if you're running it without an air cleaner or a clogged air cleaner or if a cleaner was replaced by the wrong cartridge element that allows for some air to bypass the fuel filter."

—Jamie Sauerteig,
Deutz Corporation

"One of the most simplest things in maintenance is the intake air cleaner or filter. You could have emission increases by as much as 300 or 400 percent just having a clogged intake air cleaner."

—Norbert Paas,
Paas Technology

"Maintenance: intake air and exhaust systems are checked at least once each day during their operation. Inspections are completed on a weekly basis. Inspections are done by competent persons assigned by the company to perform that work, and inspections are completed in a well-ventilated area. Results of these daily and weekly inspections are kept in a permanent record book."

—Steve Biby,
Old Ben Coal Company

The **cooling system** directly affects engine emissions by preventing scuffed cylinder walls and pistons, cracked heads, and burned valves. Liquid-cooled engines need to be kept free of mineral deposits and rust to ensure effective heat transfer. Mine water is generally high in minerals and salts, rendering it unfit for use in the cooling system. A 50 percent antifreeze and distilled water solution is optimal. Cooling fans, ducts and cowlings must also be maintained to ensure adequate cooling.

Air-cooled engines discharge heat via cooling fins, and liquid-cooled engines rely on radiators. Be sure to keep cooling fins and radiators undamaged and free of oil and dust to ensure proper heat transfer. Adjust or replace slipping fan and pump belts to ensure proper air and coolant flow, thus avoiding excessive heat buildup.

The **fuel injection system** can be damaged by contaminated fuel. To prevent this damage, fuel filters should be regularly replaced and fuel tanks should be periodically drained and cleaned. To avoid contamination, fuel should be properly handled, dispensed and the number of fuel transfer points minimized. Fuel tanks should be kept as full as possible to prevent condensation of water in the tank. Water should not be allowed to condense in fuel storage tanks. Water can be removed by the installation of fuel-water separators at the outlet of the surface storage tank, on the pump side of portable fuel trailers and on all engines. Water-absorbing additives may also be used.

The fuel pump and governor should be set to the engine manufacturer's or MSHA's specifications prior to running the engine at the mine. In addition, the mine elevation must also be considered in the final adjustment of the fuel injection pump. Air density decreases with an increase in elevation; therefore the fuel-air ratio will change as elevation increases, thus causing an adverse effect on the engine emissions. If the engine is operated at elevations above 1,000 feet, the fuel rate should be reduced as specified by MSHA or the engine manufacturer. Turbocharged engines are an exception to this rule due to excess quantities of air available from the turbocharger. MSHA or the engine manufacturer specifies the maximum operating elevation of a turbocharged diesel. Above this elevation, engine derating is necessary.

Caution should be observed in trying to increase the power output of engines: following manufacturer specifications can avoid significant increases in pollution. Minor increases in power that can be produced by adjusting the fuel-air ratio can also produce significant increases in particulate emissions. Similarly, too much advance or retardation of the fuel injection timing can have deleterious effects on NO_x, hydrocarbon, or particulate matter emissions.
The locks and seals on the fuel pump and governor must not be tampered with or removed. Faulty adjustment can result in overfueling and engine damage. Overfueling can increase emissions, especially black smoke, carbon monoxide, and particulates.

[Engines used at high elevation must be properly sized to ensure adequate power.] "Due to our elevation of approximately 7,000 feet, the 150-hp engines are derated to approximately 115 hp. Unfortunately, horsepower at the wheels on the Ramcars is down to about 90 hp."

—Bill Olsen,
Mountain Coal Company,
West Elk Mine

"...The first thing to do to reduce particulate emissions is to get the fuel injector pumps and the fuel injectors properly adjusted so they do not overfuel the engine. That will bring the particulate emissions down faster and more effectively than anything else.... It will also lower hydrocarbon and carbon monoxide emissions...."

—David Hofeldt, Ph.D.,
University of Minnesota

Failure to maintain the **lubrication system** can lead to significantly increased particulate emissions, and eventually to catastrophic engine failure. Excessive heat lowers the viscosity of engine oil and results in lost lubricity and accelerated engine wear. The quality of the lubrication oil is also important and contamination must be avoided. Worn valve guides and piston rings allow lube oil to leak into the combustion chamber and cause white and/or blue-black smoke, and the creation of significant particulate concentrations. System failures are often caused by a component failure, such as seized bearings, lubricant breakdown, lubricant contamination or engine overheating. To prevent these failures it is important to regularly replace oil filters, maintain crankcase lubricant at recommended levels and to maintain the engine's cooling system.

"...Any engine, regardless of whether it has mechanical controls or a sophisticated engine with electronic controls, if the engines have not been maintained, if they're burning oil, you will get plenty of blue smoke of all kinds.... I think we tend to confuse blue and black smoke sometimes. ...But generally, a blue exhaust gas will indicate oil consumption,

typically a low load operation, high oil consumption. Black smoke is more related to overfueling. In other words, we're talking about full-load overfueling of the engine, high temperature. It's basically the opposite of blue smoke."

—Jamie Sauerteig,
Deutz Corporation

The **exhaust system** must be periodically inspected and maintained to avoid the buildup of excessive exhaust back pressure and to ensure safe operation of the engine. Back pressure increases may result from a partially plugged water scrubber, flame trap, OCC, or filter or a dented exhaust pipe. Increased back pressure causes increased emissions and reduced performance. Back pressure should not exceed 27 to 40 inches of water or manufacturers' specification.

The tanks of water scrubbers used on permissible equipment must be filled and the float valves must be operational to meet MSHA safety requirements. Proper maintenance also ensures safe operation of the disposable diesel exhaust filters located downstream of the scrubbers.

"Water scrubbers are prone to mechanical failures, prone to maintenance problems. You can lose water, and you can have a filter catching fire...."

—Mridul Gautam, Ph.D.,
West Virginia University

Because a diesel engine operates over a wide range of duty cycles, the most accurate way to assess the content of exhaust emissions during actual mining conditions is to **take tailpipe samples while the engine is under load.** *As of November 25, 1997, weekly tests for CO in the undiluted exhaust are required for certain types of diesel-powered equipment in underground coal mines.*

A gas monitor can be used to measure the carbon monoxide level in the raw exhaust. A large increase in the carbon monoxide concentration is an indication that the engine has a maintenance problem that needs to be addressed. An increase in the carbon monoxide concentration is also a good indication that the diesel particulate concentration and observable smoke levels are increasing. Regular testing of an engine will provide information on the need for maintenance.

Engine emissions during mining operations cannot be accurately evaluated at idle conditions. On certain types of mine vehicles, such as load-haul-dumps (LHDs) and scoops, a repeatable loaded condition can be readily placed on the engine. On clutched vehicles this may not be possible.

Question:
"At our mines, we've got a multi-gas testing system hooked up through...our mine monitor system, and from what I understand, unless you test these vehicles under load, it's more or less useless; is this correct?"

—Morris Ivie,
Alabama Coal Miner (UMWA)

Response:
"Well, [yes]...just about."

—Mridul Gautam, Ph.D.,
West Virginia University

"...By tuning the engines on the dynamometer and making sure that we get the rated performance, the amount of smoke is greatly reduced, essentially eliminated."

—Scott Vail, Ph.D.,
IMC Global Carlsbad Mine

Diesel engine maintenance is the cornerstone of a diesel emission control program. Proper maintenance includes **compliance with manufacturers' recommended maintenance schedules, maintenance of accurate records and the use of proper maintenance procedures.** Inadequate maintenance, improper adjustments, wear, and other factors will cause changes in diesel exhaust emission rates. *As of November 25, 1997, diesel engines in underground coal mines must be maintained in compliance with the conditions of the MSHA approval, and examined weekly in accordance with approved checklists and manufacturer maintenance manuals.*

"...To control DPM, we've got a good strong preventative maintenance program. We bring equipment in on a regular basis on the 50, 250 and 1,000-hour intervals and do the recommended filter checks and changes as recommended by the manufacturer."

—Denny Alderman,
Turris Coal Company

"...I just want to stress the importance of a good maintenance program... We have a very good maintenance program in that it's preventive maintenance as well as, you know, when problems arise on the job, we just get it fixed."

—William Cranford,
UMWA Safety Committeeman

"The mine currently uses about 115 pieces of diesel equipment.... Although the mine has been slowly downsizing over the past five years, the number of diesel mechanics has increased, and we do this because we've upgraded our preventative maintenance. We seldom see a smoking diesel underground anymore, although once in a while, of course, we get one."

—John Marks,
Homestake Mining Company

"...A well-conceived maintenance program strives to maintain optimum engine performance and thereby control diesel exhaust emissions. The maintenance program consists of regularly scheduled replacements of fluids and filters, operating performance evaluations and additional weekly permissibility inspections,...and a training program to educate maintenance personnel in the engine operating recommendations and requirements."

—Keith Roberts,
Kerr McGee's Galatia Mine

"There's a whole section in the MSHA advisory standards on diesel maintenance almost from A to Z. It could be almost verbatim from manufacturers' manuals themselves.... They've been laying in front of mine operators' faces for 15-16 years now. Some of them [mine operators] adhere to them religiously. Others have never even seen the standards, either voluntary or mandatory, have never even opened that section of the book."

—Harry Tuggle,
United Steelworkers of America

It is worth emphasizing that if repairs and adjustments to diesel engines are to be done properly, the personnel performing such tasks must be **properly trained**. *Operators of underground coal mines where diesel-powered equipment is used, are required, as of November 25, 1997, to establish programs to ensure that persons who perform maintenance, tests, examinations and repairs on diesel-powered equipment are qualified.*

"I think the mechanics need to be trained so they understand exactly what causes the emissions."

—Norbert Paas,
Paas Technology

"It's also fundamental that the mechanics have proper and modern tools at their disposal and be trained in how to use them."

—Robert Waytulonis,
Center for Diesel Research,
University of Minnesota

WORK PRACTICES AND TRAINING

Work practices and training can have a significant effect on diesel exhaust emissions.

Care must be taken to avoid contaminating diesel fuel and lubricating oils during transfer. Fuel contamination can result from transfers taking place in a dusty and damp environment or by using the same transfer pump for different fluids. Fuel contamination will increase emissions.

Operators should avoid lugging the engine to low RPM. Lugging an engine is applying an increasing load (torque) against the engine, while the engine's fuel rack is at the maximum position, causing a decrease in the engine's RPM. An example of lugging is when a LHD operator drives the bucket into a muck pile with the accelerator to the floor and continues to work the engine causing the engine's RPM to decrease. If the engine operator continues to work the engine to a point where the engine's RPM are low but the torque demand on the engine is high, the engine may eventually stall. However, as the engine's RPM decreases and the engine torque increases, the engine's ability to efficiently burn fuel decreases causing the engine to produce excessive carbon monoxide and particulate emissions. For naturally aspirated engines and older turbocharged engines, an engine operating at a lower RPM and high load produces higher exhaust emissions than an engine operating at higher RPM and lower load. To avoid this situation, the vehicle operator should maintain higher engine RPM while performing the work. This might mean picking up a smaller load or carrying less material or shifting to a lower gear. The result will be a reduction in engine exhaust emissions.

Operators should avoid idling the engine. Idling wastes fuel, increases emissions and may overcool the engine. Overcooling results in incomplete combustion, higher emissions and may lead to varnish and sludge formation. Unburned fuel washing down cylinder walls removes the protective film of lubricating oil and results in accelerated wear. The fuel dilutes the lubricating oil resulting in reduced lubricity. Engines should be shut down and not idled except as required in normal mining operations. *As of April 25, 1997, idling of diesel-powered equipment, except as required in normal mining operations, is prohibited in underground coal mines.*

Operators of diesel-powered equipment must be trained on the operation of the equipment, in routine inspection and maintenance activities, and to promptly report any evidence of problems. For instance, operators should carry spare intake air filters, so that clogged filters can be changed as needed. *As of November 25, 1997, operators of mobile diesel-powered equipment in underground coal mines must conduct a visual examination of the equipment before placing the equipment in operation.*

"Our operators all undergo a six-week training period underground on a training panel learning to efficiently and safely operate the equipment before we turn them loose in a production panel. A big part of that is awareness and reporting. They get on equipment, the power drops off or it's smoky, they know they're supposed to report it, and we do something about it. If air volume's dropping off, it's probably because the ventilation crew hasn't kept with the panel. It's reported, we address it. So we stay on top of things."

—Scott Vail, Ph.D.,
IMC Global Carlsbad Mine

"We need education, education, education of the people who operate the equipment, of the people who maintain the equipment...and of the people that inspect the equipment for the enforcement agencies. A complete education process should start tomorrow."

—Joe Main,

United Mine Workers of America

"Equipment operation–my key thing is operators' training–to make the operator aware of exactly what a diesel machine is, what to look for, give them the ability to diagnose problems on the machine so that when he sees something, he can make a decision—should I call a mechanic in or not? Very important in the program. And a walk-around inspection?—It takes less than five minutes."

—Norbert Paas,
Paas Technology

Operators and maintenance personnel should read and be familiar with the manuals covering the machines they operate and maintain. Besides specifying how a machine is to be operated and maintained, these manuals provide useful information on servicing methods and intervals.

FLEET MANAGEMENT

Diesel fleet management includes setting policies for operator and mechanic training, diesel usage, engine replacement and determining the types, numbers and horsepower of diesel engines used underground. Establishing such policies, and purchasing the needed equipment, is usually the role of upper mine management. Several participants at the MSHA workshops stressed that these management activities could play an important role in reducing diesel emissions. They suggested that mine management must actively support operator and mechanic training and ensure that adequate shop facilities are available to maintain the diesel fleet.

"...We have service areas that advance with the panels underground because we're so spread out, and our main rebuild shop is also underground...."

—Scott Vail, Ph.D.,
IMC Global Carlsbad Mine

RESPIRATORY PROTECTIVE EQUIPMENT

While it should NOT be used as the primary method of control, **use of respiratory protective equipment** can help to reduce miner exposure to DPM until better controls can be implemented.

It is generally accepted industrial hygiene practice to eliminate or minimize hazards before resorting to personal protective equipment. As indicated by the quotations in this Toolbox, various mines are taking a variety of approaches to minimize DPM emissions and to reduce DPM concentrations in mine atmospheres. However, using the correct respiratory protective equipment in areas of the mine which are difficult to ventilate and are currently subject to high concentrations of diesel pollutants can help to protect miner health.

"Now, even before mechanization, slusher operators at Homestake wore half-face respirators as protection against the silica dust. Loader operators also are required to wear them. And with the organic mist and fume cartridges and filter pads, we figure that's removing 99 percent of any diesel particulate matter in the air."

—John Marks,
Homestake Mining Company

MEASURING THE CONCENTRATION OF DIESEL PARTICULATE MATTER IN MINES

Monitoring DPM concentrations is the ideal way for a mine to track and evaluate its progress in implementing a DPM control program.Various methods for measurement are described in Appendix C of this publication.

"...The ultimate measure...is what the air quality is in the workplace, and I think that's an issue that we need to also consider. Just having cfm blowing through a place really doesn't give you the true picture.... I want to be able to do the measurement on an ongoing basis...."

—Dan Steinhoff,
ASARCO

"The Bureau of Mines, MSHA, NIOSH and others have been working with sampling technology that's been done in a prototype phase strictly within government control. We need to take that technology and get it out in the field so people can evaluate what their own exposures are and evaluate how they might reduce those exposures."

—Mark Ellis,
U.S. Borax Inc.

Mine operators who would like assistance in measuring or evaluating DPM exposures may request help from MSHA's Office of Technical Support by contacting the MSHA District

Manager in their area. Assistance may also be obtained through the NIOSH Health Hazard Evaluation Program by calling 1-800-35NIOSH.

A DOZEN WAYS TO REDUCE EXPOSURE TO DIESEL PARTICULATE MATTER

1. **Use low emission engines.** Older engines should be replaced with modern, low emission engines whenever possible, and new diesel equipment should be powered by low emission engines.

2. **Use low sulfur fuel.** Low sulfur fuel extends engine life, reduces emissions and allows catalyzed emission control devices to perform properly.

3. Use appropriate **exhaust aftertreatment devices** such as filters and oxidation catalysts, and environmentally conditioned, enclosed cabs, where possible.

4. **No ventilation, no operation.** If ventilation in an underground mine is interrupted for any reason, all diesel equipment should be shut down.

5. **Train miners properly.** Miners must learn to recognize hazards, and to correctly operate and maintain diesel equipment. Designated maintenance personnel should be specially trained in diesel repair.

6. **Read operation and maintenance manuals.** Deviation from maintenance and operation schedules and procedures will increase emissions.

7. **Beware of black smoke.** Black smoke from a diesel engine is a result of improper fuel to air ratio. Black smoke indicates that engine maintenance is needed.

8. **No unnecessary idling.** Idling wastes fuel, increases emissions, and may overcool the engine resulting in increased wear.

9. **Keep it clean.** Dirt and dust are detrimental to engines. Periodic maintenance of the intake air system is required for peak engine performance. The air cleaner must be changed to avoid an intake air restriction that will increase emissions.

10. **Keep it cool.** Engine overheating is a frequent cause of premature engine failures. Ensure that the lubrication oil is the correct viscosity and kept at the recommended levels, and that heat exchangers are clean and undamaged.

11. **Do not operate the engine at high load and low speed** (lugging), as this increases emissions. Operators should shift gears to operate the engine at higher speed to lessen the

engine load.

12. **No overpowering.** The fuel injection pump governor must be set according to manufacturer's specifications or MSHA requirements. Tampering with the fuel system to boost power must be avoided.

APPENDICES

Appendix A: Recommended Additional Reading

1. Background

Health Effects Institute. Diesel Exhaust: A Critical Analysis of Emissions, Exposure and Health Effects. April 1995.
(For a copy contact the Health Effects Institute, 955 Massachusetts Avenue, Cambridge, MA 02139, or by calling 617-876-6700.)

Mine Safety and Health Administration, report of the Advisory Committee on Diesel-Powered Equipment in Underground Coal Mines, 1988. (For a copy, available at cost, contact: MSHA, Office of Standards, Regulations and Variances, Room 631, 4015 Wilson Boulevard, Arlington, Va. 22203-1984, or call 703-235-1910.)

2. Controls

Mine Safety and Health Administration, transcripts of three workshops on Diesel Particulate control methods, Fall 1995.
(For a copy, on paper or disk, available at cost, contact: MSHA, Office of Standards, Regulations and Variances, Room 631, 4015 Wilson Boulevard, Arlington, Va. 22203-1984, or call 703-235-1910.)
U.S. Bureau of Mines. *Diesels In Underground Mines: Measurement and Control of Particulate Emissions.* IC 9324, 1992. 132 pages.
(To receive a copy contact Robert Waytulonis, University of Minnesota Center for Diesel Research, Department of Mechanical Engineering, 125 ME, 111 Church Street, S.E., Minneapolis, MN 55455 or call 612-725-0760, x4760.)

Waytulonis, R. W. Diesel Exhaust Control, Chapter 11.5. *SME Mining Engineering Handbook*, 2nd Ed. v. 1. H. L. Hartman, ed., 1992, pp. 1040-1051.

3. Measurement techniques

Cantrell, B. K., Williams, K. L., Watts, W. F, and Jankowski, R. A., "Mine Aerosol Measurement", Chapter 27 in *Aerosol Measurement: Principles, Techniques, and Applications*, ed. K. Willeke, and P. A. Baron. Van Nostrand, 1993, pp. 591-611.

Cantrell, B. K., and Watts W. F., "Occupational exposures to diesel exhaust aerosol," Littleton, CO, Proceedings of the SMME Annual Meeting and Exhibit, Phoenix, AZ, March 11-14, 1996. Preprint No. 96-126.

Gangal, M.J., Ebersol, J., Vallieres, J., and Dainty, D., "Laboratory Study of Current (1990/91) SOOT/RCD Sampling Methodology for the Mine Environment," Mining Research Laboratories, Canada Centre for Mineral and Energy Technology, MRL 91-000510, Ottawa, Canada, 1990.

Gangal, M.J., and Dainty, E.D., "Ambient Measurement of Diesel Particulate Matter and Respirable Combustible Dust in Canadian Mines," *Proceeding of VIth U.S. Mine Ventilation Symposium*, Salt Lake City, Utah, 1993.

Haney, R.A., Saseen, G.P., and Waytulonis, R.,W., "An Overview of Diesel Particulate Exposures and Control Technology in the U.S. Mining Industry," Proceedings of the 2nd International Conference on the Health of Miners, Pittsburgh, PA., November, 1995.

Haney, R.A., and Fields, K.G., "Diesel Particulate Exposures in the Mining Industry," MINE Expo International '96, Las Vegas, NV, September 10, 1996.

McCartney T.C. and Cantrell B.K., "A Cost-Effective Personal Diesel Exhaust Aerosol Sampler," Bureau of Mines IC 9324, pp. 24-30, 1992.

Appendix B: Glossary of Terms

Aftercooling Cooling intake air prior to induction into the combustion chamber to increase power and reduce the emission of oxides of nitrogen.

Aftertreatment devices Devices such as filters which remove constituents of diesel exhaust as they leave the equipment.

Approval plate quantity Quantity of ventilating air given in cubic feet per minute (cfm) that will dilute the concentrations of gaseous exhaust contaminants from a single diesel engine to specified limits for CO_2, CO, NO and NO_2. This is sometimes called the nameplate air quantity.

Aromatic content Hydrocarbons in diesel fuel are numerous but generally fall into three families: paraffins, naphthenes and aromatics. Reducing fuel aromatic content will reduce hydrocarbons in the exhaust and the soluable organic portion of DPM.

Autoregeneration Self-cleaning of a filter by an engine which has high enough exhaust temperatures to oxidize the diesel particulate matter captured on the filter. See "regeneration" below.

Cetane number A number that describes the ignitability of diesel fuel. Fuels with high cetane numbers have low self-ignition temperatures. Fuels with low cetane numbers cause engine roughness.

Cloud point The highest temperature at which the first trace of paraffin visibly separates in the liquid fuel.

Diesel particulate matter (DPM) Small particles of matter in diesel exhaust, which can be collected on filters. The terms "diesel particulate", or "DP", mean the same thing.

Elemental carbon Elemental carbon is sometimes used as a surrogate measure for DPM. It is composed of graphitic carbon, as opposed to organic carbon, and usually accounts for 40 to 60 percent of the DPM by mass.

Exhaust back pressure Buildup of pressure against the engine created by the resistance of the exhaust flow passing through the exhaust system components.

Fuel-to-air ratio The ratio of the amount of fuel to the amount of air introduced into the diesel combustion chamber.

g/hp-h (Gram per horsepower-hour) The hourly mass of a contaminant in diesel engine exhaust emissions divided by the engine horsepower.

Impactor Device used to separate particles by size.

Nameplate quantity See approval plate quantity.

Organic carbon Non-graphitic soluble organic carbon material associated with DPM.

Oxygenates Fuel additives which contain a substantial fraction of oxygen by weight, e.g. ethanol, methanol, and methyl soyate.

Permissible Equipment on which safety components and temperature controls have been added to prevent the ignition of methane or coal dust so that it can be safely used in areas of an underground mine where methane is likely to accumulate.

Regeneration Process of oxidizing DPM collected on a diesel exhaust particulate filter to remove it. This process cleans the filter and reduces back pressure to acceptable limits.

Respirable combustible dust (RCD) Method of measuring DPM using a combustion process.

Threshold limit value (TLV®) Time-weighted average concentration (established by the American Conference for Governmental Industrial Hygienists) for a conventional 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Total Carbon Refers to the sum of the elemental and organic carbon associated with the diesel particulate matter and accounts for about 80-85 percent of the DPM mass.

Turbocharge Process of increasing the mass of intake air by pressurization to the engine which allows more fuel to be burned and results in increasing the engine's power output.

Volatility Measure of the ability of a fuel to vaporize.

Wax separation Separation of the paraffinic portion of diesel fuel from the other components which occurs at low temperature. It can cause fuel flow problems.

Appendix C: Methods of Measuring Diesel Particulate Matter (DPM)

DPM is comprised of solid elemental carbon particles, with adsorbed and condensed hydrocarbons and sulfates. The particles are arranged in chain aggregates that have a mass median diameter of about 0.2 micrometers. Several methods are available for determining DPM concentrations in the environment. They include:

- Measuring the mass (gravimetrically) of the submicrometer portion of the respirable fraction of the aerosol.

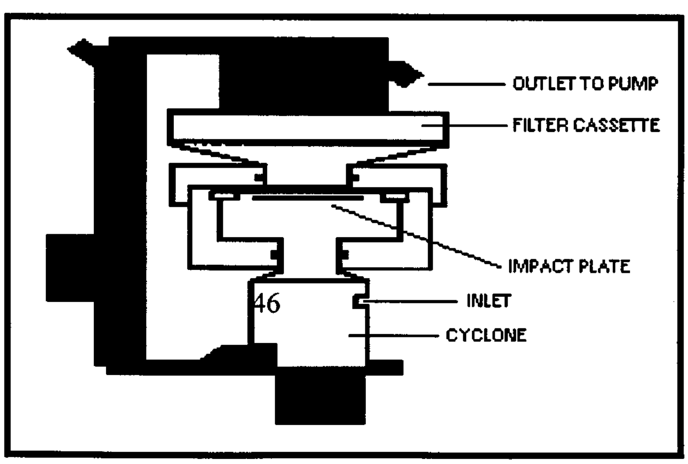
- Measuring the concentration (chemically) of the elemental and organic carbon fractions (total carbon) of either the submicrometer portion of the respirable dust aerosol or of the total respirable dust aerosol.

- Measuring the mass (gravimetrically) of the combustible fraction of the respirable aerosol (often referred to as the RCD method).

Measuring the mass of the submicrometer portion of the respirable dust sample is the most common method currently being used to determine the DPM concentration in coal mines. This method takes advantage of the facts that DPM in coal mines is generally less than 0.8 mm in size and that other mineral dust collected in a respirable dust sample is generally greater than 0.8 mm in size.

Figure 2 shows a schematic of a sampling device that can be used to collect the submicrometer fraction of the respirable dust aerosol. The sampling device is similar to the standard respirable dust sampling device, which consists of a 10 mm nylon cyclone and a sample collection filter. However, the sampling device has been modified to incorporate an inertial impactor that separates particles greater than 0.8 µm in size from the aerosol sample. Particles greater than 0.8 µm are collected on an impaction plate. The submicrometer fraction (particles less than 0.8 µm in size) is collected on the filter. Depending on the type of filter used to collect the submicrometer fraction, the collected sample can be analyzed gravi metrically to determine the DPM concentration or chemically to determine the total carbon (elemental and organic) concentration of the submicrometer particulate.

Figure 2. Personal Sampler Adapted for Submicron Sampling



For gravimetric analysis, the sample should be collected on a preweighed 5.0 µm pore size, vinyl Metricel® filter. If the submicrometer mass of the sample collected is less than 0.3 mg the DPM should be determined using chemical analysis. For the chemical analysis a preconditioned (heated in air at 400oC for 1 hour) quartz fiber-filter should be used. The total carbon content of samples collected on quartz-fiber filters can be determined using NIOSH's Analytical Method 5040.

For metal and nonmetal mining operations, samples should generally be collected without the impactor because as much as 30 percent of the DPM in such mines may be greater than 0.8 µm.

About 80-85 percent of the dpm mass is total carbon (elemental and organic).

The RCD method is applicable to certain metal and nonmetal mining operations. For the RCD method, the aerosol sample is usually collected using a typical respirable dust sampler. To measure the concentration of DPM, the respirable sample is collected on a preweighed, 0.8 µm pore size, silver membrane filter. The filter is preconditioned by heating at 400oC in an oven. After sample collection, the filter is first weighed to determine respirable dust mass and then is heated at 400oC in an oven to burn off the carbonaceous material. The sample is then reweighed. The loss in sample mass resulting from the heating represents the DPM.

The RCD method should be used with caution when a hydrated mineral dust (e.g., gypsum or trona) or a carbonaceous material other than DPM collects on the filter. Such materials are chemically altered by the heating process and produce erroneous results unless properly accounted for. Also, the potential for metal oxide formation exists, which will bias the results.

All of these methods have been used to determine the concentration of DPM in underground mines. Studies in metal and nonmetal mines of these methods have shown that DPM concentrations determined from gravimetric analysis of the submicrometer fraction of the respirable dust aerosol are approximately the same as those determined using the RCD method. Studies have also shown that in metal and nonmetal mines, total carbon concentration determined from the submicrometer fraction of the respirable aerosol is nearly equivalent to the concentration determined from the gravimetric analysis of the submicrometer fraction of the respirable aerosol. This may not be true for samples collected in mines containing other types of submicrometer combustible materials.

For further information on the appropriate use of these methods contact MSHA.

APPENDIX D: REFERENCES TO RELEVANT REGULATIONS

MSHA-Title 30, Code of Federal Regulations

Underground coal, diesel-powered equipment regulations-published in the Federal Register on October 25, 1996, Vol. 61, Number 208, pp. 55412-55534. The Toolbox makes reference to the following requirements:

approved engines required *75.1907*

approval criteria Parts *7 & 36, revised*

low sulfur fuel *75.1901(a)*

fuel additives *75.1901(c)*

maintenance of air filters *75.1914(d)*

weekly CO testing
of tailpipe emissions *75.1914(g)*

compliance with manufacturer specifications
75.1909(a)(1), 75.1914(f)(1)

maintenance personnel qualifications *75.1915*

idling restrictions *75.1916(d)*

visual exam by equipment operator *75.1914(e)*

Limitations applicable to certain diesel exhaust gases:

underground coal *75.321, 75.322*

surface coal *71.700*

underground metal/nonmetal *57.5001*

surface metal/nonmetal *56.5001*

EPA standards for new diesel engines-Title 40, Code of Federal Regulations:

1988 “on-highway” engine standards
40 CFR 86.088-11

1996 "non-road" engine standards
40 CFR 89.112-96

Pennsylvania state standards for use of diesel-powered equipment in deep coal mines:

Pennsylvania Act 182 of 1996, December 19, 1996. This Act adds a new article to the Bituminous Coal Mine Act, "Article II-A, Diesel-Powered Equipment." It took effect on February 17, 1997. For information, contact the Pennsylvania Bureau of Deep Mine Safety, 412-439-7469, or fax at 412-439-7324.

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