Diesel Maintenance at INCO **Jozef Stachulak**
INCO, Ltd.

Dr. Stachulak, as a result of listening to the Cincinnati workshop thought he should present the philosophy towards diesel engines and their maintenance at INCO mines.

Q: Joe was asked why 250 hours was used as the interval for preventative maintenance as opposed to some other number?
A: He said that was a frequency they developed base upon years of experience and engine manufacture's recommendations.

Forum

Q: Did DPF have anything to do with the turbocharger failure and the fire on the Engelhard system?
A: Joe stated that when the turbocharger gets disintegrated, oil is spayed into the exhaust system onto the hot filter and soaks the insulating blanket, which runs from the exhaust manifold to the filter, and surrounds the filter as well. Thus the fire was caused by the failure of the turbo, and not by the filter. He said it was his opinion that the turbo did not fail because of excessive backpressure. George Schnakenberg offered that they did observe slightly higher then normal backpressure on that engine prior to the failure. [The unresolved issue is whether insulating the turbo and exposing it to high backpressure can cause damage to the turbo. There are also reports of turbo failures causing a fire owing to the presence of an insulating blanket in some coal mines in the Western U.S.]

Q: There was a question as to whether the device was blanketed?
A: Yes.

Comment was made by the developer of the DST system, Norbert Paas of DST, concerning a statement made on page 35 of NIOSH IC9462 which quoted the rather low (8%) DPM reductions by the DST system observed during the laboratory tests at West Virginia University. Dr. Bugarski responded saying that the particular part of the IC was presented as a review of published results. The information was quoted from a published report. Authors are not aware of any details related to generating the results published in the original report.

A comment was made about the uncontrolled regeneration of the ECS OCTEL [ECS Unikat] system in the DEEP trap evaluation at Noranda's Brunswick Mine. The ECS representative reminded us that uncontrolled regeneration could result if you overload a filter. Exposing such a loaded filter to high temperature exhaust resulting from an operating engine at high loads [high exhaust temperatures, low oxygen] followed by load or idle [sudden increase of oxygen to a hot filter media], can trigger uncontrolled combustion of the collected soot. Under these conditions, you have the possibility of severe overheating of the filter media and enclosure. He stressed that DPF systems should be operated according to appropriate instructions not allowing the units to become overloaded.

A comment was made about the ESC Lubrizol PuriNOx System. It is a mixture of water and diesel fuel where the water and fuel are bound in such a way that the diesel fuel completely surrounds a water droplet as opposed to other fuel-water emulsions where the water surrounds the diesel fuel droplet. PuriNox could be considered as an alternate to bio-diesel, particularly if you have a NO_x problem in your mine [PuriNOx reduces combustion temperatures and lowers emissions of NO_x.] When PuriNOx is used with a diesel oxidation catalyst, DOC, the reported DPM reduction is on the order of 70%. [Elemental carbon may not be equivalently reduced. – Editor]

Q: The ESC Lubrizol representative was asked about the costs of PuriNOx?
A: He said he could not provide the information at the time since he is not working with that line of products. He would find and provide that information to those who are interested.

A comment was made about the Freeport Macmore Mine in Indonesia, a block caving operation, producing 35,000 tons per day of material. The mine was designed with an estimated ventilation rate of 150 cfm per break horsepower. In fact the ventilation rate was actually put in to practice at higher levels. However, currently, peak values of DPM concentrations are 1000 $\mu g/m^3$ with an average of 800 $\mu g/m^3$. Given that, we question whether the standard being proposed by MSHA [400 $\mu g/m^3$] is reasonable. MSHA answered by saying the MSHA has done baseline sampling and has determined that the 400 $\mu g/m^3$ interim standard is indeed reasonable as was the 160 $\mu g/m^3$ final standard. MSHA found high levels of DPM (1500 $\mu g/m^3$) prior to any controls being instituted. In the latest baseline survey they are finding personal exposures of 200 $\mu g/m^3$, even in the mines that are not using filters, but that have implemented improved ventilation, engine

maintenance and newer engines. MSHA is convinced that after implementing controls, 160 $\mu g/m^3$ levels would be feasible.

Additional comments indicated that the high DPM concentrations in this Indonesian mine could be caused by extremely high sulfur content (on the order of 2 % sulfur) in the fuel they use. The other issue is the mine elevation of 14,000 feet above sea level; the engines are operating at their factory settings [not derated for the mine elevation] and thus are quite over fueled. The comment was made that using the process explained by Steve Forbush [Skinnerization] and using better, lower sulfur fuels, they could easily get to DPM levels down at 10-20% of the levels reported.

Comment was made that both MSHA standards of 400 $\mu g/m^3$ and 160 $\mu g/m^3$ are achievable if you institute an effective maintenance program, use the right fuels, and effectively tune the engines or "Skinnerize" the engines and drive train. An additional comment was made from the floor that as a general rule, to get to 160 $\mu g/m^3$, you would need more ventilation.

Bill Pomroy from MSHA made the observation that if you double the ventilation you simply get ½ of the DPM. One can achieve a significantly higher percentage reductions making use of new engines [factor of 8 to 10] or filters [factors of 20 or more] as reported in earlier papers.

Q: The engine manufacturers (there were several representatives in the audience) were asked for some insight where new engine technology [for mining applications] was headed.
A: Robert Montgomery of Caterpillar said that they are planning to offer to the metal/non-metal industry EPA Tier II engines. They even see the possibility for providing the industry with Tier III engines in subsequent years. For coal they are looking at getting approvals for the 3126P and the 3126 mechanically injected engines. They believe that they are getting MSHA approvals in the next two to three months.

Joe Unseth of Duetz said that they would be looking at providing Tier II engines to the metal/non-metal industry. For coal they are looking at the possibility of providing Tier II electronic controlled engines for engines over 100 horsepower. For engines below 100 hp, electronic controls are still to come.

Detroit Diesel is offering Tier II engines. They anticipate the use of traps will become commonplace so they are pursuing things like insulated manifolds and turbo charges.

In a clarification statement, MSHA stated that for metal and nonmetal mines, the regulation allows not only MSHA approved or EPA certified Tier I or Tier II engines depending upon the horsepower but also any engine that was tested by a reputable laboratory and has the emission characteristics equivalent to those required by EPA for Tier I Tier II engines.

MSHA was asked whether one should consider ventilation first as opposed to the engineering controls, particularly as the regulations get tighter. MSHA said it was not its role to recommend on that issue. MSHA thinks that the mines need to make their own educated decisions on what to do. MSHA did say that, as the limits drop, it only makes sense to start to consider the use of diesel particulate filters, but that depends on the mine. There is evidence that there are mines operating below 100 $\mu g/m^3$ without the use of filters.

Q: Where is the criteria for Tier I and Tier II to be found.
A: MSHA said that information can be found in the federal register packets that they provided in this workshop.
Q: If I wanted an engine to meet MSHA requirements, do I have to specify the engine that meets requirement listed in 30 CFR Part 7?
A: MSHA said it could meet that Part 7 or it could meet the appropriate EPA standard. You need to look at the EPA label on the engine for information.

Comment was made by a Stillwater mine representative (tongue-in-cheek) that they supported the use of platinum or palladium in all applications. [Stillwater mines produce platinum and palladium – Editor]. They remarked that traps work but the active traps are orders of magnitude tougher to maintain than are the passive traps. They said that the cost of active traps is on the order of $20k where passive traps are $5k. Getting a reliable source of power for regeneration of active traps is considered to be an issue. For example, if you blast at the end of a shift and you lose power to the regeneration system, the trap and vehicle will not be ready to use for the next shift. When the heating elements of the trap break, it takes a long time to get parts. They cautioned that you would be well to be advised to do anything you can to make passive regeneration traps work.

The comment was then made that there are active traps working in the field. For example, there is an ESC active trap [off-board regeneration with trap swapping] working at the Oxbow Mine. Its cost was $7,000.

Mark Good of Greens Creek commented on the experience at his mine. Greens Creek is in Alaska. It's a drift and fill mine with cascading ventilation. They started down the path trying to use passive regeneration. They had some early failures: the systems were too big and too cumbersome. They had excessive backpressure of 80 inches of water. In one case the DPF was installed incorrectly; the exhaust pipe was butting up against the filter substrate, which channeled the exhaust flow only through the center of the filter thus they didn't make use of the entire filter. But with the experience they have now, they think that they can make the traps work. They have a trap that has accumulated 4500 hours in production. That trap was compromised by a turbo charger failure that spewed oil into the trap. This may have ultimately precipitated its failure. The trap remained in service for 1500 hours after the turbo incident before the substrate ultimately cracked. It did however operate and regenerate for a period of time after the turbo failure so it is hard to determine whether or not the turbo failure caused the trap failure. However, Mark emphasized that they do have positive experience with the use of passive traps.

They have15” x 15” units from Engelhard installed on their large equipment that have accumulated almost 2900 hours of service life. This is the longest running trial of this size of the filter. They have smaller ceramic filters installed on the units powered by 225 horsepower engines that accumulated about 3300 hours of service life. The said the key to successful application is to do your homework and get the temperature profiles before you make your decision. They have had good success. They have done an evaluation with MSHA in an isolated stope, and he anticipates that those results will be available in three weeks.

They do have an active system with 30 hours on it. So far it seems that the system is working properly. It is tough to get people to plug the units in. Greens Creek reported that the substrate for the larger 15” x 15” units on some 470 horsepower engines lost contact between media and housing; the substrate seems to be rotating in the housing losing its seal and allowing the exhaust to bypass the substrate. They contacted Engelhard and this seems to be a problem with the “canning” of 15” x 15” units [which are not quit circular because they consist of pie-shaped segments cemented together].

George Saseen from MSHA remarked on their experience on the two-week evaluation of the filter systems at Greens Creek. He noted that it is easy to spot the vehicles equipped with a DPF: when one paints the frame where the exhaust comes out, it remains clean compared to the soot-coated area in vehicles without DPFs. They had the opportunity to see the difference on the vehicle that was operated for a short period without the DPF.

Q: There was a question asked about whether they noticed an increase in NO_2 readings with the passive platinum catalyzed traps?
A: The answer was a few tenths of a percent of increase over ambient but nothing major. Engelhard, the DPF supplier has since lightened the loading of catalyst on the trap. MSHA will be looking at those lighter catalyst traps in their laboratories in the near future.

[It is very hard to obtain coating information on the Engelhard DPFs in the field and relate it to the field experiences let alone exhaust temperatures. It is NIOSH’s understanding that DPFs catalyzed with a 50 g/ft^3 Pt washcoat can cause increases in NO_2 by factors of 5 to 6 times; the Engelhard DPFs now being delivered to Greens Creek may be coated with 5 g/ft^3 Pt, and may exhibit much less NO_2 increases. – Editor]

MSHA offered the opinion that manufactures have worked to alleviate the NO_2 problem by investigating catalyst formulations using lighter loadings of platinum. One system uses a special formulation of Pt catalyst plus a fuel additive to achieve passive operation at exhaust temperatures of about 330 °C. MSHA thinks that we are seeing great strides in reducing the NO_2 problem. DPFs using base-metal catalysts do not cause an increase in NO_2.

Tony Arbaney from RAG Coal 20-mile coal mine said that they have equipped a heavy duty fleet with the Paas DST system. They have over 2500 hours of experience. They are getting about 40 hours of filter life on the single disposable “paper” filter element. They

needed to do an extensive retrofitting to prepare their equipment to receive the DST system; but once that's done the system has been very reliable. They are looking at servicing their engines every 250 hours and to scheduling preventive maintenance on their filter systems on the same schedule. He said that one of their sister mines in Illinois has tens of thousands of hours of experience using the DST system and are also seeing approximately 40 hour filter life. They equipped their permissible inby units with the DST system and are now considering using the DST system on their heavy-duty outby units as well.

MSHA observed that the coal industry is struggling with their heavy-duty outby units including compressors and generators and the need to bring those units into compliance with the regulations by July 20, 2003. MSHA has put out a best practices guide on active regeneration in coal and that's available on the MSHA website.

Q: Did Greens Creek assess workplace DPM concentrations prior to installation of filters and after the installation of the filters?
A: In July 30 2000 NIOSH (Dr. Bruce Cantrell and colleagues) did measurements in the mine and found about 550 $\mu g/m^3$ of TC. Some measurements in the stopes showed concentrations of over 1000 $\mu g/m^3$. Greens Creek also participated in the 31 mine study conducted by MSHA and measured concentrations that were in the higher band for some of the occupations. It was one of the higher readings in the 31-mine study. While as of yet there are no numbers from the recent MSHA study in the stope, the numbers are expected soon. Mark Good thought that the contribution from the vehicles operated in the stope might be on the order of 85 $\mu g/m^3$. This number is expected DPM concentration within the producing stope calculated on the basis of the expected filtration efficiency of DPFs. Since the mine ventilation system is a series system, the actual concentration of DPM within a given stope would be the sum of the concentrations of DPM in intake air plus the 85 $\mu g/m^3$ generated within the stope. In-stope concentrations were as high as 1300 $\mu g/m^3$ while total mine exhaust was at 550 $\mu g/m^3$. This was indicating low ventilation volumes in the stope. It is hard to project levels after the filter installation since filters are installed only on a limited number of equipment (roughly 7%). With series ventilation, the deeper you are in the mine, the higher the ambient levels are and the in-stope levels are even higher due to stope specific DPM production estimated at 85 $\mu g/m^3$.

The Greens Creek representative said that they anticipated no problem realizing the 400 $\mu g/m^3$ standard on big equipment, but he was worried about light duty cycle auxiliary fleet vehicles; they might have to go with active regeneration on those units because of low exhaust temperatures.

Q: Do you think you can you get to 160 $\mu g/m^3$ at Greens Creek?
A: Only with filters installed on all equipment used underground.
[Mark Good provided the following comment to this statement during the review process: The current ventilation layout precludes dilution of DPM to levels approaching 160 $\mu g/m^3$ [of TC] with more volume [of fresh air]. As eluded to in the first question, the concern is with the light duty equipment. We have not yet tested filters in this

application and are not sure as to the applicability of filter technology in this area. There are studies on-going in this application, but results have not yet been released (Kidd Creek Study through DEEP). As stated by Dr. Schnakenberg of NIOSH, the application of filter technology to 2 cycle diesel engines is questionable due to hydrocarbon emissions from these engines. We therefore have some reservations as to the applicability of filter technology to at least some of our fleet and to be able to meet the 160 $\mu g/m^3$ limit. The problem we face is that the two cycle engines we have in service are in the light duty category and these engines will last for years in this application. Engine replacement as a normal course of maintenance cannot be relied upon to remove these engines from service. We recognize that filters are our only option to hit 160 $\mu g/m^3$ but filters may not be applicable to our entire underground fleet hence a dilemma that current technology cannot yet meet.]

Stillwater mine reported that they have 12 passive and 1 active filter. They have experienced up to 3000 hours with the use of those filters. That mine has over a million cubic foot per minute of ventilation. They are anticipating a test with the NIOSH partnership in an isolated zone. They invited the equipment manufacturers to join them in making filters available for such trials.

Comment made by BHP San Juan coal: They have 8 passive soot traps. Their mines are new and they bought the equipment new equipped with soot traps installed. There were no backpressure gauges and they are working on correcting that. They had no trap failures and only had to clean the traps once. At this point they have less than 1000 hours on the traps. They have been very happy. When asked of horsepower of the engines using traps, they replied that they have 50 hp engines, 130 hp engines, 250 hp engines, 440 hp engines. They have 5 DST systems installed and have had a few problems most of which were with training and getting the people to effectively maintain the equipment including the exhaust temperature sensors used on the DST systems. They have put two such systems on Wagner scoops and they are experiencing approximately 40 hours of filter life.

Newmont in Nevada related their experience with DPFs. They started by going to Skinner (Steve Forbush) and learning about his maintenance programs. They also purchased ECOM and ENERAC exhaust gas measurement systems. They use them to take readings every month. They've seen reductions in CO. When they started the engine-out CO was about 600 to 700 ppm; now it is less than 150 ppm. They've used soot traps: they have 2 Engelhard traps on 300+ horsepower Wagner trucks. They also have ECS systems on 300 horsepower Wagner trucks. The Engelhard system is a platinum catalyzed system. They had to blow the ash out with compressed air every 1000 hours. They've had problems with backpressure monitors that were failing, but they had no runaway regeneration issues. They did have a turbocharger failure that blew oil on to the filter. They do use the ECOM system to collect soot spots. They run tests and use the Bacharach test to judge about performance of DPFs. They've seen reduction of 80 to 85 percent in soot (their work). He did say there is an issue with operators changing intake filters to often. Again he echoed comments that you need to make such changes based on emissions measurement. It was terribly important to perform temperature profiling before

you start. You really need to be guided in the early stages by that kind of information. They have some two-cycle engines; and they are of the opinion that they need to replace those engines with four-stroke engines.