DEPARTMENT OF LABOR

Mine Safety and Health Administration

30 CFR Part 57

RIN 1219–AB11

Diesel Particulate Matter Exposure of Underground Metal and Nonmetal Miners

AGENCY: Mine Safety and Health Administration (MSHA), Labor.

ACTION: Proposed rule.

SUMMARY: This proposed rule would establish new health standards for underground metal and nonmetal mines that use equipment powered by diesel engines.

The proposed rule is designed to reduce the risks to underground metal and nonmetal miners of serious health hazards that are associated with exposure to high concentrations of diesel particulate matter (dpm). DPM is a very small particle in diesel exhaust. Underground miners are exposed to far higher concentrations of this fine particulate than any other group of workers. The best available evidence indicates that such high exposures put these miners at excess risk of a variety of adverse health effects, including lung cancer.

The proposed rule for underground metal and nonmetal mines would establish a concentration limit for dpm, and require mine operators to use engineering and work practice controls to reduce dpm to that limit. Underground metal and nonmetal mine operators would also be required to implement certain ''best practice'' work controls similar to those already required of underground coal mine operators under MSHA's 1996 diesel equipment rule. These operators would also be required to train miners about the hazards of dpm exposure.

MSHA has already proposed a rule to control dpm exposures in underground coal mines in a separate notice to the public published in the **Federal Register** on April 9, 1998 (62 FR 17492).

DATES: Comments must be received on or before February 26, 1999. Submit written comments on the information collection requirements by February 26, 1999.

ADDRESSES: Comments on the proposed rule may be transmitted by electronic mail, fax, or mail, or dropped off in person at any MSHA office. Comments by electronic mail must be clearly identified as such and sent to this e-mail address: comments@msha.gov. Comments by fax must be clearly identified as such and sent to: MSHA, Office of Standards, Regulations, and Variances, 703–235–5551. Send mail comments to: MSHA, Office of Standards, Regulations, and Variances, Room 631, 4015 Wilson Boulevard, Arlington, VA 22203–1984, or any MSHA district or field office. The Agency will have copies of the proposal available for review by the mining community at each district and field office location, at the National Mine Health and Safety Health Academy, and at each technical support center. The document will also be available for loan to interested members of the public on an as needed basis. MSHA will also accept written comments from the mining community at the field and district offices, at the National Mine Health and Safety Academy, and at technical support centers. These comments will become a part of the official rulemaking record. Interested persons are encouraged to supplement written comments with computer files or disks; please contact the Agency with any questions about format.

Written comments on the information collection requirements may be submitted directly to the Office of Information and Regulatory Affairs, New Executive Office Building, 725 17th Street, NW., Rm. 10235, Washington, D.C. 20503, Attn: Desk Officer for MSHA.

FOR FURTHER INFORMATION CONTACT: Carol J. Jones, Acting Director; Office of Standards, Regulations, and Variances; MSHA; (703)235–1910.

SUPPLEMENTARY INFORMATION:

I. Questions and Answers About This Proposed Rule

(A) General Information of Interest to the Entire Mining Community

(1) What Actions Are Being Proposed?

MSHA has determined that action is essential to reduce the exposure of miners to a harmful substance emitted from diesel engines—and that regulations are needed for this purpose in underground mines. This notice proposes requirements for underground metal and nonmetal mines.

The harmful substance is known as diesel particulate matter (dpm). As shown in Figure I–1, average concentrations of dpm observed in dieselized underground mines are up to 200 times as high as average environmental exposures in the most heavily polluted urban areas and up to 10 times as high as median exposures estimated for the most heavily exposed workers in other occupational groups. The best available evidence indicates that exposure to such high concentrations of dpm puts miners at significantly increased risk of incurring serious health problems, including lung cancer.

The goal of the proposed rule is to reduce underground miner exposures to attain the highest degree of safety and health protection that is feasible.

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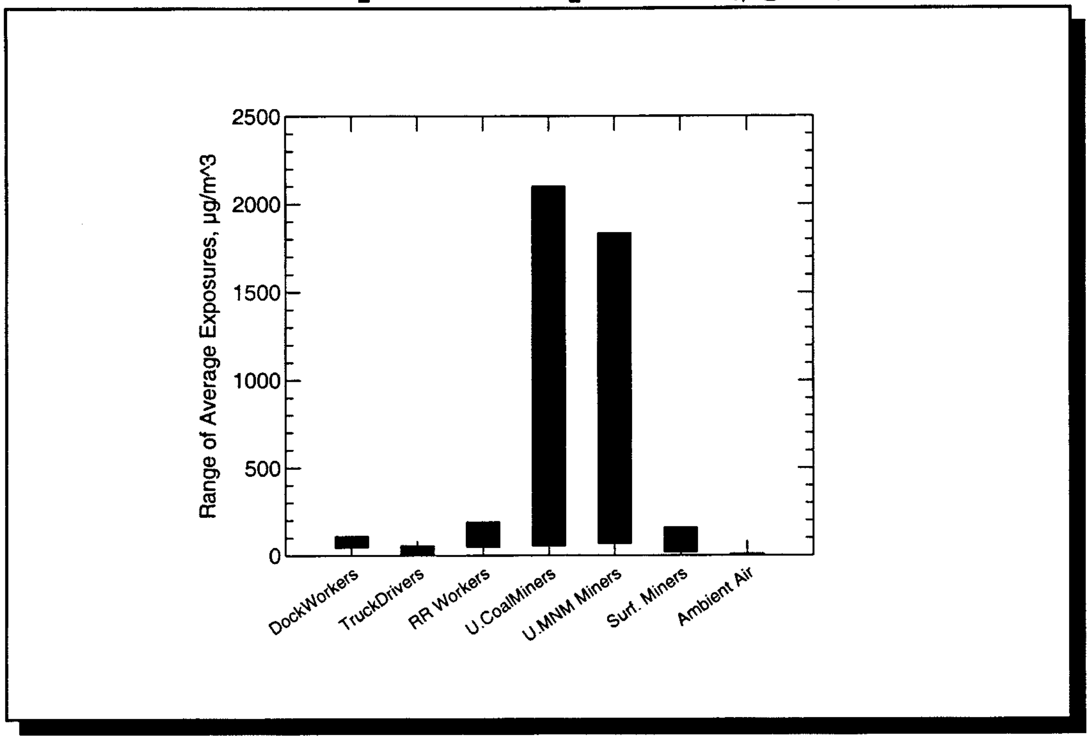
Figure I-1:
Comparative Exposures ($\mu g/m^3$)[1]



[1] Range of average dpm exposures observed at various mines for underground and surface miners compared to range of average exposures reported for other occupations and for urban ambient air. Averages are represented by median observed within mines for mine workers, by median as estimated with geometric mean reported for other occupations, and, for ambient air in urban environments, by the monthly mean estimated for different months and locations in Southern California. The range estimated for urban ambient air is roughly 1 to 10 $\mu g/m^3$. See part III for more detailed information.

Throughout this preamble, exposure information is presented in terms of "whole diesel particulate". Moreover, the information is presented in units of micrograms (μg) per cubic meter of air. However, in many of the references cited, exposure measurements may be expressed as milligrams (mg) per cubic meter of air.

1 mg/m^3 = 1 milligram per cubic meter of air
1 $\mu g/m^3$ = 1 microgram per cubic meter of air
1 milligram = 1000 micrograms.

To convert from milligrams to micrograms, multiply by 1000 -- or move the decimal point three places to the right. For example, 0.15 mg/m^3 = 150 $\mu g/m^3$.

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On April 9, 1998, (62 FR 17492), MSHA proposed a rule to achieve this goal in underground coal mines. MSHA's proposal would require the installation of high-efficiency filters on diesel-powered equipment to trap diesel particles before they enter the mine atmosphere. Following 18 months of education and technical assistance by MSHA after the rule is issued, filters would first have to be installed on permissible diesel-powered equipment. By the end of the following year (i.e., 30 months after the rule is issued), such filters would also have to be installed on any heavy-duty outby equipment. No specific concentration limit would be established in this sector; the proposed rule would require that filters be installed and properly maintained. Miner awareness training on the hazards of dpm would also be required.

With this notice, MSHA is proposing to adopt a different rule to achieve this goal in underground metal and nonmetal mines. MSHA is proposing that a limit on the concentration of dpm to which miners may be exposed would be established for underground metal and nonmetal mines. The limit would restrict dpm concentrations in underground metal and nonmetal mines to about 200 micrograms per cubic meter of air. Operators would be able to select whatever combination of engineering and work practice controls they want to keep the dpm concentration in the mine below this limit. The concentration limit would be implemented in two stages: an interim limit that would go into effect following 18 months of education and technical assistance by MSHA, and a final limit after 5 years. MSHA sampling would be used to determine compliance. The proposal for this sector would also require that all underground metal and nonmetal mines using diesel-powered equipment observe a set of ''best practices'' to reduce engine emissions—e.g., to use low-sulfur fuel. Similar practices are already in effect in underground coal mines as a result of MSHA's 1996 diesel equipment rule.

MSHA is not at this time proposing a rule applicable to surface mines. As illustrated in Figure I–1, in certain situations the concentrations of dpm at surface mines may exceed those to which rail, trucking and dock workers are exposed. Problem areas identified in this sector include production areas where miners work in the open air in close proximity to loader-haulers and trucks powered by older, out-of-tune diesel engines, or other confined spaces where diesel engines are running. The Agency believes, however, that these problems are currently limited and readily controlled through education and technical assistance. Using tailpipe exhaust extenders, or directing the exhaust across the engine fan, can dilute the high concentrations of dpm that might otherwise occur in areas immediately adjacent to mining equipment. Surface mine operators using or planning to switch to environmentally conditioned cabs to reduce noise exposure to equipment operators might also be able to incorporate filtration features that would protect these miners from high dpm concentrations as well. Completing already planned purchases of new trucks containing cleaner engines may also help reduce the isolated instances of high dpm concentrations at such mines.

The Agency would like to emphasize, however, that surface miners are entitled to the same level of protection as other miners, and that the Agency's risk assessment indicates that even short-term exposures to concentrations of dpm like those observed may result in serious health problems. Accordingly, in addition to providing education and technical assistance to surface mines, the Agency will also continue to evaluate the hazards of diesel particulate exposure at surface mines and will take any necessary action, including regulatory action if warranted, to help the mining community minimize any hazards.

(2) How Is This Notice of Proposed Rulemaking Organized? What Portions Do I Need To Read If I have Already Reviewed MSHA's Notice of Proposed Rulemaking To Limit dpm in Underground Coal Mines?

The proposed rule for underground metal and nonmetal mines can be found at the end of this Notice. The remainder of this preamble to the proposed rule (**SUPPLEMENTARY INFORMATION**) describes the Agency's rationale for what is being proposed.

Part I consists of a series of ''Questions and Answers.'' The Agency hopes they will provide most of the information you will need to formulate your comments. The first ten of these Questions and Answers (Section A) provide a general overview of this rulemaking. This is followed (Section B) by twenty additional Questions and Answers that address specific provisions of the proposed rule.

Part II provides some background information on nine topics that are relevant to this rulemaking. In order, the topics covered are: (1) The role of diesel-powered equipment in mining; (2) the composition of diesel exhaust and diesel particulate; (3) measurement of diesel particulate; (4) reducing soot at the source—EPA regulation of diesel engine design;(5) limiting the public's exposure to soot—EPA ambient air quality standards; (6) controlling diesel particulate emissions in mining—a toolbox; (7) existing mining standards that limit miner exposure to occupational diesel particulate emissions; (8) how other jurisdictions are restricting occupational exposure to diesel soot; and (9) MSHA's initiative to limit miner exposure to diesel particulate—the history of this rulemaking and related actions. Part II of this preamble is virtually identical to its counterpart in the preamble to MSHA's proposed rule to limit dpm concentrations in underground coal mines; the only exception is that the very last paragraph here, on the history of dpm rulemaking, has been updated to reflect the issuance of the proposed rule on underground coal. Appended to the end of this document, is an MSHA publication, ''Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—A Toolbox,'' includes additional information on methods for controlling dpm, and a glossary of terms.

Part III is the Agency's risk assessment. The first section presents the Agency's data on current dpm exposure levels in each sector of the mining industry. The second section reviews the scientific evidence on the risks associated with exposure to dpm. The third section evaluates this evidence in light of the Mine Act's statutory criteria. Part III of this preamble is virtually identical to its counterpart in the preamble to MSHA's proposed rule to limit dpm concentrations in underground coal mines; the only exception is the language in Section III.3.c., reflecting the fact that the proposed rules are different for each sector, and hence had to be evaluated separately as to whether they satisfy the requirements of the law.

Part IV is a detailed section-by-section explanation and discussion of the elements of the proposed rule.

Part V is an analysis of whether the proposed rule meets the Agency's statutory obligation to attain the highest degree of safety or health protection for miners, with feasibility a consideration. This part begins with a review of the law and a profile of the industry's economic position. The next part explores the extent to which the proposed rule is expected to impact existing concentration levels, reviews significant alternatives that might provide more protection than the rule being proposed but which have not been adopted by the Agency due to feasibility concerns, and then discusses the feasibility of the rule being proposed. Part V draws upon a computer simulation of how the proposed rule in underground metal and nonmetal mines is expected to impact dpm concentrations; accordingly, an Appendix to this discussion provides information about the simulation methodology. The simulation method, which can be performed using a standard spreadsheet program, can be used to model conditions and control impacts in any underground mine; copies of this model are available to the mining community from MSHA.

Part VI reviews several impact analyses which the Agency is required to provide in connection with a proposed rulemaking. This information summarizes a more complete discussion that can be found in the Agency's Preliminary Regulatory Economic Analysis (PREA). Copies of this document are available from the Agency and will be posted on the MSHA Web site (http://www.msha.gov).

Part VII is a complete list of publications referenced by the Agency in the preamble.

(3) What Evidence Does MSHA Have That Current Underground Concentrations of DPM Need To Be Controlled?

The best available evidence MSHA has at this time is that miners subjected to an occupational lifetime of dpm exposure at concentrations we presently find in underground mines face a significant risk of material impairment to their health.

It has been recognized for some time that miners working in close contact with diesel emissions can suffer acute reactions—e.g., eye, nose and throat irritations—but questions have persisted as to what component of the emissions was causing these problems, whether exposure increased the risk of other adverse health effects, and the level of exposure creating health consequences.

In recent years, there has been growing evidence that it is the very small respirable particles in diesel exhaust (dpm) that trigger a variety of adverse health outcomes. These particles are generally less than one-millionth of a meter in diameter (submicron), and so can readily penetrate into the deepest recesses of the lung. They consist of a core of the element carbon, with up to 1,800 different organic compounds adsorbed onto the core, and some sulfates as well. (A diagram of dpm can be found in Part II of this preamble—see Figure II–3). The physiological mechanism by which dpm triggers particular health outcomes is not yet known. One or more of the organic substances adsorbed onto the surface of the core of the particles may be responsible for some health effects, since these include many known or suspected mutagens and carcinogens. But some or all of the health effects might also be triggered by the physical properties of these tiny particles, since some of the health effects are observed with high exposures to any "fine particulate," whether the particle comes from diesel exhaust or another source.

There is clear evidence that exposure to high concentrations of dpm can result in a variety of serious health effects. These health effects include: (i) Sensory irritations and respiratory symptoms serious enough to distract or disable miners; (ii) death from cardiovascular, cardiopulmonary, or respiratory causes; and (iii) lung cancer.

By way of example of the non-cancer effects, there is evidence that workers exposed to diesel exhaust during a single shift suffer material impairment of lung capacity. A control group of unexposed workers showed no such impairment, and workers exposed to filtered diesel exhaust (i.e., exhaust from which much of the dpm has been removed) experienced, on average, only about half as much impairment. Moreover, there are a number of studies quantifying significant adverse health effects—as measured by lost work days, hospitalization and increased mortality rates—suffered by the general public when exposed to concentrations of fine particulate matter like dpm far lower than concentrations to which some miners are exposed. The evidence from these fine particulate studies was the basis for recent rulemaking by the Environmental Protection Agency to further restrict the exposure of the general public to fine particulates, and the evidence was given very widespread and close scrutiny before that action was made final. Of particular interest to the mining community is that these fine particulate studies indicate that those who have pre-existing pulmonary problems are particularly at risk. Many individual miners in fact have such pulmonary problems, and the mining population as a whole is known to have such conditions at a higher rate than the general public.

Although no epidemiological study is flawless, numerous epidemiological studies have shown that long term exposure to diesel exhaust in a variety of occupational circumstances is associated with an increased risk of lung cancer. With only rare exceptions, involving relatively few workers and/or observation periods too short to reliably detect excess cancer risk, the human studies have consistently shown a greater risk of lung cancer among workers exposed to dpm than among comparable unexposed workers. When results from the human studies are combined, the risk is estimated to be 30–40 percent greater among exposed workers, if all other factors (such as smoking habits) are held constant. The consistency of the human study results, supported by experimental data establishing the plausibility of a causal connection, provides strong evidence that chronic dpm exposure at high levels significantly increases the risk of lung cancer in humans.

Moreover, all of the human occupational studies indicating an increased frequency of lung cancer among workers exposed to dpm involved average exposure levels estimated to be far below the levels observed in underground mines—and even below the limits being proposed. As noted in Part III, MSHA views extrapolations from animal experiments as subordinate to results obtained from human studies. However, it is noteworthy that dpm exposure levels recorded in some underground mines have been within the exposure range that produced tumors in rats.

Based on the scientific data available in 1988, the National Institute for Occupational Safety and Health (NIOSH) identified dpm as a probable or potential human carcinogen and recommended that it be controlled. Other organizations have made similar recommendations.

MSHA carefully evaluated all the evidence available in light of the requirements of the Mine Act. Based on this evaluation, MSHA has reached several conclusions:

(1) The best available evidence is that the health effects associated with exposure to dpm can materially impair miner health or functional capacity.

(2) At levels of exposure currently observed in underground mining, many miners are presently at significant risk of incurring these material impairments over a working lifetime.

(3) The reduction in dpm exposures that is expected to result from implementation of the proposed rule for underground metal and nonmetal mines would substantially reduce the significant risks currently faced by underground metal and nonmetal miners exposed to dpm.

MSHA had its risk assessment independently peer reviewed. The risk assessment presented here incorporates revisions made in accordance with the reviewers' recommendations. The reviewers stated that:

> * * * principles for identifying evidence and characterizing risk are thoughtfully set

out. The scope of the document is carefully described, addressing potential concerns about the scope of coverage. Reference citations are adequate and up to date. The document is written in a balanced fashion, addressing uncertainties and asking for additional information and comments as appropriate. (Samet and Burke, Nov. 1997.)

The proposed rule would reduce the concentration of one type of fine particulate in underground metal and nonmetal mines—that from diesel emissions—but would not explicitly control miner exposure to other fine airborne particulates present underground. In light of the evidence presented in the Agency's risk assessment on the risks that fine particulates in general may pose to the mining population, MSHA would welcome comments as to whether the Agency should also consider restricting the exposure of underground metal and nonmetal miners to all fine particulates, regardless of the source.

(4) Aren't NIOSH and the NCI Working on a Study That Will Provide Critical Information? Why Proceed Before the Evidence Is Complete?

NIOSH and the National Cancer Institute (NCI) are collaborating on a cancer mortality study that will provide additional information about the relationship between dpm exposure levels and disease outcomes, and about which components of dpm may be responsible for the observed health effects. The study is projected to take about seven years. The protocol for the study was recently finalized.

The information the study is expected to generate will be a valuable addition to the scientific evidence on this topic. But given its conclusions about currently available evidence, MSHA believes the Agency needs to take action now to protect miners' health. Moreover, as noted by the Supreme Court in an important case on risk involving the Occupational Safety and Health Administration, the need to evaluate risk does not mean an agency is placed into a ''mathematical straightjacket.'' *Industrial Union Department, AFL–CIO* v. *American Petroleum Institute,* 448 U.S. 607, 100 S.Ct. 2844 (1980). The Court noted that when regulating on the edge of scientific knowledge, absolute scientific certainty may not be possible, and ''so long as they are supported by a body of reputable scientific thought, the Agency is free to use conservative assumptions in interpreting the data * * * risking error on the side of overprotection rather than underprotection.'' (*Id.* at 656.) This advice has special significance for the mining community, because a singular historical factor behind the enactment of the current Mine Act was the slowness in coming to grips with the harmful effects of other respirable dust (coal dust).

It is worth noting that while the cohort selected for the NIOSH/NCI study consists of underground miners (specifically, underground metal and nonmetal miners), this choice is in no way linked to MSHA's regulatory framework or to miners in particular. This cohort was selected for the study because it provides the best population for scientists to study. For example, one part of the study would compare the health experiences of miners who have worked underground in mines with long histories of diesel use with the health experiences of similar miners who work in surface areas where exposure is significantly lower. Since the general health of these two groups is very similar, this will help researchers to quantify the impacts of diesel exposure. No other population is as easy to study for this purpose. But as with any such epidemiological study, the insights gained are not limited to the specific population used in the study. Rather, the study will provide information about the relationship between exposure and health effects that will be useful in assessing the risks to any group of workers in a dieselized industry.

(5) What Are the Impacts of the Proposed Rule?

Costs. Table I–1 provides cost information. Some explanation is necessary.

Costs consist of two components: ''initial'' costs (e.g., capital costs for equipment, or the one-time costs of developing a procedure), which are then amortized over a period of years in accordance with a standardized formula to provide an ''annualized'' cost; and ''annual'' costs that occur every year (e.g., maintenance or training costs). Adding together the ''annualized'' initial costs and the ''annual'' costs provides the per year costs for the rule.

It should be noted that in amortizing the initial costs, a net present value factor was applied to certain costs: those associated with provisions where mine operators do not have to make capital expenditures until some period of time after the effective date. Detailed information on this point is contained in the Agency's Preliminary Regulatory Economic Analysis (PREA), as are the Agency's cost assumptions.

The costs per year to the underground metal and nonmetal industry are about $19.2 million. These costs are higher than the costs for the proposed rule for underground coal mines, reflecting the much more intense use of diesel-powered equipment in this sector. The Agency spent considerable time developing its cost assumptions and estimates, which are spelled out in detail in the Agency's PREA. Assumptions are based upon information provided by MSHA technical personnel, who have had discussions with manufacturers of engines and mining equipment, and from journals and reports published by independent organizations that collect data about the mining industry. The Agency would encourage the mining community to provide detailed comments in this regard so as to ensure these cost assumptions and estimates are as accurate as possible. With respect to the largest cost item—the cost to meet the proposed concentration limit in underground metal and nonmetal mines—MSHA assumed that engineering controls, such as low emission engines, ceramic filters, oxidation catalytic converters, and cabs would be needed on diesel powered equipment. Most of the engineering controls would be needed on diesel equipment used for production, while a small amount of diesel equipment that is used for support purposes would need engineering controls. In addition to these controls, MSHA assumed that some underground metal and nonmetal mines would need to make ventilation changes in order to meet the proposed concentration limits.

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Table I–1.—Compliance Cost for Underground Metal and Nonmetal Mine Operators

(Dollars X 1,000)

	Large Mines (≥20)			Small Mines (<20)			Total Mines		
Detail	(A) Total [Col.B+C]	(B) Annual-ized	(C) Annual	(D) Total [Col.E+F]	(E) Annual-ized	(F) Annual	(G) Total [Col.H+I]	(H) Annual-ized	(I) Annual
57.5060(a)	$8,369	$8,369	$0	$2,677	$2,677	$0	$11,046	$11,046	$0
57.5060(b)	$4,910	$4,910	$0	$1,627	$1,627	$0	$6,537	$6,537	$0
57.5060(c)	$10	$10	$0	$2	$2	$0	$12	$12	$0
57.5062	$5	$0	$5	$1	$0	$1	$6	$0	$6
57.5066	$30	$25	$5	$8	$6	$2	$38	$31	$7
57.5067	$731	$731	$0	$121	$121	$0	$852	$852	$0
57.5070	$198	$0	$198	$5	$0	$5	$203	$0	$203
57.5071	$364	$25	$339	$122	$0	$122	$486	$25	$461
57.5075	$3	$0	$3	$1	$0	$1	$4	$0	$4
Total	$14,620	$14,070	$550	$4,564	$4,433	$131	$19,184	$18,503	$681

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As required by the Regulatory Flexibility Act, MSHA has performed a review of the effects of the proposed rule on ''small entities''. The results—including information about the average cost for mines in each sector with less than 500 employees and mines in each sector with less than 20 miners—are summarized in response to Question 7.

Paperwork. Tables I–2 and I–3 show additional paperwork burden hours which the proposed rule would require. Only those existing or proposed regulatory requirements which would, as a result of this rulemaking, result in new burden hours, are noted. The costs for these paperwork burdens, a subset of the overall costs of the proposed rule, are specifically noted in Part VII of the Agency's PREA. Table I–2 shows the burden hours for large and small mines—those with less than 20 miners.

TABLE I–2.—UNDERGROUND METAL AND NONMETAL MINE BURDEN HOURS

Detail	Large	Small	Total
57.5060	306	123	429
57.5062	49	11	60
57.5066	207	76	283
57.5070	136	6	142
57.5071	2,600	213	2,813
57.5075	131	7	138
Total	3,429	436	3,865

Table I–3 shows the additional burden hours for diesel engine manufacturers. The compliance costs related to diesel equipment manufacturers are assumed to be passed through to underground metal and nonmetal operators as explained in the PREA. Thus, diesel equipment manufacturers are not estimated to incur any direct cost as a result of this rule.

TABLE I–3.—DIESEL ENGINE MANUFACTURERS BURDEN HOURS

Detail	Total
Part 7, Subpart E	36
Total	36

Benefits. The proposed rule would reduce the exposure of underground metal and nonmetal miners to dpm, thereby reducing the risk of adverse health effects and their concomitant effects.

The risks being addressed by this rulemaking arise because some miners are exposed to high concentrations of the very small particles produced by engines that burn diesel fuel. As discussed in Part II of the preamble, diesel powered engines are used increasingly in underground mining operations because they permit the use of mobile equipment and provide a full range of power for both heavy-duty and light-duty operations (i.e., for production equipment and support equipment, respectively), while avoiding the explosive hazards associated with gasoline. But underground mines are confined spaces which, despite ventilation requirements, tend to accumulate significant concentrations of particles and gases—both those produced by the mine itself (e.g., methane gas and silica dust liberated by mining operations) and those produced by equipment used in the mine.

As discussed in MSHA's risk assessment (Part III of this preamble), the concentrations of diesel particulates to which some underground miners are currently exposed are significantly higher than the concentrations reported for other occupations involving the use of dieselized equipment; and at such concentrations, exposure to dpm by underground miners over a working lifetime is associated with an excess risk of a variety of adverse health effects.

The nature of the adverse health effects associated with such exposures suggests the nature of the savings to be derived from controlling exposure. Acute reactions can result in lost production time for the operator and lost pay (and perhaps medical expenses) for the worker. Hospital care for acute breathing crises or cancer treatment can be expensive, result in lost income for the worker, lost income for family members who need to provide care and lost productivity for their employers, and may well involve government payments (e.g., Social Security disability and Medicare). Serious illness and death lead to long term income losses for the families involved, with the potential for costs from both employers (e.g., workers' compensation payouts, pension payouts) and society as a whole (e.g., government assisted aid programs).

The information available to the Agency suggests that as exposure is reduced, so are the adverse health consequences. For example, data collected on the effects of environmental exposure to fine particulates suggest that reducing occupational dpm exposures by as little as 75 $\mu g/m^3$ (roughly corresponding to a reduction of 25 $\mu g/m^3$ in 24-hour ambient atmospheric concentration) could lead to significant reductions in the risk of various acute responses, including mortality. And chronic occupational exposure has been linked to an estimated 30 to 40 percent increase in the risk of lung cancer. All the quantitative risk models reviewed by NIOSH suggest excess risks of lung cancer of more than one per thousand for miners who have long-term occupational exposures to dpm concentrations in excess of 1000 $\mu g/m^3$, and the epidemiologically-based risk estimates suggest higher risks. The Agency's estimate is that implementation of the proposed rule would avoid 28 lung cancers per 1,000 affected miners, or approximately 7 lung cancer cases a year over an initial 65-year period.[2] Note that because lung cancer associated with diesel particulate matter typically arises from cumulative exposure and after some latency period, these health benefits-in terms of the reduced incidence of lung cancer illness and subsequent death-will not materialize until some years after passage of the proposed rule.

The yearly reduction in excess lung cancer deaths due to reduced exposure to diesel particulate matter may occur gradually, depending on the historical cumulative exposure to diesel particulate matter among the veteran workforce. Since the average latency period for lung cancer is 20 years, the full benefit associated with a concentration limit of 200 $\mu g/m^3$ may not be seen before then.

Despite these quantitative indications, quantification of the benefits is difficult. Although increased risk of lung cancer has been shown to be associated with dpm exposure among exposed workers, a conclusive dose-response relationship upon which to base quantification of benefits has not been demonstrated. The Agency nevertheless intends, to the extent it can, to develop an appropriate analysis quantifying benefits in connection with the final rule.

The Agency does not have much experience in quantifying benefits in the case of a proposed health standard (other than its recent proposal on controlling mining noise, where years of compliance data and hearing loss studies provide a much more complete quantitative picture than with dpm). MSHA therefore welcomes suggestions for the appropriate approach to use to quantify the benefits likely to be derived from this rulemaking. Please identify scientific studies, models, and/or assumptions suitable for estimating risk at different exposure levels, and data on numbers of miners exposed to different levels of dpm.

[2] In the long run, the average approaches 464÷45=10 lung cancers avoided per year as the number of years considered increases beyond 65.

(6) Did MSHA Actively Consider Alternatives to What Is Being Proposed?

Yes. Once MSHA determined that the evidence of risk required a regulatory action, the Agency considered a number of alternative approaches, the most significant of which are reviewed in Part V of the preamble.

The consideration of options proceeded in accordance with the requirements of Section 101(a)(6)(A) of the Federal Mine Safety and Health Act of 1977 (the ''Mine Act''). In promulgating standards addressing toxic materials or harmful physical agents, the Secretary must promulgate standards which most adequately assure, on the basis of the best available evidence, that no miner will suffer material impairment of health over his/her working lifetime. In addition, the Mine Act requires that the Secretary, when promulgating mandatory standards pertaining to toxic materials or harmful physical agents, consider other factors, such as the latest scientific data in the field, the feasibility of the standard and experience gained under the Mine Act and other health and safety laws. Thus, the Mine Act requires that the Secretary, in promulgating a standard, attain the highest degree of health and safety protection for the miner, based on the ''best available evidence,'' with feasibility a consideration.

As a result, MSHA seriously considered a number of alternatives that would, if adopted as part of the proposed rule, have provided increased protection—and would also have significantly increased costs. For example, the Agency considered proposing a more stringent concentration limit for dpm in underground metal and nonmetal mines, or shortening the time frame to achieve compliance with that limit. But as discussed in more detail in Part V, MSHA concluded, however, that such an approach may not be feasible for the underground sector at this time. Options considered by the Agency included: requiring the installation of a particulate filter on every new piece of diesel-powered equipment added to the fleet of an underground metal or nonmetal mine regardless of the dpm concentration level, as an added layer of miner protection; establishing a fixed schedule for operator monitoring of the concentration of diesel particulate emissions; and requiring control plans be preapproved by MSHA before implementation to ensure their effectiveness had been verified. These approaches were not included in the proposal because MSHA concluded that less stringent alternatives could achieve the same level of protection with less adverse impact.

MSHA also considered alternatives that would have led to a significantly lower-cost proposal, e.g., establishing a less stringent concentration limit in underground metal and nonmetal mines, or increasing the time for mine operators to come into compliance. However, based on the current record, MSHA has tentatively concluded that such approaches would not be as protective as those being proposed, and that the approach proposed is both economically and technologically feasible. As a result, the Agency has not proposed to adopt these alternatives.

MSHA also explored whether to permit the use of administrative controls (e.g., rotation of personnel) and personal protective equipment (e.g., respirators) to reduce the diesel particulate exposure of miners. It is generally accepted industrial hygiene practice, however, to eliminate or minimize hazards at the source before resorting to personal protective equipment. Moreover, such a practice is generally not considered acceptable in the case of carcinogens since it merely places more workers at risk. Accordingly, the proposal explicitly prohibits the use of such approaches, except in those limited cases where MSHA approves, due to technological constraints, a 2-year extension for an underground metal and nonmetal mine on the time to comply with the final concentration limit.

MSHA did make a concerted effort to design the requirements of the proposal to minimize unnecessary burdens. Each element of the proposal was independently reviewed to ascertain whether it was really needed, as were all the paperwork requirements, and each was designed with cost-effectiveness in mind. Training and operator sampling requirements, for example, were specifically designed to be performance-oriented to minimize costs, while at the same time crafted to ensure that each operator's activities provide necessary protections.

The Agency considered requiring the underground metal and nonmetal sector to use work practice and engine controls exactly like those already applicable in the underground coal sector as a result of MSHA's diesel equipment rule (62 FR 55412). Such an alternative would have required each metal and nonmetal operator: (a) to conduct weekly emissions tests of diesel-powered equipment in underground metal and nonmetal mines instead of just tagging suspect equipment for prompt inspection; (b) to establish training programs for maintenance personnel; and (c) to turn over the mine's diesel fleet within a few years so as to have only approved engines. The agency concluded, however, that the conditions which warrant such an approach in underground coal mines had not been established for metal and nonmetal mines; and that with respect to the risks created by dpm, the approach taken in the proposed rule could provide adequate protection in a cost-effective manner.

The agency hopes that comments and suggestions from the mining community on the proposed rule will help it identify further improvements in this regard.

(7) What Will the Impact Be on the Smallest Underground Metal and Nonmetal Mines? What Consideration Did MSHA Give to Alternatives for the Smallest Mines?

The Regulatory Flexibility Act requires MSHA and other regulatory agencies to conduct a review of the effects of proposed rules on small entities. That review is summarized here; a copy of the full review is included in Part VI of this preamble, and in the Agency's PREA. The Agency encourages the mining community to provide comments on this analysis.

The Small Business Administration generally considers a small mining entity to be one with less than 500 employees. MSHA has traditionally defined a small mine to be one with less than 20 miners, and has focused special attention on the problems experienced by such mines in implementing safety and health rules, e.g., the Small Mine Summit, held in 1996. Accordingly, MSHA has separately analyzed the impact of the proposed rule on mines with 500 employees or less, and those with less than 20 miners.

Table I–4 summarizes MSHA's estimates of the average costs of the proposed rule to a small underground metal and nonmetal mine.

TABLE I–4.—AVERAGE COST PER SMALL UNDERGROUND METAL AND NONMETAL MINE

Size	UG M/NM <500	UG M/NM <20
Cost per mine ...	$87,800	$56,100

Pursuant to the Regulatory Flexibility Act, MSHA must determine whether the costs of the proposed rule constitute a ''significant impact on a substantial number of small entities.'' Pursuant to the Regulatory Flexibility Act, if an Agency determines that a proposed rule does not have such an impact, it must publish a ''certification'' to that effect. In such a case, no additional analysis is required (5 U.S.C. § 605).

In evaluating whether certification is appropriate, MSHA utilized an impact analysis comparing the costs of the proposal to the revenues of the sector involved (only the revenues for underground metal and nonmetal mines are used in this calculation).

The Agency has, as required by law (5 U.S.C. § 603), developed an initial regulatory flexibility analysis which is set forth in Part VI of this preamble (and the Agency's PREA). In addition to a succinct statement of the objects of the proposed rule and other information required by the Regulatory Flexibility Act, the analysis reviews alternatives considered by the Agency with an eye toward the nature of small business entities. MSHA welcomes comment on this analysis, on possible impacts of the proposed rule on small mines, and suggestions to ameliorate those impacts.

In promulgating standards, MSHA does not reduce protection for miners employed at small mines. But MSHA does consider the impact of its standards on even the smallest mines when it evaluates the feasibility of various alternatives. For example, a major reason why MSHA concluded it needed to stagger the effective dates of some of the requirements in the proposed rule is to ensure that it would be feasible for the smallest mines to have adequate time to come into compliance.

Consistent with recent amendments to the Regulatory Flexibility Act under SBREFA (the Small Business Regulatory Enforcement Fairness Act), MSHA has already started considering actions it can take to minimize the anticipated compliance burdens of this proposed rule on smaller mines. For example, no limit on dpm concentration would be in effect in underground metal and nonmetal mines for 18 months—and during that time, the Agency plans to provide extensive compliance assistance to the mining community. The metal and nonmetal community would also have an additional three and a half years to comply with the final concentration limit, which in many cases means these mines may have a full five years of technical assistance before any engineering controls are required. MSHA would focus its efforts on smaller operators in particular—to training them in measuring dpm concentrations, and providing technical assistance on available controls. The Agency will also issue a compliance guide, and continue its current efforts to disseminate educational materials and software. Comment is invited on whether compliance workshops or other such approaches would be valuable.

(8) Why Would the Proposed Rule Require Special Training for Underground Miners Exposed to Diesel Exhaust? And Why Does the Proposed Rule not Address Medical Surveillance and Medical Removal Protection for Affected Miners?

Training. Diesel particulate exposure has been linked to a number of serious health hazards, and the Agency's risk assessment indicates that the risks should be reduced as much as feasible. It has been the experience of the mining community that miners must be active and committed partners along with government and industry in successfully reducing these risks. Therefore, training miners as to workplace risks is a key component of mine safety and health programs. This rulemaking continues that approach.

Specifically, pursuant to proposed § 57.5070(a), any underground miner ''who can reasonably be expected to be exposed to diesel emissions'' would have to receive instruction in: (1) The health risks associated with dpm exposure; (2) in the methods used in the mine to control diesel particulate concentrations; (3) in identification of the personnel responsible for maintaining those controls; and (4) in actions miners must take to ensure the controls operate as intended. The training is to be provided annually in all mines using diesel-powered equipment, and is to be provided without charge to the miner.

MSHA does not expect this training to be a significant new burden for mine operators. The training required can be provided at minimal cost and with minimal disruption. The proposal would not require any special qualifications for instructors, nor would it specify the minimum hours of instruction. The purpose of the proposed requirement is miner awareness, and MSHA believes this can be accomplished by operators in a variety of ways. In mines that have regular safety meetings before the shift begins, devoting one of those meetings to the topic of diesel particulate would probably be a very easy way to convey the necessary information. Mines not having such a regular meeting can schedule a ''toolbox'' talk for this purpose. MSHA will be developing an outline of educational material that can be used in these settings. Simply providing miners with a copy of MSHA's toolbox, and reviewing how to use it, can cover several of the training requirements.

Operators may choose to include required dpm training under Part 48 training as an additional topic. Part 48 training plans, however, must be approved. There is no existing requirement that Part 48 training include a discussion of the hazards and control of diesel emissions. While mine operators are free to cover additional topics during the Part 48 training sessions, the topics that must be covered during the required time frame may make it impracticable to cover other matters within the prescribed time limits. Where the time is available in mines using diesel-powered equipment, operators should be free to include the dpm instruction in their proposed Part 48 training plans. The Agency does not believe special language in the proposed rule is needed to permit this action under Part 48, but welcomes comment in this regard.

The proposal would not require the mine operator to separately certify the completion of the diesel particulate training, but some evidence that the training took place would have to be produced upon request. A serial log with the employee's signature is a perfectly acceptable practice in this regard.

Medical surveillance. Another important source of information that miners and operators can use to protect health can come from medical surveillance programs. Such programs provide for medical evaluations or tests of miners exposed to particularly hazardous substances, at the operator's expense, so that a miner exhibiting symptoms or adverse test results can receive timely medical attention, ensure that personal exposure is reduced as appropriate and controls are reevaluated. Sometimes, to ensure that this source of information is effective, medical removal (transfer) protection must also be required. Medical transfer may address protection of a miner's employment, a miner's pay retention, a miner's compensation, and a miner's right to opt for medical removal.

As a general rule, medical surveillance programs have been considered appropriate when the exposures are to potential carcinogens. MSHA has in fact been considering a generic requirement for medical surveillance as part of its air quality standards rulemaking. MSHA also recently proposed a medical surveillance program for hearing, as part of the Agency's proposed rule on noise exposure (61 FR 66348).

MSHA is not proposing such a program for dpm at this time because it is still gathering information on this issue. The Agency, however, welcomes comments regarding this issue and also, on medical removal.

Specifically, the Agency would welcome comment on the following questions: (a) What kinds of examinations or tests would be appropriate to detect whether miners are suffering ill effects as a result of dpm exposure; (b) the qualifications of those who would have to perform such examinations or tests and their availability; (c) whether such examinations or tests need to be provided and how frequently once the provisions of the rule are in effect; and (d) whether medical removal protections should be a component of a medical surveillance program.

(9) What Are the Major Issues on Which MSHA Wants Comments? What If I Already Submitted Comments on the Same Point on the Proposed Rule for the Underground Coal Sector?

MSHA wants the benefit of your experience and expertise: whether as a miner or mine operator in any mining sector; a manufacturer of diesel-powered engines, equipment, or emission control devices; or as a scientist, doctor, engineer, or safety and health professional. MSHA intends to review and consider all comments submitted to the Agency.

While MSHA will endeavor to consider relevant comments on the proposed rule for underground coal mines in evaluating what to do in the underground metal and nonmetal sector (e.g., comments on risk, the effectiveness of filtration devices, etc.), the record established for each rulemaking is separate. Accordingly, the Agency encourages those who are interested in both rulemakings to submit separate or duplicate comments for each.

The following list identifies some topics on which the Agency would particularly like information; requests for information on other topics can be found throughout the preamble.

(a) *Assessment of Risk/Benefits of the Rule.* Part III of this preamble reviews information that the Agency has been able to obtain to date on the risks of dpm exposure to miners. The Agency welcomes your comments on the significance of the material already in the record, and any information that can supplement the record. For example, additional information on existing and projected exposures to dpm and to other fine particulates in various mining environments would be useful in getting a more complete picture of the situation in various parts of the mining industry. Additional information on the health risks associated with exposure to dpm—especially observations by trained observers or studies of acute or chronic effects of exposure to known levels of dpm or fine particles in general, information about pre-existing health conditions in individual miners or miners as a group that might affect their reactions to exposures to dpm or other fine particles, and information about how dpm affects human health—would help provide a more complete picture of the relationship between current exposures and the risk of health outcomes. Information on the costs to miners, their families and their employers of the various health problems linked to dpm exposure, and the prevalence thereof, would help provide a more complete picture of the benefits to be expected from reducing exposure. And as discussed in response to Question and Answer 5, the Agency would welcome advice about the assumptions and approach to use in quantifying the benefits to be derived from this rule.

(b) *Proposed rule.* Part IV of this preamble reviews each provision of the proposed rule, Part V discusses the economic and technological feasibility of the proposed rule, and Part VI reviews the projected impacts of the proposed rule. MSHA would welcome comments on each of these topics.

The Agency would like your thoughts on the specific alternative approaches discussed in Part V. The options discussed include: adjusting the concentration limit for dpm; adjusting the phase-in time for the concentration limit; and requiring that specific technology be used in lieu of establishing a concentration limit.

The Agency would also like your thoughts on more specific changes to the proposed rule that should be considered. For example, for underground metal and nonmetal mines, MSHA is proposing to measure the amount of total carbon to measure dpm concentrations. MSHA welcomes information relevant to this proposal. The Agency is also interested in obtaining as many examples as possible as to the specific situation in individual mines: the composition of the diesel fleet, what controls cannot be utilized due to special conditions, and any studies of alternative controls using the computer spreadsheet described in the Appendix to Part V of this preamble. (See Adequacy of Protection and the Feasibility of the Proposed Rule). Information about the availability and costs of various control technologies that are being developed (e.g., high-efficiency ceramic filters), experience with the use of available controls, and information that will help the Agency evaluate alternative approaches for underground metal and nonmetal mines would be most welcome. Comments from the underground coal sector on the implementation to date of diesel work practices (like the rule limiting idling, and the training of those who provide maintenance) would be helpful in evaluating related proposals for the underground metal and nonmetal sector. The Agency would appreciate information about any unusual situations that might warrant the application of special provisions.

(c) *Compliance Guidance.* The Agency welcomes comments on any topics on which initial guidance ought to be provided as well as any alternative practices which MSHA should accept for compliance before various provisions of the rule go into effect.

(d) *Minimizing Adverse Impact of the Proposed Rule.* The Agency has set forth its assumptions about impacts (e.g., costs, paperwork, and impact on smaller mines in particular) in some detail in this preamble and in the PREA, and would welcome comments on the methodology. Information on current operator equipment replacement planning cycles, tax, State requirements, or other information that might be relevant to purchasing new engines or control technology would likewise be helpful. The Agency would also welcome comments on the financial situation of the underground metal and nonmetal sector, including information that may be relevant to only certain commodities.

(10) When Will the Rule Become Effective? Will MSHA Provide Adequate Guidance Before Implementing the Rule?

Some requirements of the proposed rule would go into effect 60 days after the date of promulgation: the requirement to provide basic hazard training to miners who are exposed underground to dpm, the ‘‘best practice’’ requirements (e.g., the requirement to use only low-sulfur fuel), and some related recordkeeping requirements.

The next requirements would go into effect 18 months after the date the rule is promulgated. Underground metal and nonmetal mines would have to comply with an interim dpm concentration limit.

Finally, five years after the date the rule is promulgated, all underground metal and nonmetal mines would have to comply with a final dpm concentration limit.

MSHA intends to provide considerable technical assistance and guidance to the mining community before the various requirements go into effect, and be sure MSHA personnel are fully trained in the requirements of the rule. A number of actions have already been taken toward this end. The Agency held workshops on this topic in 1995 which provided the mining community an opportunity to share advice on how to control dpm concentrations. The Agency has published a ''toolbox'' of methods available to mining operators to achieve reductions in dpm concentration (appended to the end of this document is a copy of an MSHA publication, ''Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—A Toolbox,'' which includes additional information on methods for controlling dpm, and a glossary of terms). In addition, MSHA has developed a computer spreadsheet template which allows an operator to model the application of alternative engineering controls to reduce dpm. The design of the model, and several specific mine profiles developed illustrating its use, are discussed in part V of the preamble.

The Agency is committed to issuing a compliance guide for mine operators providing additional advice on implementing the rule. MSHA would welcome suggestions on matters that should be discussed in such a guide. MSHA would also welcome comments on other actions it could take to facilitate implementation, and in particular whether a series of additional workshops would be useful.

(B) Additional Information About the Proposed Rule for Underground Metal and Nonmetal Mines

(11) What Basic Changes Does the Proposal Make to Part 57, the Health Rules for Underground Metal and Nonmetal Mines?

What follows is a general overview of the changes proposed to Part 57. The remainder of this part is devoted to addressing the details of the proposed rule in this sector.

The first thing the proposal would do is require underground metal and nonmetal mines to observe a set of ''best practices'' to reduce engine emissions of dpm underground. Only low-sulfur diesel fuel and EPA-approved fuel additives would be permitted to be used in diesel-powered equipment in underground areas. Idling of such equipment that is not required for normal mining operations would be prohibited. In addition, diesel engines would have to be maintained in good order to ensure that deterioration does not lead to emissions increases—approved engines would have to be maintained in approved condition; the emission related components of non-approved engines would have to be maintained in accordance with manufacturer specifications; and any installed emission device would have to be maintained in effective operating condition. Equipment operators in underground metal and nonmetal mines would be authorized to tag equipment with potential emissions-related problems, and tagged equipment would have to be ''promptly'' referred for a maintenance check. As an additional safeguard in this regard, maintenance to ensure compliance with these requirements would have to be done by persons qualified by virtue of training or experience to perform the maintenance.

The proposed rule would also require that, with the exception of diesel engines used in ambulances and fire-fighting equipment, any diesel engines added to the fleet of an underground metal or nonmetal mine after the rule's promulgation must be an engine approved by MSHA under Part 7 or Part 36. The composition of the existing fleet would not be impacted by this part of the proposed rule.

While these proposed work practice controls are similar to existing rule in effect in underground coal mines, they are somewhat less stringent. For example, unlike in coal mines, the proposed maintenance rule in underground metal and nonmetal mines would not require operators to establish training programs that meet certain criteria. Nor would the proposed rule require weekly tailpipe emissions tests.

The second thing the proposal would do is establish a limit on the concentration of dpm permitted in areas of an underground metal or nonmetal mine where miners work or travel.

The proposed standard is intended to limit dpm concentrations to which miners are exposed to about 200 micrograms per cubic meter of air—expressed as 200_{DPM} µg/m³. However, in an effort to make things easier on a day-to-day basis for the mining community, the proposed concentration limit on dpm for this sector would be expressed in terms of the measurement method MSHA will use for compliance purposes to determine dpm concentrations. (That method, NIOSH Analytical Method 5040, is specified in proposed § 57.5061, and is discussed in more detail in response to Question 12. MSHA is proposing to use it because of its accuracy). The method will analyze a dust sample to determine the amount of total carbon present. Total carbon comprises 80–85% of the dpm emitted by diesel engines. Accordingly, using the lower boundary of 80%, a concentration limit of 200_{DPM} µg/m³ can be achieved by restricting total carbon to 160_{TC} µg/m³. This is the way the proposed standard is expressed:

> After [insert the date 5 years after the date of promulgation of this rule] any mine operator covered by this part shall limit the concentration of diesel particulate matter to which miners are exposed by restricting the average eight-hour equivalent full shift airborne concentration of total carbon, where miners normally work or travel, to 160 micrograms per cubic meter of air (160_{TC} µg/m³).

All underground metal and nonmetal mines would be given a full five years to meet this limit, which is referred to in this preamble as the ''final'' concentration limit. However, starting eighteen months after the rule is promulgated, underground metal and nonmetal mines would have to observe an ''interim'' dpm concentration limit—expressed as a restriction on the concentration of total carbon of 400 micrograms per cubic meter (400_{TC} µg/m³). The interim limit would bring the concentration of whole dpm in underground metal and nonmetal mines to which miners are exposed down to about 500 micrograms per cubic meter. No limit at all on the concentration of dpm would be applicable for the first eighteen months following promulgation. Instead, this period would be used to provide compliance assistance to the metal and nonmetal mining community to ensure it understands how to measure and control diesel particulate matter concentrations in individual operations (and to implement work practice controls).

A mine operator would have to use engineering or work practice controls to keep dpm concentrations below the applicable limit. Administrative controls (e.g., the rotation of miners) and personal protective equipment (e.g., respirators) are explicitly barred as a means of compliance with the interim or final concentration limit. An operator could filter the emissions from diesel-powered equipment, install cleaner-burning engines, increase ventilation, improve fleet management, or use a variety of other readily available controls; the selection of controls would be left to the operator's discretion. MSHA has published a ''toolbox'' of approaches that can be used to reduce dpm; a copy of this useful publication is appended to the end of this document. The Agency has also developed a model that can be run on a standard spreadsheet program to compare the effects of alternative controls before purchase and implementation decisions are made. The model, and some examples of its use, are presented in Part V of this preamble.

The proposal would provide that, if an operator of a metal or nonmetal mine can demonstrate that there is no combination of controls that can, due to technological constraints, be implemented within the 5 years permitted to reduce the concentration of dpm to the final concentration limit, MSHA may approve an application for an additional extension of time to comply with the dpm concentration limit. Such a special extension is available only once, and is limited to 2 years. To obtain a special extension, an operator must provide information in the application adequate for MSHA to ensure that the operator will: (a) maintain concentrations at the lowest limit which is technologically achievable; and (b) take appropriate actions to minimize miner exposure (e.g., provide suitable respiratory protection during the extension period).

Measurements to determine noncompliance with the dpm concentration limit would be made directly by MSHA, rather than having the Agency rely upon operator samples. Under the rule, a single Agency sample, using the sampling and analytical method prescribed by the rule, would be adequate to establish a violation. MSHA would take measurement uncertainty into account before issuing a citation, as discussed in response to Question 12.

The proposed rule would require that if an underground metal or nonmetal mine exceeds the applicable limit on the concentration of dpm, a diesel particulate matter compliance plan must be established and remain in effect for 3 years. The purpose of such plans is to ensure that the mine has instituted practices that will demonstrably control dpm levels thereafter. Reflecting current practices in this sector, the plan would not have to be preapproved by MSHA. The plan would include information about the diesel-powered equipment in the mine and applicable controls. The proposed rule would require operator sampling to verify that the plan is effective in bringing dpm levels down below the applicable limit, with the records kept at the mine site with the plan to facilitate review. Failure of an operator to comply with the requirements of the dpm control plan or to conduct adequate verification sampling would be a violation; MSHA would not be required to sample to establish such a violation.

To enhance miner awareness of the hazards involved, mines using diesel-powered equipment must annually train miners exposed to dpm in the hazards associated with that exposure, and in the controls being used by the operator to limit dpm concentrations. An operator may propose to include this training in the Part 48 training plan.

The proposed rule would also require all operators in this sector using diesel-powered equipment to sample as often as necessary to effectively evaluate dpm concentrations at the mine. The purpose of this requirement is to assure that operators are familiar with current dpm concentrations so as to be able to protect miners. Since mine conditions vary, MSHA is not proposing to establish a defined schedule for operator sampling; but rather, to propose a performance-oriented approach. The Agency would evaluate compliance with this sampling obligation by reviewing evidence of operator compliance with the concentration limit, as well as information retained by operators about their sampling.

Consistent with the statute, the proposed rule would require that miners and their representatives have the right to observe any operator monitoring—including any sampling required to verify the effectiveness of a dpm control plan.

(12) How Is MSHA Proposing To Measure the Amount of dpm in Underground Metal and Nonmetal Mines?

Techniques for measuring dpm concentrations are reviewed in detail in Part II of this preamble.

For a method to be used for compliance purposes, it must be able to distinguish dpm from other particles present in various mines, be accurate at the concentrations to be measured, and consistently measure dpm regardless of the mix or condition of the equipment in the mine.

The technique being proposed for compliance sampling in underground metal and nonmetal mines meets these requirements. It involves sampling with a quartz fiber filter mounted in an open face filter holder, and a chemical analysis of the filter to determine the amount of carbon collected. The entire process, NIOSH Analytical Method 5040, has been validated as meeting NIOSH's accuracy criterion—i.e., that measurements come within 25% of the true concentration at least 95% of the time. While there are other methods that can be used to provide accurate measurements of diesel particulate matter in some types of mines and under some circumstances, this technique appears to provide consistent and accurate results in all underground metal and nonmetal mining environments.

Although the NIOSH method was validated using a regular respirable dust sampler, MSHA gave consideration to the use of a size selector impactor sampler, developed by the Bureau of Mines, that would not collect any dust over 1 micrometer (micron) in diameter. Canada is exploring the use of such an approach with an alternative analytical method. However, measurements by the Agency to date indicate that in some underground metal and nonmetal mines, as much as 30% of the dpm present may be larger than 1 micron in size. The Agency is continuing to evaluate such an approach, and welcomes comments on the implications to miners and mine operators of excluding from consideration this larger fraction of dpm.

The method described in NIOSH Analytical Method 5040 provides a way to determine the amount of diesel particulate in the sample. Diesel particulate consists of a core of elemental carbon onto which are adsorbed various organic components and sulfates. The NIOSH Analytical Method separately analyzes the amount of elemental carbon and the amount of organic carbon present in the sample. These two amounts are then added together to get the amount of total carbon present in the sample. In the absence of any measurable quantity of any other organic carbon source, this method provides a way of reliably measuring dpm at concentrations at and below the proposed final concentration limit.

MSHA has also evaluated other analytical approaches—the gravimetric method (simply weighing the sample), the respirable combustible dust (RCD) analysis used in Canada, and the elemental carbon approach. As discussed in detail in Part II, use of these methods to measure dpm for compliance purposes in underground metal and nonmetal mines present various questions that the Agency has not been able to satisfactorily address at point in the rulemaking process. For example, the gravimetric method has not been validated for use at lower concentration levels, the RCD method is not recommended for use in certain types of underground metal and nonmetal mines, and there appears to be some variability in the relationship between elemental carbon and whole diesel particulate.

MSHA does not believe that either oil mists or cigarette smoke in underground metal or nonmetal mines will pose a problem in using this method. MSHA currently has no data as to the frequency of occurrence or the magnitude of any potential interference from oil mist, but during its studies of measurement methods in underground mines, MSHA has not encountered situations where oil mist was found to be an interferant. Moreover, the Agency assumes that when operators implement the proposal's maintenance requirements, this will minimize any remaining potential for such interference. Cigarette smoking can be prohibited by an operator during any testing. MSHA welcomes comments as to the scope of any possible interferences with the proposed methods and measures for addressing them.

Proposed § 57.5061(a) would explicitly provide that MSHA use the validated NIOSH procedure for total carbon, or ''any method subsequently determined by NIOSH to provide equal or improved accuracy'' in underground metal and nonmetal mines. Measurement technology is always improving, and MSHA believes that providing for some flexibility in this regard can ultimately benefit the entire mining community.

Proposed § 57.5061(b) provides that a single sample using the prescribed method would provide an adequate basis for citing noncompliance. As with the sampling methodology, MSHA is proposing to specifically state this policy as a provision of the rule itself to ensure it is clearly understood. Single shift sampling is the normal practice for OSHA and MSHA. As is its practice with other compliance determinations based on measurement, MSHA would not issue a citation unless the measurement exceeds the compliance limit by a ''margin of error'' sufficient to demonstrate noncompliance at a 95% confidence level. While MSHA is still conducting research to determine exactly what margin of error would be appropriate to establish such a confidence level, the Agency expects it to be between 10 and 20% of the concentration limit. Thus, assuming for the sake of example that the margin of error is 15%, a citation would not be issued for exceeding the final concentration limit unless the measured total carbon is above 184_{TC} μg/m^3 (115% of 160_{TC} μg/m^3).

Finally, it should be noted that the proposed limit is expressed in terms of the average airborne concentration during each full shift expressed as an 8-hour equivalent. Measuring during the full shift ensures that the entire exposure is monitored, and the limit is based on the average exposure. Using an 8-hour equivalent ensures that a miner who works extended shifts would not have a higher exposure burden than a miner who works an 8-hour shift.

(13) Would the Concentration Limit Apply in All Areas of an Underground Metal or Nonmetal Mine?

The concentration limit would apply only in underground areas where miners normally work or travel. The purpose of this restriction is to ensure that mine operators do not have to monitor particulate concentrations in areas where miners do not normally work or travel—e.g., abandoned areas of a mine.

However, it should be noted that the proposed interim and final concentration limits would apply in any area of a mine where miners ''normally'' work or travel—not just where miners might be present at the moment.

(14) Does the Rule Contemplate That MSHA Use Area Sampling To Determine Compliance?

The limit on the concentration of diesel particulate to which miners are exposed is intended to be applicable to persons, occupations or areas. This means that the Agency may sample by attaching a sampler to an individual miner, locate the sampler on a piece of equipment where a miner may work, or locate the sampler at a fixed site where miners normally work or travel.

(15) What Is the Basis for the Concentration Limit Being Proposed in Underground Metal and Nonmetal Mines?

The proposed rule would seek to reduce exposures to dpm in underground areas of underground metal and nonmetal mines to a level of around 200_{DPM} μg/m^3. (As explained in response to Question 12, the concentration limit is being expressed in terms of the total carbon measurement system MSHA will use to determine the amount of dpm, 160_{TC} μg/m^3).

Look again at Figure I–1, which compares the range of exposures of different groups of workers. You can see that capping dpm concentrations at 200_{DPM} μg/m^3 (all the information on the figure is presented in terms of estimated whole diesel particulate) will eliminate the worst mining exposures. In fact, such a cap will bring miner exposures down to a level commensurate with those reported for other groups of workers who use diesel-powered equipment. The proposed rule would not bring concentrations down as far as the proposed ACGIH TLV^R of 150_{DPM} μg/m^3. Nor does MSHA's risk assessment suggest that the proposed rule would eliminate the significant risks to miners of dpm exposure.

As a result of the Agency's statutory obligation to attain the highest degree of safety and health protection for miners, the Agency explored the option, and implications, of requiring mines in this sector to comply with a lower concentration limit than that being proposed. The Agency looked at simulations of the controls some underground metal and nonmetal mines might use to lower dpm concentrations, including at least one control with a major cost component (aftertreatment filter or new engine). The results, discussed in Part V of this preamble, indicate that although the matter is not free from question, it may not be feasible at this time for the underground metal and nonmetal mining industry as a whole to comply with a significantly lower limit than that being proposed. More information on this issue, and comments of the information presented by the Agency in Part V, would be appreciated.

The other side of this question—whether the rule that is proposed is feasible for the underground metal and nonmetal mining industry—is discussed in the next Question and Answer.

(16) Is It Feasible for the Metal and Nonmetal Industry as a Whole To Comply with the Proposed Concentration Limit?

MSHA has evaluated the feasibility of the concentration limit in the underground metal and nonmetal sector. Approximately 78 percent, of the 261 underground metal and nonmetal mines use diesel powered equipment, and MSHA estimates this sector has approximately 4,100 diesel engines. The engines can be of large size, and so tend to have high emissions. Moreover, unlike in the coal sector, there is no single control device that can be readily and widely applied to reduce dpm emissions in underground metal and nonmetal mines. The paper filter aftertreatment devices that can eliminate up to 95% of particulate matter emissions from permissible coal equipment are not available here without the addition of other controls. Permissible equipment requires the exhaust to be cooled to avoid explosive hazards; in turn, this permits paper afterfilters to be installed directly without burning. For most metal and nonmetal equipment, it is necessary to first install water scrubbers or other devices to cool the exhaust before using the paper filters. There are other types of filtering devices that could be directly applied to this equipment, but none to date that is quite as effective (although MSHA is seeking information as to whether creation of a market for filters could lead to prompt commercial development of ceramic filters with high particulate removal efficiencies). Moreover, the ventilation systems common in this sector, and the variation of mine types, suggested that a careful feasibility review is warranted.

Accordingly, MSHA undertook special analyses in which the Agency's staff experts simulated how various control methods could be used to meet the needs of some mines expected to have unusually difficult problems: an underground limestone mine, an underground (and underwater) salt mine, and an underground gold mine. The results of these analyses are discussed in Part V of the preamble, together with the methodology used in modeling the results. In each case, the analysis revealed that there are available controls that can bring dpm concentrations down to well below the final limit—even when the controls that needed to be purchased were not as extensive as those which the Agency is assuming will be needed in determining the costs of the proposed rule. As a result of these studies, the Agency has tentatively concluded that, in combination with the required ''best practices'', there are engineering and work practice controls available to bring dpm concentrations in all underground metal and nonmetal mines down to 400_{TC} μg/m³ within 18 months. Moreover, based on the mines it has examined to date, MSHA has tentatively concluded that controls are available to bring dpm concentrations in all underground metal and nonmetal mines down to 160_{TC} μg/m³ within 5 years.

The Agency would welcome comments from the mining community on the methodology of the model used in these studies, and hopes the mining community will submit the actual results of its own studies using the model. More information on the model is contained in Part V of the preamble. It uses a spreadsheet template that can be run on standard programs, and MSHA would be pleased to make copies available and answer any questions about the use of the model.

The best actions for an individual operator to take to come into compliance with the interim and final concentration limits will depend upon an analysis of the unique conditions at the mine. The proposed rule provides 18 months after it is promulgated for MSHA to provide technical assistance to individual mine operators. It also gives all mine operators in this sector an additional three and a half years to bring dpm concentrations down to the proposed final concentration limit—using an interim concentration limit during this time which the Agency is confident every mine in this sector can timely meet. And the rule provides an opportunity for a special extension for an additional two years for mines that have unique technological problems meeting the final concentration limit.

As noted during 1995 workshops co-sponsored by MSHA on methods for controlling diesel particulate, many underground metal and nonmetal mine operators have already successfully determined how to reduce diesel particulate concentrations in their mines. MSHA has disseminated the ideas discussed at these workshops to the entire mining community in a publication, ''Practical Ways to Control Exposure to Diesel Exhaust in Mining—a Toolbox'' (a copy of this publication is appended to the end of this document). The control methods are divided into eight categories: use of low emission engines; use of low sulfur fuel; use of aftertreatment devices; use of ventilation; use of enclosed cabs; diesel engine maintenance; work practices and training; fleet management; and respiratory protective equipment. And as noted above, MSHA has designed a model in the form of a computer spreadsheet that can be used to simulate the effects of various controls on dpm concentrations. This model is discussed in Part V of the preamble, and several examples are provided. This makes it possible for individual underground mine operators to evaluate the impact on diesel particulate levels of various combinations of control methods, prior to making any investments, so each can select the most feasible approach for his or her mine.

(17) Suppose an Underground Metal or Nonmetal Mine Really Does Have a Unique Technological Problem That Precludes Timely Compliance? Will MSHA Utilize Qualified and Experienced Technical Personnel To Review Operator Applications for Special Extensions of Time To Comply With the Final Concentration Limit in Underground Metal and Nonmetal Mines?

It is MSHA's intent that primary responsibility for analysis of the operator's application for a special extension will rest with MSHA's district managers. District managers are the most familiar with the conditions of mines in their districts, and have the best opportunity to consult with miners as well. At the same time, MSHA recognizes that district managers may need assistance with respect to the latest technologies and solutions being used in similar mines elsewhere in the country. Accordingly, the Agency intends to establish within its Technical Support directorate in Arlington, Va., a special panel to consult on these issues, to provide assistance to district managers, and to give final approval of any application for a special extension.

(18) If a Special Extension of Time To Comply With the Final dpm Concentration Limit Is Approved for an Underground Metal or Nonmetal Mine, What Operating Parameters Would Be Imposed on That Mine during the Duration of the Special Extension?

Any parameters will be negotiated between the individual operator and MSHA.

An operator will begin the process by filing an application for a special extension. The application must set forth what actions the operator commits to taking to maintain the lowest concentration of diesel particulate achievable. The application must also include adequate information for the Secretary to ascertain the lowest concentration of diesel particulate achievable, as demonstrated by data collected under conditions that are representative of mine conditions using the total carbon sampling method. In addition, the application must set forth what actions the operator will take to minimize the exposure of miners who will have to work or travel in areas which are going to be above the concentration limit by virtue of the extension. Since administrative controls and personal protective equipment can help reduce miner exposure, under these special circumstances operators may propose to include use of these approaches in their applications.

In some cases, what may be involved is a small area with only limited miner access; in other cases, an entire working section may be involved. Rather than establish ''one-size-fits-all'' standards for such situations, the proposal leaves it to the operator to submit a suggested approach.

The proposed rule requires a mine operator to comply with the terms of an approved extension application, and a copy would be posted at the mine site. Failure to comply with the specific commitments agreed to as part of the extension, and contained therein, would thus be citable.

(19) Why Do Underground Metal and Nonmetal Mine Operators Have To Have a Diesel Particulate Control Plan?

Underground metal and nonmetal operators will not have to have a compliance plan if they are in compliance. Considerable time is provided under the proposed rule to come into compliance, and operators can thereafter monitor their mines to ensure they stay below the required concentration limit.

But some operators may decline to take the actions necessary to achieve compliance in a timely manner, and others may need to rethink their approaches from time to time as equipment changes increase dpm concentration levels. Providing for a control plan in the event of a violation of the concentration limit ensures that there is a deliberative effort as to how to solve the dpm concentration problem, and that everybody understands what is going to be done to eliminate it. Accordingly, proposed § 57.5062 requires that in the event an operator is determined to have exceeded the applicable limit on diesel particulate concentration, the operator must establish a diesel particulate control plan if one is not already in effect, or modify the existing diesel particulate control plan.

(20) Must dpm Control Plans in Metal and Nonmetal Mines Be Pre-Approved by MSHA? How Long Would They Last?

Operator control plans would NOT have to be approved by MSHA. This is consistent with the practice in this sector concerning ventilation plans (with which the dpm control plan may be combined). The Agency gave serious consideration to requiring approval of such plans to ensure there was agreement as to their effectiveness, or at least to approval of compliance plans for repeat violators; but in light of the resource demands this might impose on the agency, and the operator verification sampling built into the proposed rule, the Agency decided not to make such a proposal. Comment on this point is welcome.

A control plan for a metal or nonmetal mine would not need to be retained and modified forever—as is the practice with plans for underground coal mines. Rather, under the proposal, a dpm control plan in a metal or nonmetal mine would stay in effect for 3 years, and during its lifetime, the plan is to be modified as appropriate to reflect changes in mining conditions.

MSHA seriously considered requiring a longer lifetime for compliance plans. First, the Agency wants to provide a strong incentive to come into compliance in a timely fashion. Second, the Agency wants to be sure that where a plan is needed to clarify compliance obligations, it stay in place at a mine long enough to ensure that the obligations undertaken in the plan become a mine routine; the goal is to maintain a mine in compliance, not just have a temporary fix. The Agency also has to be realistic about conserving the resources of its health professionals; re-sampling mines whose control plans have expired takes resources away from other priorities. The Agency is aware, however, that operating under long-term control plans is not standard practice in metal and nonmetal mines. Moreover, it recognizes the need to re-sample all mines with some regularity due to changing mining conditions. Accordingly, the proposed rule seeks to strike a balance in this regard.

(21) What Must Be Included in a dpm Control Plan If One Is Required? And How Would Its Effectiveness Be Verified?

The diesel particulate control plan would include three elements: the controls the operator will utilize to maintain the concentration of diesel particulate at the mine to the applicable limit; a list of diesel-powered units maintained by the mine operator; and information about any unit's emission control device and the parameters of any other method used to control dpm concentrations. Upon request, the plan (or amended plan) is to be submitted to the District Manager, with a copy to the authorized representative of miners—but no approval process would be required; a copy is to be maintained at the mine site. Documentation verifying the effectiveness of the plan in controlling diesel particulate to the required level would have to be maintained with the plan, and submitted to MSHA upon request.

Proposed § 57.5062(c) provides that to verify the effectiveness of a control plan or amended control plan, operators must have monitoring data, collected using the total carbon method which MSHA will be required to use for enforcement purposes, sufficient to confirm that the plan or amended plan will control the concentration of diesel particulate to the applicable limit under conditions that can be reasonably anticipated in the mine.

Verification by operators is being proposed to ensure that primary responsibility for ensuring a dpm control plan is effective is not shifted to MSHA. The Agency has only limited resources to conduct sampling. Moreover, while a single sample can demonstrate that a mine is out of compliance under the conditions sampled, it takes multiple samples to demonstrate that miners are protected under the variety of conditions that can be reasonably anticipated in the mine (e.g., during production and seasonal changes). By clarifying operator responsibilities in this regard, the proposal ensures an appropriate balance of responsibilities.

The proposed rule does not specify that any defined number of samples must be taken—the intent is that the sampling provide a representative picture of whether the plan or amended plan is working. The proposed rule does, however, specify that the total carbon method be used for verification sampling. This is an exception to the general rule that mine operators have discretion in the choice of what sampling technique to use in their own monitoring programs (see response to Question 29). The purpose of verification sampling is to verify the effectiveness of a plan established or modified in response to a violation through MSHA sampling; if operators used an alternative technique to sample, it would complicate the determination of whether the violation was being adequately addressed by the plan.

(22) Why Is the Agency Proposing That All Underground Metal and Nonmetal Mines Follow Certain ''Best Practices''—Regardless of the Concentration of Diesel Particulates at Such Mines?

The Agency's risk assessment supports reduction of dpm to the lowest level possible. But as discussed in response to Question 16, feasibility considerations dictated proposing a concentration limit that does not eliminate the significant risks that dpm exposure poses to miners.

One approach that can be used to bridge the gap between risk and feasibility is to establish an ''action level''. In the case of MSHA's noise proposal, for example, MSHA proposed a ''permissible exposure level'' of a time-weighted 8-hour average (TWA_8) of 90 dBA (decibels, A-weighted), and an ''action level'' of half that amount—a TWA_8 of 85 dBA. In that case, MSHA has determined that miners are at significant risk of material harm at a TWA_8 of 85 dBA, but technological and feasibility considerations may preclude the industry as a whole, at this time, from eliminating exposures below a TWA_8 90 dBA. Accordingly, MSHA proposed that mine operators must take certain actions to limit miner exposure to noise above a TWA_8 of 85 dBA that are feasible (e.g., provide hearing exams and hearing protectors).

MSHA considered the establishment of a similar ''action level'' for dpm—probably at half the proposed concentration limit, or 80_{TC} µg/m^3. Under such an approach, mine operators whose dpm concentrations are above the ''action level'' would be required to implement a series of ''best practices''—e.g., limits on fuel types, idling, and engine maintenance. MSHA welcomes comments on whether it should take such an approach with dpm.

In lieu of this approach, the Agency decided instead to propose an approach that it believes will be simpler for the mining community to implement: requiring compliance with the ''best practices'' in all cases. There are several reasons why the agency has proposed this approach.

First, sampling by both operators and MSHA would have to be much more frequent if a measurement trigger for additional actions were to be established. This is because many more areas of a mine would need to be checked regularly than if only a higher trigger is in place. In underground metal and nonmetal mines, most areas using diesel equipment would exceed a limit of 75_{TC} µg/m^3 anyway, so the sampling needed to confirm the situation would appear to be wasteful.

Second, diesel equipment is often moving, meaning that maintenance and fleet requirements triggered by a single sample might switch on and off in ways that are hard to predict. Moreover, using an action level in an area of a mine to trigger maintenance requirements might put certain machines in the fleet under one set of maintenance rules and other machines under an alternative set, complicating mine administration.

Third, underground coal mines which use diesel-powered equipment already observe a set of such requirements. While certain special safety hazards associated with the use of diesel-powered equipment in underground coal mines warrant certain work practices that may not be warranted in other sectors, the safety rationale for adopting some of these practices seems as valid in other sectors as in underground coal. Fourth, given the history of the mining industry with lung problems associated with this type of work, adopting a prudent approach seems a wise course when the costs of prevention are limited. This is standard health practice.

Finally, a number of the work practices proposed appear to have significant benefits—improving the efficiency of mining operations by ensuring that diesel mining equipment is maintained in good working order to meet productivity demands.

MSHA specifically solicits comments from the public on whether or not it should require ''best practices'' to lower the dpm concentration.

(23) Will the Proposed Restrictions on Fuel and Fuel Additives Increase Costs or Limit Engine Reliability?

MSHA believes the answer to both questions is no.

Under proposed § 57.5065, mine operators would be able to use only low-sulfur diesel fuel. This requirement is identical to that for underground coal diesel equipment. Number 1 and number 2 diesel fuel would be permitted. MSHA has been advised that low-sulfur diesel fuel is now readily available in all areas of the country in order to meet EPA requirements; in many places, it is the only fuel available.

Similarly, the proposal would extend to all mines the ban in underground coal mines on the use of diesel-fuel additives other than those approved by EPA. There is a long list of approved additives. Copies are available from EPA and the list is posted on its Web site, or you may link to them from MSHA's Web site (http://www.msha.gov/s&hinfo/deslreg/1901(c).htm). Using only additives that have been approved ensures that diesel particulate concentrations are not inadvertently increased, while also protecting miners against the emission of other toxic substances.

(24) How Is MSHA Going To Distinguish Between Idling That Is Permitted and Idling That Isn't Permitted?

Keeping idling to a minimum is a very important way to reduce pollution in mine atmospheres, and this would be required by proposed § 57.5065(c). Idling engines can actually produce more pollutants than engines under load. Generally of more concern, however, is the impact idling engines can have on localized exposures. In underground operations, an engine idling in an area of minimal ventilation or a ''dead air'' space could cause an excess exposure to the gaseous emissions, especially carbon monoxide, as well as to diesel particulate. Eliminating unnecessary idling can make a substantial contribution toward preventing localized exposure to high particulate concentrations.

However, there are some circumstances in which idling is necessary. The proposal would permit idling in connection with ''normal mining operations''. In the proposal, MSHA does not attempt to define this term, and would intend this rule to be administered with reference to commonly understand practices of what is necessary idling. For example, idling while waiting for a load to be unhooked, or waiting in line to pick up a load, is normally part of the job; idling while eating lunch is normally not part of the job. But if the idling is necessary due to the very cold weather conditions, it should not be barred. On the other hand, idling should not be permitted in other weather conditions just to keep balky older engines running; in such cases, the correct approach is better maintenance. MSHA recognizes that to administer this provision in a common sense manner may require the provision of examples to both MSHA inspectors and to the mining community; accordingly, the Agency welcomes specific examples of circumstances where idling should and should not be permitted. The Agency recently implemented a similar provision for the underground coal mining sector, and MSHA will consider the experience gained under that rule in formulating a final diesel particulate rule and compliance guide.

(25) Will the Proposed Rule Require That Diesel Engines and Aftertreatment Devices Used in Underground Metal and Nonmetal Mines Be Maintained in Mint Condition?

No. § 57.5066(a) of the proposed rule would, however, require that the engines and aftertreatment devices not be permitted to deteriorate to the point they create needless pollution. The air intake system, the cooling system, lubrication system, fuel injection system and exhaust system of an engine must all be maintained on a regular schedule if the toxic contaminants in the engine exhaust are to be minimized. And there is little point in having an aftertreatment device to limit pollution if it is not maintained in working order; moreover, it can damage the engine. A good preventive maintenance program can not only keep down exhaust emissions, but help maximize vehicle productivity and engine life.

It is difficult for a rule covering all types and ages of engines used in underground metal and nonmetal mines to define precisely the level of maintenance required for each engine. Further, MSHA does not believe that it is necessary: the mining community is fully cognizant of the general requirements for engine maintenance. Accordingly, proposed § 57.5066(a) sets out in general terms the standard of care required for different types of engines.

First, an ''approved'' engine is to be maintained in approved condition. MSHA approves engines under specific regulations set forth in Title 30. The approval of the engine is tied to certain parts and specifications. When these parts or specifications are changed (e.g., an incorrect part is used, or the wrong setting), then the engine is no longer considered in approved condition. The requirements in this regard are well defined. MSHA personnel at the Approval Certification Center are available to the mining community to respond to questions and provide specific guidance. MSHA's diesel equipment rule already requires underground coal mine fleets to convert entirely to approved engines, but at this time only some of the engines used in underground metal and nonmetal mines are approved.

Second, for any engine that is not an approved engine, the ''emission related components'' of the engine are to be maintained to manufacturer specifications. By the term ''emission related components,'' MSHA means the parts of the engine that directly affect the emission characteristics of the raw exhaust. These are basically the same components which MSHA examines for ''approved'' engines. They are: the piston; intake and exhaust values; cylinder head; camshaft; injector; fuel injection pump; governor; injection timing and fuel pump calibration; and, if applicable, turbocharger and after cooler.

Third, and finally, any emission or particulate control device installed on diesel-powered equipment is to be maintained in ''effective operating condition.'' The maintenance of an emission or particulate control device in effective operating condition involves such basic tasks as regularly cleaning the filter using whatever methods are recommended by the manufacturer for that purpose or inserting appropriate replacement filters, checking for and repairing any leaks, and similar obvious actions.

An MSHA inspector is not going to randomly order an engine to be taken out of service and torn down to check the condition of a piston against the shop manual. Rather, what will concern an inspector are the same kinds of signals that should concern a conscientious operator—for example, a history of complaints about the engine's reliability, an incomplete maintenance schedule, lack of required maintenance manuals or spare parts, the emission of black smoke under normal load, or a series of emission test results indicating a continuing engine problem. Evidence of such deficiencies is likely to lead to a closer examination. But a conscientious maintenance program is going to catch such problems before they occur.

MSHA's toolbox includes an extensive discussion of maintenance. It reminds operators and diesel maintenance personnel of the basic systems on diesel engines that need to be maintained, and how to avoid various problems. It includes suggestions from others in the mining community, and information on their success or difficulties in this regard. MSHA will continue to provide technical assistance to the mining community in this critical area.

(26) What Are the Responsibilities of a Miner Who Operates Diesel-Powered Equipment in an Underground Metal and Nonmetal Mine To Ensure it Is Not Polluting? And What Are The Responsibilities of Mine Management When Notified of a Potential Pollution Problem?

The miner who operates diesel-powered equipment is often the first one to spot a problem with the engine or emissions system. The engine may balk, have trouble handling a load, make unusual noises, exhaust too much smoke, or otherwise suggest to the person familiar with the engine's capabilities that it needs to be checked. In some cases, the miner may have the knowledge, parts, equipment and authority to fix the problem on the spot. In many cases, however, the miner operating the equipment may not have all of these. If the problem is to be addressed promptly, it is essential the miner report it to mine management—and that the mine management act on that report in a timely manner. If these actions by miner and mine management are not taken, the concentrations of diesel particulate are likely to quickly increase without anyone being aware of the danger until the next environmental monitoring is performed. To avoid this problem, proposed § 57.5066 would require that all underground metal and nonmetal mines using diesel equipment underground implement a few basic procedures. The details of implementation in each mine would be at the discretion of the mine operator.

Proposed § 57.5066(b)(1) would require the mine operator to authorize the operator of diesel-powered equipment to affix a tag to the equipment at any time the equipment operator notes a potential problem. Tagging provides a simple mechanism for ensuring that all mine personnel are made quickly aware that a piece of equipment needs to be checked by qualified service personnel. The tag may be affixed because the equipment operator picks up a problem through a visual exam conducted before the equipment is started (e.g., an exam pursuant to 30 CFR 57.14100), or because of a problem that comes to the attention of the equipment operator during mining operations—e.g., black smoke while the equipment is under normal load, rough idling, unusual noises, backfiring, etc.

The proposal leaves the design of the tag to each mine operator, provided that the tag can be dated. Comments are welcome on whether some or all elements of the tag should be standardized to ensure its purpose is met.

MSHA is not proposing that equipment tagged for such potential emission problems be automatically taken out of service. The proposal is not, therefore, directly comparable to a ''tag-out'' requirement like OSHA's requirement for automatically powered machinery, nor as stringent as MSHA's requirement to remove from service certain equipment ''when defects make continued operation hazardous to persons'' (see, e.g., 30 CFR 57.14100). While the emissions problem could pose a serious health hazard for miners directly exposed, there is no way to determine this with certainty until the equipment is tested. Moreover, the danger is not as immediate as, for example, an explosive hazard. Rather, proposed § 57.5066(b)(2) would require that the equipment be ''promptly'' examined by a person authorized by the mine operator to maintain diesel equipment (the qualifications for those who maintain and service diesel engines discussed in response to the next question). The Agency has not tried to define the term ''promptly'', but welcomes comment on whether it should do so—in terms, for example, of a limited number of shifts.

The proposal would require that a single log be retained of all equipment tagged. The proposal would permit a tag to be removed after an examination has been completed and a record of the examination made—with the date, the name of the person making the examination, and the action taken as a result of the examination. The presence of a tag serves as a caution sign to miners working near the equipment, as well as a reminder to mine management, as the equipment moves from task to task throughout the mine. While the equipment is not barred from service, operators would be expected to use common sense in using it in locations in which diesel particulate concentrations are known to be high. The records of the tagging and servicing, although basic, provide mine operators, miners and MSHA a history that will help all of them evaluate whether a maintenance program is being effectively implemented.

(27) Must Miners or Others Who Examine or Repair Diesel Engines Used in Underground Metal and Nonmetal Mines Have Special Qualifications or Training? Must Operators Establish Programs or Criteria for This Purpose?

The answer to the first question is a qualified ''yes'', and the answer to the second question is no.

Proposed § 57.5066(c) provides that: ''Persons authorized by a mine operator to maintain diesel equipment covered by paragraph (a) of this section must be qualified, by virtue of training or experience, to ensure that the maintenance standards of paragraph (a) of this section are observed.'' As discussed in response to Question 25, paragraph (a) of § 57.5066 provides that approved engines be maintained in approved condition, the emission related components of non-approved engines be maintained to manufacturer specifications, and emission or particulate control devices installed on the equipment be maintained in effective condition.

This means that regardless of who identifies a potential problem along these lines, the person who checks out the problem, and if necessary makes repairs, is someone who knows what he or she is doing. If examining and, if necessary, changing a filter or air cleaner is what is needed, a miner who has been shown how to do these tasks would be ''qualified by virtue of training or experience'' to do those tasks. For more sophisticated work, more sophisticated training or additional experience would be required. Training by a manufacturer's representative, completion of a general diesel engine maintenance course, or practical experience performing such repairs might be evidence of appropriate qualifications.

In the underground coal sector, MSHA requires each operator to establish a program to ensure that persons who work on diesel engines are qualified. That is not being proposed for the underground metal and nonmetal sector. The unique conditions in underground coal mines require the use of specialized equipment. Accordingly, the qualifications of the persons who maintain this equipment generally must be more sophisticated than in other sectors.

The proposed rule contemplates that if MSHA finds a situation where maintenance appears to be shoddy or where tampering has damaged engine approval status or emission control effectiveness, MSHA will ask the operator to provide evidence that the person who worked on the equipment was properly qualified by virtue of training or experience. Equipment sent off site for maintenance and repair is just as subject to this requirement as other equipment; it is the operator's obligation to ensure he has appropriate evidence of the qualifications of those who will work on the equipment.

(28) Can Underground Metal and Nonmetal Operators Continue To Use and Relocate Nonapproved Engines in Their Inventories?

Pursuant to MSHA's diesel equipment rule, the entire fleet of underground coal engines must be ''approved'' engines by the year 2000—even if operators must replace existing engines to comply. By contrast, proposed § 57.5067 would only require that, with a few exceptions, all engines ''introduced'' into underground areas of underground metal and nonmetal mines after the effective date must be engines that have been through MSHA's approval process under Part 7 of Chapter 30. Operators who have significant investments in their existing fleets will accordingly be able to retain those engines, provided they are maintained in the manner specified in the proposal and that the concentration of diesel particulate can be controlled in another way (e.g. ventilation, particulate filters, etc.).

However, after the rule's effective date, an operator would not be permitted to bring into underground areas of a mine an unapproved engine from the surface area of the same mine, an area of another mine, or from a non-mining operation. Since the safe level of diesel particulate is not known, promoting a gradual turnover of the existing fleet is an appropriate response to the health risk presented.

Some engines currently used in metal and nonmetal mines may have no approval criteria; in such cases, MSHA will work with the manufacturers to develop approval criteria consistent with those MSHA uses for other diesel engines. Based upon preliminary analysis, MSHA has tentatively concluded that any diesel engine meeting current on-highway and non-road EPA emission requirements would meet MSHA's engine approval standards of Part 7, subpart E, category B type engine. (See Section 4 of Part II of this preamble for further information about these engines). Currently, the EPA nonroad test cycle and MSHA's test cycle are the same for determining the gaseous and particulate emissions. MSHA envisions being able to use the EPA test data ran on the non-road test cycle for determining the gaseous ventilation rate and particulate index. The engine manufacturer would continue to submit the proper paper work for a specific model diesel engine to receive the MSHA approval. However, engine data ran on the EPA on-highway transient test cycle would not as easily be usable to determine the gaseous ventilation and particulate index. Comments on how MSHA can facilitate review of engines not currently approved would be welcome.

Engines in diesel-powered ambulances and fire-fighting equipment would be exempted from these requirements. This exemption is identical with that in the rule for diesel-powered equipment in underground coal mines.

(29) What Specifically Would Be the Obligations of an Underground Metal or Nonmetal Mine Operator To Monitor dpm Exposures and to Correct Overexposures?

Proposed § 57.5071 would require underground metal or nonmetal mine operators to monitor the concentration of diesel particulate, to initiate corrective action by the next work shift if the monitoring reveals that the concentration of diesel particulate exceeds the permitted limit, and to post sample results and the corrective action being taken.

There is no prescribed frequency for monitoring. But proposed § 57.5071(a) provides that sampling must be done as often as necessary to ''effectively evaluate,'' under conditions that can be reasonably anticipated in the mine:

(1) whether the dpm concentration in any area of the mine where miners work or travel exceeds the applicable limit; and (2) the average full shift airborne concentration at any location or on any person designated by MSHA. The first condition clarifies that it is the responsibility of mine operators to be aware of the concentrations of diesel particulate in all areas of the mine where miners work or travel, so as to know whether action is needed to ensure that the concentration does not exceed the applicable limit. The second condition is to ensure special attention to locations or persons known to MSHA to have a significant potential for overexposure to diesel particulate.

The proposed rule is performance oriented in that the regularity and methodology used to make this evaluation are not specified. MSHA's own measurements will assist the Agency in verifying the effectiveness of an operator's monitoring program. If an operator is ''effectively evaluating'' the concentration of dpm at designated locations, for example, MSHA would not expect to record concentrations above the limit when it samples at that location. Some record of the sampling procedure and sample results will need to be retained by operators to establish that they have complied with the general obligations of this section.

The proposed rule requires, consistent with Section 103(c) of the Mine Act, that miners and their representatives have an opportunity to observe such monitoring. In accordance with this legal requirement, the proposed rule requires a mine operator to provide affected miners and their representatives with an opportunity to observe exposure monitoring of dpm by operators. Mine operators must give prior notice to affected miners and their representatives of the date and time of intended monitoring. MSHA has proposed similar language in its proposed rule on noise.

The proposed rule does not specify a required method for sampling. In the absence of a procedure to convert total carbon measurements into equivalents under other methods, methods other than NIOSH Method 5040 would not provide exact information about compliance status, but they certainly would provide a general guide to dpm concentrations if used under proper circumstances. (More information on the proper circumstances in which various methods are appropriate can be found in Section 3 of Part II of this preamble).

The proposed rule provides that an operator who has knowledge that a concentration limit has been exceeded must initiate corrective action by the next work shift and promptly complete such action. The hazards presented by overexposure to dpm may not as immediate as an explosive hazard, but are nevertheless serious. Accordingly, although MSHA is not proposing immediate withdrawal of miners nor even immediate completion of abatement action, the agency is proposing that mine operators begin abatement action by the next shift and promptly complete such action, not allowing it to drag out while miners are being overexposed. The Agency is also proposing to require posting of the corrective action to implement the statutory requirement that notice of corrective action be provided to miners. MSHA welcomes comment on how it might clarify its expectations with respect to the initiation of corrective action, including what specific guidance to provide to operators not using the total carbon method and as to when corrective action must begin when the analysis is performed on a delayed basis off-site. MSHA also welcomes comment as to whether personal notice of corrective action would be more appropriate than posting given the health risks involved.

Proposed § 57.5071(d) provides that monitoring results must be posted on the mine bulletin board, and a copy provided to the authorized representative of miners. As with the training requirements, posting ensures that miners are kept aware of the hazard so they can actively play their role in prevention.

(30) What Records Must be Kept by Metal and Nonmetal Operators? Where Must they be Kept, and Who Has Access to Them?

Recordkeeping and retention requirements are noted in the text of each section of the proposed rule creating the requirement. For the sake of convenience, a table of record-keeping requirements is provided in proposed § 57.5075(a). The table lists the records that would be required under the proposed changes to Part 57, notes the proposed section of Part 57 creating the recordkeeping requirement, and notes the type of record and retention time. MSHA would welcome comment on whether this presentation is useful.

In some cases, the record required is expressed in general terms: e.g., ''evidence of competence to perform maintenance'', pursuant to proposed § 57.5066(c). As long as each operator has some record that establishes this fact, it does not matter that the records of one operator are not the same as the records of another operator. While an MSHA inspector may well be willing to accept oral evidence on a particular point (e.g., who performed a repair), operators should retain written documentation adequate to demonstrate the facts involved (e.g., a logbook for each engine showing who worked on it, the date, the work performed, and any follow-up needs or plans). MSHA would welcome comments on whether the agency should be more specific as to the recordkeeping systems mine operators should utilize.

The proposed rule generally provides that records required be retained at the mine site. These records need to be where an inspector can view them during the course of an inspection, as the information in the records may determine how the inspection proceeds. But if the mine site has an operative fax machine or computer terminal, this section would permit the records to be maintained elsewhere. MSHA's approach in this regard is consistent with Office of Management and Budget Circular A–1. Mine operators must promptly provide access to compliance records upon request from an authorized representative of the Secretary of Labor, the Secretary of Health and Human Services, or from the authorized representative of miners. Access to a miner's sample records must also be provided to a miner, former miner, or personal representative of a miner—the first copy at no cost, and any subsequent copies at reasonable cost.

MSHA encourages mine operators who store records electronically to provide a mechanism which will allow the continued storage and retrieval of records in the year 2000.

II. Background Information.

This part provides the context for this rulemaking. The nine topics covered are:

(1) The role of diesel-powered equipment in mining;

(2) Diesel exhaust and diesel particulate;

(3) Methods available to measure dpm;

(4) Reducing soot at the source—engine standards;

(5) Limiting the public's exposure to soot—ambient air quality standards;

(6) Controlling diesel particulate emissions in mining—a Toolbox;

(7) Existing mining standards that limit miner exposure to occupational diesel particulate emissions;

(8) How other jurisdictions are restricting occupational exposure to diesel soot; and

(9) MSHA's initiative to limit miner exposure to diesel particulates—the history of this rulemaking and related actions.

In addition, a recent MSHA publication, ''Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—A Toolbox'', contains considerable information of interest in this rulemaking. The ''Toolbox'' which includes additional information on methods for controlling dpm, and a glossary of terms, is appended to the end of this document.

These topics will be of interest to the entire mining community, even though this rulemaking is specifically confined to the underground metal and nonmetal sector.

(1) *The Role of Diesel-Powered Equipment in Mining.* Diesel engines now power a full range of mining equipment on the surface and underground, in both coal and in metal/nonmetal mining. Many in the mining industry believe that diesel-powered equipment has a number of productivity and safety advantages over electrically-powered equipment. Nevertheless, concern about miner safety and health has slowed the spread of this technology, and in certain states resulted in a complete ban on its use in

underground coal mines. As the industry has moved to realize the advantages this equipment may provide, the Agency has endeavored to address the miner safety and health issues presented.

Historical Patterns of Use. The diesel engine was developed in 1892 by the German engineer Rudolph Diesel. It was originally intended to burn coal dust with high thermodynamic efficiency. Later, the diesel engine was modified to burn middle distillate petroleum (diesel fuel). In diesel engines, liquid fuel droplets are injected into a prechamber or directly into the cylinder of the engine. Due to compression of air in the cylinder the temperature rises high enough in the cylinder to ignite the fuel.

The first diesel engines were not suited for many tasks because they were too large and heavy (weighing 450 lbs. per horsepower). It was not until the 1920's that the diesel engine became an efficient lightweight power unit. Since diesel engines were built ruggedly and had few operational failures, they were used in the military, railway, farm, construction, trucking, and busing industries. The U.S. mining industry was slow, however, to begin using these engines. Thus, when in 1935 the former U.S. Bureau of Mines published a comprehensive overview on metal mine ventilation (McElroy, 1935), it did not even mention ventilation requirements for diesel-powered equipment. By contrast, the European mining community began using these engines in significant numbers, and various reports on the subject were published during the 1930's. According to a 1936 summary of these reports (Rice, 1936), the diesel engine had been introduced into German mines by 1927. By 1936, diesel engines were used extensively in coal mines in Germany, France, Belgium and Great Britain. Diesel engines were also used in potash, iron and other mines in Europe. Their primary use was in locomotives for hauling material.

It was not until 1939 that the first diesel engine was used in the United States mining industry, when a diesel haulage truck was used in a limestone mine in Pennsylvania. In 1946 diesel engines were introduced in coal mines. Today, however, diesel engines are used to power a wide variety of equipment in all sectors of U.S. mining, such as: air compressors; ambulances; crane trucks; ditch diggers; foam machines; forklifts; generators; graders; haul trucks; load-haul-dump machines; longwall retrievers; locomotives; lube units; mine sealant machines; personnel cars; hydraulic pump machines; rock dusting machines; roof/floor drills; shuttle cars; tractors; utility trucks; water spray units and welders.

Estimates of Current Use. Estimates of the current inventory of diesel engines in the mining industry are displayed in Table II–1. Not all of these engines are in actual use. Some may be retained rather than junked, and others are spares. MSHA has been careful to take this into account in developing cost estimates for this proposed rule; its assumptions in this regard are detailed in the Agency's PREA.

TABLE II–1.—DIESEL EQUIPMENT IN THREE MINING SECTORS

Mine type	# Mines [2]	# Mines w/ diesel	# Engines
Underground Coal	971	[3] 173	[4] 2,950
Small [1]	426	15	50
Large	545	158	2,900
Underground M/NM	261	203 [5]	[6] 4,100
Small [1]	130	82	625
Large	131	121	3,475
Surface Coal	1,673	[7] 1,673	[8] 22,000
Small [1]	1,175	1,175	7,000
Large	498	498	15,000
Surface M/NM	10,474	[9] 10,474	[10] 97,000

Notes on Table II–1:

(1) A mine with less than 20 miners. MSHA traditionally regards mines with less than 20 miners as ''small'' mines, and those with 20 or more miners as ''large'' mines based on differences in operation. However, in examining the impact of the proposed regulations on the mining community, MSHA, consistent with the Small Business Administration definition for small mines, which refers to employers with 500 employees or less, has analyzed impact for this size. This is discussed in the Agency's preliminary regulatory economic analysis for this proposed rule.
(2) Preliminary 1996 MSHA data.
(3) Data from MSHA approval and certification center, Oct. 95.
(4) Actual inventory, rounded to nearest 50.
(5) Estimates are based on a January 1998 count, by MSHA inspectors, of underground mines that use diesel powered equipment.
(6) The estimates are based on a January 1998 count, by MSHA inspectors, of diesel powered equipment normally in use.
(7) Based on assumption that all surface coal mines had some diesel powered equipment.
(8) Based on MSHA inventory of 25% of surface coal mines.
(9) MSHA assumes all surface M/NM mines use some diesel engines.
(10) Derived by applying ratios (engines per mine) from MSHA inventory of surface coal mines to M/NM mines.

As noted in Table II–1, a majority of underground metal and nonmetal mines, and all surface mines, use diesel-powered equipment. This is not true in underground coal mines—in no small measure because, as discussed later in this part, several key underground coal states have for many years banned the use of diesel-powered equipment in such mines.

Neither the diesel engines nor the diesel-powered equipment are identical from sector to sector. This relates to the equipment needs in each sector. This is important information because the type of engine, and the type of equipment in which it is installed, can have important consequences for particulate production and control.

As the horsepower size of the engine increases, the mass of dpm emissions produced per hour increases. (A smaller engine may produce the same or higher levels of particulate emissions per volume of exhaust as a large engine, due to the airflow, but the mass of particulate matter increases with the engine size). Accordingly, as engine size increases, control of emissions may require additional efforts.

Diesel engines in metal and nonmetal underground mines, and in surface coal mines, range up to 750 HP or greater; by contrast, in underground coal mines, the average engine size is less than 150 HP. The reason for this disparity is the nature of the equipment powered by diesel engines. In underground metal and nonmetal mines, and surface mines, diesel engines are widely used in all types of equipment — both the equipment used under the heavy stresses of production and the equipment used for support. By contrast, the great majority of the diesel usage in underground coal mines is in support equipment. For example, in underground metal and nonmetal mines, of the approximate 4,100 pieces of diesel equipment normally in use, about 1,800 units are for loading and hauling. By contrast, of the approximate 3,000 pieces of diesel equipment in underground coal, MSHA estimates that less than 50 pieces are for coal haulage. The largest diesel engines are used in surface operations; in underground metal and nonmetal mines, the size of the engine can be limited by the size of the shaft opening.

The type of equipment in the sectors also varies in another way that can affect particulate control directly, as well as constrain engine size. In underground coal, equipment that is used in face (production) areas of the coal mine must be MSHA-approved Part 36 permissible equipment. These locations are the areas where methane gas is likely to accumulate in higher concentrations. This includes the in-by section starting at the tailpiece (coal dump point) and all returns. Part 36 permissible equipment for coal requires the use of flame arresters on the intake and exhaust systems and surface temperature control to below 302°F. As discussed in more detail elsewhere in this notice, the cooler exhaust from these permissible pieces of equipment permits the direct installation of particulate filtration devices such as paper type filters that cannot be used directly on engines with hot exhaust. In addition, the permissibility requirements have had the effect of limiting engine size. This is because prior to MSHA's issuance of a diesel equipment rule in 1996, surface temperature control was done by water jacketing. This limited the horsepower range of the permissible engines because manufacturers have not expended resources to develop systems that could meet the 302°F surface temperature limitation using a water jacketed turbocharger.

In the future, larger engines may be used on permissible equipment, because the new diesel rule allows the use of new technologies in lieu of water jacketing. This new technology, plus the introduction of air-charged aftercoolers on diesel engines, may lead to the application of larger size diesel engines for underground coal production units. Moreover, if manufacturers choose to develop this type of technology for underground coal production units, the number of diesel production machines may increase.

There are also a few underground metal and nonmetal mines that are gassy, and these require the use of Part 36 permissible equipment. Permissible equipment in metal and nonmetal mines must be able to control surface temperatures to 400°F. MSHA estimates that there are currently less than 15 metal and nonmetal mines classified as gassy and which, therefore, must use Part 36 permissible equipment if diesels are utilized in areas where permissible equipment is required. These gassy metal and nonmetal mines have been using the same permissible engines and power packages as those approved for underground coal mines. (MSHA has not certified a diesel engine exclusively for a Part 36 permissible machine for the metal and nonmetal sector since 1985 and has certified only one permissible power package; however, that engine model has been retired and is no longer available as a new purchase to the industry). As a result, these mines are in a similar situation as underground coal mines: engine size (and thus dpm production of each engine) is more limited, and the exhaust is cool enough to add the paper type of filtration device directly to the equipment.

In nongassy underground metal and nonmetal mines, and in all surface mines, mine operators can use conventional construction equipment in their production sections without the need for modifications to the machines. Two examples are haulage vehicles and dump trucks. Some construction vehicles may be redesigned and articulated for sharper turns in underground mines; however, the engines are still the industrial type construction engines. As a result, these mines can and do use engines with larger horsepower. At the same time, since the exhaust is not cooled, paper-type filters cannot be added directly to this equipment without first adding a water scrubber, heat exchanger or other cooling device. The same is true for the equipment used in outby areas of coal mines, where the methane levels do not require the use of permissible equipment.

Future Demand and Emissions. MSHA expects there will be more diesel-powered equipment added to the Nation's mines. While other types of power sources for mining equipment are available, many in the mining industry believe that diesel power provides both safety and economic advantages over alternative power sources available today. Not many studies have been done recently on these contentions, and the studies which have been reviewed by MSHA do not clearly support this hypothesis; but as long as this view remains prevalent, continued growth is likely.

There are additional factors that could increase growth. As noted above, permissible equipment can now be designed in such a way to permit the use of larger engines, and in turn more use of diesel-powered production equipment in underground coal and other gassy mines. Moreover, state laws banning the use of diesel engines in the underground coal sector are under attack. As noted in section 8 of this part, until recently, three major underground coal states, Pennsylvania, West Virginia, and Ohio, have prohibited the use of diesel engines in underground coal mines. In late 1996, Pennsylvania passed legislation (PA Senate Bill No. 1643) permitting such use under conditions defined in the statute. West Virginia passed legislation lifting its ban as of May, 1997 (WV House Bill 2890), subject to regulations to be developed by a joint labor-industry commission. This makes the need to address safety and health concerns about the use of such engines very pressing.

In the long term, the mining industry's diesel fleet will become cleaner, even if the size of the fleet expands. This is because the old engines will eventually be replaced by new engines that will emit fewer particulates than they do at present. As discussed in Section 4 of this part, EPA regulations limiting the emissions of particulates and various gasses from new diesel engines are already being implemented for some of the smaller engines used in mining. Under a defined schedule, these new standards will soon apply to other new engines, including the larger engines used in mining. Moreover, over time, the emission standards which new engines will have to pass will become more and more stringent. Under international accords, imported engines are also likely to be cleaner: European countries have already established more stringent emission requirements (Needham, 1993; Sauerteig, 1995).

Based on the feasibility using the estimator, new engine technology, catalytic converters, and current ventilation should reduce dp levels down below the $400_{TC}um^3$. However, to reduce to the $160_{TC}um^3$ level, dp filters or cabs will still be needed on a certain number of equipment, based on mining conditions and diesel usage. The particulate index values listed for the MSHA approved engines provides information on the dp emissions and also can be used to help determine how low engine technology alone can lower dp exposures. When filters are used, the cleaner engines allow the filters to last longer between change out or cleaning. The newer technology engines, especially the electronic models, also add the benefit of diagnostic control. The engines computer can inform the mechanic on the condition of the engine and warn the mechanic when an engine is in need of maintenance.

But MSHA believes that turnover of the mining fleet to these new, cleaner engines will take a very long time because the mining industry tends to purchase for mining use older equipment that is being discarded by other industries. In the meantime, the particulate burden on miners as a group is expected to remain at current levels or even grow.

(2) *Diesel Exhaust and Diesel Particulate.* The emissions from diesel engines are actually a complex mixture of compounds, containing gaseous and particulate fractions. The specific composition of the diesel exhaust in a mine will vary with the type of engines being used and how they are used. Factors such as type of fuel, load cycle, engine maintenance, tuning, and exhaust treatment will affect the composition of both the gaseous and particulate fractions of the exhaust. This complexity is compounded by the multitude of environmental settings in which diesel-powered equipment is operated. Elevation, for example, is a factor. Nevertheless, there are a few basic facts about diesel emissions that are of general applicability.

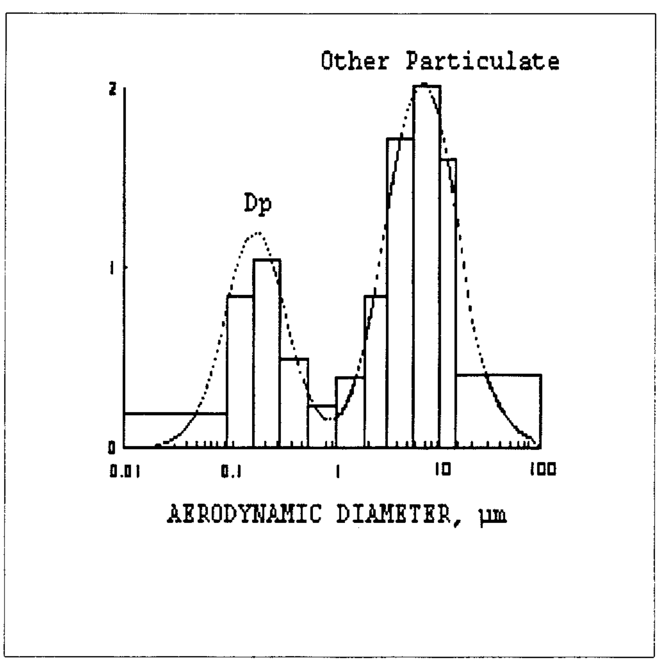
The gaseous constituents of diesel exhaust include oxides of carbon, nitrogen and sulfur, alkanes and alkenes (e.g., butadiene), aldehydes (e.g., formaldehyde), monocyclic aromatics (e.g., benzene, toluene), and polycyclic aromatic hydrocarbons (e.g., phenanthrene, fluoranthene). The oxides of nitrogen (NO_x) are worth particular mention because in the atmosphere they can precipitate into particulate matter. Thus, controlling the emissions of NO_x is one way that engine manufacturers can control particulate production indirectly. (See Section 4 of this part.)

The particulate fraction of diesel exhaust—what is known as soot—is made up of very small individual particles. Each particle consists of an insoluble, elemental carbon core and an adsorbed, surface coating of relatively soluble organic carbon (hydrocarbon) compounds. There can be up to 1,800 different organic compounds adsorbed onto the elemental carbon core. A portion of this hydrocarbon material is the result of incomplete combustion of fuel; however, the majority is derived from the engine lube oil. In addition, the diesel particles contain a fraction of non-organic adsorbed materials.

Diesel particles released to the atmosphere can be in the form of individual particles or chain aggregates (Vuk, Jones, and Johnson, 1976). In underground coal mines, more than 90% of these particles and chain aggregates are submicrometer in size—i.e., less than 1 micrometer (1 micron) in diameter. In underground metal and nonmetal mines, a greater portion of the aggregates may be larger than 1 micron in size because of the equipment used. Dust generated by mining and crushing of material—e.g., silica dust, coal dust, rock dust—is generally not submicrometer in size.

Figure II–1 shows a typical size distribution of the particles found in the environment of a mine that uses equipment powered by diesel engines (Cantrell and Rubow, 1992). The vertical axis represents relative concentration, and the horizontal axis the particle diameter. As can be seen, the distribution is bimodal, with dpm generally being well less than 1 µm in size and dust generated by the mining process being well greater than 1 µm. Because of their small size, even when diesel particles are present in large quantities, the environment might not be perceived as ''dusty''. Rather, the perception might be primarily of a vaporous, dirty and smelly ''soot'' or ''smoke''.

Figure II-1 -Typical distribution of dpm relative to distribution of other mining particulates.



The particulate nature of diesel soot has special significance for the mining community, which has a history of significant health and safety problems associated with dusts in the mining atmosphere. As a result of this long experience, the mining community is familiar with the standard techniques to control particulate concentrations. It knows how to use ventilation systems, for example, to reduce dust levels in underground mines. It knows how to water down particulates capable of being impacted by that approach, and to divert particulates away from where miners are actively working. Moreover, the mining community has long experience in the sampling and measurement of particulates—and in all the problems associated therewith. Miners and mine operators are very familiar with sampling devices that are worn by miners during normal work activities or placed in specific locations to collect dust. They understand the significance of sample integrity, the validity of laboratory analysis, and the concept of statistical error in individual samples. They know that weather and mine conditions can affect particulate production, as can changes in mine operations in an area of the mine. MSHA and the former Bureau of Mines have conducted considerable research into these topics. While the mining community has often argued over these points, and continues to do so, the sophistication of the arguments reflects the thorough familiarity of the mining community with particulate sampling and analysis techniques.

(3) *Methods Available to Measure DPM.* There are a number of methods which can measure dpm concentrations with reasonable accuracy when it is at high concentrations and when the purpose is exposure assessment. Measurements for the purpose of compliance determinations must be more accurate, especially if they are to measure compliance with a dpm concentration as low as 200 µg/m^3 or lower. It is with these considerations in mind that MSHA has carefully analyzed the available methods for measuring dpm.

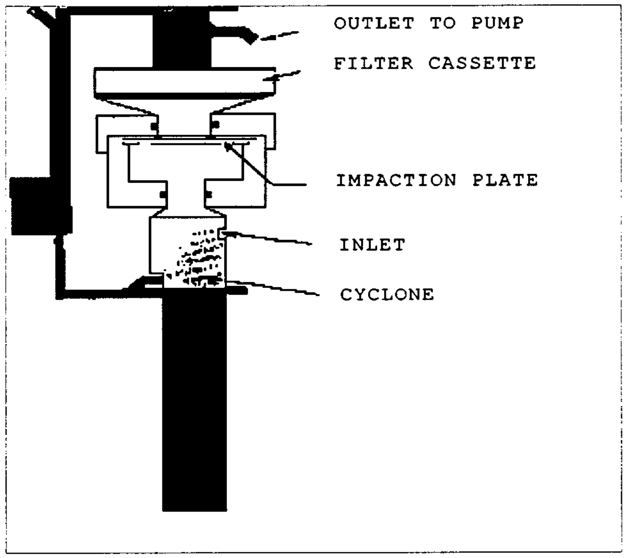
Comments. In its advanced notice of proposed rulemaking (ANPRM) in 1992, MSHA sought information on whether there are methodologies available for assessing occupational exposures to diesel particulate.

Some commenters argued that at that time there was no validated sampling method for diesel exhaust and there had been no valid analytical method developed to determine the concentration of diesel exhaust. According to the American Mining Congress, (AMC 1992), sampling methods commonly in use were prototypic in nature, were primarily being utilized by government agencies and were subject to interference. Commenters also stated that sampling instrumentation was not commercially available and that the analytical procedures could only be conducted in a limited number of laboratories. Several industry commenters submitted results of studies to support their position on problems with measuring diesel particulate in underground mines. A problem with sampler performance was noted in a study using prototype dichotomous sampling devices. Another commenter indicated that the prototype sampler developed by the former Bureau of Mines (discussed later in this section) for collecting the submicrometer respirable dust was difficult to assemble but easy to use, and that no problems were encountered. Problems associated with gravimetric analysis were also noted in assessing a short term exposure limit (STEL). Another commenter (Morton, 1992) indicated the cost of the sampling was prohibitive.

Another issue addressed by commenters to the 1992 ANPRM was ‘‘Are existing sampling and exposure monitoring methods sufficiently sensitive, accurate and reliable?’’ If not, what methods would be more suitable? Some commenters indicated their views that sampling methods had not been validated at that time for compliance sampling. They asserted that, depending on the level of measurement, both the size selective and elemental carbon techniques have some utility. The measurement devices give a precise measurement; however, because of interferants, corrections may need to be made to obtain an accurate measurement. Commenters also expressed the view that all of the sampling devices are sophisticated and require some expertise to assemble and analyze the results, and that MSHA should rely on outside agencies to evaluate and validate the sampling methods. An on-board sampler being developed by Michigan Technological University was the only other emission measurement technology discussed in the comments. However, this device is still in the development stage. Another commenter indicated that the standard should be based on the hazard and that the standard would force the development of measurement technology.

Submicrometer Sampling. The former Bureau of Mines (BOM) submitted information on the development of a prototype dichotomous impactor sampling device that separates and collects the submicrometer respirable particulate from the respirable dust sampled (See Figure II–2).

Figure II- 2
Personal Sampler For Submicrometer Particulate Sampling



The sampling device was designed to help measure dpm in coal mine environments, where, as noted in the last section of this part, nearly all the dpm is submicrometer (less than 1 micron) in size. In its submission to MSHA, the former BOM noted it had redesigned a prototype and had verified the sampler's performance through laboratory and field tests.

As used by the former BOM in its research, the submicrometer respirable particulate was collected on a pre-weighed filter. Post-weighing of the filter provides a measure of the submicrometer respirable particulate. The relative insensitivity of the gravimetric method only allows for a lower limit of detection of approximately 200 $\mu g/m^3$.

Because submicrometer respirable particulate can contain particulate material other than diesel particulate, measurements can be subject to interference from other submicrometer particulate material.

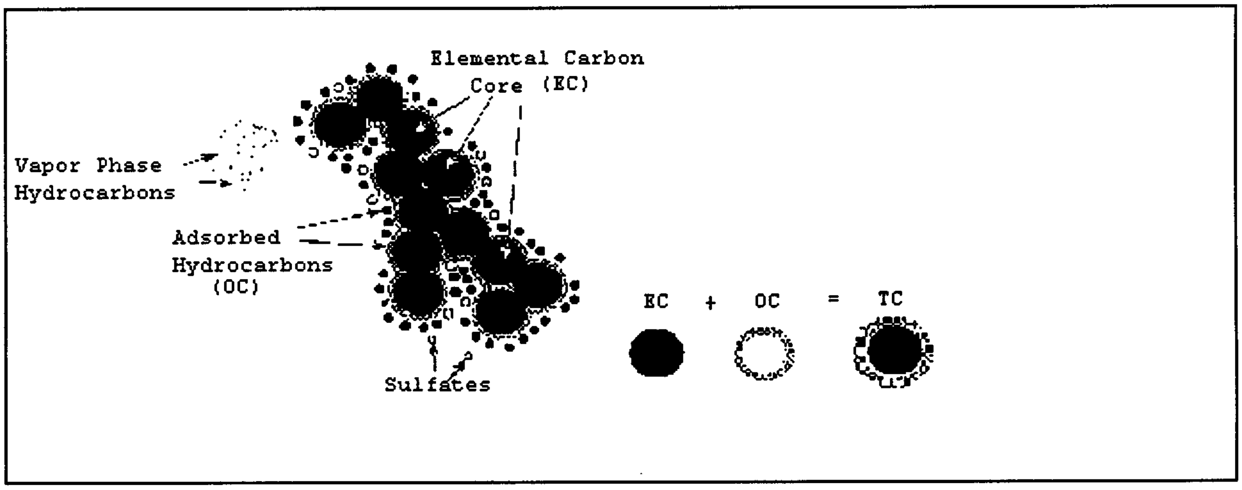
NIOSH Method 5040. In response to the ANPRM, NIOSH submitted information relative to the development of a sampling and analytical method to assess the diesel particulate concentration in an environment by measuring the amount of total carbon.

As discussed earlier in this part, diesel particulate consists of a core of elemental carbon (EC), adsorbed organic carbon (OC) compounds, sulfates, vapor phase hydrocarbons and traces of other compounds. The method developed by NIOSH provides for the collection of a sample on a quartz fiber filter. The filter is mounted in an open face filter holder that allows for the sample to be uniformly deposited on the filter surface. After sampling, a section of the filter is analyzed using a thermal-optical technique (Birch and Cary, 1996). This technique allows the EC and OC species to be separately identified and quantified. Adding the EC and OC species together provides a measure of the total carbon concentration in the environment. This is indicated diagrammatically in Figure II–3.

Studies have shown that the sum of the carbon (C) components (EC+OC) associated with dpm accounts for 80–85% of the total dpm concentration when low sulfur fuel is used (Birch and Cary, 1996). Since the TC:DPM relationship is consistent, it provides a method for determining the amount of dpm.

The method can detect as little as 1 µ g/m3 of TC. Moreover, NIOSH has investigated the method and found it to meet NIOSH's accuracy criterion (NIOSH, 1995); i.e., that measurements come within 25 percent of the true TC concentration at least 95 percent of the time.

Figure II-3
DPM components



NIOSH Method 5040 is directly applicable for the determination of diesel particulate levels in underground metal and nonmetal mines. The only potential sources of carbon in such mines would be organic carbon from oil mist and cigarette smoke. Oil mist may occur when diesel equipment malfunctions or is in need of maintenance.

MSHA, currently, has no data as to the frequency of occurrence or the magnitude of the potential interference from oil mist. However, during studies conducted by MSHA to evaluate different methods used to measure diesel particulate concentrations in underground mines, MSHA has not encountered situations where oil mist was found to be an interferant. Moreover, the Agency assumes that full operator implementation of maintenance standards to minimize dpm emissions (which are part of MSHA's proposed rule) will minimize any remaining potential for such interference. MSHA welcomes comments or data relative to oil mist interference. Cigarette smoke is under the control of operators, during sampling times in particular, and hence should not be a consideration.

While samples in underground metal and nonmetal mines could be taken with a submicrometer impactor, this could lead to underestimating the total amount of dpm present. This is because the fraction of dpm particles greater than 1 micron in size in the environment of noncoal mines can be as great as 20% (Vuk, Jones, and Johnson, 1976).

When sampling diesel particulate in coal mines, the NIOSH method recommends that a specialized impactor with a submicrometer cut point, such as the one developed by the former BOM, be used. Use of the submicron impactor minimizes the collection of coal particles, which have an organic carbon content. However, if 10% of coal particles are submicron, this means that up to 200 micrograms of submicrometer coal dust could be collected in face areas under current coal dust standards. Accordingly, for samples collected in underground coal mines, an adjustment may have to be made for interference from submicrometer coal dust; however, outby areas where little coal mine dust is present may not need such an adjustment.

NIOSH further recommends that in using its method in coal mines, the sample only be analyzed for the EC component. Measuring only the EC component ensures that only diesel particulate material is being measured in such cases. However, there are no established relationships between the concentration of EC and total dpm under various operating conditions. (The organic carbon component of dpm can vary with engine type and duty cycle; hence, the amount of whole dpm present for a measured amount of EC may vary). The Agency welcomes data and suggestions that would help it ascertain if and how measurements of submicrometer elemental carbon could realistically be used to measure dpm concentrations in underground coal mines.

Although NIOSH Method 5040 requires no specialized equipment for collecting a dpm sample, the sample would most probably require analysis by a commercial laboratory. MSHA recognizes that the number of laboratories currently capable of analyzing samples using the thermal-optical method is limited. However, there are numerous laboratories available that have the ability to perform a TC analysis without identifying the different species of carbon in the sample. Total carbon determinations using these laboratories would provide the mine with good information relative to the levels of dpm to which miners are potentially exposed. MSHA believes that once there is a need (e.g., as a result of the requirements of the proposed rule), more commercial laboratories will develop the capability to analyze dpm samples using the thermo-optical analytical method. Currently, the cost to analyze a submicrometer particulate sample for its TC content ranges from $30 to $50. This cost is consistent with costs associated with similar analysis of minerals such as quartz.

RCD Method. Another method, referred to as the Respirable Combustible Dust Method (RCD), has been developed in Canada for measuring dpm concentrations in noncoal mines. Respirable dust is collected with a respirable dust sampler consisting of a 10 millimeter nylon cyclone and a filter capsule containing a preweighed, preconditioned silver membrane filter. Samples are collected at a flow rate of 1.7 liters per minute. The respirable sample collected includes both combustible and noncombustible particulate matter.

Samples collected in accordance with the RCD method require analysis by a commercial laboratory. Total respirable dust is determined gravimetrically by weighing the filter after the sample is collected. After the sample has been subjected to a controlled combustion process at 400 °C for two hours, the remainder of the sample is weighed, and the amount of the particulate burned off determined by subtraction. This is the RCD. The combustible particulate matter consists of the soluble organic fraction, the EC core of the dpm, and any other combustible material collected. Thus, only a portion of the RCD is attributable to dpm. Oil mist and other combustible matter collected on the filter are interferants that can affect the accuracy of dpm concentration determination using this method. Because the mass of RCD is determined by weighing, the relative insensitivity of this method is similar to that obtained with the size selective gravimetric method (approximately 200 $\mu g/m^3$).

One commenter (Inco Limited) indicated experience with this method for identifying diesel particulate in their mining operations and suggested that this technique may be appropriate for determining eight hour exposures. Although this method was commonly used by the commenter for assessing dpm levels, concerns for the efficiency of the cyclones used to sample the respirable fraction of the particulate along with interference from oil mist were expressed.

Canada is now experimenting with the use of a submicron impactor with the RCD method.

Sampler Availability. The components for conducting sampling according to the submicrometer and the RCD methods are commercially available, as are those for NIOSH Method 5040, without a submicrometer particulate separator (impactor).

A reusable impactor can be manufactured by machine shops following the design specifications developed by the former U.S. Bureau of Mines (BOM IC 9324, 1992). The use of the size-selective samplers requires some training and laboratory time to prepare the impaction plate and assemble the unit. The cost to manufacture the size-selective units is approximately $35.

In addition, MSHA has requested NIOSH to develop and provide a commercially available disposable submicrometer particulate separator that would be used with existing personal respirable dust sampling equipment. The commercially available separator will be manufactured according to design criteria specified by NIOSH. It is anticipated that other sampling instrument manufacturers will develop commercial units once there is an established need for such a sampling device.

Use of Alternative Surrogates to Assess DPM Concentrations. A number of commenters on the ANPRM indicated that a number of surrogates were available to monitor diesel particulate. Of the surrogates suggested, the most desirable to use would be carbon dioxide because of its ease of measurement. In 1992 the former Bureau of Mines (BOM IC 9324, 1992) reported on research being conducted to investigate the use of CO_2 as a surrogate to assess mine air quality where diesel equipment is utilized. However, because the relationship between CO_2 and other exhaust components depends on the number, type and duty cycle of the engines in operation, no acceptable measurement method based on the use of CO_2 has been developed.

(4) *Reducing Soot at the Source—Engine Standards.* One way to limit diesel particulate emissions is to redesign diesel engines so they produce fewer pollutants. Engine manufacturers around the world are being pressed to do this pursuant to environmental regulations. These cleaner engine requirements are sometimes referred to as tailpipe standards because compliance is measured by checking for pollutants as the exhaust emerges from the engine's tailpipe—before any aftertreatment devices. This section reviews developments in this area, and explains the relationship between the environmental standards on new engines and MSHA engine ''approval'' requirements.

The Clean Air Act and Mobile Sources. The Clean Air Act authorized the Federal Environmental Protection Agency (EPA) to establish nationwide standards for new mobile vehicles, including those powered by diesel engines. These standards are designed, over time, to reduce the volume of certain harmful atmospheric pollutants emanating from mobile sources: particulate matter, nitrogen oxides (which as previously noted, can result in the generation of particulates in the atmosphere), hydrocarbons and carbon monoxide.

California has its own standards. New engines destined for use in California must meet standards under the law of that State. The standards are issued and administered by the California Air Resources Board (CARB). In recent years, EPA and CARB have worked together with industry in establishing their respective standards, so most of them are identical.

Regulatory responsibility for implementation of the Clean Air Act is vested in the Office of Mobile Sources (OMS), part of the Office of Air and Radiation of the EPA. Some of the discussion which follows was derived from materials which can be accessed from the OMS home page on the World Wide Web at (http://www.epa.gov/docs/omswww/omshome.htm). Information about the CARB standards may be found at the home page of that agency at (http://www.arbis.arb.ca.gov/homepage.htm).

Engines are generally divided into three broad categories for purposes of environmental emissions standards, in accordance with the primary use for which the type of engine is designed: (1) cars and light duty trucks (i.e., to power passenger transport); (2) heavy duty trucks (i.e., to power over-the-road hauling); and (3) nonroad vehicles (i.e., to power small equipment, construction equipment, locomotives and other non-highway uses). Engines used in mining equipment are not regulated as a separate category in this regard, but engines in all three categories are engaged in mining work, from generator sets to pickup trucks to huge earth movers and haulers.

New vs. Used. The environmental tailpipe requirements are applicable only to new engines. In the mining industry, used engines are often purchased; and, of course, the existing fleet consists of engines that are not new. Thus, although these tailpipe requirements will bring about gradual reduction in the overall contribution of diesel pollution to the atmosphere, the beneficial effects on mining atmospheres may require a longer timeframe, absent actions to accelerate the turnover of mining fleets to the cleaner engines.

In underground coal mining, MSHA has already taken actions which will have such an effect on the fleet. The diesel equipment rule issued in late 1996 requires that by November 25, 1999, all diesel equipment used in underground coal mines use an approved engine and maintain that engine in approved condition (30 CFR 75.1907). MSHA expects this will result in the replacement of about 47 percent of the diesel engines now in the underground coal mine inventory with engines that emit fewer pollutants. The timeframe permitted for the turnover was based upon MSHA's estimates of the useful life in an underground mining environment of the ''outby'' equipment involved.

Technology-Forcing Schedule. As noted above, the exact environmental tailpipe requirements which a new diesel engine must meet varies with the date of manufacture. The Clean Air Act, which was most recently amended in 1990, establishes a schedule for the reduction of particular pollutants from mobile sources. EPA and CARB, working closely with the diesel engine industry, have endeavored to turn this into a regulatory schedule that forces technology while taking into account certain technological realities (e.g., actions taken to reduce particulate emissions may increase NO_X emissions, and vice versa). Existing EPA regulations for on-highway engines (both for light duty vehicles and heavy duty trucks) and non-road engines schedule the tailpipe standards that must be met for the rest of this century. Agreements between EPA, CARB and the engine industry are now leading to proposed rules for engine standards to be met during the early part of the next century. These standards will be stricter and will lower the levels of diesel emissions.

Light-Duty Engines. The current regulations on light duty vehicle engines (cars and passenger trucks) were set in 1991 (56 FR 25724). EPA is currently considering proposing new standards for this category. Pursuant to a specific requirement in the Clean Air Act Amendments of 1990, EPA is to study and report to Congress on whether further reductions in this category should be pursued. A public workshop was held in the Spring of 1997. EPA plans provide for a draft report to be available for public comment by Spring of 1998, and a final report completed by July 1998, although a notice of citizen suit has been filed to speed the process. Up-to-date information about the progress of this initiative can be found at the home page for the study (http://www.epa.gov/omswww/tr2home.htm).

On-highway Heavy Duty Truck Engines. The first phase of the on-highway standards for heavy duty diesel engines was applicable to engines manufactured in 1985 (40 CFR 86.085–11). For the first time, separate standards for nitrogen oxide (NO_X) and hydrocarbons (HC) were established. The nitrogen oxides and hydrocarbons are precursors of ground level ozone, a major component of smog. A number of hydrocarbons are also toxic, while nitrogen oxides contribute to the formation of acid rain and can, as previously noted, precipitate into particulate matter. In 1988, a specific standard limiting particulate matter emitted from the heavy duty on-highway diesel engines went into effect (40 CFR 86.088–11). The Clean Air Act Amendments and the regulations provided for phasing in even tighter controls on NO_X and particulate matter through 1998. Reductions in NO_X took place in 1990 and 1991 and are to occur again in 1998, and reductions in PM took place in 1991 and 1994. Certain types of trucks in particularly polluted urban areas must reach even tighter requirements.

On October 21, 1997, EPA issued a new rule for on-highway engines that will take effect for engine model years starting in 2004 (62 FR 54693). The rule establishes a combined requirement for NO_X and HC. The combined standard is set at 2.5gm/bhp-hr, which includes a cap of 0.5gm/bhp-hr for HC. Prior to the rule, the EPA, CARB, and the engine manufacturers signed a Statement of Principles (SOP) that agreed on harmonization of the emission standards and the feasible levels that could be achieved. The rule allows manufacturers a choice of two combinations of NO_X and HC, with a net expected reduction in NO_X emissions of 50%. The rule does not require further reductions in tailpipe emissions of PM.

Non-road Engines. Of particular interest to the mining community is the EPA's regulatory work on the standards that will be applicable to non-road engines, for these include the engines used in the heaviest mining equipment.

The 1990 Clean Air Act Amendments specifically directed EPA to study the contribution of nonroad engines to air pollution, and regulate them if warranted. In 1991, EPA released a study that documented higher than expected emission levels across a broad spectrum of nonroad engines and equipment (EPA Fact Sheet, EPA420–F–96–009, 1996). In response, EPA initiated several regulatory programs. One of these set emission standards for land-based nonroad engines greater than 50 horsepower (other than for rail use). Limits are established for tailpipe emissions of hydrocarbons, carbon monoxide, NO_X, and dpm. The limits are phased in from 1996 to 2000: starting in 1996 with nonroad engines from 175 to 750 hp, then smaller engines, and by 2000 the larger nonroad engines. Moreover, in February 1997, restrictions on nonroad engines for locomotives were proposed (62 FR 6366).

In September 1996, EPA announced another Statement of Principles (SOP) with the engine industry and CARB on new rounds of restrictions for non-road engines to begin to take place in this century. This led in September 1997 to a proposed rule setting standards for almost all types of engines in this category manufactured after 1999–2006 (the actual year depends on the category) (62 FR 50151). The applicable standards for an engine category would be gradually tightened through three tiers. They would set a cap on the combined NO_X and HC (similar to the on-highway), set CO standards, and lower standards on PM. The implementation of the final tier of the proposed reductions is subject to a technology review in 2001 to ensure that the appropriateness of the levels to be set is feasible.

Will the Diesel Engine Industry Meet Mining Industry Requirements? Concern has been expressed from time to time that the diesel industry might not be able to meet the ever tightening standards on tailpipe emissions, and might, therefore, stop producing certain engines needed by the mining community or other industries (Gushee, 1995). To date, however, such concerns have not been realized. The fact that the most recent regulations have been developed through a consensus process with the engine industry, and that the non-road plan includes a scheduled technology review to ensure the proposed emission standards can really be achieved, suggests that although the EPA standards are technology forcing, diesel engines will continue to be available to meet the needs of the mining community for the foreseeable future. In addition, the nonroad engine agreement with the industry calls for development of a separate research agreement involving stakeholders in the exploration of technologies that can achieve very low emission levels of NO_X and PM ''while preserving performance, reliability, durability, safety, efficiency, and compatibility with nonroad equipment'' (EPA420–F–96–015, September 1996). Also, Vice President Gore has recently noted that the Administration is committed to emissions research that would clean up both the diesels currently on the road, as well as enabling these engines an opportunity to compete as a new generation of vehicles is developed that are far more efficient than today's vehicles (White House Press Release, July 23, 1997). It is always possible, of course, that some new technological problems could emerge that could impact diesel engine availability—e.g., confirmation that some of the newer engines produce high levels of ''nanoparticles'' particulates and that such emissions pose some sort of a health problem. Research of nanoparticles and their health effects is currently a topic of investigation (Bagley et al., 1996).

A related question has been whether the costs of the ''high-tech'' diesel engines will make them unaffordable in practice to the mining community.

MSHA believes the new engines will be affordable. The fact that the engine industry has agreed to the new standards, and has some assurance of what the applicable standards will be for the foreseeable future, should help keep costs in check.

In theory, underground mines can control costs by purchasing certain types of new engines that do not have to meet the new EPA standards. The rules on heavy duty on-highway truck engines were not applied to engines intended to be used in underground coal mines (59 FR 31336), and the new proposed rules on nonroad vehicles would likewise not be mandatory for engines intended for any underground mining use. In practice, however, it is not likely that engine manufacturers will produce special engines once they switch over their production lines to meet the new EPA standards, because there are few types and sizes of engines in production for which the mining community is the major market. Moreover, the larger engines (above 750 hp) are specifically covered by the EPA nonroad rules (*Engine Manufacturers Assn.* v. *EPA*, 88 F.3d 1075, 319 U.S. App.D.C. 12 (1996).

MSHA Approved Engines. Acting under its own authority to protect miner safety and health, MSHA requires that diesel engines used in certain types of mining operations be ''approved'' as meeting certain tailpipe standards.

In some ways, the standards are akin to those of EPA and CARB. For example, MSHA, CARB and EPA generally use the same tests to check emissions. MSHA uses a steady state, 8-mode test cycle, the same as EPA and CARB use to test engines designed for use in off-road equipment; however, EPA uses a different, transient test for on-highway engines.

But to be approved by MSHA, an engine does not have to be as clean as the newer diesel engines, every generation of which must meet ever tighter EPA and CARB tailpipe standards. Approval of an engine by MSHA merely ensures that the tailpipe emissions from that engine meet certain basic standards of cleanliness—cleaner than the engines which many mines continue to use.

The MSHA approval rules were revised in 1996 (as part of the 1996 rule on the use of diesel equipment in underground coal mines) to provide the mining community with additional information about the cleanliness of the emissions emerging from the tailpipe of various engines. Specifically, the agency now requires that a particulate index (PI) be reported as part of MSHA's engine approval. This index permits operators to evaluate the contribution of a proposed new addition to the fleet to the mine's particulate concentrations.

There is no requirement that approved engines meet a particular PI; rather, the requirement is for information purposes only. In its 1996 rulemaking addressing diesel equipment in underground coal mines, MSHA explicitly deferred until this rulemaking the question of whether to require engines used in mining environments to meet a particular PI (61 FR 55420–21, 55437). The Agency has decided not to take that approach, for the reasons discussed in Part V of this preamble.

(5) *Limiting the Public's Exposure to Soot—Ambient Air Quality Standards.* Pursuant to the Clean Air Act, EPA is responsible for setting air pollution standards to protect the public from toxic air contaminants. These include standards to limit exposure to particulate matter. The pressures to comply with these limits have an impact upon the mining industry, which contributes various types of particulate matter into the environment during mining operations, and a special impact on the coal mining industry whose product is used extensively in emission-generating power facilities. But those standards hold interest for the mining community in other ways as well, for underlying some of them is a large body of evidence on the harmful effects of airborne particulate matter on human health. Increasingly, that evidence has pointed toward the risks of the smallest particulates—including the particles generated by diesel engines.

This section provides an overview of EPA rulemaking on particulate matter. For more detailed information, commenters are referred to ''The Plain English Guide to the Clean Air Act,'' EPA 400–K–93–001, 1993, to the ''Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information'', EPA–452/R–96–013, 1996; and, on the latest rule, to EPA Fact Sheets, July 17, 1997. These and other documents are available from EPA's Web site.

Background. Air quality standards involve a two-step process: standard setting by EPA, and implementation by each State.

Under the law, EPA is specifically responsible for reviewing the scientific literature concerning air pollutants, and establishing and revising National Ambient Air Quality Standards (NAAQS) to minimize the risks to health and the environment associated with such pollutants. It is supposed to do a review every five years. Feasibility of compliance by pollution sources is not supposed to be a factor in establishing NAAQS. Rather, EPA is required to set the level that provides ''an adequate margin of safety'' in protecting the health of the public.

Implementation of each national standard is the responsibility of the states. Each must develop a state implementation plan that ensures air quality in the state consistent with the ambient air quality standard. Thus, each state has a great deal of flexibility in targeting particular modes of emission (e.g., mobile or stationary, specific industry or all, public sources of emissions vs. private-sector sources), and in what requirements to impose on polluters. However, EPA must approve the state plans pursuant to criteria it establishes, and then take pollution measurements to determine whether all counties within the state are meeting each ambient air quality standard. An area not meeting an NAAQS is known as a ''nonattainment area''.

TSP. Particulate matter originates from all types of stationary, mobile and natural sources, and can also be created from the transformation of a variety of gaseous emissions from such sources. In the context of a global atmosphere, all these particles are mixed together, and both people and the environment are exposed to a ''particulate soup'' the chemical and physical properties of which vary greatly with time, region, meteorology, and source category. The first ambient air quality standards dealing with particulate matter did not distinguish among these particles. Rather, the EPA established a single NAAQS for ''total suspended particulates'', known as ''TSP.'' Under this approach, the states could come into compliance with the ambient air requirement by controlling any type or size of TSP. As long as the total TSP was under the NAAQS—which was established based on the science available in the 1970s—the state met the requirement.

PM_{10}. When the EPA completed a new review of the scientific evidence in the mid-eighties, its conclusions led it to revise the particulate NAAQS to focus more narrowly on those particulates less than 10 microns in diameter, or PM_{10}. The standard issued in 1987 contained two components: an annual average limit of 150 $\mu g/m^3$, and a 24-hour limit of 50 $\mu g/m^3$. This new standard required the states to reevaluate their situations and, if they had areas that exceeded the new PM_{10} limit, to refocus their compliance plans on reducing those particulates smaller than 10 microns in size. Sources of PM_{10} include power plants, iron and steel production, chemical and wood products

manufacturing, wind-blown and roadway fugitive dust, secondary aerosols and many natural sources.

Some state implementation plans required surface mines to take actions to help the state meet the PM_{10} standard. In particular, some surface mines in Western states were required to control the coarser particles—e.g., by spraying water on roadways to limit dust. The mining industry has objected to such controls, arguing that the coarser particles do not adversely impact health, and has sought to have them excluded from the EPA ambient air standards (Shea, 1995; comments of Newmont Gold Company, March 11, 1997, EPA docket number A–95–54, IV–D–2346).

$PM_{2.5}$. The next scientific review was completed in 1996, following suit by the American Lung Association and others. A proposed rule was published in November of 1996, and, after public hearings and review by the Office of the President, a final rule was promulgated on July 18, 1997 (62 FR 38651).

The new rule further modifies the standard for particulate matter. Under the new rule, the existing national ambient air quality standard for PM_{10} remains basically the same—an annual average limit of 150 $\mu g/m^3$ (with some adjustment as to how this is measured for compliance purposes), and a 24-hour ceiling of 50 $\mu g/m^3$. In addition, however, a new NAAQS has now been established for ''fine particulate matter'' that is less than 2.5 microns in size. The $PM_{2.5}$ annual limit is set at 15 $\mu g/m^3$, with a 24-hour ceiling of 65 $\mu g/m^3$.

The basis for the $PM_{2.5}$ NAAQS is a new body of scientific data suggesting that particles in this size range are the ones responsible for the most serious health effects associated with particulate matter. The evidence was thoroughly reviewed by a number of scientific panels through an extended process. (A chart of the scientific review process is available on EPA's web site—http://ttnwww.rtpnc.epa.gov/naaqspro/pmnaaqs.gif). The proposed rule resulted in considerable press attention, and hearings by Congress, in which this scientific evidence was further discussed. Following a careful review, President Clinton announced his concurrence with the rulemaking in light of the scientific evidence of risk. However, the implementation schedule for the rule is long enough so that the next review of the science is scheduled to be completed before the states are required to meet the new NAAQS for $PM_{2.5}$—hence, adjustment of the standard is still possible before implementation.

Implications for the Mining Community. As noted earlier in this part, diesel particulate matter is mostly less than 1.0 micron in size. It is, therefore, a fine particulate. The body of evidence of human health risk from environmental exposure to fine particulates must, therefore, be considered in assessing the risk of harm to miners of occupational exposure to one type of fine particulate—diesel particulate. MSHA has accordingly done so in its risk assessment (see Part III of this preamble).

(6) *Controlling Diesel Particulate Emissions in Mining—a Toolbox*. Efforts to control diesel particulate emissions have been under review for some time within the mining community, and accordingly, there is considerable practical information available about controls—both in general terms, and with respect to specific mining situations.

Workshops. In 1995, MSHA sponsored three workshops ''to bring together in a forum format the U.S. organizations who have a stake in limiting the exposure of miners to diesel particulate (including) mine operators, labor unions, trade organizations, engine manufacturers, fuel producers, exhaust aftertreatment manufacturers, and academia.'' (McAteer, 1995). The sessions provided an overview of the literature and of diesel particulate exposures in the mining industry, state-of-the-art technologies available for reducing diesel particulate levels, presentations on engineering technologies toward that end, and identification of possible strategies whereby miners' exposure to diesel particulate matter can be limited both practically and effectively. One workshop was held in Beckley, West Virginia on September 12 and 13, and the other two were held on October 6, and October 12 and 13, 1995, in Mt Vernon, Illinois and Salt Lake City, Utah, respectively. A transcript was made. During a speech early the next year, the Deputy Assistant Secretary for MSHA characterized what took place at these workshops:

> The biggest debate at the workshops was whether or not diesel exhaust causes lung cancer and whether MSHA should move to regulate exposures. Despite this debate, what emerged at the workshops was a general recognition and agreement that a health problem seems to exist with the current high levels of diesel exhaust exposure in the mines. One could observe that while all the debate about the studies and the level of risk was going on, something else interesting was happening at the workshops: one by one miners, mining companies, and manufacturers began describing efforts already underway to reduce exposures. Many are actively trying to solve what they clearly recognize is a problem. Some mine operators had switched to low sulfur fuel that reduces particulate levels. Some had increased mine ventilation. One company had tried a soy-based fuel and found it lowered particulate levels. Several were instituting better maintenance techniques for equipment. Another had hired extra diesel mechanics. Several companies had purchased electronically controlled, cleaner, engines. Another was testing a prototype of a new filter system. Yet another was using disposable diesel exhaust filters. These were not all flawless attempts, nor were they all inexpensive. But one presenter after another described examples of serious efforts currently underway to reduce diesel emissions. (Hricko, 1996).

Toolbox. In March of 1997, MSHA issued, in draft form, a publication entitled ''Practical Ways to Control Exposure to Diesel Exhaust in Mining—a Toolbox''. The draft publication was disseminated by MSHA to all underground mines known to use diesel equipment and posted on MSHA's Web site. Following comment, the Toolbox was finalized in the Fall of 1997 and disseminated. For the convenience of the mining community, a copy is appended to the end of this document.

The material on controls is organized as a ''Toolbox'' so that mine operators have the option of choosing the control technology that is most applicable to their mining operation for reducing exposures to dpm. The Toolbox provides information about nine types of controls that can reduce dpm emissions or exposures: low emission engines; fuels; aftertreatment devices; ventilation; enclosed cabs; engine maintenance; work practices and training; fleet management; and respiratory protective equipment.

The Estimator. MSHA has developed a model that can help mine operators evaluate the effect of alternative controls on dpm concentrations. The model is in the form of a template that can be used on standard computer spreadsheet programs; as information about a new combination of controls is entered, the results are promptly displayed. A complete description of this model, referred to as ''the Estimator,'' and several examples, are presented in Part V of this preamble. MSHA intends to make this model widely available to the mining community, and hopes to receive comments in connection with this rulemaking based on the results of estimates conducted with this model.

History of diesel aftertreatment devices in mining. For many years, the majority of the experience has been with the use of oxidation catalytic converters (OCCs), but in more recent years both ceramic and paper filtration systems have also been used more widely.

OCCs began to be used in underground mines in the 1960's to control carbon monoxide, hydrocarbons and odor (Haney, Saseen, Waytulonis, 1997). That use has been widespread. It has been estimated that more than 10,000 OCCs have been put into the mining industry over the years (McKinnon, dpm Workshop, Beckley, WV, 1995).

When such catalysts are used in conjunction with low sulfur fuel, there is a reduction of up to 90 percent of carbon monoxide, hydrocarbons and aldehyde emissions, and nitric oxide can be transformed to nitrogen dioxide. Moreover, there is also an approximately 20 percent reduction in diesel particulate mass. The diesel particulate reduction comes from the elimination of the soluble organic compounds that, when condensed through the cooling phase in the exhaust, will attach to the elemental carbon cores of diesel particulate. Unfortunately, this effect is lost if the fuel contains more than 0.05 percent sulfur. In such cases, sulfates can be produced which "poison" the catalyst, severely reducing its life. With the use of low sulfur fuel, some engine manufacturers have certified diesel engines with catalytic converter systems to meet EPA requirements for lower particulate levels (see Section 4 of this part).

The particulate trapping capabilities of some OCCs are even higher. In 1995, the EPA implemented standards requiring older buses in urban areas to reduce the dpm emissions from rebuilt bus engines (40 CFR 85.1403). Aftertreatment manufacturers developed catalytic converter systems capable of reducing dpm by 25%. Such systems are available for larger diesel engines common in the underground metal and nonmetal sector.

Other types of aftertreatment devices capable of more significant reductions in particulate levels began to be developed for commercial applications following EPA rules in 1985 limiting diesel particulate emissions from heavy duty diesel engines. The wall flow type ceramic honeycomb diesel particulate filter system was initially the most promising approach (SAE, SP–735, 1988). However, due to the extensive work performed by the engine manufacturers on new technological designs of the diesel engine's combustion system, and the use of low sulfur fuel, particulate traps turned out to be unnecessary to comply with the EPA standards of the time.

While this work was underway, efforts were also being made to transfer this aftertreatment technology to the mining industry. The former Bureau of Mines investigated the use of catalyzed diesel particulate filters in underground mines in the United States (BOM, RI–9478, 1993). The investigation demonstrated that filters could work, but that there were problems associated with their use on individual unit installations, and the Bureau made recommendations for installation of ceramic filters on mining vehicles. But as noted by one commenter at one of the MSHA workshops in 1995, "while ceramic filters give good results early in their life cycle, they have a relatively short life, are very expensive and unreliable." (Ellington, dpm Workshop, Salt Lake City, UT, 1995).

Canadian mines also began to experiment with ceramic traps in the 1980's with similar results (BOM, IC 9324, 1992). Work in Canada today continues under the auspices of the Diesel Emission Evaluation Program (DEEP), established by the Canadian Centre for Mineral and Energy Technology in 1996 (DEEP Plenary Proceedings, November 1996). The goals of DEEP are to: (1) evaluate aerosol sampling and analytical methods for dpm; and (2) evaluate the in-mine performance and costs of various diesel exhaust control strategies.

Work with ceramic filters in the last few years has led to the development of the ceramic fiber wound filter cartridge (SAE, SP–1073, 1995). The ceramic fiber has been reported by the manufacturer to have dpm reduction efficiencies up to 80 percent. This system has been used on vehicles to comply with German requirements that all diesel engines used in confined areas be filtered. Other manufacturers have made the wall flow type ceramic honeycomb dpm filter system commercially available to meet the German standard. In the case of some engines, a choice of the two types is available; but depending upon horsepower, this may not always be the case.

In the early 1990's, MSHA worked with the former Bureau of Mines and a filter manufacturer to successfully develop and test a pleated paper filter for wet water scrubber systems of permissible diesel powered equipment. The dpm reduction from these filters has been determined in the field by the former BOM to be up to 95% (BOM, IC 9324). The same type of filter has been used in recently developed dry systems for permissible machines, with reported laboratory reductions in dpm of 98% (Paas, dpm Workshop, Beckley WV, 1995).

ANPRM Comments. The ANPRM requested information about several kinds of work practices that might be useful in reducing dpm concentrations. These comments were provided well before the workshops mentioned above, and before MSHA issued its diesel equipment standard for underground coal mines, and are thus somewhat dated. But, solely to illustrate the range of comments received, the following sections review the comments concerning certain work practices—fuel type, fuel additives, and maintenance practices.

Type of Diesel Fuel Required. It has been well established that the quality of diesel fuel influences emissions. Sulfur content, cetane number, aromatic content, density, viscosity, and volatility are interrelated fuel properties which can influence emissions. Sulfur content can have a significant effect on diesel emissions.

Use of low sulfur diesel fuel reduces the sulfate fraction of dpm matter emissions, reduces objectionable odors associated with diesel exhaust and allows oxidation catalysts to perform properly. The use of low sulfur fuel also reduces engine wear and maintenance costs. Fuel sulfur content is a particularly important parameter when the fuel is used in low emission diesel engines. Low sulfur diesel fuel is available nationwide due to EPA regulations (40 CFR Parts 80 and 86). In MSHA's ANPRM, information was requested on what reduction in concentration of diesel particulate can be achieved through the use of low sulfur fuel. Information was also solicited as to whether the use of low sulfur fuel reduces the hazard associated with diesel emissions.

Responses from commenters stated that there would be a positive reduction in particulate with the use of low sulfur fuel. One commenter stated that the brake specific exhaust emissions (grams/brake horsepower-hour) of particulate would decrease by about 0.06 g/bhp-hr for a fuel sulfur reduction of 0.25 weight percent sulfur. The particulate reduction effect is proportional to the change in sulfur content. Another commenter stated that a typical No. 2 diesel fuel containing 0.25 percent weight sulfur will include 1 to 1.6 grams of sulfate particulate per gallon of fuel consumed. A fuel containing 0.05 percent weight sulfur will reduce sulfate particulate to 0.2–0.3 grams per gallon of fuel consumed, an 80 percent reduction.

In responding to the question on whether reducing the sulfur content of the fuel will reduce the health hazard associated with diesel emissions, several commenters stated that they knew of no evidence that sulfur reduction reduces the hazard of the particulate. MSHA also is not aware of any data supporting the proposition that reducing the sulfur content of the fuel will reduce the health hazard associated with diesel emissions. However, in the preamble to the final rule for the EPA requirement for the use of low sulfur fuel, EPA stated that there were a number of benefits which could be attributed to lowering the sulfur content of diesel fuel. The first area was in exhaust aftertreatment technology. Reductions in fuel sulfur content will result in small reductions in sulfur compounds being emitted. This will cause the whole particulate concentration from the engine to be reduced. However, the number of carbon particles are is not reduced, therefore, the total carbon concentration would be the same.

The major benefit of using low sulfur fuel is that the reduction of sulfur allows for the use of some aftertreatment devices such as catalytic converters, and catalyzed particulate traps which were prohibited with fuels of high sulfur content (greater than 0.05 percent sulfur). The high sulfur content led to sulfate particulate that when passed through the catalytic converter or catalyzed traps was changed to sulfuric acid when the sulfates came in contact with water vapor. Using low sulfur fuel permits these devices to be used.

The second area of benefits that the EPA noted was that of reduced engine wear with the use of low sulfur fuel. Reducing engine wear will help maintain engines in their near manufactured condition that would help limit increases in particulate matter due to lack of maintenance or age of the engine.

Other questions posed in the ANPRM requested information concerning the differences in No. 1 and No. 2 diesel fuel regarding particulate formation; the current sulfur content of diesel fuel used in mines; and when would 0.05 percent sulfur fuel be available to the mining industry.

In response to those questions, commenters stated that a difference in No. 1 and No. 2 fuel regarding particulate formation would be that No. 1 fuel typically has less sulfur than No. 2 fuel and would therefore be expected to produce less particulate. Also, the No. 1 fuel has a lower density, boiling range and aromatic content and a higher cetane number. All of these fuel property differences tend to cause lower particulate emissions.

Commenters also stated that the sulfur content of fuels commercially available for diesel-powered equipment can vary from nearly zero to 1 percent. The national average sulfur content for commercial No. 2 diesel fuel is approximately 0.25 percent. One commenter stated that sulfur content varied from region to region and the National Institute of Petroleum and Energy Research survey could be used to get the answers for specific regions.

Commenters noted that low sulfur fuel, less than 0.05 percent sulfur, would be available for on-highway use as mandated by the EPA by October 1993. Also, California requires the statewide availability of 0.05 percent sulfur fuel for all diesel engine applications by the same date. Although the EPA mandate ensures that low sulfur fuel will be available throughout the nation, commenters indicated the availability for off-road and mining application was uncertain at that time.

The ANPRM also requested information on the differences in the per gallon costs among No. 1, No. 2 and 0.05 percent sulfur fuel; how much fuel is used annually in the mining industry; and what would be the economic impact on mining of using 0.05 percent sulfur fuel. In response, commenters stated that No. 1 fuel typically costs the user 10 to 20 percent more than does No. 2 fuel. They also stated that the price of 0.05 percent sulfur fuel will eventually be set by the competitive market conditions. No information was submitted for accurately estimating fuel usage costs to the industry. The economic impact on the mining industry of using 0.05 percent fuel will vary greatly from mine to mine. Factors influencing that cost are a mine's dependence on diesel powered equipment, the location of the mine and existing regulation. Mines relying heavily on diesel equipment will be most impacted.

Another commenter stated that the price for 0.05 percent fuel is forecast to average about 2 cents per gallon higher than the price for typical current No. 2 fuel. Kerosene and No. 1 distillate are forecast as 2 to 4 cents per gallon above 0.05 percent fuel and 4 to 6 cents above current No. 2 fuel. A recent census of mining and manufacturing dated 1987 showed mining industry energy consumption from all sources to total 1968.4 trillion BTU per year. Coal mining alone used 9.96 million barrels annually of distillate, at a cost of 258.1 million dollars. Included in these quantities was diesel fuel for surface equipment and vehicles at or around the mine site. The commenter also stated that applying a cost increase of 2 cents per gallon to the total industry distillate consumption would increase annual fuel costs by $24.3 million. For coal mining only, the cost increase would be $8.4 million annually.

While MSHA does not have an opinion on the accuracy of the information received in this regard, it is in any event dated. Since the time that the ANPRM was open, the availability of low sulfur fuel has become more common. Comments received at MSHA's Diesel Workshops indicate that low sulfur fuel is readily available and that all that is needed to obtain it is to specify the desired fuel quality on the purchase order. The differences in the fuel properties of No. 1 and No. 2 fuel are consistent with specifications provided by ASTM and other literature information concerning fuel properties.

Fuel Additives. Information relative to fuel additives was requested in MSHA's ANPRM. The ANPRM requested information on the availability of fuel additives that can reduce dpm or additives being developed; what diesel emissions reduction can be expected through the use of these fuel additives; the cost of additives and advantages to their use; and will these fuel additives introduce other health hazards. One commenter stated that cetane improvers and detergent additives can reduce dpm from 0 to 10 percent. The data, however, does not indicate consistent benefits as in the case with sulfur reduction. Oxygenate additives can give larger benefits, as with methanol, but then the oxygenate is not so much an additive as a fuel blend. Another commenter stated the cost depended on the price and concentration of the additive. This commenter estimated the cost to be between three and seven cents per gallon of fuel.

Another commenter stated that some additives are used for reducing injector tip fouling, other alternative additives also are offered specifically for the purpose of reducing smoke or dpm such as organometallic compounds, i.e., copper, barium, calcium, iron or platinum; oxygenate supplements containing alcohols or peroxides; and other proprietary hydrocarbons. The commenter did not quantify the expected reductions in dpm.

The former Bureau of Mines commented on an investigation of barium-based, manganese based, and ferrocene fuel additives. Details of the investigation are found in the literature (BOM, IC 9238, 1990). In general, fuel additives are not widely used by the mining industry to reduce dpm or to reduce regeneration temperatures in ceramic particulate filters. Research has shown aerosol reductions of about 30 percent without significant adverse impacts although new pollutants derived from the fuel additive remain a question.

One commenter stated that a cetane improver and detergent additives should not exceed 1 cent per gallon at the treat rates likely to be used. The use of oxygenates depends on which one and how much but would be perhaps an order of magnitude higher than the use of a cetane improver. One commenter also added that any fuel economy advantages would be very small.

In response to the creation of a health hazard when using additives, one commenter stated that excessive exposure to cetane improver (alkyl nitrates), which is hazardous to humans, requires special handling because of poor thermal stability. Detergent additives are similar to those used in gasoline and probably have similar safety and health issues. Except at low load operation, additives are not likely to result in any significant quantity in the exhaust. Another commenter stated that the effect on human health of new chemical exhaust species that may result from the use of some of these additives has not been determined. Engine manufacturers also are concerned about the use of such products because their effectiveness has not always been adequately demonstrated and, in many cases, the effect on engine durability has not been well-documented for different designs and operating conditions.

MSHA agrees with the commenters that fuel additives can affect engine performance and exhaust emissions. MSHA's experience with additives has shown that they can enhance fuel quality by increasing the cetane number, depressing the cloud point, or in the case of a barium based additive, affect the combustion process resulting in a reduction of particulate output. MSHA's experience also has shown that in most cases the effects of an additive on engine performance or emissions cannot be adequately determined without extensive research. The additives listed on EPA's list of ''registered additives'' meet the requirements of EPA's standards in 40 CFR Part 79.

MSHA is concerned about the use of untested fuel additives. A large number of additives are currently being marketed to reduce emissions. These additives include cetane improvers that increase the cetane number of the fuel, which may reduce emissions and improve starting; detergents that are used primarily to keep the fuel injectors clean; dispersants or surfactants that prevent the formation of thicker compounds that can form deposits on the fuel injectors or plug filters. While the use of many of these additives will result in reduced particulate emission, some have been found to introduce harmful agents into the environment. For this reason, it is a good idea to limit the use of additives to those that have been registered by the EPA.

Maintenance Practices. The ANPRM requested information concerning what maintenance procedures are effective in reducing diesel particulate emissions from existing diesel-powered equipment, and what additional maintenance procedures would be required in conjunction with anticipated developments of new diesel particulate reduction technology. Information was also requested about the amount of time to perform the maintenance procedures and if any, loss of production time.

Commenters stated that some maintenance procedures have a very dramatic impact on particulate emissions, while other procedures that are equally important for other reasons have little or no impact at all on particulates. Another commenter stated that maintenance procedures are intended to ensure that the engine operates and will continue to operate as intended. Such procedures will not reduce diesel particulate below that of the new, original equipment. A commenter stated that the diesel engine industry experience has demonstrated that emissions deterioration over the useful life of an engine is minimal.

Commenters stated that depending on the implied technology, the need for additional maintenance will be based on complexity of the control devices. Also, time for maintenance will be dependent on complexity of the control device. Some production loss will occur due to increased maintenance procedures.

MSHA agrees with the commenters' view that maintenance does affect engine emissions, some more dramatically than others. Research has clearly shown that without engine maintenance, all engine emissions will increase greatly. For example, the former Bureau of Mines, in conjunction with Southwest Research, conducted extensive research on the effects of maintenance on diesel engines which indicated this result (BOM contract H–0292009, 1979). MSHA agrees that emissions increase is minimal over the useful life of the engine only when proper maintenance is performed daily. However, MSHA believes that with the awareness of the increased maintenance, production may not be lost due to the increased time that the machines are able to operate without unwanted down time due to poor maintenance practices.

MSHA's diesel ''Toolbox'' includes an extensive discussion on the importance of maintenance. It reminds operators and diesel maintenance personnel of the basic systems on diesel engines that need to be maintained, and how to avoid various problems. It includes suggestions from others in the mining community, and information on their success or difficulties in this regard.

(7) *Existing Mining Standards that Limit Miner Exposure to Occupational Diesel Particulate Emissions.* MSHA already has in place various requirements that help to control miner exposure to diesel emissions in underground mines—including exposure to diesel particulate. These include ventilation requirements, engine approval requirements, and explicit restrictions on the concentration of various gases in the mine environment.

In addition, in 1996, MSHA promulgated a rule governing the use of diesel-powered equipment in underground coal mines (61 FR 55412). While the primary focus of the rulemaking was to promote the safe use of diesel engines in the hazardous environment of underground coal mines, various parts of the rule will help to control exposure to harmful diesel emissions in those mines. The new rule revised and updated MSHA's diesel engine approval requirements and the ventilation requirements for underground coal mines using diesel equipment, and established requirements concerning diesel fuel sulfur content and the idling, maintenance and emissions testing of diesel engines in underground coal mines.

Background. Beginning in the 1940s, mining regulations were promulgated to promote the safe and healthful use of diesel engines in underground mines. In 1944, Part 31 established procedures for limiting the gaseous emissions and establishing the recommended dilution air quantity for mine locomotives that use diesel fuel. In 1949, Part 32 established procedures for testing of mobile diesel-powered equipment for non-coal mines. In 1961, Part 36 was added to provide requirements for the use of diesel equipment in gassy noncoal mines, in which engines must be temperature controlled to prevent explosive hazards. These rules responded to research conducted by the former Bureau of Mines.

Continued research by the former Bureau of Mines in the 1950s and 1960s led to refinements of its ventilation recommendations, particularly when multiple engines are in use. An airflow of 100 to 250 cfm/bhp was recommended for engines that have a properly adjusted fuel to air ratio (Holtz, 1960). An additive ventilation requirement was recommended for operation of multiple diesel units, which could be relaxed based on the mine operating procedures. This approach was subsequently refined to become a 100–75–50 percent guideline (MSHA Policy Memorandum 81–19MM, 1981). Under this guideline, when multiple pieces of diesel equipment are operated, the required airflow on a split of air would be the sum of: (a) 100 percent of the nameplate quantity for the vehicle with the highest nameplate air quantity requirement; (b) 75 percent of the nameplate air quantity requirement of the vehicle with the next highest nameplate air quantity requirement; and (c) 50 percent of the nameplate airflow for each additional piece of diesel equipment.

Diesel Equipment Rule. On October 6, 1987, MSHA published in the **Federal Register** (52 FR 37381) a notice establishing a committee to advise the Secretary of Labor on health and safety standards related to the use of diesel-powered equipment in underground coal mines. The ''Mine Safety and Health Advisory Committee on Standards and Regulations for Diesel-Powered Equipment in Underground Coal Mines'' (the Advisory Committee) addressed three areas of concern: the approval of diesel-powered equipment, the safe use of diesel equipment in underground coal mines, and the protection of miners' health. The Advisory Committee submitted its recommendations in July 1988.

With respect to the approval of diesel-powered equipment, the Advisory Committee recommended that all diesel equipment except for a limited class, be approved for use in underground coal mines. This approval would involve both safety (e.g., fire suppression systems) and health factors (e.g., maximum exhaust emissions).

With respect to the safe use of diesel equipment in underground coal mines, the Advisory Committee recommended that standards be developed to address the safety aspects of the use of diesel equipment, including such concerns as equipment maintenance, training of mechanics, and the storage and transport of diesel fuel.

The Advisory Committee also made recommendations concerning miner health, discussed later in this section.

As a result of the Advisory Committee's recommendations on approval and safe use, MSHA developed and, on October 25, 1996, promulgated as a final rule, standards for the ''Approval, Exhaust Gas Monitoring, and Safety Requirements for the Use of Diesel-Powered Equipment in Underground Coal Mines'' (61 FR 55412).

The October 25, 1996 final rule on diesels focuses on the safe use of diesels in underground coal mines. Integrated requirements are established for the safe storage, handling, and transport of diesel fuel underground, training of mine personnel, minimum ventilating air quantities for diesel powered equipment, maintenance requirements, fire suppression, and design features for nonpermissible machines. While the focus was on safety, certain rules related to emissions are included in the final rule. For example, the final rule requires maintenance on diesel powered equipment. Regular maintenance on diesel powered equipment should keep the diesel engine and vehicle operation at its original or baseline condition. However, as a check that the maintenance is being performed, MSHA wrote a standard for checking the gaseous CO emission levels on permissible and heavy duty outby machines to determine the need for maintenance. The CO check requires that a regular repeatable loaded engine condition be run on a weekly basis and the CO measured. Carbon monoxide is a good indicator of engine condition. If the CO measurement increases to a higher concentration than what was normally measured during the past weekly checks, then a maintenance person would know that either the regular maintenance was missed or a problem has developed that is more significant than could be identified by a general daily maintenance program.

Consistent with the Advisory Committee's recommendation, the final rule, among other things, requires that virtually all diesel-powered engines used in underground coal mines be approved by MSHA (30 CFR Part 7 (approval requirements), Part 36 (permissible machines defined), and Part 75 (use of such equipment in underground coal mines). The approval requirements, among other things, are designed to require clean-burning engines in diesel-powered equipment (61 FR 55417). In promulgating the final rule, MSHA recognized that clean-burning engines are ''critically important'' to reducing toxic gasses to levels that can be controlled through ventilation. (Id.). To achieve the objective of clean-burning engines, the rule sets performance standards which must be met for virtually all diesel-powered equipment in underground coal mines (30 CFR Part 7).

Consistent with the recommendation of the Advisory Committee, the technical requirements for approved diesel engines include undiluted exhaust limits for carbon monoxide and oxides of nitrogen (61 FR 55419). As recommended by the Advisory Committee, the limits for these gasses are derived from existing 30 CFR Part 36 (61 FR 55419). Also, consistent with the recommendation of the Advisory Committee, the final rule requires that as part of the approval process, ventilating air quantities necessary to maintain the gaseous emissions of diesel engines within existing required ambient limits be set (61 FR 55420). As recommended by the Advisory Committee, the ventilating air quantities are required to appear on the engine's approval plate (61 FR 55421).

The final rule also implements the Advisory Committee's recommendation that a particulate index be set for diesel engines (61 FR 55421). Although, as discussed below, there is not yet a specific standard limiting miners' exposure to diesel particulate, the particulate index is nonetheless useful in providing information to the mining community so that operators can compare the particulate levels generated by different engines (61 FR 55421).

Also consistent with the recommendation of the Advisory Committee, the final rule addresses the monitoring and control of gaseous diesel exhaust emissions (30 CFR part 70; 61 FR 55413). In this regard, the final rule requires that mine operators take samples of carbon monoxide and nitrogen dioxide (61 FR 55413, 55430–55431). Samples exceeding an action level of 50 percent of the threshold limits set forth in 30 CFR 75.322, trigger corrective action by the mine operator (30 CFR part 70, 61 FR 55413). Also consistent with the Advisory Committee's recommendation, the final rule requires that diesel-powered equipment be adequately maintained (30 CFR 75.1914; 61 FR 55414). Among other things, as recommended by the Advisory Committee, the rule requires the weekly examination of diesel-powered equipment, including testing of undiluted exhaust emissions for certain types of equipment (30 CFR 75.1914(g)). In addition, consistent with the Advisory Committee's recommendation, operators are required to establish programs to ensure that those performing maintenance on diesel equipment are qualified (61 FR 55414). As explained in the preamble, maintenance requirements were included because of MSHA's recognition that inadequate equipment maintenance can, among other things, result in increased levels of harmful gaseous and particulate components from diesel exhaust (61 FR 55413–55414).

Consistent with the Advisory Committee's recommendation, the final rule also requires that underground coal mine operators use low sulfur diesel fuel (30 CFR 75.1901; 61 FR 55413). The use of low sulfur fuel lowers not only the amount of gaseous emissions, but also the amount of diesel particulate emissions. (Id.). To further reduce miners' exposure to diesel exhaust, the final rule prohibits operators from unnecessarily idling diesel-powered equipment (30 CFR 75.1916(d)).

Also consistent with the recommendation of the Advisory Committee, the final rule establishes minimum air quantity requirements in areas of underground coal mines where diesel-powered equipment is operated (30 CFR 75.325). As set forth in the preamble, MSHA believes that effective mine ventilation is a key component in the control of miners' exposure to gasses and particulate emissions generated by diesel equipment (61 FR 55433). The final rule also requires generally that mine operators maintain the approval plate quantity minimum airflow in areas of underground coal mines where diesel-powered equipment is operated (30 CFR 75.325 [3]).

The diesel equipment rule will help the mining community use diesel-powered equipment more safely in underground coal mines. As discussed throughout this preamble, the diesel equipment rule has many features which, though it was not their primary purpose, will incidently reduce harmful diesel emissions in underground coal mines—including the particulate component of these emissions. (The requirements of the diesel equipment rule are highlighted with a special typeface in MSHA's publication, ''Practical Ways to Control Exposure to Diesel Exhaust in Mining—a Toolbox''). An example is the requirement in the diesel equipment rule that all engines used in underground coal mines be approved engines, and be maintained in approved condition—thus reducing emissions at the source.

In developing this safety rule, however, MSHA did not explicitly consider the risks to miners of a working lifetime of dpm exposure at very high levels, nor the actions that could be taken to specifically reduce those exposure levels in underground coal mines. Moreover, the rule does not apply to the remainder of the mining industry, where the use of diesel machinery is much more intense than in underground coal.

Gas limits. Various organizations have established or recommended limits for many of the gasses occurring in diesel exhaust. Some of these are listed in Table II–2, together with information about the limits currently enforced by MSHA. MSHA requires mine operators to comply with gas specific threshold limit values (TLV(TM)s) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1972 (for coal mines) and in 1973 (for metal and nonmetal mines).

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[3] On December 23, 1997, the National Mining Association and Energy West Mining Company filed petitions for review of the final rule. *National Mining Association* v. *Secretary of Labor,* Nos. 96–1489 and 96–1490. These cases were consolidated and held in abeyance pending discussions between the mining industry and the Secretary. On March 19, 1998, petitioners filed an Unopposed Joint Motion for Voluntary Dismissal. In April 1998, the Court granted the Motion for Dismissal.

TABLE II-2 GASEOUS EXPOSURE LIMITS (PPM)

Pollutant	Range of Limits Recommended		MSHA Limits	
			Coal$_A$	M/NM$_B$
HCHO	0.016$_C$	0.3$_D$	2	2
CO	25$_D$	50	50	50
CO_2	5,000$_C$	5,000	5,000	5,000
NO	25$_{C,D,E}$	25	25	25
NO_2	1$_F$	3$_D$	5	5
SO_2	2$_{C,D}$	5$_E$	2	5

Table Notes:

A) ACGIH, 1972

B) ACGIH, 1973

C) NIOSH recommended exposure limit (REL), based on a 10-hour, time-weighted average

D) ACGIH, 1996

E) OSHA permissible exposure limit (PEL)

F) NIOSH recommends only a 1-ppm, 15-minutes, short-term exposure limit (STEL)

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In 1989, MSHA proposed changing some of these limits in the context of a proposed rule on air quality standards (54 FR 35760). Following opportunity for comment and hearings, a portion of that proposed rule, concerning control of drill dust, has been promulgated, but the other components are still under review. To change a limit at this point in time requires a regulatory action; the rule does not provide for their automatic updating.

(8) How Other Jurisdictions Are Restricting Occupational Exposure to Diesel Soot.

On April 9, 1998, MSHA published a proposed rule to limit the exposure of underground coal miners to dpm. With this proposed rule, MSHA's rulemaking is the first effort by the Federal government to deal with the special risks faced by workers exposed to diesel exhaust on the job—because, as described in detail in the Part III of this preamble, miner exposures are an order of magnitude above those of any other group of workers. But others have been looking at the problem of exposure to diesel soot.

MSHA's Final Rule for Underground Coal Mines. In 1996, MSHA published a final rule on addressing the safe use of diesels in underground coal mines. Integrated requirements are established for the safe storage, handling, and transport of diesel fuel underground, training of mine personnel, minimum ventilating air quantities for diesel powered equipment, maintenance requirements, fire suppression, and design features for nonpermissible machines.

States. As noted in the first section of this part, few underground coal mines now use diesel engines. Several states have had bans on the use of such equipment: Pennsylvania, West Virginia, and Ohio.

Recently, Pennsylvania has replaced its ban with a special law that permits the use of diesel-powered equipment in deep coal mines under certain circumstances. The Pennsylvania statute goes beyond MSHA's new regulation on the use of diesel-powered equipment in underground coal mines. Of particular interest is that it specifically addresses diesel particulate. The State did not set a limit on the exposure of miners to dpm, nor did it establish a limit on the concentration of dpm in deep coal mines. Rather, it approached the issue by imposing controls that will limit dpm emissions at the source.

First, all diesel engines used in underground deep coal mines in Pennsylvania must be MSHA-approved engines with an "exhaust emissions control and conditioning system" that meets certain tests. (Article II–A, Section 203–A, Exhaust Emission Controls). Among these are dpm emissions from each engine no greater than "an average concentration of 0.12 mg/m^3 diluted by fifty percent of the MSHA approval plate ventilation for that diesel engine." In addition, any exhaust emissions control and conditioning system must include a "Diesel Particulate Matter (DPM) filter capable of an average of ninety-five percent or greater reduction of dpm emissions." It also requires the use of an oxidation catalytic converter. Thus, the Pennsylvania statute requires the use of low-emitting engines, and then the use of aftertreatment devices that significantly reduce what particulates are emitted from these engines.

The Pennsylvania law also has a number of other requirements for the safe use of diesel-powered equipment in the particularly hazardous environments of underground coal mines. Many of these parallel the requirements in MSHA's rule. Like MSHA's requirements, they too can result in reducing miner exposure to diesel particulate—e.g., regular maintenance of diesel engines by qualified personnel and equipment operator examinations. The requirements in the Pennsylvania law take into account the need to maintain the aftertreatment devices required to control diesel particulate (see, e.g., Section 217–A (b)(6)).

West Virginia has also lifted its ban, subject to rules to be developed by a joint labor-management commission. MSHA understands that pursuant to the West Virginia law lifting the ban, the Commission has only a limited time to determine the applicable rules, or the matter is to be referred to an arbitrator for resolution.

Other Countries. Concerns about air pollution have been a major impetus for most countries' standards on vehicle emissions, including diesel particulate. Most industrialized nations recognize the fundamental principle that their citizens should be protected against recognized health risks from air pollution and that this requires the control of particulate such as diesel exhaust. In November of 1995, for example, the government of the United Kingdom recommended a limit on PM10, and noted it would be taking further actions to limit airborne particulate matter (including a special study of dust from surface minerals workings).

Concerns about international trade have been another impetus. Diesel engines are sold to an international market to power many types of industrial and nonindustrial machinery and equipment. The European Union manufacturers exported more than 50 percent of their products, mainly to South Korea, Taiwan, China, Australia, New Zealand and the United States. Germany and the United Kingdom, two major producers, have pushed for harmonized world standards to level the playing field among the various countries' engine producers and to simplify the acceptance of their products by other countries (Financial Times, 1996). This includes products that must be designed to meet pollution standards. The European Union (EU) is now considering a proposal to set an EU-wide standard for the control of the emission of pollutants from non-road mobile machinery (Official Journal of European Communities, 1995). The proposal would largely track that of the U.S. Environmental Protection Agency's final rule on the Control of Air Pollution Determination of Significance for Nonroad Sources and Emission Standards for New Nonroad Compression-Ignition Engines at or above 37 kilowatts (50 HP)p (discussed in Section 3 of this part of the preamble).

A third impetus to action has been the studies of the health effects of worker exposure to diesel exhaust—many of which have been epidemiological studies concerning workers in other countries. As noted in Part III of this preamble, the studies include cohorts of Swedish dock workers and bus garage workers, Canadian railway workers and miners, French workers, London transport workers, and Danish chimney sweeps.

Below, the agency summarizes some information obtained on exposure limits of other countries. Due to differences in regulatory schemes among nations considering the effects of diesel exhaust, countries which have addressed the issue are more likely to have issued recommendations rather than a mandatory maximum exposure limit. Some of these may have issued mandatory design features for diesel equipment to assist in achieving the recommended exposure level. Measurement systems also vary.

Germany. German legislation on dangerous substances classifies diesel engine emissions as carcinogenic. Therefore, diesel engines must be designed and operated using the latest technology to cut emissions. This always requires an examination to determine whether the respective operations and activities may be carried out using other types of less polluting equipment. If, as a result of the examination, it is decided that the use of diesel engines is necessary, measures must be instituted to reduce emissions. Such measures can include low-polluting diesel engines, low sulphur fuels, regular maintenance, and, where technology permits, the use of particulate traps. To reduce exposure levels further, diesel engine emissions may be regulated directly at the source; ventilation systems may be required to be installed.

The use of diesel vehicles in a fully or partly enclosed working space—such as in an underground mine—may be restricted by the government, depending on the necessary engine power or load capacity and on whether the relevant operation could be accomplished using a non-polluting vehicle, e.g. an electrically powered vehicle. When determining whether alternate equipment is to be used, the burden to the operator to use such equipment is also considered.

In April of 1997, the following permissible exposure limits (TRK[4]) for diesel engine emissions were instituted for workplaces in mining.

(1) non-coal underground mining and construction work: TRK = 0.3 mg/m^3 of colloid dust[5]
(2) other: TRK = 0.1 mg/m^3 of colloid dust
(3) The average concentration of diesel engine emissions within a period of 15 minutes should never be higher than four times the TRK value.

The TRK is ascertained by determining the fraction of elemental carbon in the colloid (fine) dust by coulometric analysis. Determining the fraction of elemental carbon always involves the determination of total organic carbon in the course of analysis. If the workplace analysis shows that the fraction of elemental carbon in total carbon (elemental carbon plus organic carbon) is lower than 50%, or is subject to major fluctuations, then the TRK limits total carbon in such workplaces to 0.15 mg/m^3.

Irrespective of the TRK levels, the following additional measures are considered necessary once the concentration reaches 0.1 mg/m^3 colloid dust:

(1) Informing employees concerned;
(2) Limited working hours for certain staff categories;
(3) Special working hours; and
(4) Medical checkups.

If concentrations continue to fail to meet the TRK level, the employer must:

(1) Provide appropriate, effective, hygienic breathing apparatus, and
(2) Ensure that workers are not kept at the workplace for longer than absolutely necessary and that health regulations are observed.

Workers must use the breathing apparatus if the TRK levels for diesel engine emissions at the work place are exceeded. Due to the interference of recognized analysis techniques in coal mining, it is currently impossible to ascertain exposure levels in the air in coal mines. As a consequence, the coal mining authorities require the use of special low-polluting engines in underground mining and impose special requirements on the supply of fresh air to the workplace.

European Standards. On April 21, 1997, the draft of a European directive that applied to emissions from non-road mobile machinery was prepared. The directive proposed technical measures that would result in a reduction in emissions from internal-combustion engines (gasoline and diesel) installed in non-road mobile machinery, and type-approval procedures that would provide uniformity among the member nations for the approval of these engines.

The directive proposed a two-stage process. Stage 1, proposed to begin December 31, 1997, was for three different engine categories:

—A: 130 kW <= P <= 560 kW,
—B: 75 kW <= P < 130 kW,
—C: 37 kW <= P < 75 kW.

Stage 2, proposed to begin December 31, 1999, consisted of four engine categories being phased-in over a four-year period:

—D: after December 31,1999 for engines of a power output of 18 kW <= P < 37 kW,
—E: after December 31, 2000 for engines of a power output of 130 kW <= P <= 560 kW,
—F: after December 31, 2001 for engines of a power output of 75 kW <= P < 130 kW,
—G: after December 31, 2002 for engines of a power output of 37 kW <= P <= 75 kW.

The emissions shown in the following table for carbon monoxide, hydrocarbons, oxides of nitrogen and particulates are to be met for the respective engine categories described for stage I.

Net power (P) (kW)	Carbon Monoxide (P) (g/kWh)	Hydrocarbons (HC) (g/kWh)	Oxides of Nitrogen (No_X) (g/kWh)	Particulates (PT) (g/kWh)
130 ≤ P < 560	5.0	1.3	9.2	0.54
75 ≤ P < 130	5.0	1.3	9.2	0.70
37 ≤ P < 75	6.5	1.3	9.2	0.85

The engine emission limits that have to be achieved for stage II are shown in the following table. The emissions limits shown are engine-out limits and are to be achieved before any aftertreatment device is used.

Net power (P) (kW)	Carbon Monoxide (P) (g/kWh)	Hydrocarbons (HC) (g/kWh)	Oxides of Nitrogen (No_X) (g/kWh)	Particulates (PT) (g/kWh)
130 ≤ P < 560	3.5	1.0	6.0	0.2
75 ≤ P < 130	5.0	1.0	6.0	0.3
37 ≤ P < 75	5.0	1.3	7.0	0.4
18 ≤ P < 37	5.5	1.5	8.0	0.8

[4] TRK is the technical exposure limit of a hazardous material that defines the concentration of gas, vapour or airborne particulates which is the minimum possible with current technology and which serves as a guide for necessary protective measures and monitoring in the workplace.

[5] Colloid dust is defined as that part of total respirable dust in a workplace that passes the alveolar ducts of the worker.

Canada (Related developments in Canada). The Mining and Minerals Research Laboratories (MMRL) of the Canada Centre for Mineral and Energy Technology (CANMET), an arm of the Federal Department of Natural Resources Canada (NRCAN), began work in the early 1970s to develop measurement tools and control technologies for diesel particulate matter (dpm). In 1978, I.W. French and Dr. Anne Mildon produced a CANMET-sponsored contract study entitled: ''Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions.'' In this document, an Air Quality Index (AQI) was developed involving several major diesel contaminants (CO, NO, NO2, SO2 and RCD—respirable combustible dust which is mostly dpm). These concentrations were divided by their then current permissible exposure limits, and the sum of the several ratios indicates the level of pollution in the mine atmosphere. The maximum value for this Index was fixed at 3.0. This criterion was determined by the known health hazard associated with small particle inhalation, and the known chemical composition of dpm, among other matters.

Subsequently, in 1986, the Canadian Ad hoc Diesel Committee was formed from all segments of the mining industry, including: mine operators, the labor force, equipment manufacturers, research agencies including CANMET, and Canadian regulatory bodies. The objective was the identification of major problems for research and development attention, the undertaking of the indicated studies, and the application of the results to reduce the impact of diesel machines on the health of underground miners.

In 1990–91, CANMET developed an RCD mine sampling protocol on behalf of the Ad hoc Committee. Then current underground sampling studies indicated an average ratio of RCD to dpm of 1.5. This factor accounted for the presence of other airborne combustible liquids including fuel, lubrication and particularly drilling oils, in addition to the dpm.

The original 1978 French-Mildon study was updated under a CANMET contract in 1990. It recommended that the dpm levels be reduced to 0.5 mg/m^3 (suggesting a corresponding RCD level of 0.75 mg/m^3).

However, in 1991, the AD HOC Committee decided to set an interim recommended RCD level of 1.5 mg/m^3 (the equivalent 1.0 mg/m^3). This value matched the then recommended, but not promulgated, MSHA 'Ventilation Index' value for dpm of 1.0 mg/m^3. Consequently, all of the North American mining industry then seemed to be accepting the same maximum levels of dpm.

It should be noted that for coal mine environments or other environments where a non-diesel carbonaceous aerosol is present, RCD analysis is not an appropriate measure of dpm levels.

Neither CANMET nor the Ad hoc Committee is a regulatory body. In Canada, mining is regulated by the individual provinces and territories. However, the federal laboratories provide: research and development facilities, advice based on research and development, and engine/machine certification services, in order to assist the provinces in their diesel-related mining regulatory functions.

Prior to the 1991 recommendation of the Ad hoc Committee, Quebec enacted regulations requiring: ventilation, a maximum of 0.25% sulfur content in diesel fuel; a prohibition on black smoke; exhaust cooling to a maximum temperature of 85°C; and the setting of maximum contaminant levels. Since 1997, new regulations add the CSA Standard for engine certification, a maximum RCD level of 1.5 mg/m^3, and the application of an exhaust treatment system.

Further, after the Ad hoc Committee recommendation was published in 1991 (RCDmax = 1.5 mg/m^3), various provinces took the following actions:

(1) Five provinces—British Columbia, Ontario, Quebec, New Brunswick, and Nova Scotia, and the Northwest Territories, adopted an RCD limit of 1.5 mg/m^3.

(2) Two others, Manitoba and Newfoundland/Labrador, have been adopting the ACGIH TLVs.

(3) Two provinces, Alberta and Saskatchewan, and the Yukon Territory, continue to have no dpm limit.

Most Canadian Inspectorates accept the CSA Standard for diesel machine/engine certification. This Standard specifies the undiluted Exhaust Quality Index (EQI) criterion for calculation of the ventilation in cfm, required for each diesel engine/machine. Fuel sulfur content, type of aftertreatment device and rated engine load factor are on-site, variable factors which may alter the ventilation ultimately required. Diesel fuel may not exceed 0.50% sulfur, and must have a minimum flash point of 52°C. However, most mines in Canada now use fuel containing less than 0.05% sulfur by weight.

In addition to limiting the RCD concentration, Ontario, established rules in 1994 that required diesel equipment to meet the Canadian Standards Association ''Non-Rail-Bound Diesel-Powered Machines for use in Non-Gassy Underground Mines'' (CSA M424.2–M90) Standard, excepting the ventilation assessment clauses. As far as fuel sulfur and flashpoint are concerned, Ontario is intending to change to: Smax = 0.05% from 0.25%, and maximum fuel flash point = 38°C from 52°C.

New Brunswick, in addition to limiting the RCD concentration, requires mine operators to submit an ambient air quality monitoring plan. Diesel engines above 100 horsepower must be certified, and there is a minimum ventilation requirement of 105 cfm/bhp.

Since 1996, the Ad hoc organization and the industry consortium called the Diesel Emissions Evaluation Program (DEEP) have been cooperating in a research and development program designed to reduce dpm levels in mines.

World Health Organization (WHO). Environmental Health Criteria 171 on ''Diesel Fuel and Exhaust Emissions'' is a 1996 monograph published under joint sponsorship of the United Nations Environment Programme, the International Labour Organisation, and the World Health Organization. The monograph provides a comprehensive review of the literature and evaluates the risks for human health and the environment from exposure to diesel fuel and exhaust emissions.

The following tables compiled in the monograph show diesel engine exhaust limits for various exhaust components and illustrate that there is international concern about the amount of diesel exhaust being released into the environment.

TABLE II–3.—INTERNATIONAL LIMIT VALUES FOR COMPONENTS OF DIESEL EXHAUST LIGHTDUTY VEHICLES (G/KM)

Region	Carbon monoxide	Nitrogen oxides	Hydrocarbons	Particulates	Comments
Austria	2.1	0.62	0.25	0.124	≤3.5t; since 1991; from 1995, adoption of European Union standards planned.

TABLE II–3.—INTERNATIONAL LIMIT VALUES FOR COMPONENTS OF DIESEL EXHAUST LIGHTDUTY VEHICLES (G/KM)—Continued

Region	Carbon monoxide	Nitrogen oxides	Hydrocarbons	Particulates	Comments
Canada	2.1	0.62	0.25	0.12	Since 1987.
European Union	2.72	0.97 (with hydrocarbons).		0.14	Since 1992.
	1.0	0.7		0.08	From 1996.
Finland					Since 1993.
Japan	2.1	0.7	0.62	None	Since 1986.
	2.1	0.5	0.4	0.2	Since 1994.
Sweden, Norway	2.1	0.62 (city)	0.25	0.124	≤3.5t; from motor year 1992.
		0.76 (highway)			
Switzerland	2.1	0.62 (city)	0.25	0.124	≤3.5t; since 1988; from 1995, adoption of European Union standard planned.
USA (California)	2.1–5.2	0.2–0.6	0.2–0.3 (except methane).	0.05 (up to 31 000 km).	Depending on mileage.
US Environmental Protection Agency.	2.1–2.6	0.6–0.8	0.2	0.05–0.12	Depending on mileage.

TABLE II–4.—INTERNATIONAL LIMIT VALUES FOR COMPONENTS OF DIESEL EXHAUST HEAVY-DUTY VEHICLES (G/KWH)

Region	Carbon monoxide	Nitrogen oxides	Hydro-carbons	Particulates	Comments
Austria	4.9	9.0	1.23	0.4	
Canada	15.5	5.0	1.3	0.25	g/bhp-h.
	15.5	5.0	1.3	0.1	g/bhp-h; from 1995–97.
European Union	4.5	8.0	1.1	0.36	Since 1992.
	4.0	7.0	1.1	0.15	From 1995–96.
Japan	7.4	5.0	2.9	0.7	Indirect injection engines.
	7.4	6.0	2.9	0.7	Direct injection engines.
Sweden	4.9	9.0	1.23	0.4	
USA	15.5	5.0	1.3	0.07	g/bhp-h; bus.
	15.5	4.0	1.3	0.1	g/bhp-h; truck.
	15.5	5.0	1.3	0.05	g/bhp-h; bus; from 1998
	15.5	4.0	1.3	0.1	g/bhp-h; truck; from 1998.

Adapted from Mercedes-Benz AG (1994b).

With respect to the protection of human health, the monograph states that the data reviewed supports the conclusion that inhalation of diesel exhaust is of concern with respect to both neoplastic and non-neoplastic diseases. The monograph found that diesel exhaust ''is probably carcinogenic to humans.'' It also states that the particulate phase appears to have the greatest effect on health, and both the particle core and the associated organic materials have biological activity, although the gas-phase components cannot be disregarded. The monograph recommends the following actions for the protection of human health:

(1) Diesel exhaust emissions should be controlled as part of the overall control of atmospheric pollution, particularly in urban environments.

(2) Emissions should be controlled strictly by regulatory inspections and prompt remedial actions.

(3) Urgent efforts should be made to reduce emissions, specifically of particulates, by changing exhaust train techniques, engine design, and fuel consumption.

(4) In the occupational environment, good work practices should be encouraged, and adequate ventilation must be provided to prevent excessive exposure.

The monograph made no recommendations as to what constitutes excessive exposure.

International Agency for Research on Cancer (IARC)

The carcinogenic risks for human beings were evaluated by a working group convened by the International Agency for Research on Cancer in 1988 (International Agency for Research on Cancer, 1989b). The conclusions were:

(1) There is sufficient evidence for the carcinogenicity in experimental animals of the whole diesel engine exhaust.

(2) There is inadequate evidence for the carcinogenicity in animals of gas-phase diesel engine exhaust (with particles removed).

(3) There is sufficient evidence for the carcinogenicity in experimental animals of extracts of diesel engine exhaust particles.

(4) There is limited evidence for the carcinogenicity in humans of engine exhausts (unspecified as from diesel or gasoline engines).

Overall IARC Evaluation

Diesel engine exhaust is probably carcinogenic to humans (Group 2A).

(9) *MSHA's Initiative To Limit Miner Exposure to Diesel Particulate—a Brief History of This Rulemaking and Related Actions*

As discussed in part III of this preamble, by the early 1980's, the evidence indicating that exposure to diesel exhaust might be harmful to miners, particularly in underground mines, had started to grow. As a result, formal agency actions were initiated to investigate this possibility and to determine what, if any, actions might be appropriate. These actions are summarized here in chronological sequence, without comment as to the basis of any action or conclusion.

In 1984, in accordance with the § 102(b) of the Mine Act, NIOSH established a standing Mine Health Research Advisory Committee to advise it on matters involving or related to mine health research. In turn, that group established a subgroup to determine if:

> * * * there is a scientific basis for developing a recommendation on the use of diesel equipment in underground mining operations and defining the limits of current knowledge, and recommending areas of research for NIOSH, if any, taking into account other investigators' ongoing and planned research. (49 FR 37174).

In 1985, MSHA established an Interagency Task Group with the National Institute for Occupational Safety and Health (NIOSH) and the former Bureau of Mines (BOM) to assess the health and safety implications of the use of diesel-powered equipment in underground coal mines. In part, as a result of the recommendation of the Task Group, MSHA, in April 1986, began drafting proposed regulations on the approval and use of diesel-powered equipment in underground coal mines. Also in 1986, the subgroup of the NIOSH advisory committee studying this issue summarized the evidence available at that time as follows:

> It is our opinion that although there are some data suggesting a small excess risk of adverse health effects associated with exposure to diesel exhaust, these data are not compelling enough to exclude diesels from underground mines. In cases where diesel equipment is used in mines, controls should be employed to minimize exposure to diesel exhaust. (Interagency Task Group Report, 1986).

As noted previously in Section 7 of this part, in discussing MSHA's diesel equipment rule, on October 6, 1987, pursuant to Section 102(c) of the Mine Act, 30 U.S.C. 812(c), MSHA appointed an advisory committee ''to provide advice on the complex issues concerning the use of diesel-powered equipment in underground coal mines.'' (52 FR 37381). MSHA appointed nine members to the Advisory Committee. As required by Section 101(a)(1), MSHA provided the Advisory Committee with draft regulations on the approval and use of diesel-powered equipment in underground coal mines. The draft regulations did not include standards setting specific limitations on diesel particulate, nor had MSHA at that time determined that such standards should be promulgated.

In July 1988, the Advisory Committee completed its work with the issuance of a report entitled ''Report of the Mine Safety and Health Administration Advisory Committee on Standards and Regulations for Diesel-Powered Equipment in Underground Coal Mines.'' The Advisory Committee recommended that MSHA promulgate standards governing the approval and use of diesel-powered equipment in underground coal mines. The Advisory Committee recommended that MSHA promulgate standards limiting underground coal miners' exposure to diesel exhaust.

With respect to diesel particulate, the Advisory Committee recommended that MSHA ''set in motion a mechanism whereby a diesel particulate standard can be set.'' (MSHA, 1988). In this regard, the Advisory Committee determined that because of inadequacies in the data on the health effects of diesel particulate matter and inadequacies in the technology for monitoring the amount of diesel particulate matter at that time, it could not recommend that MSHA promulgate a standard specifically limiting the level of diesel particulate matter. (*Id*. 64–65). Instead, the Advisory Committee recommended that MSHA request NIOSH and the former BOM to prioritize research in the development of sampling methods and devices for diesel particulate. The Advisory Committee also recommended that MSHA request a study on the chronic and acute effects of diesel emissions (*Id*). In addition, the Advisory Committee recommended that the control of diesel particulate ''be accomplished through a combination of measures including fuel requirements, equipment design, and in-mine controls such as the ventilation system and equipment maintenance in conjunction with undiluted exhaust measurements.'' The Advisory Committee further recommended that particulate emissions ''be evaluated in the equipment approval process and a particulate emission index reported.'' (*Id*. at 9).

In addition, the Advisory Committee recommended that ''the total respirable particulate, including diesel particulate, should not exceed the existing two milligrams per cubic meter respirable dust standard.'' (*Id*. at 9). Section 202(b)(2) of the Mine Act requires that coal mine operators maintain the average concentration of respirable dust at their mines at or below two milligrams per cubic meter which effectively prohibits diesel particulate matter in excess of two milligrams per cubic meter, 30 U.S.C. 842(b)(2).

Also in 1988, NIOSH issued a Current Intelligence Bulletin recommending that whole diesel exhaust be regarded as a potential carcinogen and controlled to the lowest feasible exposure level (NIOSH, 1988). In its bulletin, NIOSH concluded that although the excess risk of cancer in diesel exhaust exposed workers has not been quantitatively estimated, it is logical to assume that reductions in exposure to diesel exhaust in the workplace would reduce the excess risk. NIOSH stated that ''[g]iven what we currently know there is an urgent need for efforts to be made to reduce occupational exposures to DEP [dpm] in mines.''

Consistent with the Advisory Committee's research recommendations, MSHA, in September 1988, formally requested NIOSH to perform a risk assessment for exposure to diesel particulate (57 FR 500). MSHA also requested assistance from NIOSH and the former BOM in developing sampling and analytical methodologies for assessing exposure to diesel particulate in mining operations. (*Id*.). In part, as a result of the Advisory Committee's recommendation, MSHA also participated in studies on diesel particulate sampling methodologies and determination of underground occupational exposure to diesel particulate. A list of the studies requested and reports thereof is set forth in 57 FR 500–501.

On October 4, 1989, MSHA published a Notice of Proposed Rulemaking on approval requirements, exposure monitoring, and safety requirements for the use of diesel-powered equipment in underground coal mines (54 FR 40950). The proposed rule, among other things, addressed, and in fact followed, the Advisory Committee's recommendation that MSHA promulgate regulations requiring the approval of diesel engines (54 FR 40951); limiting gaseous pollutants from diesel equipment, (*Id*.); establishing ventilation requirements based on approval plate dilution air quantities (54 FR 40990); requiring equipment maintenance (54 FR 40958); requiring that trained personnel work on diesel-powered equipment; (54 FR 40995), establishing fuel requirements, (*Id*.); establishing gaseous contaminant monitoring (54 FR 40989); and requiring that a particulate index indicating the quantity of air needed to dilute particulate emissions from diesel engines be established (54 FR 40953).

On January 6, 1992, MSHA published an Advance Notice of Proposed Rulemaking (ANPRM) indicating that it was in the early stages of developing a rule specifically addressing miners' exposure to diesel particulate (57 FR 500). In the ANPRM, MSHA, among other things, sought comment on specific reports on diesel particulate prepared by NIOSH and the former BOM. (*Id*.). MSHA also sought comment on reports on diesel particulate which were prepared by or in conjunction with MSHA (57 FR 501). The ANPRM also sought comments on the health effects, technological and economic feasibility, and provisions which should be considered for inclusion in a diesel particulate rule (57 FR 501). The notice also identified five specific areas where the agency was particularly interested in comments, and about which it asked a number of detailed questions: (1) exposure limits, including the basis therefore; (2) the validity of the NIOSH risk assessment model and the validity of various types of studies; (3) information about non-cancer risks, non-lung routes of entry, and the confounding effects of tobacco smoking; (4) the availability, accuracy and proper use of sampling and monitoring methods for diesel particulate; and (5) the technological and economic feasibility of various types of controls, including ventilation, diesel fuel, engine design, aftertreatment devices, and maintenance by mechanics with specialized training. The notice also solicited specific information from the mining community on ''the need for a medical surveillance or screening program and on the use of respiratory equipment.'' (57 FR 500). The comment period on the ANPRM closed on July 10, 1992.

While MSHA was completing a ''comprehensive analysis of the comments and any other information received'' in response to the ANPRM (57 FR 501), it took several actions to encourage the mining community to begin to deal with this problem, and to provide the knowledge and equipment needed for this task. As described earlier in this part, the Agency held several workshops in 1995, published a ''Toolbox'' of controls, and developed a spreadsheet template that allows mine operators to compare the impacts of various controls on dpm concentrations in individual mines.

On October 25, 1996, MSHA published a final rule addressing approval, exhaust monitoring, and safety requirements for the use of diesel-powered equipment in underground coal mines (61 FR 55412). The final rule addresses and in large part is consistent with the specific recommendations made by the Advisory Committee for limiting underground coal miners' exposure to diesel exhaust. (A further summary of this rule is contained in Section 7 of this part).

On February 26, 1997, the United Mine Workers of America petitioned the U.S. Court of Appeals for the D.C. Circuit to issue a writ of mandamus ordering the Secretary of Labor to promulgate a rule on diesel particulate. In Re: International Union, United Mine Workers of America , D.C. Cir. Ct. Appeals, No. 97–1109. The matter was scheduled for oral argument on September 12, 1997. On September 11, 1997, the Court granted the parties' joint motion to continue oral argument and hold the proceedings in abeyance. The Court directed the parties to file status reports or motions to govern future proceedings at 90-day intervals. On April 9, 1998, (63 FR 17492), MSHA published a proposed rule to limit the exposure of underground coal miners to dpm. On April 30, 1998, the Secretary filed a Motion To Dismiss based on the issuance of the notice of proposed rulemaking to limit the exposure of underground coal miners to dpm. On June 26, 1998, the Court dismissed the petition for Writ of Mandamus insofar as it sought regulations addressing diesel particulate.

III. Risk Assessment

Table of Contents

Introduction. MSHA has reviewed the scientific literature to evaluate the potential health effects of diesel particulate at occupational exposures encountered in the mining industry. Based on its review of the currently available information, this part of the preamble assesses the risks associated with those exposures. Additional material submitted for the record will be considered by MSHA before final determinations are made.

Agencies sometimes place risk assessments in the rulemaking record and provide only a summary in the preamble for a proposed rule. MSHA has decided that, in this case, it is important to disseminate a discussion of risk widely throughout the mining community. Therefore, the full assessment is being included as part of the preamble.

The risk assessment begins with a discussion of dpm exposure levels observed in the mining industry. This is followed by a review of information available to MSHA on health effects that have been associated with diesel particulate exposure. Finally, in the section entitled ''Characterization of Risk,'' the Agency considers three questions that must be addressed for rulemaking under the Mine Act, and relates the available information about risks of dpm exposure at current levels to the regulatory requirements.

A risk assessment must be technical enough to present the evidence and describe the main controversies surrounding it. At the same time, an overly technical presentation could cause stakeholders to lose sight of the main points. MSHA is guided by the first principle the National Research Council established for risk characterization: that the approach be—

> [a] decision driven activity, directed toward informing choices and solving problems*** Oversimplifying the science or skewing the results through selectivity can lead to the inappropriate use of scientific information in risk management decisions, but providing full information, if it does not address key concerns of the intended audience, can undermine that audience's trust in the risk analysis.

MSHA intends this risk assessment to further the rulemaking process. The purpose of a proposed rulemaking is to notify the regulated community of what information the agency is evaluating, how the agency believes it should evaluate that information, and what tentative conclusions the agency has drawn. Comments, supporting data, and guidance from all interested members of the public are encouraged. The risk assessment presented here is meant to facilitate public comment, thus helping to ensure that final rulemaking is based on as complete a record as possible—on both the evidence itself and the manner in which it is to be evaluated by the Agency. Those who want additional detail are welcome to examine the materials cited in this part, copies of which are included in MSHA's rulemaking record.

While this rulemaking covers only the underground metal and nonmetal sector, the risk assessment was prepared so as to enable MSHA to assess the risks throughout the mining industry. Accordingly, this information will be of interest to the entire mining community. With the exception of the discussion in Sec. III.3.c quantifying by how much the proposed rule may be expected to reduce current risks, this risk assessment is substantially the same as that published with MSHA's proposed rule to reduce dpm concentrations in underground coal mines (63 FR 17521).

MSHA had this risk assessment independently peer reviewed. The risk assessment presented here incorporates revisions made in accordance with the reviewers' recommendations. The reviewers stated that:

> * * * principles for identifying evidence and characterizing risk are thoughtfully set out. The scope of the document is carefully described, addressing potential concerns about the scope of coverage. Reference citations are adequate and up to date. The document is written in a balanced fashion, addressing uncertainties and asking for additional information and comments as appropriate. (Samet and Burke, Nov. 1997).

III.1. Exposures of U.S. Miners

Information about U.S. miner exposures comes from published studies and from additional mine inventories conducted by MSHA since 1993.[6] Previously published studies of U.S. miner exposure to dpm are: Watts (1989, 1992), Cantrell (1992, 1993), Haney (1992), and Tomb and Haney (1995). MSHA has also conducted inventories subsequent to the period covered in Tomb and Haney (1995), and the previously unpublished data are included here. The period covered on which this section is based, is late 1988 through mid 1997.

MSHA's field studies involved measuring dpm concentrations at a total of 48 mines: 25 underground metal and nonmetal (M/NM) mines, 12 underground coal mines, and 11 surface mining operations (both coal and M/NM). At all surface mines and all underground coal mines, dpm measurements were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor. With two exceptions, dpm measurements at underground M/NM mines were made using the RCD method (with no submicrometer impactor). Measurements at the two remaining underground M/NM mines were made using the size-selective method, as in coal and surface mines. The various methods of measuring dpm are explained in Part II of this preamble. Weighing errors inherent in the gravimetric analysis required for both size-selective and RCD methods become statistically insignificant at the relatively high dpm concentrations observed. Mines were selected from sites known to have diesel exposures. They do not constitute a random sample of mines, and care was taken in the text not to represent results as applying to the industry as a whole.

Each underground study typically included personal dpm exposure measurements for approximately five production workers. Also, area samples were collected in return airways of underground mines to determine diesel particulate emission rates. Operational information such as the amount and type of equipment, airflow rates, fuel, and maintenance was also recorded. In general, MSHA's studies focused on face production areas of mines, where the highest concentrations of dpm could be expected; but, since some miners do not spend their time in face areas, studies were performed in other areas as well, to get a more complete picture of miner exposure. Because of potential interferences from tobacco smoke in underground M/NM mines, samples were not collected on or near smokers.

Table III–1 summarizes key results from MSHA's studies. The higher concentrations in underground mines were typically found in the haulageways and face areas where numerous pieces of equipment were operating, or where insufficient air was available to ventilate the operation. In production areas and haulageways of underground mines where diesel powered equipment is used, the mean dpm concentration observed was 755 $\mu g/m^3$. By contrast, in travelways of underground mines where diesel powered equipment is used, the mean dpm concentration (based on 107 samples not included in Table III–1) was 307 $\mu g/m^3$. In surface mines, the higher concentrations were generally associated with truck drivers and front-end loader operators. The mean dpm concentration observed was less than 200 $\mu g/m^3$ at all 11 of the surface mines in which measurements were made. More information about the dpm concentrations observed in each sector is presented in the material that follows.

TABLE III–1.—FULL SHIFT DIESEL PARTICULATE MATTER CONCENTRATIONS OBSERVED IN PRODUCTION AREAS AND HAULAGEWAYS OF 48 DIESELIZED U.S. MINES. INTAKE AND RETURN AREA SAMPLES ARE EXCLUDED.

Mine type	Number of samples	Mean exposure $\mu g/m^3$	Exposure range $\mu g/m^3$
Surface	45	88	9–380
Underground Coal	226	644	0–3,650
Underground Metal and Nonmetal	331	830	10–5,570

[6] MSHA has only limited information about miner exposures in other countries. Based on 223 personal and area samples, average exposures at 21 Canadian noncoal mines were reported to range from 170 to 1300 $\mu g/m^3$ (respirable combustible dust), with maximum measurements ranging from 1020 to 3100 $\mu g/m^3$ (Gangel and Dainty, 1993). Among 622 full shift measurements collected since 1989 in German underground noncoal mines, 91 (15%) exceeded 400 $\mu g/m^3$ (total carbon) (Dahmann et al., 1996). As explained in Part II of this preamble, 400 $\mu g/m^3$ (total carbon) corresponds to approximately 500 $\mu g/m^3$ dpm.

III.1.a. Underground Coal Mines

Approximately 170 out of the 971 existing underground coal mines currently utilize diesel powered equipment. Of these 170 mines, fewer than 20 currently use diesel equipment for face coal haulage. The remaining mines use diesel equipment for transportation, materials handling and other support operations. MSHA focused its efforts in measuring dpm concentrations in coal mines on mines that use diesel powered equipment for face coal haulage. Twelve mines using diesel-powered face haulage were sampled. Mines with diesel powered face haulage were selected because the face is an area with a high concentration of vehicles operating at a heavy duty cycle at the furthest end of the mine's ventilation system.

Diesel particulate levels in underground mines depend on: (1) the amount, size, and workload of diesel equipment; (2) the rate of ventilation; and, (3) the effectiveness of whatever diesel particulate control technology may be in place. In the dieselized mines studied by MSHA, the sections used either two or three diesel coal haulage vehicles. In eastern mines the haulage vehicles were equipped with a nominal 100 horsepower engine. In western mines the haulage vehicles were equipped with a nominal 150 horsepower engine. Ventilation rates ranged from the nameplate requirement, based on the 100–75–50 percent rule (Holtz, 1960), to ten times the nameplate requirement. In most cases, the section airflow was approximately twice the name plate requirement. Control technology involved aftertreatment filters and fuel. Two types of aftertreatment filters were used. These filters included a disposable diesel emission filter (DDEF) and a Wire Mesh Filter (WMF). The DDEF is a commercially available product; the WMF was developed by and only used at one mine. Both low sulfur and high sulfur fuels were used.

Figure III–1 displays the range of exposure measurements obtained by MSHA in the field studies it conducted in underground coal mines. A study normally consisted of collecting samples on the continuous miner operator and ramcar operators for two to three shifts, along with area samples in the haulageways. A total of 142 personal samples and 84 area samples were collected. No statistically significant difference was observed in mean dpm concentration between the personal and area samples.

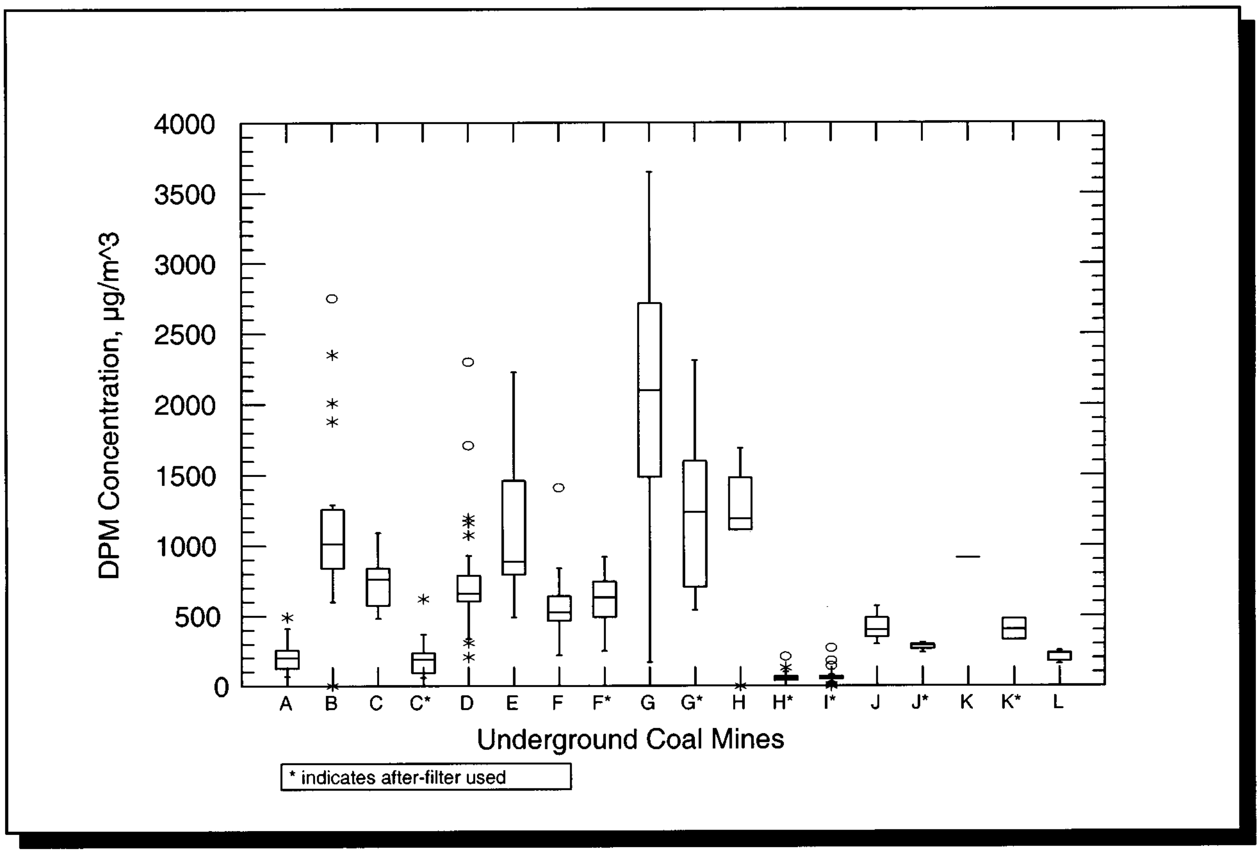

Figure III-1.-- Box plots (Tukey, 1977) for dpm concentrations observed at 12 underground coal mines. Top and bottom of each box represent upper and lower quartiles, respectively. "Belt" inside box represents median. Vertical lines span nearly all measurements. Isolated points are outliers, representing unusually high or low measurements compared to other observations at the same mine. All DPM measurements were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor.

In six mines, measurements were taken both with and without employment of disposable after treatment filters, so that a total of eighteen studies, carried out in twelve mines, are displayed.

Without employment of after treatment filters, average observed dpm concentrations exceeded 500 μg/m³ in eight of the twelve mines and exceeded 1000 μg/m³ in four. [7]

The highest dpm concentrations observed at coal mines were collected at Mine ''G.'' Eight of these samples were collected during employment of DDEF's, and eight were collected while filters were not being employed. Without filters, the mean dpm concentration observed at Mine ''G'' was 2052 μg/m³ (median = 2100 μg/m³). With disposable filters, the mean dropped to 1241 μg/m³ (median = 1235 μg/m³).

Filters were employed in three of the four studies showing median dpm concentration at or below 200 μg/m³. After adjusting for outby sources of dpm, exposures were found to be reduced by up to 95 percent in mines using the DDEF and by up to 50 percent in the mine using the WMF.

[7] In coal mine E, the average as expressed by the mean exceeded 1000 μg/m³, but the median did not.

The higher dpm concentrations observed at the mine using the WMF are attributable partly to the lower section airflow. The only study without filters showing a median concentration at or below 200 μg/m³ was conducted in a mine (Mine ''A'') which had section airflow approximately ten times the nameplate requirement. The section airflow at the mine using the WMF was approximately the nameplate requirement.

III.1.b. Underground Metal and Nonmetal Mines

Currently there are approximately 260 underground M/NM mines in the United States. Nearly all of these mines utilize diesel powered equipment, and twenty-five of those doing so were sampled by MSHA for dpm.[8] The M/NM studies typically included measurements of dpm exposure for dieselized production equipment operators (such as truck drivers, roof bolters, haulage vehicles) on two to three shifts. A number of area samples were also collected. None of the M/NM mines studied were using diesel particulate afterfilters.

[8] MSHA will provide copies of these studies upon request.

Figure III–2 displays the range of dpm concentrations measured by MSHA in the twenty-five underground M/NM mines studied. A total of 254 personal samples and 77 area samples were collected. No statistically significant difference was observed in mean dpm concentration between the personal and area samples. Personal exposures observed ranged from less than 100 μg/m³ to more than 3500 μg/m³. With the exception of Mine ''V'', personal exposures were for face workers. Mine ''V'' did not use dieselized face equipment.

Average observed dpm concentrations exceeded 500 μg/m³ in 17 of the 25 M/NM mines and exceeded 1000 μg/m³ in 12.[9] The highest dpm concentrations observed at M/NM mines were collected at Mine ''E''. Based on 16 samples, the mean dpm concentration observed at Mine ''E'' was 2008 μg/m³ (median = 1835 μg/m³). Twenty-five percent of the dpm measurements at this mine exceeded 2400 μg/m³. All four of these were based on personal samples.

[9] At M/NM mines C, I, J, and P, the average as expressed by the mean exceeded 1000 μg/m³ but the median did not. At M/NM mines H and S, the median exceeded 1000 μg/m³ but the mean did not. At M/NM mine K, the mean exceeded 500 μg/m³, but the median did not.

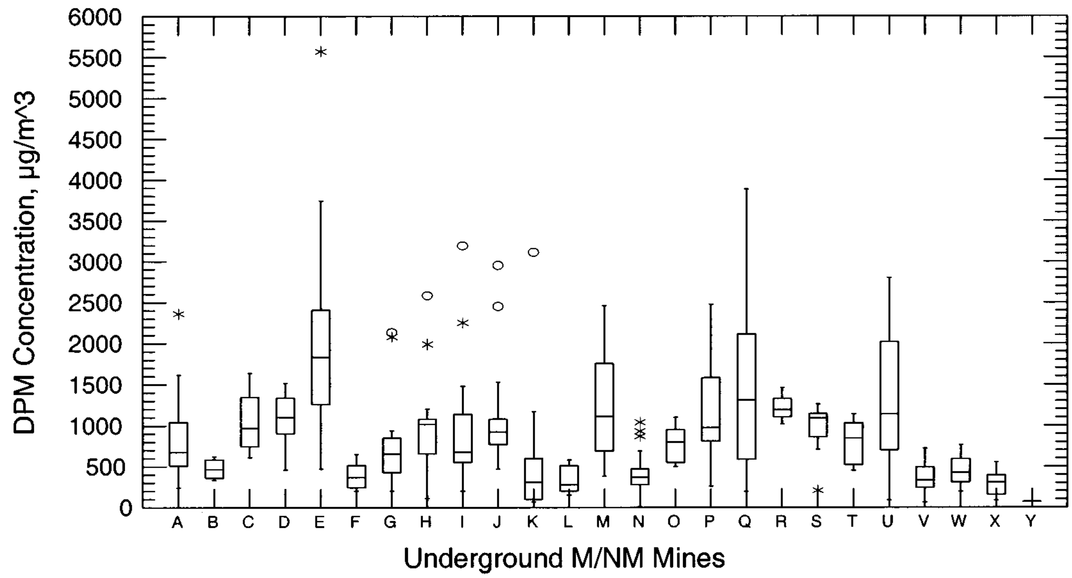

Figure III-2.-- Box plots (Tukey, 1977) for dpm concentrations observed at 25 underground metal and nonmetal mines. Top and bottom of each box represent upper and lower quartiles, respectively. "Belt" inside box represents median. Vertical lines span nearly all measurements. Isolated points are outliers, representing unusually high or low measurements compared to other observations at the same mine. Measurements at mines other than "D" and "T" were made using RCD method. Measurements at mines "D" and "T" were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor. Because of potential interferences from cigarette smoke, samples were not collected on or near smokers.

As with underground coal mines, dpm levels in underground M/NM mines are related to the amount and size of equipment, to the ventilation rate, and to the effectiveness of the diesel particulate control technology employed. In the dieselized M/NM mines studied by MSHA, front-end-loaders were used either to load ore onto trucks or to haul and load ore onto belts. Additional pieces of diesel powered support equipment, such as bolters and mantrips, were also used at the mines. The typical piece of production equipment was rated at 150 to 350 horsepower.

Ventilation rates in the M/NM mines studied mostly ranged from 100 to 200 cfm per horsepower of equipment. In only a few of the mines inventoried did ventilation exceed 200 cfm/hp. For single-level mines, working areas were ventilated in series, i.e., the exhaust air from one area became the intake for the next working area. For multi-level mines, each level typically had a separate fresh air supply. One or two working areas could be on a level. Control technology used to reduce diesel particulate emissions in mines inventoried included oxidation catalytic converters and engine maintenance programs. Both low sulfur and high sulfur fuel were used; some mines used aviation grade low sulfur fuel.

III.1.c. Surface Mines

Currently, there are approximately 12,200 surface mining operations in the United States. The total consists of approximately 1,700 coal mines and 10,500 M/NM mines. Virtually all of these mines utilize diesel powered equipment.

MSHA conducted diesel particulate studies at eleven surface mining operations: eight coal mines and three M/NM mines. To help select those surface facilities likely to have significant dpm concentrations, MSHA first made a visual examination (based on blackness of the filter) of surface mine respirable dust samples collected during a November 1994 study of surface coal mines. This preliminary screening of samples indicated that higher exposures to diesel particulate are typically associated with front-end-loader operators and haulage-truck operators; accordingly, sampling focused on these operations. A total of 45 samples were collected.

Figure III–3 displays the range of dpm concentrations measured at the eleven surface mines. The average dpm concentration observed was less than 200 µg/m^3 at all mines sampled. The maximum dpm concentration observed was less than or equal to 200 µg/m^3 in 8 of the 11 mines (73%). The surface mine studies indicate that even when sampling is performed at the areas of surface mines believed most likely to have high exposures, dpm concentrations are generally less than 200 µg/m^3.

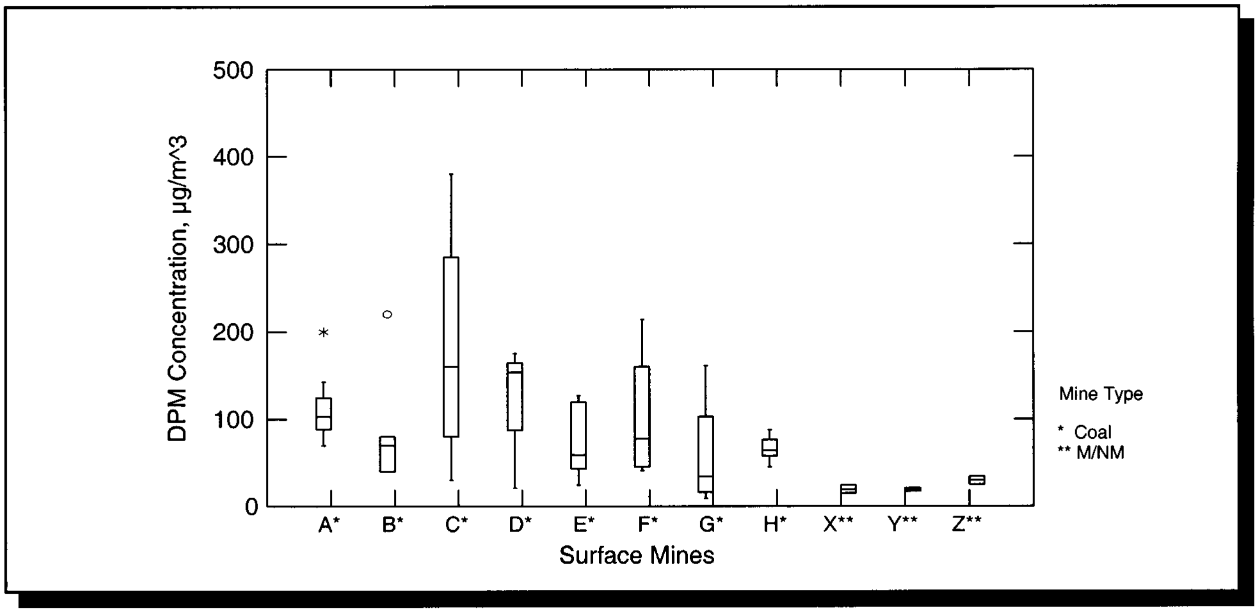

Figure III-3.--Box plots for dpm concentrations observed at 11 surface mines. Top and bottom of each box represent upper and lower quartiles, respectively. "Belt" inside box represents median. Vertical lines span nearly all measurements. Isolated points are outliers, representing unusually high or low measurements compared to other observations at the same mine (Tukey, 1977). All DPM measurements were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor. Because of potential interferences from cigarette smoke, samples were not collected on smokers who worked inside enclosures.

III.1.d. Comparison of Miner Exposures to Exposures of Other Groups

Occupational exposure to diesel particulate primarily originates from industrial operations employing equipment powered with diesel engines. Diesel engines are used to power ships, locomotives, heavy duty trucks, heavy machinery, as well as a small number of light-duty passenger cars and trucks. NIOSH estimates that approximately 1.35 million workers are occupationally exposed to the combustion products of diesel fuel in approximately 80,000 workplaces in the United States. Workers who are likely to be exposed to diesel emissions include: mine workers; bridge and tunnel workers; railroad workers; loading dock workers; truck drivers; fork-lift drivers; farm workers; and, auto, truck, and bus maintenance garage workers (NIOSH, 1988). Besides miners, groups for which occupational exposures have been reported and health effects have been studied include dock workers, truck drivers, and railroad workers.

As estimated by the geometric mean, median occupational exposures reported for dock workers either operating or otherwise exposed to diesel fork lift trucks have ranged from 23 to 55 µg/m^3, as measured by submicrometer elemental carbon (NIOSH, 1990; Zaebst et al., 1991). Watts (1995) states that "elemental carbon generally accounts for about 40% to 60% of diesel particulate mass." Assuming that, on average, the submicrometer elemental carbon constituted approximately 50% by mass of the whole diesel particulate, this would correspond to a range of 46 to 110 µg/m^3 in median dpm concentrations at various docks.

In a study of dpm exposures in the trucking industry, Zaebst et al. (1991) reported geometric mean concentrations of submicrometer carbon ranging from 2 to 7 µg/m^3 for drivers to 5 to 28 µg/m^3 for mechanics, depending on weather conditions. Again assuming that, on average, the mass concentration of whole diesel particulate is about twice that of submicrometer elemental carbon, the corresponding range of median dpm concentrations would be 4 to 56 µg/m^3.

Exposures of railroad workers to dpm were estimated by Woskie et al. (1988) and Schenker et al. (1990). As measured by total respirable particulate matter other than cigarette smoke, Woskie et al. reported geometric mean concentrations for various occupational categories of exposed railroad workers ranging from 49 to 191 µg/m^3.

Figure III–4 shows the range of median dpm concentrations observed for mine workers at different mines compared to the range of median concentrations estimated for dock workers (including forklift drivers at loading docks), truck drivers and mechanics, railroad workers, and urban ambient air.[10] The range for ambient air, 1 to 10 µg/m^3, was obtained from Cass and Gray (1995). For dock workers, truck drivers, and railroad workers, the estimated range of median exposures is respectively 46 to 110 µg/m^3, 4 to 56 µg/m^3, and 49 to 191 µg/m^3. The range of medians observed at different underground coal mines is 55 to 2100 µg/m^3, with filters employed at mines showing the lower concentrations. For underground M/NM mines, the corresponding range is 68 to 1835

[10] In the studies reviewed, investigators have used various statistical parameters, such as mean, median, or geometric mean, to summarize the dpm concentrations observed. Since the raw data are not available, MSHA was not able to summarize the data in exactly the same way for each category depicted in Figure III–4.

μg/m3, and for surface mines it is 19 to 160 μg/m3.

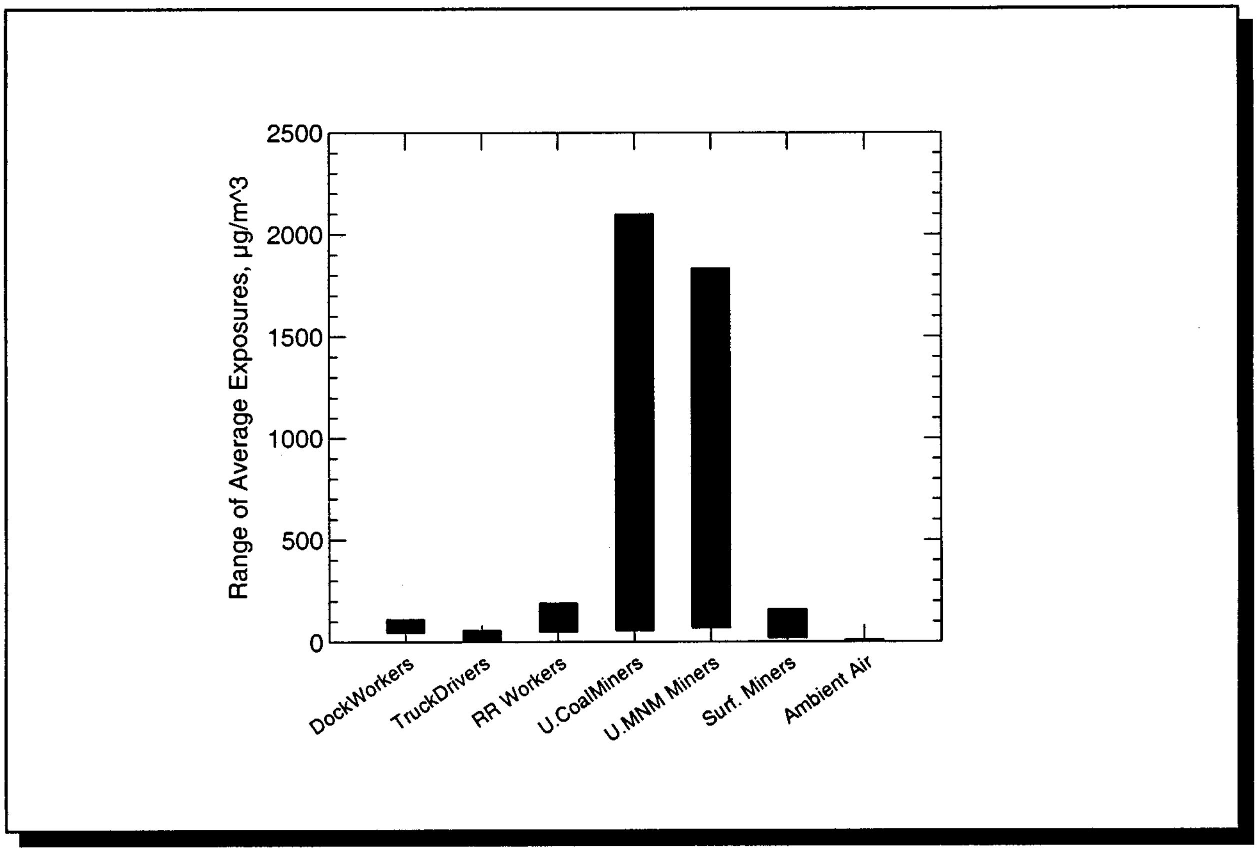

Figure III-4.--Range of average dpm exposures observed at various mines for underground and surface miners compared to range of average exposures reported for other occupations and for urban ambient air. Averages are represented by median observed within mines for mine workers, by median as estimated with geometric mean reported for other occupations, and, for ambient air in urban environments, by the monthly mean estimated for different months and locations in Southern California. The range estimated for urban ambient air is roughly 1 to 10 $\mu g/m^3$.

As shown in Figure III–4, some miners are exposed to far higher concentrations of dpm than are any other populations for higher concerntrations of dpm than are any other populations for which data have been collected. Indeed, median dpm concentrations observed in some underground mines are up to 200 times as high as average environmental exposures in the most heavily polluted urban areas, and up to 10 times as high as median exposures estimated for the most heavily exposed workers in other occupational groups.

III.2. Health Effects Associated With DPM Exposures

This section reviews all the various health effects (of which MSHA is aware) that may be associated with exposure to diesel particulate. The review is divided into three main sections: acute effects, such as diminished pulmonary function and eye irritation; chronic effects, such as lung cancer; and mechanisms of toxicity. Prior to that review, however, the relevance of certain types of information will be considered. This discussion will address the relevance of health effects observed in animals, health effects that are reversible, and health effects associated with fine particulate matter in the ambient air.

III.2.a. Relevancy Considerations

III.2.a.i. Relevance of Health Effects Observed in Animals

Since the lungs of different species may react differently to particle inhalation, it is necessary to treat the results of animal studies with some caution. Evidence from animal studies can nevertheless be valuable, and those respondents to MSHA's ANPRM who addressed this question urged consideration of all animal studies related to the health effects of diesel exhaust.

Unlike humans, laboratory animals are bred to be homogeneous and can be randomly selected for either non-exposure or exposure to varying levels of a potentially toxic agent. This permits setting up experimental and control groups of animals that do not differ biologically prior to exposure. The consequences of exposure can then be determined by comparing responses in the experimental and control groups. After a prescribed duration of deliberate exposure, laboratory animals can also be sacrificed, dissected, and examined. This can contribute to an understanding of mechanisms by which inhaled particles may exert their effects on health. For this reason, discussion of the animal evidence is placed in the section entitled ''Mechanisms of Toxicity'' below.

Animal evidence also can help isolate the cause of adverse health effects observed among humans exposed to a variety of potentially hazardous substances. If, for example, the epidemiological data are unable to distinguish between several possible causes of increased risk of disease in a certain population, then controlled animal studies may provide evidence useful in suggesting the most likely explanation—and provide that information years in advance of definitive evidence from human observations.

Furthermore, results from animal studies may also serve as a check on the credibility of observations from epidemiological studies of human populations. If a particular health effect is observed in animals under controlled laboratory conditions, this tends to corroborate observations of similar effects in humans.

Accordingly, MSHA believes that judicious use of evidence from animal studies is appropriate. The extent to which MSHA relies upon such evidence to draw specific conclusions will be discussed below in connection with those conclusions.

III.2.a.ii. Relevance of Health Effects That are Reversible

Some reported health effects associated with dpm are apparently reversible—i.e., if the worker is moved away from the source for a few days, the health problem goes away. A good example is eye irritation.

In response to the ANPRM, questions were raised as to whether so-called ''reversible'' effects can constitute a ''material'' impairment. For example, one commenter argued that ''it is totally inappropriate for the agency to set permissible exposure limits based on temporary, reversible sensory irritation'' because such effects cannot be a ''material'' impairment of health or functional capacity within the definition of the Mine Act (American Mining Congress, 87–0–21, Executive Summary, p. 1, and Appendix A).

MSHA does not agree with this categorical view. Although the legislative history of the Mine Act is silent concerning the meaning of the term ''material impairment of health or functional capacity,'' and the issue has not been litigated within the context of the Mine Act, the statutory language about risk in the Mine Act is similar to that under the OSH Act. A similar argument was dispositively resolved in favor of the Occupational Safety and Health Administration (OSHA) by the 11th Circuit Court of Appeals in *AFL–CIO* v. *OSHA,* 965 F.2d 962, 974 (1992) (popularly known as the ''PEL's'' decision).

In that case, OSHA proposed new limits on 428 diverse substances. It grouped these into 18 categories based upon the primary health effects of those substances: e.g., neuropathic effects, sensory irritation, and cancer. (54 FR 2402). Challenges to this rule included the assertion that a ''sensory irritation'' was not a ''material impairment of health or functional capacity'' which could be regulated under the OSH Act. Industry petitioners argued that since irritant effects are transient in nature, they did not constitute a ''material impairment.'' The Court of Appeals decisively rejected this argument.

The court noted OSHA's position that effects such as stinging, itching and burning of the eyes, tearing, wheezing, and other types of sensory irritation can cause severe discomfort and be seriously disabling in some cases. Moreover, there was evidence that workers exposed to these sensory irritants could be distracted as a result of their symptoms, thereby endangering other workers and increasing the risk of accidents. (Id. at 974). This evidence included information from NIOSH about the general consequences of sensory irritants on job performance, as well as testimony by commenters on the proposed rule supporting the view that such health effects should be regarded as material health impairments. While acknowledging that ''irritation'' covers a spectrum of effects, some of which can be trivial, OSHA had concluded that the health effects associated with exposure to these substances warranted action—to ensure timely medical treatment, reduce the risks from increased absorption, and avoid a decreased resistance to infection (Id at 975). Finding OSHA's evaluation adequate, the Court of Appeals rejected petitioners' argument and stated the following:

> We interpret this explanation as indicating that OSHA finds that although minor irritation may not be a material impairment, there is a level at which such irritation becomes so severe that employee health and job performance are seriously threatened, even though those effects may be transitory. We find this explanation adequate. OSHA is not required to state with scientific certainty or precision the exact point at which each type of sensory or physical irritation becomes a material impairment. Moreover, section 6(b)(5) of the Act charges OSHA with addressing all forms of ''material impairment of health or functional capacity,'' and not exclusively ''death or serious physical harm'' or ''grave danger'' from exposure to toxic substances. See 29 U.S.C. 654(a)(1), 655(c). [Id. at 974].

III.2.a.iii. Relevance of Health Effects Associated with Fine Particulate Matter in Ambient Air

There have been many studies in recent years designed to determine whether the mix of particulate matter in ambient air is harmful to health. The evidence linking particulates in air pollution to health problems has long been compelling enough to warrant direction from the Congress to limit the concentration of such particulates (see part II, section 5 of this preamble). In recent years, the evidence of harmful effects due to airborne particulates has increased, and, moreover, has suggested that ''fine'' particulates (i.e., particles less than 2.5 µm in diameter) are more strongly associated than ''coarse'' particulates (i.e., respirable particles greater than 2.5 µm in diameter) with the adverse health effects observed (EPA, 1996).

MSHA recognizes that there are two difficulties involved in utilizing the evidence from such studies in assessing risks to miners from occupational dpm exposures. First, although dpm is a fine particulate, ambient air also contains fine particulates other than dpm. Therefore, health effects associated with exposures to fine particulate matter in air pollution studies are not associated specifically with exposures to dpm or any other one kind of fine particulate matter. Second, observations of adverse health effects in segments of the general population do not necessarily apply to the population of miners. Since, due to age and selection factors, the health of miners differs from that of the public as a whole, it is possible that fine particles might not affect miners, as a group, to the same extent as the general population.

Nevertheless, there are compelling reasons to consider this body of evidence. Since dpm is a type of respirable particle, information about health effects associated with exposures to respirable particles in general, and especially to fine particulate matter, is certainly relevant, even if difficult to apply directly to dpm exposures. Adverse health effects in the general population have been observed at ambient atmospheric particulate concentrations well below those studied in occupational settings. Furthermore, there is extensive literature showing that occupational dust exposures contribute to Chronic Obstructive Pulmonary Diseases (COPD), thereby compromising the pulmonary reserve of some miners, and that miners experience COPD at a significantly higher rate than the general population (Becklake 1989, 1992; Oxman 1993; NIOSH 1995). This would appear to place affected miners in a subpopulation specifically identified as susceptible to the adverse health effects of respirable particle pollution (EPA, 1996). The Mine Act requires that standards ''* * * most adequately assure on the basis of the best available evidence that *no miner* suffer material impairment of health or functional capacity * * *'' (Section 101(a)(6), emphasis added).

In sum, MSHA believes it would be a serious omission to ignore the body of evidence from air pollution studies and the Agency is, therefore, taking that evidence into account. The Agency would, however, welcome additional scientific information and analysis on ways of applying this body of evidence to miners experiencing acute and/or chronic dpm exposures. MSHA is especially interested in receiving information on whether the elevated prevalence of COPD among miners makes them, as a group, highly susceptible to the harmful effects of fine particulate air pollution, including dpm.

III.2.b. Acute Health Effects

Information relating to the acute health effects of dpm includes anecdotal reports of symptoms experienced by exposed miners, studies based on exposures to diesel emissions, and studies based on exposures to particulate matter in the ambient air. These will be discussed in turn.

III.2.b.i. Symptoms Reported by Exposed Miners

Miners working in mines with diesel equipment have long reported adverse effects after exposure to diesel exhaust. For example, at the workshops on dpm conducted in 1995, a miner reported headaches and nausea among several operators after short periods of exposure (dpm Workshop; Mt. Vernon, IL, 1995). Another miner reported that the smoke from equipment using improper fuel or not well maintained is an irritant to nose and throat and impairs vision. ''We've had people sick time and time again * * * at times we've had to use oxygen for people to get them to come back around to where they can feel normal again.'' (dpm Workshop; Beckley, WV, 1995). Other miners (dpm Workshops; Beckley, WV, 1995; Salt Lake City, UT, 1995), reported similar symptoms in the various mines where they worked.

Kahn *et al.* (1988) conducted a study of the prevalence and seriousness of such complaints, based on United Mine Workers of America records and subsequent interviews with the miners involved. The review involved reports at five underground coal mines in Utah and Colorado between 1974 and 1985. Of the 13 miners reporting symptoms: 12 reported mucous membrane irritation, headache and light-headiness; eight reported nausea; four reported heartburn; three reported vomiting and weakness, numbness, and tingling in extremities; two reported chest tightness; and two reported wheezing (although one of these complained of recurrent wheezing without exposure). All of these incidents were severe enough to result in lost work time due to the symptoms (which subsided within 24 to 48 hours).

MSHA welcomes additional information about such effects including information from medical personnel who have treated miners and information on work time lost, together with information about the exposures of miners for whom such effects have been observed. The Agency would be especially interested in comparisons of effects observed in workers subjected to filtered exhaust as compared to those subjected to unfiltered exhaust.

III.2.b.ii. Studies Based on Exposures to Diesel Emissions

Several scientific studies have been conducted to investigate acute effects of exposure to diesel emissions.

In a clinical study (Battigelli, 1965), volunteers were exposed to different levels of diesel exhaust and then the degree of eye irritation was measured. Exposure for ten minutes to diesel exhaust produced ''intolerable'' irritation in some subjects while the average irritation score was midway between ''some'' irritation and a ''conspicuous but tolerable'' irritation level. Cutting the exposure by 50% significantly reduced the irritation.

In a study of underground iron ore miners exposed to diesel emissions, Jörgensen and Svensson (1970), found no difference in spirometry measurements taken before and after a work shift. Similarly, Ames *et al.* (1982), in a study of coal miners exposed to diesel emissions, detected no statistically significant relationship between exposure and pulmonary function. However, the authors noted that the lack of a positive result might be due to the low concentrations of diesel emissions involved.

Gamble *et al.* (1978) did observe decreases in pulmonary function over a single shift in salt miners exposed to diesel emissions. Pulmonary function appeared to deteriorate in relation to the concentration of diesel exhaust, as indicated by NO_2; but this effect was confounded by the presence of NO_2 due to the use of explosives.

Gamble *et al.* (1987a) assessed response to diesel exposure among 232 bus garage workers by means of a questionnaire and before- and after-shift spirometry. No significant relationship was detected between diesel exposure and change in pulmonary function. However, after adjusting for age and smoking status, a significantly elevated prevalence of reported symptoms was found in the high-exposure group. The strongest associations with exposure were found for eye irritation, labored breathing, chest tightness, and wheeze. The questionnaire was also used to compare various acute symptoms reported by the garage workers and a similar population of workers at a lead acid battery plant who were not exposed to diesel fumes. The prevalence of work-related eye irritations, headaches, difficult or labored breathing, nausea, and wheeze was significantly higher in the diesel bus garage workers, but the prevalence of work-related sneezing was significantly lower.

Ulfvarson *et al.* (1987) studied effects over a single shift on 47 stevedores exposed to dpm at particle concentrations ranging from 130 $\mu g/m^3$ to 1000 $\mu g/m^3$. A statistically significant loss of pulmonary function was observed, with recovery after 3 days of no occupational exposure.

To investigate whether removal of the particles from diesel exhaust might reduce the ''acute irritative effect on the lungs'' observed in their earlier study, Ulfvarson and Alexandersson (1990) compared pulmonary effects in a group of 24 stevedores exposed to unfiltered diesel exhaust to a group of 18 stevedores exposed to filtered exhaust, and to a control group of 17 occupationally unexposed workers. Workers in all three groups were nonsmokers and had normal spirometry values, adjusted for sex, age, and height, prior to the experimental workshift.

In addition to confirming the earlier observation of significantly reduced pulmonary function after a single shift of occupational exposure, the study found that the stevedores in the group exposed only to filtered exhaust had 50–60% less of a decline in forced vital capacity (FVC) than did those stevedores who worked with unfiltered equipment. Similar results were observed for a subgroup of six stevedores who were exposed to filtered exhaust on one shift and unfiltered exhaust on another. No loss of pulmonary function was observed for the unexposed control group. The authors suggested that these results ''support the idea that the irritative effects of diesel exhausts to the lungs [sic] is the result of an interaction between particles and gaseous components and not of the gaseous components alone.'' They concluded that ''* * * it should be a useful practice to filter off particles from diesel exhausts in work places even if potentially irritant gases remain in the emissions.''

Rudell *et al.*, (1996) carried out a series of double-blind experiments on 12 healthy, non-smoking subjects to investigate whether a particle trap on the tailpipe of an idling diesel engine would reduce acute effects of diesel exhaust, compared with exposure to unfiltered exhaust. Symptoms associated with exposure included headache, dizziness, nausea, tiredness, tightness of chest, coughing, and difficulty in breathing, but the most prominent were found to be irritation of the eyes and nose, and a sensation of unpleasant smell. Among the various pulmonary function tests performed, exposure was found to result in significant changes only as measured by increased airway resistance and specific airway resistance. The ceramic wall flow particle trap reduced the number of particles by 46 percent, but resulted in no significant attenuation of symptoms or lung function effects. The authors concluded that diluted diesel exhaust caused increased symptoms of the eyes and nose, unpleasant smell, and bronchoconstriction, but that the 46 percent reduction in median particle number concentration observed was not sufficient to protect against these effects in the populations studied.

Wade and Newman (1993) documented three cases in which railroad workers developed persistent asthma following exposure to diesel emissions while riding immediately behind the lead engines of trains having no caboose. None of these workers were smokers or had any prior history of asthma or other respiratory disease. Although this is the only published report MSHA knows of directly relating exposure to diesel emissions with the development of asthma, there have been a number of recent studies indicating that dpm exposure can induce bronchial inflammation and respiratory immunological allergic responses in humans. These are reviewed in Peterson and Saxon (1996) and Diaz-Sanchez (1997).

III.2.b.iii. Studies Based on Exposures to Particulate Matter in Ambient Air

As early as the 1930's, as a result of an incident in Belgium's industrial Meuse Valley, it was known that large increases in particulate air pollution, created by winter weather inversions, could be associated with large simultaneous increases in mortality and morbidity. More than 60 persons died from this incident, and several hundred suffered respiratory problems. The mortality rate during the episode was more than ten times higher than normal, and it was estimated that over 3,000 sudden deaths would occur if a similar incident occurred in London. Although no measurements of pollutants in the ambient air during the episode are available, high PM levels were obviously present (EPA, 1996).

A significant elevation in particulate matter (along with SO_2 and its oxidation products) was measured during a 1948 incident in Donora, PA. Of the Donora population, 42.7 percent experienced some adverse health effect, mainly due to irritation of the respiratory tract. Twelve percent of the population reported difficulty in breathing, with a steep rise in frequency as age progressed to 55 years (Schrenk, 1949).

Approximately as projected by Firket (1931), an estimated 4,000 deaths occurred in response to a 1952 episode of extreme air pollution in London. The nature of these deaths is unknown, but there is clear evidence that bronchial irritation, dyspnea, bronchospasm, and, in some cases, cyanosis occurred with unusual prevalence (Martin, 1964).

These three episodes ''left little doubt about causality in regard to the induction of serious health effects by very high concentrations of particle-laden air pollutant mixtures'' and stimulated additional research to characterize exposure-response relationships (EPA, 1996). Based on several analyses of the 1952 London data, along with several additional acute exposure mortality analyses of London data covering later time periods, the U.S. Environmental Protection Agency (EPA) concluded that increased risk of mortality is associated with exposure to particulate and SO_2 levels in the range of 500–1000 $\mu g/m^3$. The EPA also concluded that relatively small, but statistically significant increases in mortality risk exist at particulate levels below 500 $\mu g/m^3$, with no indications of any specific threshold level yet indicated at lower concentrations (EPA, 1986).

Subsequently, between 1986 and 1996, increasingly sophisticated particulate measurements and statistical techniques have enabled investigators to address these questions more quantitatively. The studies on acute effects carried out since 1986 are reviewed in the 1996 EPA Air Quality Criteria for Particulate Matter, which forms the basis for the discussion below (EPA, 1996).

At least 21 studies have been conducted that evaluate associations between acute mortality and morbidity effects and various measures of fine particulate levels in the ambient air. These studies are identified in Tables III–2 and III–3. Table III–2 lists 11 studies that measured primarily fine particulate matter using filter-based optical techniques and, therefore, provide mainly qualitative support for associating observed effects with fine particles. Table III–3 lists quantitative results from 10 studies that reported gravimetric measurements of either the fine particulate fraction or of components, such as sulfates, that serve as indicators.

A total of 38 studies examining relationships between short-term particulate levels and increased mortality, including nine with fine particulate measurements, were published between 1988 and 1996 (EPA, 1996). Most of these found statistically significant positive associations. Daily or several-day elevations of particulate concentrations, at average levels as low as 18–58 $\mu g/m^3$, were associated with increased mortality, with stronger relationships observed in those with preexisting respiratory and cardiovascular disease. Overall, these studies suggest that an increase of 50 $\mu g/m^3$ in the 24-hour average of PM_{10} is associated with a 2.5 to 5-percent increase in the risk of mortality in the general population. Based on Schwartz et al. (1996), the relative risk of mortality in the general population increases by about 2.6 to 5.5 percent per 25 $\mu g/m^3$ of fine particulate ($PM_{2.5}$) (EPA, 1996).

A total of 22 studies were published on associations between short-term particulate levels and hospital admissions, outpatient visits, and emergency room visits for respiratory disease, Chronic Obstructive Pulmonary Disease (COPD), pneumonia, and heart disease (EPA, 1996). Fifteen of these studies were focussed on the elderly. Of the seven that dealt with all ages (or in one case, persons less than 65 years old), all showed positive results. All of the five studies relating fine particulate measurements to increased hospitalization, listed in Tables III–2 and III–3, dealt with general age populations and showed statistically significant associations. The estimated increase in risk ranges from 3 to 16 percent per 25 $\mu g/m^3$ of fine particulate. Overall, these studies are indicative of acute morbidity effects being related to fine particulate matter and support the mortality findings.

Most of the 14 published quantitative studies on ambient particulate exposures and acute respiratory symptoms were restricted to children (EPA, 1996). Although they generally showed positive associations, and may be of considerable biological relevance, evidence of toxicity in children is not necessarily applicable to adults. The few studies on adults have not produced statistically significant evidence of a relationship.

Fourteen studies since 1982 have investigated associations between ambient particulate levels and loss of pulmonary function (EPA, 1996). In general, these studies suggest a short term effect, especially in symptomatic groups such as asthmatics, but most were carried out on children only. In a study of adults with mild COPD, Pope and Kanner (1993) found a 29±10 ml decrease in 1-second Forced Expiratory Volume (FEV_1) per 50 μg/m^3 increase in PM_{10}, which is similar in magnitude to the change generally observed in the studies on children. In another study of adults, with PM_{10} ranging from 4 to 137 μg/m^3, Dusseldorp et al. (1995) found 45 and 77 ml/sec decreases, respectively, for evening and morning Peak Expiratory Flow Rate (PEFR) per 50 μg/m^3 increase in PM_{10} (EPA, 1996). In the only study carried out on adults that specifically measured fine particulate ($PM_{2.5}$), Perry et al. (1983) did not detect any association of exposure with loss of pulmonary function. This study, however, was conducted on only 24 adults (all asthmatics) exposed at relatively low concentrations of $PM_{2.5}$ and, therefore, had very little power to detect any such association.

III.2.c. Chronic Health Effects

During the 1995 dpm workshops, miners reported observable adverse health effects among those who have worked a long time in dieselized mines. For example, a miner (dpm Workshop; Salt Lake City, UT, 1995), stated that miners who work with diesel ''have spit up black stuff every night, big black—what they call black (expletive) * * * [they] have the congestion every night * * * the 60-year-old man working there 40 years.'' Scientific investigation of the chronic health effects of dpm exposure includes studies based specifically on exposures to diesel emissions and studies based more generally on exposures to fine particulate matter in the ambient air. Only the evidence from human studies will be addressed in this section. Data from genotoxicology studies and studies on laboratory animals will be discussed later, in the section on potential mechanisms of toxicity.

III.2.c.i. Studies Based on Exposures to Diesel Emissions

The discussion will summarize the epidemiological literature on chronic effects other than cancer, and then concentrate on the epidemiology of cancer in workers exposed to dpm.

III.2.c.i.A. Chronic Effects Other Than Cancer

There have been a number of epidemiological studies that investigated relationships between diesel exposure and the risk of developing persistent respiratory symptoms (i.e., chronic cough, chronic phlegm, and breathlessness) or measurable loss in lung function. Three studies involved coal miners (Reger *et al.*, 1982; Ames *et al.*, 1984; Jacobson *et al.*, 1988); four studies involved metal and nonmetal miners (Jörgenson & Svensson, 1970; Attfield, 1979; Attfield *et al.*, 1982; Gamble *et al.*, 1983). Three studies involved other groups of workers—railroad workers (Battigelli *et al.*, 1964), bus garage workers (Gamble *et al.*, 1987), and stevedores (Purdham *et al.*, 1987).

Reger *et al.* (1982) examined the prevalence of respiratory symptoms and the level of pulmonary function among more than 1,600 underground and surface coal miners, comparing results for workers (matched for smoking status, age, height, and years worked underground) at diesel and non-diesel mines. Those working at underground dieselized mines showed some increased respiratory symptoms and reduced lung function, but a similar pattern was found in surface miners who presumably would have experienced less diesel exposure. Miners in the dieselized mines, however, had worked underground for less than 5 years on average.

In a study of 1,118 coal miners, Ames *et al.* (1984) did not detect any pattern of chronic respiratory effects associated with exposure to diesel emissions. The analysis, however, took no account of baseline differences in lung function or symptom prevalence, and the authors noted a low level of exposure to diesel-exhaust contaminants in the exposed population.

In a cohort of 19,901 coal miners investigated over a 5-year period, Jacobsen *et al.* (1988) found increased work absence due to self-reported chest illness in underground workers exposed to diesel exhaust, as compared to surface workers, but found no correlation with their estimated level of exposure.

Jörgenson & Svensson (1970) found higher rates of chronic productive bronchitis, for both smokers and nonsmokers, among underground iron ore miners exposed to diesel exhaust as compared to surface workers at the same mine. No significant difference was found in spirometry results.

Using questionnaires collected from 4,924 miners at 21 metal and nonmetal mines, Attfield (1979) evaluated the effects of exposure to silica dust and diesel exhaust and obtained inconclusive results with respect to diesel exposure. For both smokers and non-smokers, miners occupationally exposed to diesel for five or more years showed an elevated prevalence of persistent cough, persistent phlegm, and shortness of breath, as compared to miners exposed for less than five years, but the differences were not statistically significant. Four quantitative indicators of diesel use failed to show consistent trends with symptoms and lung function.

Attfield *et al.* (1982) reported on a medical surveillance study of 630 white male miners at 6 potash mines. No relationships were found between measures of diesel use or exposure and various health indices, based on self-reported respiratory symptoms, chest radiographs, and spirometry.

In a study of salt miners, Gamble and Jones (1983) observed some elevation in cough, phlegm, and dyspnea associated with mines ranked according to level of diesel exhaust exposure. No association between respiratory symptoms and estimated cumulative diesel exposure was found after adjusting for differences among mines. However, since the mines varied widely with respect to diesel exposure levels, this adjustment may have masked a relationship.

Battigelli *et al.* (1964) compared pulmonary function and complaints of respiratory symptoms in 210 railroad repair shop employees, exposed to diesel for an average of 10 years, to a control group of 154 unexposed railroad workers. Respiratory symptoms were less prevalent in the exposed group, and there was no difference in pulmonary function; but no adjustment was made for differences in smoking habits.

In a study of workers at four diesel bus garages in two cities, Gamble *et al.* (1987b) investigated relationships between tenure (as a surrogate for cumulative exposure) and respiratory symptoms, chest radiographs, and pulmonary function. The study population was also compared to an unexposed control group of workers with similar socioeconomic background. After indirect adjustment for age, race, and smoking, the exposed workers showed an increased prevalence of cough, phlegm, and wheezing, but no association was found with tenure. Age- and height-adjusted pulmonary function was found to decline with duration of exposure, but was elevated on average, as compared to the control group. The number of positive radiographs was too small to support any conclusions. The authors concluded that the exposed workers may have experienced some chronic respiratory effects.

Purdham *et al.* (1987) compared baseline pulmonary function and respiratory symptoms in 17 exposed stevedores to a control group of 11 port office workers. After adjustment for smoking, there was no statistically significant difference in self-reported respiratory symptoms between the two groups. However, after adjustment for smoking, age, and height, exposed workers showed lower baseline pulmonary function, consistent with an obstructive ventilatory defect, as compared to both the control group and the general metropolitan population.

In a recent review of these studies, Cohen and Higgins (1995) concluded that they did not provide strong or consistent evidence for chronic, nonmalignant respiratory effects associated with occupational exposure to diesel exhaust. These reviewers stated, however, that ''several studies are suggestive of such effects * * * particularly when viewed in the context of possible biases in study design and analysis.'' MSHA agrees that the studies are inconclusive but suggestive of possible effects.

III.2.c.i.B. Cancer

Because diesel exhaust has long been known to contain carcinogenic compounds (e.g., benzene in the gaseous fraction and benzopyrene and nitropyrene in the dpm fraction), a great deal of research has been conducted to determine if occupational exposure to diesel exhaust actually results in an increased risk of cancer. Evidence that exposure to dpm increases the risk of developing cancer comes from three kinds of studies: human studies, genotoxicity studies, and animal studies. MSHA places the most weight on evidence from the human epidemiological studies and views the genotoxicological and animal studies as lending support to the epidemiological evidence.

In the epidemiological studies, it is generally impossible to disassociate exposure to dpm from exposure to the gasses and vapors that form the remainder of whole diesel exhaust. However, the animal evidence shows no significant increase in the risk of lung cancer from exposure to the gaseous fraction alone (Heinrich *et al.*, 1986; Iwai *et al.*, 1986; Brightwell *et al.*, 1986). Therefore, dpm, rather than the gaseous fraction of diesel exhaust, is assumed be the agent associated with an excess risk of lung cancer.

III.2.c.i.B.i. Lung Cancer

Beginning in 1957, at least 43 epidemiological studies have been published examining relationships between diesel exhaust exposure and the prevalence of lung cancer. The most recent published reviews of these studies are by Mauderly (1992), Cohen and Higgins (1995), Stöber and Abel (1996), Morgan et al. (1997), and Dawson et al. (1998). In addition, in response to the ANPRM, several commenters provided MSHA with their own reviews. Two comprehensive statistical ''meta-analyses'' of the epidemiological literature are also available: Lipsett and Alexeeff (1998) and Bhatia et al. (1998). These meta-analyses, which analyze and combine results from the various epidemiological studies, both suggest a statistically significant increase of 30 to 40 percent in the risk of lung cancer, attributable to occupational dpm exposure. The studies themselves, along with MSHA's comments on each study, are summarized in Tables III–4 (24 cohort studies) and III–5 (19 case-control studies).[11] Presence or absence of an adjustment for smoking habits is highlighted, and adjustments for other potentially confounding factors are indicated when applicable.

Some degree of association between occupational dpm exposure and an excess risk of lung cancer was observed in 38 of the 43 studies reviewed by MSHA: 18 of the 19 case-control studies and 20 of the 24 cohort studies. However, the 38 studies reporting a positive association vary considerably in the strength of evidence they present. As shown in Tables III–4 and III–5, *statistically significant* results were reported in 24 of the 43 studies: 10 of the 18 positive case-control studies and 14 of the 20 positive cohort studies.[12] In six of the 20 cohort studies and nine of the 18 case-control studies showing a positive association, the association observed was not statistically significant.

Because workers tend to be healthier than non-workers, the incidence of disease found among workers exposed to a toxic substance may be lower than the rate prevailing in the general population, but higher than the rate occurring in an unexposed population of workers. This phenomenon, called the ''healthy worker effect,'' also applies when the rate observed among exposed workers is greater than that found in the general population. In this case, assuming a study is unbiased with respect to other factors such as smoking, comparison with the general population will tend to *underestimate* the excess risk of disease attributable to the substance being investigated. Several studies drew comparisons against the general population, including both workers and nonworkers, with no compensating adjustment for the healthy worker effect. Therefore, in these studies, the excess risk of lung cancer attributable to dpm exposure is likely to have been underestimated, thereby making it more difficult to obtain a statistically significant result.

Five of the 43 studies listed in Tables III–4 and III–5 are negative—i.e., a lower rate of lung cancer was found among exposed workers than in the control population used for comparison. None of these five results, however, were statistically significant. Four of the five were cohort studies that drew comparisons against the general population and did not take the healthy worker effect into account. The remaining negative study was a case-control study in which vehicle drivers and locomotive engineers were compared to clerical workers.

Two cohort studies (Waxweiler et al., 1973; Ahlman et al., 1991) were performed specifically on groups of miners, and one (Boffetta et al., 1988) addressed miners as a subgroup of a larger population. Although an elevated prevalence of lung cancer was found among miners in both the 1973 and 1991 studies, the results were not statistically significant. The 1988 study found, after adjusting for smoking patterns and other occupational exposures, an 18-percent increase in the lung cancer rate among all workers occupationally exposed to diesel exhaust and a 167-percent increase

[11] For simplicity, the epidemiological studies considered here are placed into two broad categories. A *cohort study* compares the health of persons having different exposures, diets, etc. A *case-control study* starts with two defined groups that differ in terms of their health and compares their exposure characteristics.

[12] A statistically significant result is a result unlikely to have arisen by chance in the group, or statistical *sample*, of persons being studied. An association arising by chance would have no predictive value for workers outside the sample. Failure to achieve statistical significance in an individual study can arise because of inherent limitations in the study, such as a small number of subjects in the sample or a short period of observation. Therefore, the lack of statistical significance in an individual study does not demonstrate that the results of that study were due merely to chance—only that the study (viewed in isolation) is inconclusive.

among miners (relative risk = 2.67). The latter result is statistically significant.

In addition, four case-control studies, all of which adjusted for smoking, found elevated rates of lung cancer associated with mining. The results for miners in three of these studies (Benhamou et al., 1988; Morabia et al., 1992; Siemiatycki et al., 1988) are given little weight because of potential confounding by occupational exposures to other carcinogens. The other study (Lerchen et al., 1987) showed a marginally significant result for underground non-uranium miners, but this was based on very few cases and the extent of diesel exposure among these miners was not reported. Although they do not pertain specifically to mining environments, other studies showing statistically significant results (most notably those by Garshick et al., 1987 and 1988) are based on far more data, contain better diesel exposure information, and are less susceptible to confounding by extraneous risk factors.

Since none of the existing human studies is perfect and many contain major deficiencies, it is not surprising that reported results differ in magnitude and statistical significance. Shortcomings identified in both positive and negative studies include: possible misclassification with respect to exposure; incomplete or questionable characterization of the exposed population; unknown or uncertain quantification of diesel exhaust exposure; incomplete, uncertain, or unavailable history of exposure to tobacco smoke and other carcinogens; and insufficient sample size, dpm exposure, or latency period (i.e., time since exposure) to detect a carcinogenic effect if one exists. Indeed, in their review of these studies, Stöber and Abel (1996) conclude that ''In this field * * * epidemiology faces its limits (Taubes, 1995) * * * Many of these studies were doomed to failure from the very beginning.''

Such problems, however, are not unique to epidemiological studies involving diesel exhaust but are common sources of uncertainty in virtually all epidemiological research involving cancer. Indeed, deficiencies such as exposure misclassification, small sample size, and short latency make it difficult to detect a relationship even when one exists. Therefore, the fact that 38 out of 43 studies showed any excess risk of lung cancer associated with dpm exposure may itself be a significant result, even if the evidence in most of those 38 studies is relatively weak.[13] The sheer number of studies showing such an association readily distinguishes this body of evidence from those criticized by Taubes (1995), where weak evidence is available from only a single study.

At the same time, MSHA recognizes that simply tabulating outcomes can sometimes be misleading, since there are generally a variety of outcomes that could render a study positive or negative and some studies use related data sets. Therefore, rather than limiting its assessment to such a tabulation, MSHA is basing its evaluation with respect to lung cancer largely on the two comprehensive meta-analyses (Lipsett and Alexeeff, 1998; Bhatia et al., 1998) described later, in the ''material impairments'' section of this risk assessment. In addition to restricting themselves to independent studies meeting certain minimal requirements, both meta-analyses investigated and rejected publication bias as an explanation for the generally positive results reported.

All of the studies showing negative or statistically insignificant positive associations were either based on relatively short observation or follow-up periods, lacked good information about dpm exposure, involved low duration or intensity of dpm exposure, or, because of inadequate sample size, lacked the statistical power to detect effects of the magnitude found in the ''positive'' studies. As stated by Boffetta et al. (1988, p. 404), studies failing to show a statistically significant association—

> * * * often had low power to detect any association, had insufficient latency periods, or compared incidence or mortality rates among workers to national rates only, resulting in possible biases caused by the ''healthy worker effect.''

Some respondents to the ANPRM argued that such methodological weaknesses may explain why not all of the studies showed a statistically significant association between dpm exposure and an increased prevalence of lung cancer. According to these commenters, if an epidemiological study shows a statistically significant result, this often occurs *in spite of* methodological weaknesses rather than because of them. Limitations such as potential exposure misclassification, inadequate latency, inadequate sample size, and insufficient duration of exposure all make it more difficult to obtain a statistically significant result when a real relationship exists.

On the other hand, Stöber and Abel (1996) argue, along with Morgan et al. (1997) and some commenters, that even in those epidemiological studies showing a statistically significant association, the magnitude of relative or excess risk observed is too small to demonstrate any causal link between dpm exposure and cancer. Their reasoning is that in these studies, errors in the collection or interpretation of smoking data can create a bias in the results larger than any potential contribution attributable to diesel particulate. They propose that studies failing to account for smoking habits should be disqualified from consideration, and that evidence of an association from the remaining studies should be discounted because of potential confounding due to erroneous, incomplete, or otherwise inadequate characterization of smoking histories.

MSHA concurs with Cohen and Higgins (1995), Lipsett and Alexeeff (1998), and Bhatia et al. (1998) in not accepting this view. MSHA does recognize that unknown exposures to tobacco smoke or other human carcinogens, such as asbestos, can distort the results of some lung cancer studies. MSHA also agrees that significant differences in the distribution of confounding factors, such as smoking history, between study and control groups can lead to misleading results. MSHA also recognizes, however, that it is not possible to design a human epidemiological study that perfectly controls for all potentially confounding factors. Some degree of informed subjective judgement is always required in evaluating the potential significance of unknown or uncontrolled factors.

Sixteen of the published epidemiological studies involving lung cancer did, in fact, control or adjust for exposure to tobacco smoke, and some of these also controlled or adjusted for exposure to asbestos and other carcinogenic substances (e.g., Garshick *et al.*, 1987; Steenland *et al.*, 1990; Boffetta *et al.*, 1988). All but one of these 16 epidemiological studies reported some degree of excess risk associated with exposure to diesel particulate, with statistically significant results reported in seven. These results are less likely to be confounded than results from studies with no adjustment. In addition, several of the other studies drew comparisons against internal control groups or control groups likely

[13] The high proportion of positive studies is statistically significant according to the 2-tailed sign test, which rejects, at a high confidence level, the null hypothesis that each study is equally likely to be positive or negative. Assuming that the studies are independent, and that there is no systematic bias in one direction or the other, the probability of 38 or more out of 43 studies being either positive or negative is less than one per million under the null hypothesis.

to have similar smoking habits as the exposed groups (e.g., Garshick *et al.*, 1988; Gustavsson *et al.*, 1990; and Hansen, 1993). MSHA places more weight on these studies than on studies drawing comparisons against dissimilar groups with no controls or adjustments.

According to Stöber and Abel, the potential confounding effects of smoking are so strong that they could explain even statistically significant results observed in studies where smoking was explicitly taken into account. MSHA agrees that variable exposures to non-diesel lung carcinogens, including relatively small errors in smoking classification, could bias individual studies. However, the potential confounding effect of tobacco smoke and other carcinogens can cut in either direction. Spurious positive associations of dpm exposure with lung cancer would arise only if the group exposed to dpm had a greater exposure to these confounders than the unexposed control group used for comparison. If, on the contrary, the control group happened to be more exposed to confounders, then this would tend to make the association between dpm exposure and lung cancer appear negative. Therefore, although smoking effects could potentially distort the results of any single study, this effect could reasonably be expected to make only about half the studies that were explicitly adjusted for smoking come out positive. Smoking is unlikely to have been responsible for finding an excess prevalence of lung cancer in 15 out of 16 studies in which a smoking adjustment was applied. Based on a 2-tailed sign test, this possibility can be rejected at a confidence level greater than 99.9 percent.

Even in the 27 studies involving lung cancer for which no smoking adjustment was made, tobacco smoke and other carcinogens are important confounders only to the extent that the populations exposed and unexposed to diesel exhaust differed systematically with respect to these other exposures. Twenty-three of these studies, however, reported some degree of excess lung cancer risk associated with diesel exposure. This result could be attributed to non-diesel exposures only in the unlikely event that, in nearly all of these studies, diesel-exposed workers happened to be more highly exposed to these other carcinogens than the control groups of workers unexposed to diesel. All five studies not showing any association (Kaplan, 1959; DeCoufle, 1977; Waller, 1981; Edling, 1987; and Bender, 1989) may have failed to detect such a relationship because of too small a study group, lack of accurate exposure information, low duration or intensity of exposure, and/or insufficient latency or follow-up time.

It is also significant that the two most comprehensive, complete, and well-controlled studies available (Garshick *et al.*, 1987 and 1988) both point in the direction of an association between dpm exposure and an excess risk of lung cancer. These studies took care to address potential confounding by tobacco smoke and asbestos exposures. In response to the ANPRM, a consultant to the National Coal Association who was critical of all other available studies acknowledged that these two:

> * * * have successfully controlled for severally [sic] potentially important confounding factors * * * Smoking represents so strong a potential confounding variable that its control must be nearly perfect if an observed association between cancer and diesel exhaust is * * * [inferred to be causal]. In this regard, two observations are relevant. First, both case-control [Garshick *et al.*, 1987] and cohort [Garshick *et al.*, 1988] study designs revealed consistent results. Second, an examination of smoking related causes of death other than lung cancer seemed to account for only a fraction of the association observed between diesel exposure and lung cancer. A high degree of success was apparently achieved in controlling for smoking as a potentially confounding variable. [Submission 87–0–10, Robert A. Michaels, RAM TRAC Corporation, prepared for National Coal Association].

Potential biases due to extraneous risk factors are unlikely to account for a significant part of the excess risk in all studies showing an association. Excess rates of lung cancer were associated with dpm exposure in all epidemiologic studies of sufficient size and scope to detect such an excess. Although it is possible, in any individual study, that the potentially confounding effects of differential exposure to tobacco smoke or other carcinogens could account for the observed elevation in risk otherwise attributable to diesel exposure, it is unlikely that such effects would give rise to positive associations in 38 out of 43 studies. As stated by Cohen and Higgins (1995):

> * * * elevations [of lung cancer] do not appear to be fully explicable by confounding due to cigarette smoking or other sources of bias. Therefore, at present, exposure to diesel exhaust provides the most reasonable explanation for these elevations. The association is most apparent in studies of occupational cohorts, in which assessment of exposure is better and more detailed analyses have been performed. The largest relative risks are often seen in the categories of most probable, most intense, or longest duration of exposure. In general population studies, in which exposure prevalence is low and misclassification of exposure poses a particularly serious potential bias in the direction of observing no effect of exposure, most studies indicate increased risk, albeit with considerable imprecision. [Cohen and Higgins (1995), p. 269].

MSHA solicits comment on the issue of the potential for biases in these studies.

III.2.c.i.B.ii. Bladder Cancer

With respect to cancers other than lung cancer, MSHA's review of the literature identified only bladder cancer as a possible candidate for a causal link to dpm. Cohen and Higgins (1995) identified and reviewed 14 epidemiological case-control studies containing information related to dpm exposure and bladder cancer. All but one of these studies found elevated risks of bladder cancer among workers in jobs frequently associated with dpm exposure. Findings were statistically significant in at least four of the studies (statistical significance was not evaluated in three).

These studies point quite consistently toward an excess risk of bladder cancer among truck or bus drivers, railroad workers, and vehicle mechanics. However, the four available cohort studies do not support a conclusion that exposure to dpm is responsible for the excess risk of bladder cancer associated with these occupations. Furthermore, most of the case-control studies did not distinguish between exposure to diesel-powered equipment and exposure to gasoline-powered equipment for workers having the same occupation. When such a distinction was drawn, there was no evidence that the prevalence of bladder cancer was higher for workers exposed to the diesel-powered equipment.

This, along with the lack of corroboration from existing cohort studies, suggests that the excessive rates of bladder cancer observed may be a consequence of factors other than dpm exposure that are also associated with these occupations. For example, truck and bus drivers are subjected to vibrations while driving and may tend to have different dietary and sleeping habits than the general population. For these reasons, MSHA does not find that convincing evidence currently exists for a causal relationship between dpm exposure and bladder cancer.

III.2.c.ii. Studies Based on Exposures to Fine Particulate in Ambient Air

Longitudinal studies examine responses at given locations to changes in conditions over time, whereas *cross-sectional studies* compare results from locations with different conditions at a given point in time. Prior to 1990, cross sectional studies were generally used to evaluate the relationship between mortality and long-term exposure to particulate matter, but unaddressed spatial confounders and other methodological problems inherent in such studies limited their usefulness (EPA, 1996).

Two recent prospective cohort studies provide better evidence of a link between excess mortality rates and exposure to fine particulate, although the uncertainties here are greater than with the short-term exposure studies conducted in single communities. The two studies are known as the Six Cities study (Dockery *et al.*, 1993), and the American Cancer Society (ACS) study (Pope *et al.*, 1995).[14] The first study followed about 8,000 adults in six U.S. cities over 14 years; the second looked at survival data for half a million adults in 151 U.S. cities for 7 years. After adjusting for potential confounders, including smoking habits, the studies considered differences in mortality rates between the most polluted and least polluted cities.

Both the Six Cities Study and the ACS study found a significant association between increased concentration of $PM_{2.5}$ and total mortality.[15] The authors of the Six Cities Study concluded that the results suggest that exposures to fine particulate air pollution ''contributes to excess mortality in certain U.S. cities.'' The ACS study, which not only controlled for smoking habits and various occupational exposures, but also, to some extent, for passive exposure to tobacco smoke, found results qualitatively consistent with those of the Six Cities Study.[16] In the ACS study, however, the estimated increase in mortality associated with a given increase in fine particulate exposure was lower, though still statistically significant. In both studies, the largest increase observed was for cardiopulmonary mortality. Both studies also showed an increased risk of lung cancer associated with increased exposure to fine particulate, but these results were not statistically significant.

[14] A third such study only looked at TSP, rather than fine particulate. It did not find a significant association between total mortality and TSP. It is known as the California Seventh Day Adventist study (Abbey et al., 1991).

[15] The Six Cities study also found such relationships at elevated levels of $PM_{15/10}$ and sulfates. The ACS study was designed to follow up on the fine particle result of the Six Cities Study, but also looked at sulfates.

[16] The Six Cities study did not find a statistically significant increase in risk among non-smokers, suggesting that this group might not be as sensitive to adverse health effects from exposure to fine particulate; however, the ACS study, with more statistical power, did find an association even for non-smokers.

The few studies on associations between chronic $PM_{2.5}$ exposure and morbidity in adults show effects that are difficult to separate from measures of PM_{10} and measures of acid aerosols. The available studies, however, do show positive associations between particulate air pollution and adverse health effects for those with pre-existing respiratory or cardiovascular disease; and as mentioned earlier, there is a large body of evidence showing that respiratory diseases classified as COPD are significantly more prevalent among miners than in the general population. It also appears that PM exposure may exacerbate existing respiratory infections and asthma, increasing the risk of severe outcomes in individuals who have such conditions (EPA, 1996).

III.2.d. Mechanisms of Toxicity

As described in Part II, the particulate fraction of diesel exhaust is made up of aggregated soot particles. Each soot particle consists of an insoluble, elemental carbon core and an adsorbed, surface coating of relatively soluble organic compounds, such as polycyclic aromatic hydrocarbons (PAH's). When released into an atmosphere, the soot particles formed during combustion tend to aggregate into larger particles.

The literature on deposition of fine particles in the respiratory tract is reviewed in Green and Watson (1995) and U.S. EPA (1996). The mechanisms responsible for the broad range of potential particle-related health effects will vary depending on the site of deposition. Once deposited, the particles may be cleared from the lung, translocated into the interstitium, sequestered in the lymph nodes, metabolized, or be otherwise transformed by various mechanisms.

As suggested by Figure II–1 of this preamble, most of the aggregated particles making up dpm never get any larger than one micrometer in diameter. Particles this small are able to penetrate into the deepest regions of the lungs, called *alveoli*. In the alveoli, the particles can mix with and be dispersed by a substance called *surfactant*, which is secreted by cells lining the alveolar surfaces.

MSHA would welcome any additional information, not already covered cited above, on fine particle deposition in the respiratory tract, especially as it might pertain to lung loading in miners exposed to a combination of diesel particulate and other dusts. Any such additional information will be placed into the public record and considered by MSHA before a final rule is adopted.

III.2.d.i. Effects Other than Cancer

A number of controlled animal studies have been undertaken to ascertain the toxic effects of exposure to diesel exhaust and its components. Watson and Green (1995) reviewed approximately 50 reports describing noncancerous effects in animals resulting from the inhalation of diesel exhaust. While most of the studies were conducted with rats or hamsters, some information was also available from studies conducted using cats, guinea pigs, and monkeys. The authors also correlated reported effects with different descriptors of dose. From their review of these studies, Watson and Green concluded that:

(a) Animals exposed to diesel exhaust exhibit a number of noncancerous pulmonary effects, including chronic inflammation, epithelial cell hyperplasia, metaplasia, alterations in connective tissue, pulmonary fibrosis, and compromised pulmonary function.

(b) Cumulative weekly exposure to diesel exhaust of 70 to 80 mg•hr/m^3 or greater are associated with the presence of chronic inflammation, epithelial cell proliferation, and depressed alveolar clearance in chronically exposed rats.

(c) The extrapolation of responses in animals to noncancer endpoints in humans is uncertain. Rats were the most sensitive animal species studied.

Subsequent to the review by Watson and Green, there have been a number of animal studies on allergic immune responses to dpm. Takano et al. (1997) investigated the effects of dpm injected into mice through an intratracheal tube and found manifestations of allergic asthma, including enhanced antigen-induced airway inflammation, increased local expression of cytokine proteins, and increased production of antigen-specific immunoglobulins. The authors concluded that the study demonstrated dpm's enhancing effects on allergic asthma and that the results suggest that dpm is ''implicated in the increasing prevalence of allergic asthma in recent years.'' Similarly, Ichinose et al. (1997) found that five different strains of mice injected intratracheally with dpm exhibited manifestations of allergic asthma, as expressed by enhanced airway inflammation, which were correlated with an increased production of antigen-specific immunoglobulin due to the dpm. The authors concluded that dpm enhances manifestations of allergic airway inflammation and that ''* * * the cause of individual differences in humans at the onset of allergic asthma may be related to differences in antigen-induced immune responses * * *.''

Several laboratory animal studies have been performed to ascertain whether the effects of diesel exhaust are attributable specifically to the particulate fraction. (Heinrich *et al.*, 1986; Iwai *et al.*, 1986; Brightwell et al., 1986). These studies compare the effects of chronic exposure to whole diesel exhaust with the effects of filtered exhaust containing no particles.

The studies demonstrate that when the exhaust is sufficiently diluted to nullify the effects of gaseous irritants (NO_2 and SO_2), irritant vapors (aldehydes), CO, and other systemic toxicants, diesel particles are the prime etiologic agents of noncancer health effects. Exposure to dpm produced changes in the lung that were much more prominent than those evoked by the gaseous fraction alone. Marked differences in the effects of whole and filtered diesel exhaust were also evident from general toxicological indices, such as body weight, lung weight, and pulmonary histopathology. This provides strong evidence that the toxic component in diesel emissions producing the effects noted in other animal studies is due to the particulate fraction.

The mechanisms that may lead to adverse health effects in humans from inhaling fine particulates are not fully understood, but potential mechanisms that have been hypothesized for non-cancerous outcomes are summarized in Table III–6. A comprehensive review of the toxicity literature is provided in U.S. EPA (1996).

Deposition of particulates in the human respiratory tract could initiate events leading to increased airflow obstruction, impaired clearance, impaired host defenses, or increased epithelial permeability. Airflow obstruction could result from laryngeal constriction or bronchoconstriction secondary to stimulation of receptors in extrathoracic or intrathoracic airways. In addition to reflex airway narrowing, reflex or local stimulation of mucus secretion could lead to mucus hypersecretion and could eventually lead to mucus plugging in small airways.

Pulmonary changes that contribute to cardiovascular responses include a variety of mechanisms that can lead to hypoxemia, including bronchoconstriction, apnea, impaired diffusion, and production of inflammatory mediators. Hypoxia can lead to cardiac arrhythmias and other cardiac electrophysiologic responses that, in turn, may lead to ventricular fibrillation and ultimately cardiac arrest. Furthermore, many respiratory receptors have direct cardiovascular effects. For example, stimulation of C-fibers leads to bradycardia and hypertension, and stimulation of laryngeal receptors can result in hypertension, cardiac arrhythmia, bradycardia, apnea, and even cardiac arrest. Nasal receptor or pulmonary J-receptor stimulation can lead to vagally mediated bradycardia and hypertension (Widdicombe, 1988).

In addition to possible acute toxicity of particles in the respiratory tract, chronic exposure to particles that deposit in the lung may induce inflammation. Inflammatory responses can lead to increased permeability and possibly diffusion abnormality. Furthermore, mediators released during an inflammatory response could cause release of factors in the clotting cascade that may lead to an increased risk of thrombus formation in the vascular system (Seaton, 1995). Persistent inflammation, or repeated cycles of acute lung injury and healing, can induce chronic lung injury. Retention of the particles may be associated with the initiation and/or progression of COPD.

III.2.d.ii. Lung Cancer

III.2.d.ii.A. Genotoxicological Evidence

Many studies have shown that diesel soot, or its organic component, can increase the likelihood of genetic mutations during the biological process of cell division and replication. A survey of the applicable scientific literature is provided in Shirnamé-Moré (1995). What makes this body of research relevant to the risk of cancer is that mutations in critical genes can sometimes initiate, promote, or advance a process of carcinogenesis.

The determination of genotoxicity has frequently been made by treating diesel soot with organic solvents such as dichloromethane and dimethyl sulfoxide. The solvent removes the organic compounds from the carbon core. After the solvent evaporates, the mutagenic potential of the extracted organic material is tested by applying it to bacterial, mammalian, or human cells propagated in a laboratory culture. In general, the results of these studies have shown that various components of the organic material can induce mutations and chromosomal aberrations.

A critical issue is whether whole diesel particulate is mutagenic when dispersed by substances present in the lung. Since the laboratory procedure for extracting organic material with solvents bears little resemblance to the physiological environment of the lung, it is important to establish whether dpm as a whole is genotoxic, without solvent extraction. Early research indicated that this was not the case and, therefore, that the active genotoxic materials adhering to the carbon core of diesel particles might not be biologically damaging or even available to cells in the lung (Brooks et al., 1980; King et al., 1981; Siak et al., 1981). A number of more recent research papers, however, have shown that dpm, without solvent extraction, can cause DNA damage when the soot is dispersed in the pulmonary surfactant that coats the surface of the alveoli (Wallace et al., 1987; Keane et al., 1991; Gu et al., 1991; Gu et al., 1992). From these studies, NIOSH has concluded:

> * * * the solvent extract of diesel soot and the surfactant dispersion of diesel soot particles were found to be active in procaryotic cell and eukaryotic cell *in vitro* genotoxicity assays. The cited data indicate that respired diesel soot particles on the surface of the lung alveoli and respiratory bronchioles can be dispersed in the surfactant-rich aqueous phase lining the surfaces, and that genotoxic material associated with such dispersed soot particles is biologically available and genotoxically active. Therefore, this research demonstrates the biological availability of active genotoxic materials without organic solvent interaction. [Cover letter to NIOSH response to ANPRM].

From this conclusion, it follows that dpm itself, and not only its organic extract, can cause genetic mutations when dispersed by a substance present in the lung.

The biological availability of the genotoxic components is also supported directly by studies showing genotoxic effects of exposure to whole dpm. The formation of DNA adducts is an important indicator of genotoxicity and potential carcinogenicity. If DNA adducts are not repaired, then a mutation or chromosomal aberration can occur during normal mitosis (i.e., cell replication). Hemminki et al. (1994) found that DNA adducts were significantly elevated in nonsmoking bus maintenance and truck terminal workers, as compared to a control group of hospital mechanics, with the highest adduct levels found among garage and forklift workers. Similarly, Nielsen et al. (1996) found that DNA adducts were significantly increased in bus garage workers and mechanics exposed to dpm as compared to a control group.

III.2.d.ii.B. Evidence From Animal Studies

Bond et al. (1990) investigated differences in peripheral lung DNA adduct formation among rats, hamsters, mice, and monkeys exposed to dpm at a concentration of 8100 $\lambda g/m^3$ for 12 weeks. Mice and hamsters showed no increase of DNA adducts in their peripheral lung tissue, whereas rats and monkeys showed a 60 to 80% increase. The increased prevalence of lung DNA adducts in monkeys suggests that, with respect to DNA adduct formation, the human lungs' response to dpm inhalation may more closely resemble that of the rat than that of the hamster or mouse.

Mauderly (1992) and Busby and Newberne (1995) provide reviews of the scientific literature relating to excess lung cancers observed among laboratory animals chronically exposed to filtered and unfiltered diesel exhaust. The experimental data demonstrate that chronic exposure to whole diesel exhaust increases the risk of lung cancer in rats and that dpm is the causative agent. This carcinogenic effect has been confirmed in two strains of rats and in at least five laboratories. Experimental results for animal species other than the rat, however, are either inconclusive or, in the case of Syrian hamsters, suggestive of no carcinogenic effect. This is consistent with the observation, mentioned above, that lung DNA adduct formation is increased among exposed rats but not among exposed hamsters or mice.

The conflicting results for rats and hamsters indicate that the carcinogenic effects of dpm exposure may be species-dependent. Indeed, monkey lungs have been reported to respond quite differently than rat lungs to both diesel exhaust and coal dust (Nikula, 1997). Therefore, the results from rat experiments do not, by themselves, establish that there is any excess risk due to dpm exposure for humans. The human epidemiological data, however, indicate that humans comprise a species that, like rats and unlike hamsters, do suffer a carcinogenic response to dpm exposure. Therefore, MSHA considers the rat studies at least relevant to an evaluation of the risk for humans.

When dpm is inhaled, a number of adverse effects that may contribute to carcinogenesis are discernable by microscopic and biochemical analysis. For a comprehensive review of these effects, see Watson and Green (1995). In brief, these effects begin with phagocytosis, which is essentially an attack on the diesel particles by cells called alveolar macrophages. The macrophages engulf and ingest the diesel particles, subjecting them to detoxifying enzymes. Although this is a normal physiological response to the inhalation of foreign substances, the process can produce various chemical byproducts injurious to normal cells. In attacking the diesel particles, the activated macrophages release chemical agents that attract neutrophils (a type of white blood cell that destroys microorganisms) and additional alveolar macrophages. As the lung burden of diesel particles increases, aggregations of particle-laden macrophages form in alveoli adjacent to terminal bronchioles, the number of Type II cells lining particle-laden alveoli increases, and particles lodge within alveolar and peribronchial tissues and associated lymph nodes. The neutrophils and macrophages release mediators of inflammation and oxygen radicals, which have been implicated in causing various forms of chromosomal damage, genetic mutations, and malignant transformation of cells (Weitzman and Gordon, 1990). Eventually, the particle-laden macrophages are functionally altered, resulting in decreased viability and impaired phagocytosis and clearance of particles. This series of events may result in pulmonary inflammatory, fibrotic, or emphysematous lesions that can ultimately develop into cancerous tumors.

Such reactions have also been observed in rats exposed to high concentrations of fine particles with no organic component (Mauderly et al., 1994; Heinrich et al., 1994 and 1995; Nikula et al., 1995). Rats exposed to titanium dioxide or pure carbon (''carbon-black'') particles, which are not considered to be genotoxic, developed lung cancers at about the same rate as rats exposed to whole diesel exhaust. Therefore, it appears that the toxicity of dpm, at least in some species, may result largely from a biochemical response to the particle itself rather than from specific effects of the adsorbed organic compounds.

Some researchers have interpreted the carbon-black and titanium dioxide studies as also suggesting that (1) the carcinogenic mechanism in rats depends on massive overloading of the lung and (2) that this may provide a mechanism of carcinogenesis specific to rats which does not occur in other rodents or in humans (Oberdörster, 1994; Watson and Valberg, 1996). Some commenters on the ANPRM cited the lack of any link between lung cancer and coal dust or carbon black exposure as evidence that carbon particles, by themselves, are not carcinogenic in humans. Coal mine dust, however, consists almost entirely of particles larger than those forming the carbon core of dpm or used in the carbon-black and titanium dioxide rat studies. Furthermore, although there have been nine studies reporting no excess risk of lung cancer among coal miners (Liddell, 1973; Costello *et al.*, 1974; Armstrong *et al.*, 1979; Rooke *et al.*, 1979; Ames *et al.*, 1983; Atuhaire *et al.*, 1985; Miller and Jacobsen, 1985; Kuempel *et al.*, 1995; Christie *et al.*, 1995), five studies have reported an elevated risk of lung cancer for those exposed to coal dust (Enterline, 1972; Rockette, 1977; Correa *et al.*, 1984; Levin *et al.*, 1988; Morfeld *et al.*, 1997). The positive results in two of these studies (Enterline, 1972; Rockette, 1977) were statistically significant. Furthermore, excess lung cancers have been reported among carbon black production workers (Hodgson and Jones, 1985; Siemiatycki, 1991; Parent *et al.*, 1996). MSHA is not aware of any evidence that a mechanism of carcinogenesis due to fine particle overload is inapplicable to humans. Studies carried out on rodents certainly do not provide such evidence.

The carbon-black and titanium dioxide studies indicate that lung cancers in rats exposed to dpm may be induced by a mechanism that does not require the bioavailability of genotoxic organic compounds adsorbed on the elemental carbon particles. These studies do not, however, prove that the only significant agent of carcinogenesis in rats exposed to diesel particulate is the non-soluble carbon core. Nor do the carbon-black studies prove that the only significant mechanism of carcinogenesis due to diesel particulate is lung overload. Due to the relatively high doses administered in the rat studies, it is conceivable that an overload phenomenon masks or parallels other potential routes to cancer. It may be that effects of the genotoxic organic compounds are merely masked or displaced by overloading in the rat studies. Gallagher et al. (1994) exposed different groups of rats to diesel exhaust, carbon black, or titanium dioxide and detected species of lung DNA adducts in the rats exposed to dpm that were not found in the controls or rats exposed to carbon black or titanium dioxide.

Particle overload may provide the dominant route to lung cancer at very high concentrations of fine particulate, while genotoxic mechanisms may provide the primary route under lower-level exposure conditions. In humans exposed over a working lifetime to doses insufficient to cause overload, carcinogenic mechanisms unrelated to overload may dominate, as indicated by the human epidemiological studies and the data on human DNA adducts cited above. Therefore, the carbon black results observed in the rat studies do not preclude the possibility that the organic component of dpm has important genotoxic effects in humans (Nauss et al., 1995).

Even if the genotoxic organic compounds in dpm were biologically unavailable and played no role in human carcinogenesis, this would not rule out the possibility of a genotoxic route to lung cancer (even for rats) due to the presence of dpm particles themselves. For example, as a byproduct of the biochemical response to the presence of dpm in the alveoli, free oxidant radicals may be released as macrophages attempt to digest the particles. There is evidence that dpm can both induce production of active oxygen agents and also depress the activity of naturally occurring antioxidant enzymes (Mori, 1996; Sagai, 1993). Oxidants can induce carcinogenesis either by reacting directly with DNA, or by stimulating cell replication, or both (Weitzman and Gordon, 1990). This would provide a mutagenic route to lung cancer with no threshold. Therefore, the carbon black and titanium dioxide studies cited above do not prove that dpm exposure has no incremental, genotoxic effects or that there is a threshold below which dpm exposure poses no risk of causing lung cancer.

It is noteworthy, however, that dpm exposure levels recorded in some mines have been almost as high as laboratory exposures administered to rats showing a clearly positive response. Intermittent, occupational exposure levels greater than about 500 $\mu g/m^3$ dpm may overwhelm the human lung clearance mechanism (Nauss et al., 1 995). Therefore, concentrations at levels currently observed in some mines could be expected to cause overload in some humans, possibly inducing lung cancer by a mechanism similar to what occurs in rats. MSHA would like to receive additional scientific information on this issue, especially as it relates to lung loading in miners exposed to a combination of diesel particulate and other dusts.

As suggested above, such a mechanism would not necessarily be the only route to carcinogenesis in humans and, therefore, would not imply that dpm concentrations too low to cause overload are safe for humans. Furthermore, a proportion of exposed individuals can always be expected to be more susceptible than normal. Therefore, at lower dpm concentrations, particle overload may still provide a route to lung cancer in susceptible humans. At even lower concentrations, other routes to carcinogenesis in humans may predominate, possibly involving genotoxic effects.

III.3. Characterization of Risk.

Having reviewed the evidence of health effects associated with exposure to dpm, MSHA has evaluated that evidence to ascertain whether exposure levels currently existing in mines warrant regulatory action pursuant to the Mine Act. The criteria for this evaluation are established by the Mine Act and related court decisions. Section 101(a)(6)(A) provides that:

> The Secretary, in promulgating mandatory standards dealing with toxic materials or harmful physical agents under this subsection, shall set standards which most adequately assure on the basis of the best available evidence that no miner will suffer material impairment of health or functional capacity even if such miner has regular exposure to the hazards dealt with by such standard for the period of his working life.

Based on court interpretations of similar language under the Occupational Safety and Health Act, there are three questions that need to be addressed: (1) Whether health effects associated with dpm exposure constitute a ''material impairment'' to miner health or functional capacity; (2) whether exposed miners are at significant excess risk of incurring any of these material impairments; and (3) whether the proposed rule will substantially reduce such risks.

The criteria for evaluating the health effects evidence do not require scientific certainty. As noted by Justice Stevens in an important case on risk involving the Occupational Safety and Health Administration, the need to evaluate risk does not mean an agency is placed into a ''mathematical straightjacket.'' [*Industrial Union Department, AFL-CIO* v. *American Petroleum Institute,* 448 U.S. 607, 100 S.Ct. 2844 (1980), hereinafter designated the ''Benzene'' case]. When regulating on the edge of scientific knowledge, certainty may not be possible; and—

> so long as they are supported by a body of reputable scientific thought, the Agency is free to use conservative assumptions in interpreting the data * * * risking error on the side of overprotection rather than underprotection. [Id. at 656].

The statutory criteria for evaluating the health evidence do not require MSHA to wait for absolute precision. In fact, MSHA is required to use the ''best *available* evidence.'' (Emphasis added).

III.3.a. Material Impairments to Miner Health or Functional Capacity

From its review of the literature cited in Part III.2, MSHA has tentatively concluded that underground miners exposed to current levels of dpm are at excess risk of incurring the following three kinds of material impairment: (i) sensory irritations and respiratory symptoms; (ii) death from cardiovascular, cardiopulmonary, or respiratory causes; and (iii) lung cancer. The basis for linking these with dpm exposure is summarized in the following three subsections.

III.3.a.i. Sensory Irritations and Respiratory Symptoms

Kahn et al. (1988), Battigelli (1965), Gamble et al. (1987a) and Rudell et al. (1996) identified a number of debilitating acute responses to diesel exhaust exposure: irritation of the eyes, nose and throat; headaches, nausea, and vomiting; chest tightness and wheeze. These symptoms were also reported by miners at the 1995 workshops. In addition, Ulfvarson et al. (1987, 1990) found evidence of reduced lung function in workers exposed to dpm for a single shift.

Although there is evidence that such symptoms subside within one to three days of no occupational exposure, a miner who must be exposed to dpm day after day in order to earn a living may not have time to recover from such effects. Hence, the opportunity for a so-called ''reversible'' health effect to reverse itself may not be present for many miners. Furthermore, effects such as stinging, itching and burning of the eyes, tearing, wheezing, and other types of sensory irritation can cause severe discomfort and can, in some cases, be seriously disabling. Also, workers experiencing sufficiently severe sensory irritations can be distracted as a result of their symptoms, thereby endangering other workers and increasing the risk of accidents. For these reasons, MSHA considers such irritations to constitute ''material impairments'' of health or functional capacity within the meaning of the Act, regardless of whether or not they are reversible. Further discussion of why MSHA believes reversible effects can constitute material impairments can be found earlier in this risk assessment, in the section entitled ''Relevance of Health Effects that are Reversible.''

The best available evidence also points to more severe respiratory consequences of exposure to dpm. Significant associations have been detected between acute environmental exposures to fine particulates and debilitating respiratory impairments in adults, as measured by lost work days, hospital admissions, and emergency room visits. Short-term exposures to fine particulates, or particulate air pollution in general, have been associated with significant increases in the risk of hospitalization for both pneumonia and COPD (EPA, 1996).

The risk of severe respiratory effects is exemplified by specific cases of persistent asthma linked to diesel exposure (Wade and Newman, 1993). There is considerable evidence for a causal connection between dpm exposure and increased manifestations of allergic asthma and other allergic respiratory diseases, coming from recent experiments on animals and human cells (Peterson and Saxon, 1996; Diaz-Sanchez, 1997; Takano et al., 1997; Ichinose et al., 1997). Such health outcomes are clearly ''material impairments'' of health or functional capacity within the meaning of the Act.

III.3.a.ii. Excess Risk of Death from Cardiovascular, Cardiopulmonary, or Respiratory Causes

The evidence from air pollution studies identifies death, largely from cardiovascular or respiratory causes, as an endpoint significantly associated with acute exposures to fine particulates. The weight of epidemiological evidence indicates that short-term ambient exposure to particulate air pollution contributes to an increased risk of daily mortality. Time-series analyses strongly suggest a positive effect on daily mortality across the entire range of ambient particulate pollution levels. Relative risk estimates for daily mortality in relation to daily ambient particulate concentration are consistently positive and statistically significant across a variety of statistical modeling approaches and methods of adjustment for effects of relevant covariates such as season, weather, and co-pollutants. After thoroughly reviewing this body of evidence, the U.S. Environmental Protection Agency (EPA) concluded:

It is extremely unlikely that study designs not yet employed, covariates not yet identified, or statistical techniques not yet developed could wholly negate the large and consistent body of epidemiological evidence * * *.

There is also substantial evidence of a relationship between chronic exposure to fine particulates and an excess (age-adjusted) risk of mortality, especially from cardiopulmonary diseases. The Six Cities and ACS studies of ambient air particulates both found a significant association between chronic exposure to fine particles and excess mortality. In both studies, after adjusting for smoking habits, a statistically significant excess risk of cardiopulmonary mortality was found in the city with the highest average concentration of fine particulate (i.e., $PM_{2.5}$) as compared to the city with the lowest. Both studies also found excess deaths due to lung cancer in the cities with the higher average level of $PM_{2.5}$, but these results were not statistically significant (EPA, 1996). The EPA concluded that—

* * * the chronic exposure studies, taken together, suggest there may be increases in mortality in disease categories that are consistent with long-term exposure to airborne particles and that at least some fraction of these deaths reflect cumulative PM impacts above and beyond those exerted by acute exposure events * * * There tends to be an increasing correlation of long-term mortality with PM indicators as they become more reflective of fine particle levels (EPA, 1996).

Whether associated with acute or chronic exposures, the excess risk of death that has been linked to pollution of the air with fine particles like dpm is clearly a ''material impairment'' of health or functional capacity within the meaning of the Act.

III.3.a.iii. Lung Cancer

It is clear that lung cancer constitutes a ''material impairment'' of health or functional capacity within the meaning of the Act. Questions have been raised however, as to whether the evidence linking dpm exposure with an excess risk of lung cancer demonstrates a causal connection (Stöber and Abel, 1996; Watson and Valberg, 1996; Cox, 1997; Morgan et al., 1997; Silverman, 1998).

MSHA recognizes that no single one of the existing epidemiological studies, viewed in isolation, provides conclusive evidence of a causal connection between dpm exposure and an elevated risk of lung cancer in humans. Consistency and coherency of results, however, do provide such evidence. Although no epidemiological study is flawless, studies of both cohort and case-control design have quite consistently shown that chronic exposure to diesel exhaust, in a variety of occupational circumstances, is associated with an increased risk of lung cancer. With only rare exceptions, involving too few workers and/or observation periods too short to have a good chance of detecting excess cancer risk, the human studies have shown a greater risk of lung cancer among exposed workers than among comparable unexposed workers.

Lipsett and Alexeeff (1998) performed a comprehensive statistical meta-analysis of the epidemiological literature on lung cancer and dpm exposure. This analysis systematically combined the results of the studies summarized in Tables III–4 and III–5. Some studies were eliminated because they did not allow for a period of at least 10 years for the development of clinically detectable lung cancer. Others were eliminated because of bias resulting from incomplete ascertainment of lung cancer cases in cohort studies or because they examined the same cohort population as another study. One study was excluded because standard errors could not be calculated from the data presented. The remaining 30 studies were analyzed using both a fixed-effects and a random-effect analysis of variance (ANOVA) model. Sources of heterogeneity in results were investigated by subset analysis; using categorical variables to characterize each study's design; target population (general or industry-specific); occupational group; source of control or reference population; latency; duration of exposure; method of ascertaining occupation; location (North America or Europe); covariate adjustments (age, smoking, and/or asbestos exposure); and absence or presence of a clear healthy worker effect (as manifested by lower than expected all-cause mortality in the occupational population under study).

Sensitivity analyses were conducted to evaluate the sensitivity of results to inclusion criteria and to various assumptions used in the analysis. This included substitution of excluded ''redundant'' studies of same cohort population for the included studies and exclusion of studies involving questionable exposure to dpm. An influence analysis was also conducted to examine the effect of dropping one study at a time, to determine if any individual study had a disproportionate effect on the ANOVA. Potential effects of publication bias were also investigated. The authors concluded:

The results of this meta-analysis indicate a consistent positive association between occupations involving diesel exhaust exposure and the development of lung cancer. Although substantial heterogeneity existed in the initial pooled analysis, stratification on several factors identified a relationship that persisted throughout various influence and sensitivity analyses* * *.

This meta-analysis provides evidence consistent with the hypothesis that exposure to diesel exhaust is associated with an increased risk of lung cancer. The pooled estimates clearly reflect the existence of a positive relationship between diesel exhaust and lung cancer in a variety of diesel-exposed occupations, which is supported when the most important confounder, cigarette smoking, is measured and controlled. There is suggestive evidence of an exposure-response relationship in the smoking adjusted studies as well. Many of the subset analyses indicated the presence of substantial heterogeneity among the pooled estimates. Much of the heterogeneity observed, however, is due to the presence or absence of adjustment for smoking in the individual study risk estimates, to occupation-specific influences on exposure, to potential selection biases, and other aspects of study design.

A second, independent meta-analysis of epidemiological studies published in peer-reviewed journals was conducted by Bhatia et al. (1998).[17] In this analysis, studies were excluded if actual work with diesel equipment ''could not be confirmed or reliably inferred'' or if an inadequate latency period was allowed for cancer to develop, as indicated by less than 10 years from time of first exposure to end of follow-up. Studies of miners were also excluded, because of potential exposure to radon and silica. Likewise, studies were excluded if they exhibited selection bias or examined the same cohort population as a study published later. A total of 29 independent studies from 23 published sources were identified as meeting the inclusion criteria. After assigning each of these 29 studies a weight proportional to its estimated precision, pooled relative risks were calculated based on the following groups of studies: all 29 studies; all case-control studies; all cohort studies; cohort studies using internal reference populations; cohort studies making external comparisons; studies adjusted for smoking; studies not adjusted for smoking; and studies grouped by occupation (railroad workers, equipment operators, truck drivers, and bus workers). Elevated risks were shown for exposed workers overall and within every individual group of studies analyzed. A positive duration-response relationship was observed in those studies presenting results according to employment duration. The weighted, pooled estimates of relative risk were identical for case-control and cohort studies and nearly identical for studies with or without smoking adjustments. Based on their stratified analysis, the authors argued that—

> the heterogeneity in observed relative risk estimates may be explained by differences between studies in methods, in populations studied and comparison groups used, in latency intervals, in intensity and duration of exposure, and in the chemical and physical characteristics of diesel exhaust.

They concluded that the elevated risk of lung cancer observed among exposed workers was unlikely to be due to chance, that confounding from smoking is unlikely to explain all of the excess risk, and that ''this meta-analysis supports a causal association between increased risks for lung cancer and exposure to diesel exhaust.''

As discussed earlier in the section entitled ''Mechanisms of Toxicity,'' animal studies have confirmed that diesel exhaust can increase the risk of lung cancer in some species and shown that dpm (rather than the gaseous fraction of diesel exhaust) is the causal agent. MSHA, however, views results from animal studies as subordinate to the results obtained from human studies. Since the human studies show increased risk of lung cancer at dpm levels lower than what might be expected to cause overload, they provide evidence that overload may not be the only mechanism at work among humans. The fact that dpm has been proven to cause lung cancer in laboratory rats is of interest primarily in supporting the plausibility of a causal interpretation for relationships observed in the human studies.

Similarly, the genotoxicological evidence provides additional support for a causal interpretation of associations observed in the epidemiological studies. This evidence shows that dpm dispersed by alveolar surfactant can have mutagenic effects, thereby providing a genotoxic route to carcinogenesis independent of overloading the lung with particles. Chemical byproducts of phagocytosis may provide another genotoxic route. Inhalation of diesel emissions has been shown to cause DNA adduct formation in peripheral lung cells of rats and monkeys, and increased levels of human DNA adducts have been found in association with occupational exposures. Therefore, there is little basis for postulating that a threshold exists, demarcating overload, below which dpm would not be expected to induce lung cancers in humans.

Results from the epidemiological studies, the animal studies, and the genotoxicological studies are coherent and mutually reinforcing. After considering all these results, MSHA has concluded that the epidemiological studies, supported by the experimental data establishing the plausibility of a causal connection, provide strong evidence that chronic occupational dpm exposure increases the risk of lung cancer in humans.

III.3.b. Significance of the Risk of Material Impairment to Miners

The fact that there is substantial evidence that dpm exposure can materially impair miner health in several ways does not imply that miners will necessarily suffer such impairments at a significant rate. This section will consider the significance of the risk faced by miners exposed to dpm.

III.3.b.i. Definition of a Significant Risk

The benzene case, referred to earlier in this section, provides the starting point for MSHA's analysis of this issue. Soon after its enactment in 1970, OSHA adopted a ''consensus'' standard on exposure to benzene, as required and authorized by the OSH Act. The basic part of the standard was an average exposure limit of 10 parts per million over an 8-hour workday. The consensus standard had been established over time to deal with concerns about poisoning from this substance (448 U.S. 607, 617). Several years later, NIOSH recommended that OSHA alter the standard to take into account evidence suggesting that benzene was also a carcinogen. (*Id.* at 619 *et seq.*). Although the ''evidence in the administrative record of adverse effects of benzene exposure at 10 ppm is sketchy at best,'' OSHA was operating under a policy that there was no safe exposure level to a carcinogen. (*Id.*, at 631). Once the evidence was adequate to reach a conclusion that a substance was a carcinogen, the policy required the agency to set the limit at the lowest level feasible for the industry. (*Id.* at 613). Accordingly, the Agency proposed lowering the permissible exposure limit to 1 ppm.

The Supreme Court rejected this approach. Noting that the OSH Act requires ''safe or healthful employment,'' the court stated that—

> * * *'safe' is not the equivalent of 'risk-free'* * *a workplace can hardly be considered 'unsafe' unless it threatens the workers with a significant risk of harm. Therefore, before he can promulgate any permanent health or safety standard, the Secretary is required to make a threshold finding that a place of employment is unsafe—in the sense that significant risks are present and can be eliminated or lessened by a change in practices. [Id., at 642, italics in original].

The court went on to explain that it is the Agency that determines how to make such a threshold finding:

> First, the requirement that a 'significant' risk be identified is not a mathematical straitjacket. It is the Agency's responsibility to determine, in the first instance, what it considered to be a 'significant' risk. Some risks are plainly acceptable and others are plainly unacceptable. If, for example, the odds are one in a billion that a person will die from cancer by taking a drink of chlorinated water, the risk clearly could not be considered significant. On the other hand, if the odds are one in a thousand that regular inhalation of gasoline vapors that are 2% benzene will be fatal, a reasonable person might well consider the risk significant and take appropriate steps to decrease or eliminate it. Although the Agency has no duty to calculate the exact probability of

[17] To address potential publication bias, the authors identified several unpublished studies on truck drivers and noted that elevated risks for exposed workers observed in these studies were similar to those in the published studies utilized. Based on this and a ''funnel plot'' for the included studies, the authors concluded that there was no indication of publication bias.

harm, it does have an obligation to find that a significant risk is present before it can characterize a place of employment as 'unsafe.' [*Id.*, at 655].

The court noted that the Agency's "*** determination that a particular level of risk is 'significant' will be based largely on policy considerations." (Id., note 62).

III.3.b.ii. *Evidence of Significant Risk at Current Exposure Levels.* In evaluating the significance of the risks to miners, a key factor is the very high concentrations of diesel particulate to which a number of those miners are currently exposed—compared to ambient atmospheric levels in even the most polluted urban environments, and to workers in diesel-related occupations for which positive epidemiological results have been observed. Figure III–4 compared the range of median dpm exposures measured for mine workers at various mines to the range of geometric means (i.e., estimated medians) reported for other occupations, as well as to ambient environmental levels. Figure III–5 presents a similar comparison, based on the highest mean dpm level observed at any individual mine, the highest mean level reported for any occupational group other than mining, and the highest monthly mean concentration of dpm estimated for ambient air at any site in the Los Angeles basin.[18] As shown in Figure III–5, underground miners are currently exposed at mean levels up to 10 times higher than the highest mean exposure reported for other occupations, and up to 100 times higher than comparable environmental levels of diesel particulate.

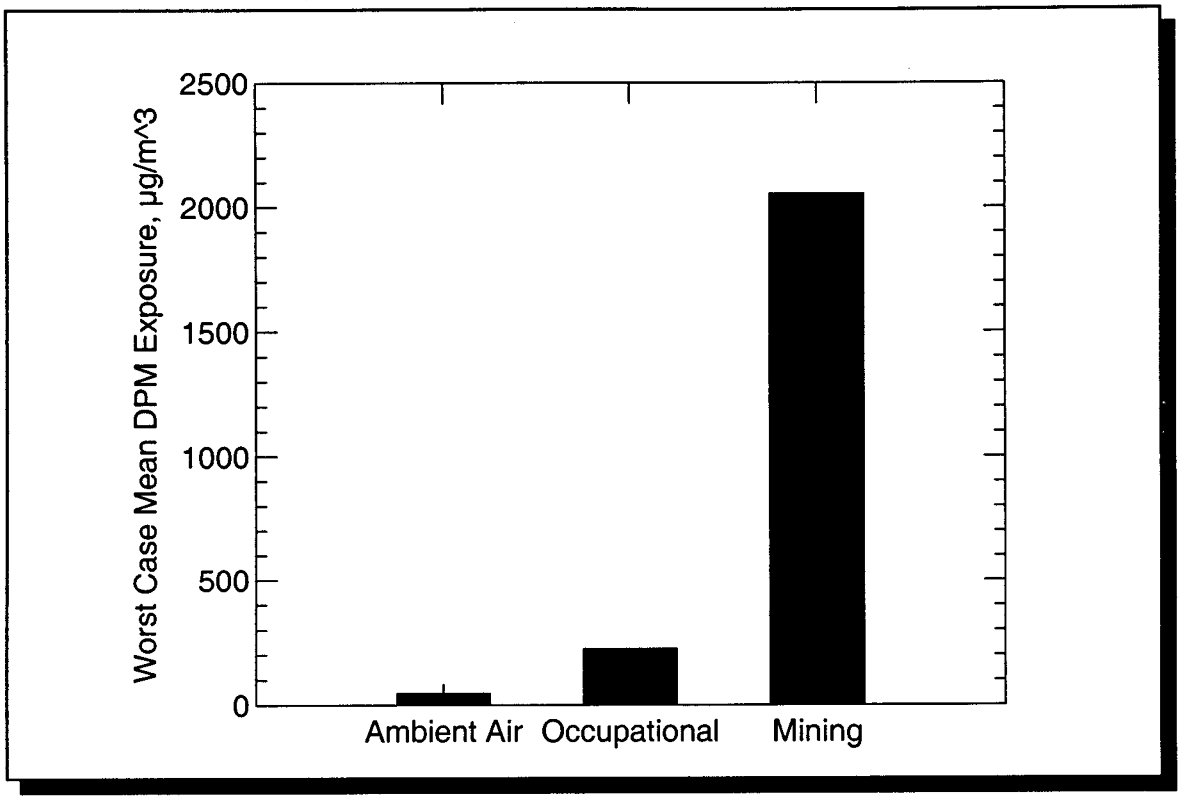

Figure III-5.--Worst case observed or reported mean diesel particulate exposure concentrations for urban ambient air, occupations other than mining, and mining. Worst case for mining is mean dpm measured within an underground mine. Worst case for occupations other than mining is mean respirable particulate matter, other than cigarette smoke, reported for railroad workers classified as hostlers (Woskie et al., 1988). Worst case for ambient air is mean estimated for peak months at most heavily polluted site in Los Angeles area (Cass and Gray, 1995), multiplied by 4.7 to adjust for comparability with occupational lifetime exposure levels. For additional information on means and ranges see section III.1.d.

Given the significantly increased mortality and other acute, adverse health effects associated with increments of 25 µg/m³ in fine particulate concentration (Table III–3), the relative risk for some miners, especially those already suffering respiratory problems, appears to be extremely high. Acute responses to dpm

[18] For comparability with occupational lifetime exposure levels, the environmental ambient air concentration has been multiplied by a factor of approximately 4.7. This factor reflects a 45-year occupational lifetime with 240 working days per year, as opposed to a 70-year environmental lifetime with 365-days per year, and assumes that air inhaled during a work shift comprises half the total air inhaled during a 24-hour day.

exposures have been detected in studies of stevedores, whose exposure was likely to have been less than one tenth the exposure of some miners on the job.

Both existing meta-analyses of human studies relating dpm exposure and lung cancer suggest that, on average, occupational exposure is responsible for a 30 to 40-percent increase in lung cancer risk across all industries studied (Lipsett and Alexeeff, 1998; Bhatia et al., 1998). Moreover, the epidemiological studies providing the evidence of this increased risk involved average exposure levels estimated to be far below levels to which some underground miners are currently exposed. Specifically, the elevated risk of lung cancer observed in the two most extensively studied industries—trucking (including dock workers) and railroads—was associated with average exposure levels estimated to be far below levels observed in underground mines. The highest average concentration of dpm reported for dock workers—the most highly exposed occupational group within the trucking industry—is about 55 µg/m^3 total elemental carbon at an individual dock (NIOSH, 1990). This translates, on average, to no more than about 110 µg/m^3 of dpm. Published measurements of dpm for railworkers have generally been less than 140 µg/m^3 (measured as respirable particulate matter other than cigarette smoke). The reported mean of 224 µg/m^3 for hostlers displayed in Figure III–5 represents only the worst case occupational subgroup (Woskie et al., 1988). Indeed, although MSHA views extrapolations from animal studies as subordinate to results obtained from human studies, it is noteworthy that dpm exposure levels recorded in some underground mines (Figures III–1 and III–2) have been well within the exposure range that produced tumors in rats (Nauss et al., 1995).

The significance of the lung cancer risk to exposed underground miners is also supported by a recent NIOSH report (Stayner et al., 1998), which summarizes a number of published quantitative risk assessments. These assessments are broadly divided into those based on human studies and those based on animal studies. Depending on the particular studies, assumptions, and methods of assessment used, estimates of the exact degree of risk vary widely even within each broad category. MSHA recognizes that a conclusive assessment of the quantitative relationship between lung cancer risk and specific exposure levels is not possible at this time, given the limitations in currently available epidemiological data and questions about the applicability to humans of responses observed in rats. However, all of the very different approaches and methods published so far, as described in Stayner et al. 1998, have produced results indicating that levels of dpm exposure measured at some underground mines present an unacceptably high risk of lung cancer for miners—a risk significantly greater than the risk they would experience without the dpm exposure.

Quantitative risk estimates based on the human studies were generally higher than those based on analyses of the rat inhalation studies. As indicated by Tables 3 and 4 of Stayner et al. 1998, a working lifetime of exposure to dpm at 500 µg/m^3 yields estimates of excess lung cancer risk ranging from about 1 to 200 excess cases of lung cancer per thousand workers based on the rat inhalation studies and from about 50 to 800 per 1000 based on the epidemiological assessments. Even the lowest of these estimates indicates a risk that is clearly significant under the quantitative rule of thumb established in the benzene case. [*Industrial Union* v. *American Petroleum*; 448 U.S. 607, 100 S.Ct. 2844 (1980)].

Stayner et al. 1998 concluded their report by stating:

> The risk estimates derived from these different models vary by approximately three orders of magnitude, and there are substantial uncertainties surrounding each of these approaches. Nonetheless, the results from applying these methods are consistent in predicting relatively large risks of lung cancer for miners who have long-term exposures to high concentrations of DEP [i.e., dpm]. This is not surprising given the fact that miners may be exposed to DEP [dpm] concentrations that are similar to those that induced lung cancer in rats and mice, and substantially higher than the exposure concentrations in the positive epidemiologic studies of other worker populations.

The Agency is also aware that a number of other governmental and nongovernmental bodies have concluded that the risks of dpm are of sufficient significance that exposure should be limited:

(1) In 1988, after a thorough review of the literature, the National Institute for Occupational Safety and Health (NIOSH) recommended that whole diesel exhaust be regarded as a potential occupational carcinogen and controlled to the lowest feasible exposure level. The document did not contain a recommended exposure limit.

(2) In 1995, the American Conference of Governmental Industrial Hygienists placed on the Notice of Intended Changes in their Threshold Limit Values (TLV's) for Chemical Substances and Physical Agents and Biological Exposure Indices Handbook a recommended TLV of 150 µg/m^3 for exposure to whole diesel particulate.

(3) The Federal Republic of Germany has determined that diesel exhaust has proven to be carcinogenic in animals and classified it as an A2 in their carcinogenic classification scheme. An A2 classification is assigned to those substances shown to be clearly carcinogenic only in animals but under conditions indicative of carcinogenic potential at the workplace. Based on that classification, technical exposure limits for dpm have been established, as described in part II of this preamble. These are the minimum limits thought to be feasible in Germany with current technology and serve as a guide for providing protective measures at the workplace.

(4) The Canada Centre for Mineral and Energy Technology (CANMET) currently has an interim recommendation of 1000 µg/m^3 respirable combustible dust. The recommendation was made by an Ad hoc committee made up of mine operators, equipment manufacturers, mining inspectorates and research agencies. As discussed in part II of this preamble, the committee has presently established a goal of 500 µg/m^3 as the recommended limit.

(5) Already noted in this preamble is the U.S. Environmental Protection Agency's recently enacted regulation of fine particulate matter, in light of the significantly increased health risks associated with environmental exposure to such particulates. In some of the areas studied, fine particulate is composed primarily of dpm; and significant mortality and morbidity effects were also noted in those areas.

(6) The California Environmental Protection Agency (CALEPA) has identified dpm as a toxic air contaminant, as defined in their Health and Safety Code, Section 39655. According to that section, a toxic air contaminant is an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health. This conclusion, unanimously adopted by the California Air Resources Board and its Scientific Review Panel on Toxic Air Contaminants, initiates a process of evaluating strategies for reducing dpm concentrations in California's ambient air.

(7) The International Programme on Chemical Safety (IPCS), which is a joint venture of the World Health Organization, the International Labour Organisation, and the United Nations Environment Programme, has issued a health criteria document on diesel fuel and exhaust emissions (IPCS, 1996). This document states that the data support a conclusion that inhalation of diesel exhaust is of concern with respect to both neoplastic and non-neoplastic diseases. It also states that the particulate phase appears to have the greatest effect on health, and both the particle core and the associated organic materials have biological activity, although the gas-phase components cannot be disregarded.

Based on both the epidemiological and toxicological evidence, the IPCS criteria document concluded that diesel exhaust is ''probably carcinogenic to humans'' and recommended that ''in the occupational environment, good work practices should be encouraged, and adequate ventilation must be provided to prevent excessive exposure.'' Quantitative relationships between human lung cancer risk and dpm exposure were derived using a dosimetric model that accounted for differences between experimental animals and humans, lung deposition efficiency, lung particle clearance rates, lung surface area, ventilation, and elution rates of organic chemicals from the particle surface.

As the Supreme Court pointed out in the benzene case, the appropriate definition of significance also depends on policy considerations of the Agency involved. In the case of MSHA, those policy considerations include special attention to the history of the Mine Act. That history is intertwined with the toll to the mining community due to silicosis and coal miners' pneumoconiosis (''black lung''), along with billions of dollars in Federal expenditures.

At one of the 1995 workshops on diesel particulate co-sponsored by MSHA, a miner noted:

People, they get complacent with things like this. They begin to believe, well, the government has got so many regulations on so many things. If this stuff was really hurting us, they wouldn't allow it in our coal mines * * * (dpm Workshop; Beckley, WV, 1995).

Referring to some commenters' position that further scientific study was necessary before a limit on dpm exposure could be justified, another miner said:

* * * if I understand the Mine Act, it requires MSHA to set the rules based on the best set of available evidence, not possible evidence * * * Is it going to take us 10 more years before we kill out, or are we going to do something now * * *? (dpm Workshop; Beckley, WV, 1995).

Concern with the risk of waiting for additional scientific evidence to support regulation of dpm was also expressed by another miner who testified:

What are the consequences that the threshold limit values are too high and it's loss of human lives, sickness, whatever, compared to what are the consequences that the values are too low? I mean, you don't lose nothing if they're too low, maybe a little money. But *** I got the indication that the diesel studies in rats could no way be compared to humans because their lungs are not the same * * * But * * * if we don't set the limits, if you remember probably last year when these reports come out how the government used human guinea pigs for radiation, shots, and all this, and aren't we doing the same thing by using coal miners as guinea pigs to set the value? (dpm Workshop; Beckley, WV, 1995).

III.3.c. Substantial Reduction of Risk by Proposed Rule

A review of the best available evidence indicates that reducing the very high exposures currently existing in underground mines can substantially reduce health risks to miners—and that greater reductions in exposure would result in even lower levels of risk. Although there are substantial uncertainties involved in converting 24-hour environmental exposures to 8-hour occupational exposures, Table III–3 suggests that reducing occupational dpm concentrations by as little as 75 $\mu g/m^3$ (corresponding to a reduction of 25 $\mu g/m^3$ in 24-hour ambient atmospheric concentration) could lead to significant reductions in the risk of various adverse acute responses, ranging from respiratory irritations to mortality.

Schwartz et al. (1996) found an increase of 1.5 percent in daily mortality associated with each increment of 10 $\mu g/m^3$ in the concentration of fine particulates. Somewhat higher increases were reported specifically for ischemic heart disease (IHD: 2.1 percent) and chronic obstructive pulmonary disease (COPD: 3.3 percent). Within the range of dust concentrations studied, the response appeared to be linear, with no threshold. Nor did Schwartz et al. find an association between increased mortality and the atmospheric concentration of larger particles.

If the 24-hour average concentrations measured by Schwartz et al. are assumed equivalent, in their acute effects, to eight-hour average concentrations that are three times as high, then (assuming the mining and general populations respond in similar ways) each increment of 30 $\mu g/m^3$ would, in an 8-hour shift occupational setting, be associated with a 1.5-percent increase in daily mortality. Since COPD and IHD were the diseases most clearly identified with acute diesel exposures, a conservative approach would be to limit consideration of any reduction in daily mortality risk under the proposed rule to deaths from IHD and COPD. IHD and COPD accounted for about one-third of the overall mortality. Thus, for purposes of estimating potential benefits, each reduction of 30 $\mu g/m^3$ in 8-hour average dpm concentration may be assumed to correspond to a 0.5-percent reduction (i.e., one-third of 1.5 percent) in daily mortality. This estimate is somewhat conservative, insofar as the reported effects on IHD and COPD mortality were both greater than the effects on overall mortality.

There are, however, additional problems in applying this incremental risk factor to underground M/NM miners. First, the levels of fine particulate concentration studied averaged around 20 $\mu g/m^3$, which is only about 10 percent of the final dpm concentration limit proposed and an even smaller fraction of average dpm concentrations measured at some underground M/NM mines. It is unclear whether the same incremental effects on mortality risks would apply at these much higher exposure levels. Second, Schwartz et al. studied fine particulate concentrations, which, though generally related to combustion products, include but are not limited to dpm. It is unclear how closely these results would match the effects of fine particulate dust made up exclusively of dpm. Third, and also discussed elsewhere in MSHA's risk assessment, is the question of whether underground M/NM mine workers comprise a population less, equally, or more susceptible than the general population to acute mortality effects of fine particulates. It is unclear how similar an exposure-response relationship for miners would be to the relationship observed for the general population. For these reasons, benefits of the proposed rule, as it impacts deaths related to IHD and/or COPD among M/NM miners, cannot be quantified with a high degree of confidence. Subject to these caveats, however, applying the findings of Schwartz et al. (adjusted as discussed above) would suggest that, for miners currently exposed to dpm at an average concentration of 830 $\mu g/m^3$ (i.e., the average of measurements made by MSHA at underground M/NM mines), the proposed rule would reduce the acute risk of IHD/COPD mortality by about 10 percent [$(830 - 200)\ \mu g/m^3 \times (0.5\% \div 30\ \mu g/m^3)$].

Quantitative assessments of the relationship between human dpm exposures and lung cancer, which would show just how many cases of lung cancer a given reduction in exposure could be expected to prevent, have produced varying results and are subject to considerable uncertainty (Stayner *et al.*, 1998; US–EPA, 1998). None of the human-based dose-response relationships has been widely accepted in the scientific community, most likely due to a lack of precisely quantified dpm exposures in the available epidemiological studies. Although future studies may provide a better foundation for quantitative risk assessment, the Agency believes it would not be prudent to postpone protection of miners exposed to extremely high dpm levels until a conclusive dose-response relationship becomes available. In the meantime, the published, human-based quantitative risk assessments reviewed by Stayner et al. (1998) provide the best available means of estimating the reduction in lung cancer risk to underground M/NM miners that may be expected from reducing dpm exposures.

Among the human-based assessments reviewed, even the lowest estimate of unit risk of developing lung cancer is 10^{-4} per each µg/m³ of dpm exposure over a 45-year occupational lifetime at 8 hours of exposure per workday. It should be noted that this risk estimate was derived from exposures estimated to be generally below the proposed final limit. As Stayner et al. point out, there are some questions raised by extrapolating estimated risks to exposure levels up to 10 times as high, but doing so is unavoidable in order to estimate benefits based on existing data. On the other hand, the issue of whether a threshold exists is of little or no concern when assessing risk at these higher exposure levels. MSHA specifically requests information regarding any studies on miner mortality at high dpm exposures and the accuracy of the assumption of linearity.

Assuming this dose-response relationship, it is possible to estimate the reduction in lung cancers that could be expected as a result of implementing the proposed rule. To form such an estimate, however, measures of both current and proposed levels of dpm exposure are also required.

Table III–7 presents three estimates of current dpm exposure levels:

TABLE III–7.—MEASURES OF DPM EXPOSURE IN PRODUCTION AREAS AND HAULAGEWAYS OF UNDERGROUND M/NM MINES

	Employment size of mine			
	<20	20 to 500	>500	All Affected Mines
Number of Affected Mines	82	114	7	203
Number of Affected Miners	460	3,770	3,270	7,500
Dpm Concentration Estimated from Diesel Equipment Inventory				
Based on Test Data (µg/m³)	2,766	1,880	1,232	1,863
Adjusted for Observed Duty Cycle (µg/m³)	1,951	1,331	877	1,319
Mean dpm Concentration Level Observed in Underground M/NM Mines (µg/m³)				830

In its inventory of underground M/NM mines, MSHA collected data on diesel powered equipment, ventilation throughput, and the volume of the work areas. MSHA then estimated dpm concentration levels in the mines by combining these data with emissions data for the diesel engines obtained during testing in accordance with MSHA's engine approval process. The estimate of mean dpm concentration obtained by this method is 1,863 µg/m³.

MSHA then compared the duty cycles for the diesel powered equipment used in the tests to the duty cycles observed in the mines. Recalibrating the results for the observed duty cycles lowered the estimated dpm concentrations by approximately 30 percent. The adjusted estimate of mean dpm concentration is 1,319 µg/m³.

The third estimate of current mean dpm concentration shown in Table III–7 is the mean dpm concentration measured during MSHA's field studies, as shown in Table III–1 of this preamble. MSHA's dpm measurements averaged 830 µg/m³ at underground M/NM mines.

Applying the 10^{-4} estimate of unit risk to these three dpm concentration levels produces estimates of excess risk, for a 45-year period of exposure, of 186 cancers per 1,000 miners, 132 cancers per 1,000 miners, and 83 cancers per 1,000 miners, respectively. These estimates assume that the 45-year period of occupational exposure begins at age 20 and that the excess risk of dying from lung cancer is accumulated from age 20 through age 85-a span of 65 years.

Approximately 9,400 miners work in underground areas of M/NM mines that use diesel powered equipment, and MSHA estimates that about 80 percent (i.e., 7,500) of these work in production or development areas including haulageways. Therefore, if the 7,500 affected miners were all exposed for a full 45 years, this dose-response relationship would yield, over the 65-year period from time of first occupational exposure, 1,395 excess cancers, 990 excess cancers, or 622 excess cancers, corresponding to the three estimates of current mean exposure. For purposes of projecting benefits of the proposed rule, MSHA is restricting its attention to the lowest of these estimates, since it is based on actual measurements of dpm concentration.

Although many individual miners may work in underground M/NM mines for a full 45 years (and the Mine Act requires MSHA to set standards that protect workers exposed for a full working lifetime), MSHA believes that it may also be appropriate to estimate benefits of the proposed rule based on the mean duration of exposure. If the mean exposure time is actually 20 years, then the estimated excess risk of lung cancer could be reduced by roughly a factor of 20/45, from 83 per thousand miners to about 37 per thousand miners. However, since the total number of miners exposed during a given 45-year period will now be increased by a factor of 45/20, the total number of excess lung cancers expected at current exposure levels remains the same: 622, or an average of 9.6 per year, spread over an initial 65-year period.

After final implementation of the proposed rule, dpm concentrations in underground M/NM mines would be limited to a maximum of approximately 200 µg/m³ on each and every shift. Therefore, since concentrations would be expected to generally fall below their maximum value, it would be reasonable to assume that the average concentration would fall below 200 µg/m³. (MSHA's sampling found concentrations under controlled conditions as low as 55 µg/m³). So as not to overstate benefits, MSHA has projected residual risk under the proposed rule assuming the concentration limit of 200 µg/m³ is exactly met on all shifts at all mines.

From Table IV of Stayner et al. (1998), the lowest human-based risk estimate among workers occupationally exposed to 200 ⁼g/m³ for 45 years is 21 excess lung cancers per 1000 exposed miners. For the population of 7,500 underground M/NM mine workers, this would amount to 158 excess lung cancers over an initial 65-year period, or an average of 2.4 excess lung cancers per year. If, as before, a 20-year average is assumed for occupational exposure, this reduces an individual miner's risk to a hypothetical 9.3 excess lung cancers per thousand exposed miners under the proposed rule, but the total number of excess lung cancers expected over the initial 65-year period remains the same. Thus, under the assumptions stated, the benefit of the proposed rule in reducing incidents of lung cancer can be expressed as:

• 622 − 158 = 464 lung cancers avoided over an initial 65-year period;[19] or

• 464 ÷ 65 = approximately 7 lung cancers avoided per year over an initial 65-year period; or

• 83 − 21 = 62 lung cancers avoided per 1,000 miners occupationally exposed for 45 years; or

• 37 − 9.3 = 28 lung cancers avoided per 1,000 miners occupationally exposed for 20 years.

The Agency recognizes that a conclusive, quantitative dose-response relationship has not been established between dpm and lung cancer in humans. However, the epidemiological studies relating dpm exposure to excess lung cancer were conducted on populations whose average exposure is estimated to be less than 200 μg/m³ and less than one tenth of average exposures observed in some underground mines. Therefore, the best available evidence indicates that lifetime occupational exposure at levels currently existing in some underground mines presents a significant excess risk of lung cancer.

In the case of underground M/NM mines, the proposed rule limits dpm concentration to 200 μg/m³ by limiting the measured concentration of total carbon to 160 μg/m³. The Agency recognizes that although health risks would be substantially reduced, the best available evidence indicates a significant risk of adverse health effects would remain at these levels. However, as explained in Part V of this preamble, MSHA has concluded that, because of both technology and cost considerations, the underground M/NM mining sector as a whole cannot feasibly reduce dpm concentrations further at this time.

Conclusions. MSHA has reviewed a considerable body of evidence to ascertain whether and to what level dpm should be controlled. It has evaluated the information in light of the legal requirements governing regulatory action under the Mine Act. Particular attention was paid to issues and questions raised by the mining community in response to the Agency's Advance Notice of Proposed Rulemaking and at workshops on dpm held in 1995. Based on its review of the record as a whole to date, the agency has tentatively determined that the best available evidence warrants the following conclusions:

1. The health effects associated with exposure to dpm can materially impair miner health or functional capacity.

These material impairments include sensory irritations and respiratory symptoms; death from cardiovascular, cardiopulmonary, or respiratory causes; and lung cancer.

2. At exposure levels currently observed in underground M/NM mines, many miners are presently at significant risk of incurring these material impairments over a working lifetime.

3. The proposed rule for underground M/NM mines is justified because the reduction in dpm exposure levels that would result from implementation of the proposed rule would substantially reduce the significant health risks currently faced by underground M/NM miners exposed to dpm.

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[19] In the long run, the average approaches 464 ÷ 45 = 10 lung cancers avoided per year as the number of years considered increases beyond 65.

Table III-2. Studies of acute health effects using filter based optical indicators of fine particles in the ambient air.

City	Study Years	Indicator*	Reference
Acute Mortality			
London	1963-1972, winters 1965-1972, winters	BS	Thurston et al., 1989 Ito et al., 1993
Athens	1975-1987 July, 1987 1984-1988	BS	Katsouyanni et al., 1990 Katsouyanni et al., 1993 Touloumi et al., 1994
Los Angeles	1970-1979 1970-1979	KM	Shumway et al., 1988 Kinney and Ozkaynak, 1991
Santa Clara	1980-1986, winters	COH	Fairley, 1990
Increased Hospitalization			
Barcelona	1985-1989	BS	Sunyer et al., 1993
Acute Change in Pulmonary Function			
Wageningen, Netherlands		BS	Hoek and Brunkreef, 1993
Netherlands		BS	Roemer et al., 1993

*BS (black smoke), KM (carbonaceous material), and COH (coefficient of haze) are optical measurements that are most directly related to elemental carbon concentrations, but only indirectly to mass. Site specific calibrations and/or comparisons of such optical measurements with gravimetric mass measurements in the same time and city are needed to make inferences about particle mass. However, all three of these indicators preferentially measure carbon particles found in the fine fraction of total airborne particulate matter. (EPA, 1996).

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TABLE III–3.—STUDIES OF ACUTE HEALTH EFFECTS USING GRAVIMETRIC INDICATORS OF FINE PARTICLES IN THE AMBIENT AIR

	Indicator	RR(± CI)/25µg/m³ PM increase	Mean PM levels (min/max)†
Acute Mortality			
Six Cities[A]			
Portage, WI	$PM_{2.5}$	1.030 (0.993,1.071)	11.2 (±7.8)
Topeka, KS	$PM_{2.5}$	1.020 (0.951,1.092)	12.2 (±7.4)
Boston, MA	$PM_{2.5}$	1.056 (1.038,1.0711)	15.7 (±9.2)
St. Louis, MO	$PM_{2.5}$	1.028 (1.010,1.043)	18.7 (±10.5)
Kingston/Knoxville, TN	$PM_{2.5}$	1.035 (1.005,1.066)	20.8 (±9.6)
Steubenville, OH	$PM_{2.5}$	1.025 (0.998,1.053)	29.6 (±21.9)
Increased Hospitalization			
Ontario, CAN[B]	$SO_4^=$	1.03 (1.02, 1.04)	Min/Max = 3.1 – 8.2
Ontario, CAN[C]	$SO_4^=$	1.03 (1.02, 1.04)	Min/Max = 2.0 – 7.7
	O_3	1.03 (1.02, 1.05)	
NYC/Buffalo, NY[D]	$SO_4^=$	1.05 (1.01, 1.10)	NR
Toronto, CAN[D]	H+ (Nmo1/m³)	1.16 (1.03, 1.30) *	28.8 (NR/391)
	$SO_4^=$	1.12 (1.00, 1.24)	7.6 (NR, 48.7)
	$PM_{2.5}$	1.15 (1.02, 1.78)	18.6 (NR, 66.0)
Increased Respiratory Symptoms			
Southern California[F]	$SO_4^=$	1.48 (1.14, 1.91)	R = 2 – 37
Six Cities[G] (Cough)	$PM_{2.5}$	1.19 (1.01, 1.42)**	18.0 (7.2, 37)***
	$PM_{2.5}$ Sulfur	1.23 (0.95, 1.59)**	2.5 (3.1, 61)***
	H+	1.06 (0.87, 1.29)**	18.1 (0.8, 5.9)***
Six Cities[G] (Lower Resp. Symp.)	$PM_{2.5}$	1.44 (1.15 – 1.82)**	18.0 (7.2, 37)***
	$PM_{2.5}$ Sulfur	1.82 (1.28 – 2.59)**	2.5 (0.8, 5.9)***
	H+	1.05 (0.25 – 1.30)**	18.1 (3.1, 61)***
Denver, CO[P] (Cough, adult asthmatics)	$PM_{2.5}$	0.0012 (0.0043)***	0.41 – 73
	$SO_4^=$	0.0042 (0.00035)***	0.12 – 12
	H+	0.0076 (0.0038)***	2.0 – 41
Decreased Lung Function			
Uniontown, PA[E]	$PM_{2.5}$	PEFR 23.1 (–0.3, 36.9) (per 25 µg/m³).	25/88 (NR/88)
Seattle, WA[Q] Asthmatics	$b_{ext.}$ calibrated by $PM_{2.5}$	FEV1 42 ml (12, 73) FVC 45 ml (20, 70)	5/45

(EPA, 1996).
[A] Schwartz et al. (1996a).
[B] Burnett et al. (1994).
[C] Burnett et al. (1995) O_3.
[D] Thurston et al. (1992, 1994).
[E] Neas et al. (1995).
[F] Ostro et al. (1993).
[G] Schwartz et al. (1994).
[Q] Koenig et al. (1993).
[P] Ostro et al. (1991).
† Min/Max 24 – h PM indicator level shown in parentheses unless otherwise noted as (±S.D), 10 and 90 percentile (10, 90).
* Change per 100 nmoles/m³.
** Change per 20 µg/m³ for $PM_{2.5}$; per 5 µg/m³ for $PM_{2.5}$; sulfur; per 25 nmoles/m³ for H+.
*** 50th percentile value (10, 90 percentile).
**** Coefficient and SE in parenthesis.

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Table III-4. Summary of published information from cohort studies on lung cancer and exposure to diesel exhaust.

Authors (Date)	Occupation	No. of Subjects	Follow-up period	Exposure Assessment	Smk Adj.	Findings[a]	Stat. Sig.[b]	Comments
Ahlberg et al. (1981)	Male truck drivers	35,883	1961-73	Occupation only		RR = 1.33 for drivers of "ordinary" trucks.	*	Risk relative to males employed in trades thought to have no exposure to "petroleum products or other chemicals." Comparison controlled for age and province of residence (Sweden). Based on comparison of smoking habits between truck drivers and general Stockholm population, authors concluded that excess rate of lung cancer could not be entirely attributed to smoking.
Ahlman et al. (1991)	Underground sulfide ore miners	597	1968-86	Job histories from personnel records. Measurements of alpha energy concentration from radon daughters at each mine worked.		RR = 1.45 overall. RR = 2.9 for 45-64 age group.		Age-adjusted relative risk compared to males living in same area of Finland. No excess observed among 338 surface workers at same mines, with similar smoking and alcohol consumption, based on questionnaire. Based on calculation of expected lung cancers due to radon, excess risk attributed by author partly to radon exposure and partly to diesel exhaust.
Balarajan & McDowall (1988)	Professional drivers	3,392	1950-84	Occupation only		SMR = 0.86 for taxi drivers. SMR = 1.42 for bus drivers. SMR = 1.59 for truck drivers.	 *	Possibly higher rates of smoking among bus and truck drivers than among taxi drivers.
Bender et al. (1989)	Highway maintenance workers	4,849	1945-84	Occupation only		SMR = 0.69		No adjustment for healthy worker effect.
Boffetta et al. (1988)	Railroad Wrkr. Truck driver Heavy Eq. Op. Miner General Popula.	2,973 16,208 855 2,034 476,648	1982-84	Occupation and diesel exposure by questionnaire	✔	RR = 1.59 for railroad workers. RR = 1.24 for truck drivers. RR = 2.60 for heavy Eq. Op's. RR = 2.67 for miners. RR = 1.18 for subjects reporting diesel exposure compared to subjects reporting no diesel exposure.	 * *	Overall RR adjusted for occupational exposures to asbestos, coal and stone dusts, coal tar & pitch, and gasoline exhaust (in addition to age and smoking). Possible biases due to volunteered participation and relatively high lung cancer rate among 98,026 subjects with unknown dpm exposure.

Dubrow & Wegman (1984)	Truck & tractor drivers	not reported	1971-73	Occupation only		sMOR = 1.73 based on 176 deaths.	*	Excess cancers observed over the entire respiratory system and upper alimentary tract.
Edling et al. (1987)	Bus workers	694	1951-83	Occupation only		SMR = 0.7 for overall cohort		Small size of cohort lacks statistical power to detect excess risk of lung cancer. No adjustment for healthy worker effect.
Garshick et al. (1988)	Railroad workers	55,407	1959-80	Job in 1959 & years of diesel exposure since 1959		RR = 1.20 for 1-4 yr. exposure. RR = 1.24 for 5-9 yr. exposure. RR = 1.32 for 10-14 yr. exposure. RR = 1.72 for ≥15 yr. exposure. Higher RR for each exposure group if shopworkers and hostlers are excluded. RR = 1.45 within highest-exposed age group (40-44).	* * * * *	Exposure groups based on exposure accumulated more than 4 yr prior to observation. Subjects with likely asbestos exposure excluded from cohort. Statistically significant results corroborated if 12,872 shopworkers and hostlers possibly exposed to asbestos are also excluded. Missing 12% of death certificates. Cigarette smoking judged to be uncorrelated with diesel exposure within cohort.
Guberan et al. (1992)	Professional drivers	1,726	1961-86	Occupation only		SMR = 1.50	*	Approx. 1/3 to 1/4 of cohort reported to be long-haul truck drivers. SMR based on regional lung cancer mortality rate.
Gustafsson et al. (1986)	Dock workers	6,071	1961-80	Occupation only		SMR = 1.32 (mortality). SMR = 1.68 (morbidity).	* *	
Gustavsson et al. (1990)	Bus garage workers	708	1952-86	Semi-quantitative based on job history & exposure intensity estimated for each job.		SMR = 1.22 for overall cohort. SMR = 1.27 for highest-exposed subgroup.		Lack of statistical significance may be attributed to small size of cohort.

Hansen (1993)	Truck drivers	14,225	1970-80	Occupation only		SMR = 1.60 for overall cohort. Some indication of increasing SMR with age (i.e., greater cumulative exposure).	*	Compared to unexposed control group of 38,301 laborers considered to "resemble the group of truck drivers in terms of work-related demands on physical strength and fitness, educational background, social class, and life style." Correction for estimated differences in smoking habits between cohort and control group reduces SMR from 1.60 to 1.52. Results judged "unlikely *** [to] have been seriously confounded by smoking habit differences."
Howe et al. (1983)	Railroad workers	43,826	1965-77	Jobs classified by diesel exposure		Rr = 1.20 for "possibly exposed." RR = 1.35 for "probably exposed."	* *	Risk is relative to unexposed subgroup of cohort. Similar results obtained for coal dust exposure. Possible confounding with asbestos and coal dust.
Kaplan (1959)	Railroad workers	32000 (Approx.)	1953-58	Jobs classified by diesel exposure		SMR=0.88 for operationally exposed. SMR = 0.72 for somewhat exposed. SMR = 0.80 for rarely exposed.		No adjustment for healthy worker effect. Clerks (in rarely exposed group) found more likely to have had urban residence than occupationally exposed workers. No attempt to distinguish between diesel and coal-fired locomotives. Results may be attributable to short duration of exposure and/or inadequate follow-up time.
Leupker & Smith (1978)	Truck drivers	183,791	May-July, 1976	Occupation only		SMR = 1.21		Lack of statistical significance may be due to inadequate follow-up period.
Lindsay et al. (1993)	Truck drivers	not reported	1965-79	Occupation only		SMR = 1.15	*	
Menck & Henderson (1976)	Truck drivers	34,800 estimated	1968-73	Occupation only		SMR = 1.65	*	Number of subjects in cohort estimated from census data.
Raffle (1957)	Transport engineers	2,666 Est. from man-years at risk	1950-55	Occupation only		SMR = 1.42		SMR calculated by combining data presented for four quadrants of London.

Rafnsson & Gunnarsdottir (1991)	Truck drivers	868	1951-88	Occupation only		SMR = 2.14	*	No trend of increasing risk with increased duration of employment or increased follow-up time. Based on survey of smoking habits in cohort compared to general male population, and fact that there were fewer than expected deaths from respiratory disease, authors concluded that differences in smoking habits were unlikely to be enough to explain excess rate of lung cancer. However, not all trucks were diesel prior to 1951, and there is possible confounding by asbestos exposure.
Rushton et al. (1983)	Bus maintenance workers	8,480	5.9 yrs (mean)	Occupation only		SMR = 1.01 for overall cohort. SMR = 1.33 for "general hand" subgroup.	*	Short follow-up period. SMR based on comparison to national rates, with no adjustment for regional or socioeconomic differences, which could account for excess lung cancers observed among general hands.
Schenker et al. (1984)	Railroad workers	2,519	1967-79	Job histories, with exposure classified as unexposed, high, low, or undefined.		RR = 1.50 for low exposure subgroup. RR = 2.77 for high exposure subgroup.		Risk relative to unexposed subgroup. Jobs considered to have similar socioeconomic status. Differences in smoking calculated to be insufficient to explain findings. Possible confounding by asbestos exposure.
Waller (1981)	Bus workers	16,828 Est. from manyears at risk	1950-74	Occupation only		SMR = 0.79 for overall cohort.		Lung cancers occurring after retirement or resignation from London Transport Authority were not counted. No adjustment for healthy worker effect.
Waxweiler et al. (1973)	Potash miners	3,886	1941-67	Miners classified as underground or surface		SMR = 1.12 for surface miners. SMR = 1.08 for underground miners.		No adjustment for healthy worker effect. SMR based on national lung cancer mortality, which is about 1/3 higher than lung cancer mortality rate in New Mexico, where miners resided. A substantial percentage of the underground subgroup may have had little or no occupational exposure to diesel exhaust.
Wong et al. (1985)	Heavy equipment operators	34,156	1964-78	Job histories, latency, & years of union membership		SMR = 0.99 for overall cohort. SMR = 1.07 for ≥20 yr member. SMR = 1.12 for ≥20 yr. latency. SMR = 1.30 for 4,075 "normal" retirees.	*	Increasing trend in SMR with latency and (up to 15 yr) with duration of union membership. Statistically significant excess lung cancers for dozer operators with 15-19 yr union membership and ≥20 yr latency. No adjustment for healthy worker effect.

a RR = Relative Risk; SMR = Standardized Mortality Ratio. Values greater than 1.0 indicate excess prevalence of lung cancer associated with diesel exposure.

b An asterisk (*) indicates statistical significance based on 2-tailed test at confidence level of at least 95%.

Table III-5 – Summary of published information from case-control studies on lung cancer and exposure to diesel exhaust.

Authors (Date)	Cases	Controls	No. of Cases	No. of Controls	Exposure Assessment	Matching: Smk.	Matching: Additional	Findings[a]	Stat. Sig.[b]	Comments
Benhamou et al. (1988)	Histologically confirmed lung cancers	Non-tobacco related diseases	1,625	3,091	Occupational history by questionnaire.	✔	Sex, age at diagnosis, hospital, interviewer.	RR = 2.14 for miners RR = 1.42 for professional drivers.	* *	Mine type not reported. No evidence of an increase in risk with duration of exposure
Boffetta et al. (1990)	Hospitalized males with lung cancer	Hospitalized males with no tobacco related disease	2,584	5,099	Occupation classified by probability of diesel exposure	✔	Sex, age, hospital, year of interview.	OR = 0.88 for truck drivers. OR = 0.95 for probable exposure.		Adjusted for race, asbestos exposure, education.
			477	846	Occupational history & duration of diesel exposure by interview			OR = 1.21 for any self-reported diesel exposure. OR = 2.39 for than 30 yr of self-reported diesel exposure.		
Buiatti et al. (1985)	Histologically confirmed lung cancers	Patients at same hospital	376	892	Occupational history from interview	✔	Sex, age, admission date.	OR = 1.8 for taxi drivers.		
Coggon et al. (1984)	Lung cancer deaths of males under 40	Deaths from other causes in males under 40	598	1,180	Occupation from death certificate, classified as high, low, or no diesel exposure		Sex, death year, region, and birth year (approx.)	RR = 1.3 for all jobs with diesel exposure. RR=1.1 for jobs classified as high exposure.	*	Only most recent full-time occupation recorded on death certificate.
Damber & Larsson (1985)	Male patients with lung cancer	One living and one deceased without lung cancer	604	1,071	Job, with tenure, from mailed questionnaire	✔	Sex, death year, age, municipality	RR = 1.9 for non-smoking truck drivers aged <70 yr. RR = 4.5 for non-smoking truck drivers aged ≥70 yr.	 *	Ex-smokers who did not smoke for at least last 10 years included with non-smokers.

DeCoufle et al. (1977)	Male patients with lung cancer	Non-neoplastic disease patients	Not reported	Not reported	Occupation only, from questionnaire	✔	Unmatched	RR = 0.92 for bus, taxi, and truck drivers. RR = 0.94 for locomotive engineers.		Selected occupation compared to clerical workers. Positive associations found before smoking adj.
Emmelin et al. (1993)	Deaths from primary lung cancer among dock workers	Dock workers without lung cancer	50	154	Semi-quantitative from work history & records of diesel fuel usage	✔	Date of birth, port, and survival to within 2 years of case's diagnosis of lung cancer	RR = 1.6 for "medium" duration of exposure. RR = 2.9 for "high" duration of exposure.		Increasing relative risk also observed using exposure estimates based on machine usage & diesel fuel consumption. Confounding from asbestos may be significant.
Garshick et al. (1987)	Deaths with primary lung cancer among railroad workers	Deaths from other than cancer, suicide, accidents, or unknown causes	1,256	2,385	Job history and tenure combined with current exposure levels measured for each job	✔	Date of birth and death	RR = 1.41 for 20+diesel-years in workers aged≤64 yr. RR = 0.91 for workers aged ≥65 yr.	*	Adjusted for asbestos exposure. Older workers had relatively short diesel exposure, or none.
Gustavsson et al. (1990)	Deaths from lung cancer among bus garage workers	Non-cases within cohort mortality study	20	120	Semi-quantitative based on job, tenure, & exposure class for each job		Born within two years of case.	RR = 1.34, 1.81, and 2.43 for increasing cumulative diesel exposure categories, relative to lowest exposure category.	*	Authors judged smoking habits to be similar for different exposure categories. RR did not increase with increasing asbestos exposure
Hall & Wynder (1984)	Hospitalized males with lung cancer	Hospitalized males with no tobacco-related diseases	502	502	Usual occupation by interview	✔	Age, race, hospital, and hospital room status	RR = 1.4 for jobs with diesel exposure.		Confounding with other occupational exposures possible.

Hayes et al. (1989)	Lung cancer deaths pooled from 3 studies	Various lung disease excluded --	2,291	2,570	Occupational history by interview	✔	Sex, age, and either race or area of residence	OR = 1.5 for ≥10 yr truck driving. OR = 2.1 for ≥10 yr operating heavy equipment. OR = 1.7 for ≥10 yr bus driving.	*	OR adjusted for birth-year cohort and state of residence (FL, NJ, or LA), in addition to average cigarette use. Smaller OR for <10 yr in these jobs.
Lerchen et al. (1987)	New Mexico residents with lung cancer	Medicare recipients	506	771	Occupational history, industry, & self-reported exposure, by interview	✔	Sex, age, ethnicity	OR = 0.6 for ≥1 yr occupational exposure to diesel exhaust. OR = 2.1 for underground non-uranium mining.		Small number of cases and controls in diesel-exposed jobs. Possibly insufficient exposure duration. Not matched on date of birth or death.
Milne et al. (1983)	Lung cancer deaths	Deaths from any other cancer	925	6,565	Occupation from death certificate		None	OR = 3.5 for bus drivers. OR = 1.6 for truck drivers.	*	
Morabia et al. (1992)	Male lung cancer patients	Patients without lung cancer or other tobacco-related condition	1,793	3,228	Job, with coal and asbestos exposure durations, by interview	✔	Race, age, hospital, and smoking history	OR = 2.3 for miners. OR = 1.1 for bus drivers. OR = 1.0 for truck or tractor drivers.		Lung cancer reported to be associated with increasing duration of exposure to coal.
Pfluger and Minder (1994)	Professional drivers	Workers in occupational categories with no known excess lung cancer risk.	284	1,301	Occupation only, from death certificate.		None.	OR = 1.48 for professional drivers.	*	Stratified by age. Indirectly adjusted for smoking, based on smoking-rate for occupation.

Siemiatycki et al. (1988)	Squamous cell lung cancer patients by type of lung cancer	Other cancer patients	359	1,523	Semi-quantitative, from Occupa. history by interview, & exposure class for each job	✔	None	OR = 1.2 for diesel exposure; OR = 2.8 for mining.		Stratified by age, socioeconomic status, ethnicity, and blue- vs. white-collar job history. Examination of files indicated that most miners "were exposed to diesel exhaust for short periods of time."
Steenland et al. (1990)	Deaths from lung CA among Teamsters	Deaths excluding LC, bladder cancer, and motor vehicle accidents	996	1,085	Occupational history and tenure from next-of-kin, supplemented by IH data	✔	None	OR = 1.27 for diesel truck drivers with 1-24 yr. tenure. OR = 1.26 for diesel truck drivers with 25-34 yr. tenure. OR = 1.89 for diesel truck drivers with ≥35 yr. tenure.	*	Years of tenure not necessarily all at main job (i.e., diesel truck driver). OR adjusted for asbestos exposure.

Swanson et al. (1993) See also Burns & Swanson (1991)	Detroit lung cancers	Colon or rectal cancer cases	5,935	3,956	Occupational history from interview	✔	None	OR = 1.4 for heavy truck drivers with 1-9 yr tenure. OR = 1.6 for heavy truck drivers with 10-19 yr tenure. OR = 2.4 for heavy truck drivers with ≥20 yr tenure. ------------------ OR = 1.2 for railroad workers with 1-9 yr tenure. OR = 2.5 for railroad workers with ≥10 yr tenure. ------------------ OR = 5.03 for mining machine operators.	* * *	OR for truck drivers & RR workers is for white males, relative to corresponding group with <1 yr tenure, adjusted for age at diagnosis. Pattern of increasing risk with duration of employment also reported for black male railroad workers, based on fewer cases. OR for mining machine operators is for all males, adj. for race and age at diagnosis.
Williams et al. (1977)	Male lung cancer patients	Other male cancer patients	432	2,817	Main lifetime occupation from interview	✔	Sex	OR = 1.52 for male truck drivers.		Controlled for age, race, alcohol use, and socioeconomic status. Unexplained discrepancies in reported number of controls.

[a] RR = Relative Risk; OR = Odds Ratio. Values greater than 1.0 indicate excess prevalence of lung cancer associated with diesel exposure.
[b] An asterisk (*) indicates statistical significance based on 2-tailed test at confidence level of at least 95%.

Table III-6. — Hypothesized Mechanisms of Particulate Toxicity[a]

Response	Description
Increased Airflow Obstruction	PM exposure may aggravate existing respiratory symptoms which feature airway obstruction. PM-induced airway narrowing or airway obstruction from increased mucous secretion may increase abnormal ventilation/perfusion ratios in the lung and create hypoxia. Hypoxia may lead to cardiac arrhythmias and other cardiac electrophysiologic responses that in turn may lead to ventricular fibrillation and ultimately cardiac arrest. For those experiencing airflow obstruction, increased airflow into non-obstructed areas of the lung may lead to increased particle deposition and subsequent deleterious effects on remaining lung tissue, further exacerbating existing disease processes. More frequent and severe symptoms may be present or more rapid loss of function.
Impaired Clearance	PM exposure may impair clearance by promoting hypersecretion of mucus which in turn results in plugging of airways. Alterations in clearance may also extend the time that particles or potentially harmful biogenic aerosols reside in the tracheobronchial region of the lung. Consequently alterations in clearance from either disturbance of the mucociliary escalator or of macrophage function may increase susceptibility to infection, produce an inflammatory response, or amplify the response to increased burdens of PM. Acid aerosols impair mucociliary clearance.
Altered Host Defense	Responses to an immunological challenge (e.g., infection), may enhance the subsequent response to inhalation of nonspecific material (e.g., PM). PM exposure may also act directly on macrophage function which may not only affect clearance of particles but also increase susceptibility and severity of infection by altering their immunological function. Therefore, depression or over-activation of the immune system, caused by exposure to PM, may be involved in the pathogenesis of lung disease. Decreased respiratory defense may result in increased risk of mortality from pneumonia and increased morbidity (e.g., infection).
Cardiovascular Perturbation	Pulmonary responses to PM exposure may include hypoxia, bronchoconstriction, apnea, impaired diffusion, and production of inflammatory mediators that can contribute to cardiovascular perturbation. Inhaled particles could act at the level of the pulmonary vasculature by increasing pulmonary vascular resistance and further increase ventilation/perfusion abnormalities and hypoxia. Generalized hypoxia could result in pulmonary hypertension and interstitial edema that would impose further workload on the heart. In addition, mediators released during an inflammatory response could cause release of factors in the clotting cascade that may lead to increased risk of thrombus formation in the vascular system. Finally, direct stimulation by PM of respiratory receptors found throughout the respiratory tract may have direct cardiovascular effects (e.g., bradycardia, hypertension, arrhythmia, apnea and cardiac arrest).
Epithelial Lining Changes	PM or its pathophysiological reaction products may act at the alveolar capillary membrane by increasing the diffusion distances across the respiratory membrane (by increasing its thickness) and causing abnormal ventilation/perfusion ratios. Inflammation caused by PM may increase "leakiness" in pulmonary capillaries leading eventually to increased fluid transudation and possibly to interstitial edema in susceptible individuals. PM induced changes in the surfactant layer leading to increased surface tension would have the same effect.
Inflammatory Response	Diseases which increase susceptibility to PM toxicity involve inflammatory response (e.g., asthma, COPD, and infection). PM may induce or enhance inflammatory responses in the lung which may lead to increased permeability, diffusion abnormality, or increased risk of thrombus formation in vascular system. Inflammation from PM exposure may also decrease phagocytosis by alveolar macrophages and therefore reduce particle clearance. (See discussions above for other inflammatory effects from PM exposure.)

[a]This table reproduces Table V-2 of the EPA staff paper. The citation in the staff paper indicates the table is derived from information in the EPA criteria document on particulate matter (p. 13-67 to 72; p. 11-179 to 185) and information in Appendix D of EPA staff paper.

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IV. Discussion of Proposed Rule

This part of the preamble explains, section-by-section, the provisions of the proposed rule. As appropriate, this part references discussions in other parts of this preamble: in particular, the background discussions on measurement methods and controls in Part II, and the feasibility discussions in Part V.

The proposed rule would add nine new sections to 30 CFR Part 57 immediately following § 57.5015. It would not amend any existing sections of that part.

Section 57.5060 Limit on Concentration of Diesel Particulate Matter

This section of the proposed rule limits the concentration of dpm in underground metal and nonmetal mines. It has four subsections.

Paragraph (a) of § 57.5060 provides that 18 months after the date of promulgation, dpm concentrations to which miners are exposed would be limited by restricting total carbon to 400 micrograms per cubic meter of air. As proposed by the rule, this limit would apply only for a period of 36 months; accordingly, it is sometimes referred to in this preamble as the ''interim'' concentration limit.

Paragraph (b) of § 57.5060 provides that after five years the proposed concentration limit would be reduced, restricting total carbon to 160 micrograms per cubic meter of air. This is sometimes referred to in this preamble as the ''final'' concentration limit.

Paragraph (c) of § 57.5060 provides for a special extension of up to two additional years in order for a mine to comply with the final concentration limit. This special extension is only available when the mine operator can establish that the final concentration limit cannot be met within the five years allotted due to technological constraints. The proposed rule establishes the details that must be provided in the application process, and conditions that must be observed during the special extension period. Paragraph (c) of the proposed rule refers to this extension as ''special'' because the proposed rule would also provide all mines in this sector with up to five years to meet the final concentration limit.

Paragraph (d) of § 57.5060 provides that an operator shall not utilize personal protective equipment to comply with either the interim or final concentration limit. Moreover, it provides that an operator shall not utilize administrative controls to comply with either the interim or final concentration limit. These restrictions do not explicitly apply to an operator who has been provided with a special extension of time to comply with the final concentration limit pursuant to paragraph (c).

Choice of Controls. With the exceptions specified in paragraph (d), the proposed rule contemplates that an operator of an underground metal or nonmetal mine have complete discretion over the controls utilized to meet the interim and final concentration limits. No specific controls would be required for any type of diesel engine, for any type of diesel equipment, or for any type of mine in this sector. An operator could filter the emissions from diesel-powered equipment, install cleaner-burning engines, increase ventilation, improve fleet management, or use a variety of other available controls.

Because information on available controls has been described in Part II of this preamble, including the ''Toolbox'' (appended to the end of this document is a copy of an MSHA publication, ''Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—A Toolbox''), further discussion is not provided here. Reviewers are also referred to the extensive discussion of available controls in Part V of this preamble concerning the technological and economic feasibility of this rule for the underground metal and nonmetal mining sector.

To help mine operators decide among various alternative combinations of engineering and ventilation controls, MSHA has developed a model that it believes will assist an operator to determine, for a production area of a mine, the effect of any combination of controls on existing dpm concentrations in that area. This model, known as the ''Estimator'', is in the form of a spreadsheet template; this permits instant display of outcomes as inputs are altered. The model is described in detail in Part V of this preamble, and some examples illustrating its potential utility are described there. MSHA welcomes comments from the mining community concerning this model, and encourages mine operators to submit their results as part of their comments.

Expression of Limits. The interim and final concentration limits on diesel particulate matter are expressed in terms of a restriction on the amount of total carbon present. The purpose of the interim and final concentration limits is to limit the amount of diesel particulate matter to which miners are exposed; but the limit is being expressed in terms of the measurement method that MSHA intends to utilize to determine the concentration of dpm. The idea is to enable miners, mine operators and inspectors to directly compare a measurement result with the applicable limit.

As discussed in connection with proposed § 57.5061(a), MSHA intends to use a sampling and analytical method developed by NIOSH (NIOSH Analytical Method 5040) to measure dpm concentrations for compliance purposes. NIOSH's Analytical Method 5040 accurately determines the amount of total carbon (TC) contained in a dpm sample from any underground metal and nonmetal mine.

As explained in detail in Part II of this preamble, whole diesel particulate matter can be measured in a variety of ways. But to date, a method that measures whole dpm directly has not been validated as providing accurate measurements at lower concentration levels with the consistency desirable for compliance purposes. However, MSHA believes that for underground metal and nonmetal mines, there is a surrogate method with the requisite accuracy. The surrogate is a method that determines the amount of certain component parts of whole dpm. Whole dpm basically consists of: the elemental carbon (EC) making up the core of the dpm particle; the organic carbon (OC) contained in adsorbed hydrocarbons; and some sulfates. (See Figure II–3 for a graphic representation of a dpm particle). The total carbon (TC) consists of the EC and the OC. NIOSH Method 5040 has been shown to measure TC with adequate accuracy. As discussed in Part II, MSHA is not aware at this time of any interferents that would in practice preclude MSHA from using this method to obtain consistent results in underground metal and nonmetal mines; hence, the Agency is proposing to use this method for compliance.

TC represents approximately 80–85 percent of the total mass of dpm emitted in the exhaust of a diesel engine (the remaining 15–20 percent consists of sulfates and the various elements bound up with the organic carbon to form the adsorbed hydrocarbons). Using the lower boundary of this range, limiting the concentration of total carbon to 400 micrograms per cubic meter (400_{TC} $\mu g/m^3$) limits the concentration of whole diesel particulate to about 500_{DPM} $\mu g/m^3$. Similarly, limiting the concentration of total carbon to 160_{TC} $\mu g/m^3$ limits the concentration of whole diesel particulate to about 200_{DPM} $\mu g/m^3$.

By way of comparison, MSHA has measured dpm average concentrations in underground metal and nonmetal mines from about 68_{DPM} $\mu g/m^3$ to $1{,}835_{DPM}$ $\mu g/m^3$. MSHA has recorded some concentrations as high as $5{,}570_{DPM}$ $\mu g/m^3$. Complete information about these measurements, and the methods used in measuring them, are discussed in Part III of this preamble.

Where the Concentration Limit Applies. The concentration limits—both interim and final—would apply only in areas where miners normally work or travel. The purpose of this restriction is to ensure that mine operators do not have to monitor particulate concentrations in areas where miners do not normally work or travel — e.g., abandoned areas of a mine. However, the appropriate concentration limit would need to be maintained in any area of a mine where miners normally work or travel even if miners might not be present at any particular time. (For a discussion of MSHA's proposed sampling strategy, see the discussion of proposed § 57.5061(a)).

Full-shift, 8-hour Equivalent. The proposed interim and final concentration limits are expressed in terms of the average airborne concentration during each full shift expressed as an 8-hour equivalent. Measuring over a full shift ensures that average exposure is monitored over the same period to which the limit applies. Using an 8-hour equivalent dose ensures that a miner who works extended shifts—and many do—would not be exposed to more dpm than a miner who works a normal shift. The Agency welcomes comment on whether a more explicit definition is required in this regard.

Concentration Limit: Time to Meet. As noted, the dpm limitation being proposed would require metal and nonmetal mines to reduce dpm concentrations in areas where miners normally work or travel to about 200 micrograms per cubic meter of air (specifically, total carbon would have to be restricted to 160 micrograms per cubic meter of air). Proposed § 57.5060 provides an extension of time for underground metal and nonmetal mines to meet the concentration limit. Mines would not have to meet any limit within 18 months of the rule's promulgation. This period would be used to provide compliance assistance to the metal and nonmetal mining community to ensure it understands how to measure and control diesel particulate matter concentrations in individual operations. Moreover, the proposed rule would provide all mines in this sector three and a half additional years to meet the final concentration limit established by proposed § 57.5060(b). During this time, however, all mines would have to bring dpm concentrations down to 500 micrograms per cubic meter by complying with a restriction on the concentration of submicrometer total carbon of 400 micrograms per cubic meter.

MSHA established these requirements after carefully reviewing questions presented by the mining community regarding economic and technological feasibility of requiring all mines in this sector to meet the proposed concentration limit with available controls. This review is presented in Part V of this preamble. MSHA has studied a number of metal and nonmetal mines in which it believed dpm might be particularly difficult to control. The Agency has tentatively concluded that in combination with the ''best practices'' required under other provisions of the proposed rule (§§ 57.5065, 57.5066 and 57.5067), engineering and work practice controls are available that can bring dpm concentrations in all underground metal and nonmetal mines down to or below 400_{TC} $\mu g/m^3$ within 18 months. Moreover, based on the mines it has examined to date, the Agency has tentatively concluded that controls are available to bring dpm concentrations in underground metal and nonmetal mines down to or below 160_{TC} $\mu g/m^3$ within 5 years.

The Agency has tentatively concluded that it may not be feasible to require this sector, as a whole, to lower dpm concentrations further, or to implement the required controls more swiftly. Nevertheless, as noted in Part V, the Agency is seeking information, examples and comment that will assist it in making a final determination on these points.

Special Extension. An operator may request more than five years to comply with the final concentration limit only in the case of technological constraints that preclude compliance. MSHA has determined that it is economically feasible for the mining industry as a whole to comply with the proposed concentration limit within five years. In light of the risks to miners posed by dpm, the Agency does not believe the economic constraints of a particular operator should provide an adequate basis for a further extension of time for that operator, and the proposal would not provide for any extension grounded on economic concerns. Moreover, if it is technologically feasible for an operator to reduce dpm concentrations to the final limit in time through any approach, no extension would be permitted even if a more cost effective solution might be available in the future for that operator.

However, the Agency believes that if an operator can actually demonstrate that there is no technological solution that could reduce the concentration of dpm within five years, a special extension would be warranted. As a practical matter, MSHA believes that very few, if any, underground metal and nonmetal mining operations should need a special extension. MSHA bases this belief on information discussed in Part V of this preamble with respect to the feasibility of the proposed standard, and comments on that information are specifically solicited. Despite this information, and just in case a few mines experience technical problems that cannot be foreseen at this time, the proposed rule would make provision for a special extension to allow up to an additional two years to comply with the final concentration limit.

Extension Application. Proposed § 57.5060(c)(1) provides that if an operator of an underground metal or nonmetal mine can demonstrate that there is no combination of controls that can, due to technological constraints, be implemented within five years to reduce the concentration of dpm to the limit, MSHA may approve an application for an additional extension of time to comply with the dpm concentration limit. Under the proposal, such a special extension is available only once, and is limited to 2 years. To obtain a special extension, an operator must show that diesel powered equipment was used in the mine prior to publication of the rule, demonstrate that there is no off-the-shelf technology available to reduce dpm to the limit specified in § 57.5060, and establish the lowest achievable concentration of dpm attainable. The proposed rule further requires that to establish the lowest achievable concentration, the operator is to provide sampling data obtained using NIOSH Method 5040 (the method MSHA will use when determining concentrations for compliance purposes). The sampling method is further discussed in connection with proposed § 57.5061(a).

The application would also require the mine operator to specify the actions that are to be taken to ''maintain the lowest concentration of diesel particulate achievable'' (such as strict adherence to an established control plan) and to minimize miner exposure to dpm (e.g., provide suitable respirators). MSHA's intent is to ensure that personal protective equipment and administrative controls are permitted only as a last and temporary resort to bridge the gap between what can be accomplished with engineering and work practice controls and the concentration limit. It is not the Agency's intent that personal protective equipment or administrative controls be permitted during the extension period as a substitute for engineering and work practice controls that can be implemented immediately. The Agency would welcome comments on whether more explicit clarification of this point in the proposed rule is required.

Filing, Posting and Approval of Extension Application. The proposed rule would require that an application for an extension be filed (after being posted for 30 days at the mine site) no later than 6 months (180 days) in advance of the date of the final concentration limit (160tc µg/m^3). The proposed rule would also require that a copy of the approved extension be posted at the mine site for the duration of the extension period. In addition, a copy of the application would also have to be provided to the authorized representative of the miners.

The application would be required to be approved by MSHA before it becomes effective. While pre-approval of plans is not the norm in this sector, an exception to the final concentration limit cannot be provided without careful scrutiny. Moreover, in some cases, the examination of the application may enable MSHA to point out to the operator the availability of solutions not considered to date.

While the proposed rule is not explicit on the point, it is MSHA's intent that primary responsibility for approval of the operator's application for an extension will rest with MSHA's district managers. This ensures familiarity with the mine conditions, and provides an opportunity to consult with miners as well. At the same time, MSHA recognizes that district managers may not have the expertise required to keep fully abreast of the latest technologies and of solutions being used in similar mines elsewhere in the country. Accordingly, the Agency intends to establish, within its Technical Support directorate in Washington, D.C., a special panel to consult on these issues and to provide assistance to its district managers. MSHA would welcome comments on this matter, and as to whether it should incorporate further specifics in this regard into the final rule.

Personal Protective Equipment and Administrative Controls. Paragraph (d) provides that an operator shall not utilize personal protective equipment (e.g., respirators) or administrative controls (e.g., rotation of miners) to comply with either the interim or final concentration limit. Moreover, it provides that an operator shall not utilize administrative controls (e.g., the rotation of miners) to comply with either the interim or final concentration limit.

Limiting individual miner exposure through rotation or through the use of respirators would not reduce the airborne concentrations of particulate matter. It is accepted industrial hygiene practice to eliminate or minimize hazards at the source by using engineering or work practices, before resorting to alternative controls. Moreover, administrative controls are not considered acceptable in the case of potential carcinogens, since they result in placing more workers at risk.

MSHA intends that the normal meaning be given to the terms personal protective equipment and administrative controls, and welcomes comments as to whether more specificity would be useful. For example, the Agency assumes the mining community understands that an environmentally controlled cab for a piece of equipment is not a piece of personal protective equipment; indeed, the cost estimates for the proposed rule assume that such cabs will be a commonly used control to meet the proposed limits in those situations in which the only miners present in an area are equipment operators (see Part V of this preamble and the Agency's PREA).

Section 57.5061 Compliance Determinations

Under the proposed rule, compliance sampling would be performed by MSHA directly, and a single sample would be adequate to establish a violation.

The proposed rule further provides that MSHA will collect and analyze dpm samples for total carbon (TC) content using NIOSH Method 5040 (or by using any method subsequently determined by NIOSH to provide equal or improved accuracy in mines subject to this part). NIOSH Method 5040 provides for sample collection using a dust sampler pump and an open face filter. The filters are analyzed for elemental carbon (EC) and organic carbon (OC) content using the thermo-optical technique; the EC and OC concentration determinations are then added together to obtain the TC concentration of the sample.

Measurement Method for Compliance. Section 3 of Part II of this preamble discusses alternative methods for measuring dpm concentrations. As noted in that discussion, after considering the comments received in response to MSHA's ANPRM, reviewing the available technical information submitted in response to the ANPRM and reviewing the status of current technology, MSHA believes that NIOSH Method 5040 provides an accurate method of determining the total carbon content of a sample collected in any underground metal or nonmetal mine when using the sampling procedures specified in Method 5040. At the present time, Method 5040 is the only method that meets NIOSH's accuracy criterion for determinations of both EC and OC down to concentrations as low as those that will need to be measured to determine compliance with the final concentration limit being proposed. Accordingly, MSHA proposes to use this method for determining TC concentrations for compliance purposes.

Margin of Error. Before issuing a citation, MSHA intends to take into consideration uncertainty associated with the sampling and analytical process, as it does in other cases. While the measurement uncertainty has not been established for samples collected in mines, NIOSH has established the variability associated with Method 5040 to be approximately 6% (one relative standard deviation). If MSHA used the variability value established by NIOSH and allowed for a confidence level of 95%, MSHA would not issue a citation until the measured value was greater than 1.10 times the levels established in § 57.5060. For example, if the variability established by NIOSH is used, during the interim period when the limit is 400_{TC} µg/m^3 a noncompliance determination would not be made unless the TC measurement exceeded 440 µg/m^3.

MSHA recognizes that the measurement uncertainty may be higher for samples collected in mines, and intends to establish as the ''margin of error'' required to achieve a 95% confidence level for all noncompliance determinations based on samples collected in mines. The Agency anticipates that the margin of error will end up being somewhere between 10% and 20%, but will be governed by the actual data on this point.

Sampling Strategy. Proposed § 57.5060 would establish a concentration limit for areas of a mine where miners normally work or travel to limit miner exposure to dpm. In using this language, MSHA intends that the limits on the concentration of dpm would apply to persons, occupations or areas, as with coal dust. Accordingly, MSHA intends that inspectors have the flexibility to determine, on a mine by mine basis, the most appropriate method to assess the level of hazard that exists. The Agency may sample by attaching a sampler to an individual miner, or by locating the sampler on a piece of equipment where a miner may work, or at a fixed site where miners normally work or travel.

Sampling strategy was discussed by commenters who responded to the ANPRM. Several commenters indicated that the sampling strategy should ensure that samples taken are representative of actual exposure. Other commenters stated that the sampling strategy would be dictated by the measurement method, and that several strategies could be used to determine the hazard. They stated that the strategy should not be defined so narrowly as to exclude development of new sampling methods.

A related issue addressed by the commenters was whether personal or area sampling would be more appropriate. Most commenters indicated that personal sampling was the most reliable indicator of worker exposure. Some noted that in underground mines which use mobile diesel equipment, the positions of diesel-powered vehicles with respect to intake and return air streams vary from hour to hour. Therefore, it is virtually impossible to obtain meaningful information from stationary instruments. Several commenters stated that area sampling was appropriate to define action levels that may trigger personal sampling or to evaluate effectiveness of controls. Some additional concerns were raised concerning the accuracy of the sampling device when worn by a miner.

MSHA agrees that there may be circumstances when either area or personal sampling may be appropriate. Considering the mobility of the equipment it may not always be feasible to sample individual workers; for example, if work practice would include rotation of workers into an area. In this case, area sampling would be more appropriate to establish a hazard. MSHA does recognize that the diesel particulate is ultimately transported to return entries or exhaust openings of a mine.

The purpose of these entries is to provide a means to transport contaminated air away from the active workings. MSHA does not intend to conduct area sampling in these areas; however, personal sampling of workers who enter these areas could be conducted. These circumstances would be evaluated on a mine-by-mine basis during mine inspections. Accordingly, MSHA will utilize either area or personal (within 36'' of a miners breathing zone) sampling to determine whether corrective actions must be taken by a mine operator. In return entries, measurements made in the immediate area where diesel equipment is being operated will be collected at locations that are no closer than five feet from any piece of operating diesel equipment.

Section 57.5062 Diesel Particulate Matter Control Plan

A determination of noncompliance with either the interim or final concentration limit prescribed by § 57.5060 would trigger a requirement that: first, the operator establish a diesel particulate matter control plan (dpm control plan)— or modify the plan if one is already in effect; and second, the operator demonstrate that the new or modified plan is effective in controlling the concentration of dpm to the applicable concentration limit.

No Advance Approval Required. The agency proposes to continue to observe the metal and nonmetal mine plan tradition by not requiring a formal plan approval process. That is, the plan would not require advance approval of the MSHA District Manager. A dpm control plan would, however, have to meet certain requirements set forth in the proposed rule, and it would be a violation of § 57.5062 if MSHA determines the operator has failed to include the necessary particulars.

Elements of Plan. Under proposed § 57.5062(b), a dpm control plan must describe the controls the operator will utilize to maintain the concentration of diesel particulate matter to the applicable limit specified by § 57.5060. The plan must also include a list of diesel-powered units used by the mine operator, together with information about any unit's emission control device, and the parameters of any other methods used to control the concentration of diesel particulate matter.

Relationship to Ventilation Plan. At the discretion of the operator, the dpm control plan may be consolidated with the ventilation plan required by § 57.8520.

Demonstration of Plan Effectiveness. The proposed rule would require monitoring to verify that the dpm control plans are actually effective in reducing dpm concentrations in the mine to the applicable concentration limit. Because the dpm control plan was initiated as a result of a compliance action, the proposed rule would require the use of the same measurement method used by MSHA in compliance determinations—total carbon using NIOSH Method 5040—to conduct verification sampling.

Effectiveness must be demonstrated by ''sufficient'' monitoring to confirm that the plan or amended plan will control the concentration of diesel particulate to the applicable limit under conditions that can be ''reasonably anticipated'' in the mine. The proposed rule does not specify that any defined number of samples must be taken—the intent is that the sampling provide a fair picture of whether the plan or amended plan is working. MSHA will determine compliance with this obligation based on a review of the situation involved. While an MSHA compliance sample may be an indicator that the operator has not fulfilled their obligation under this section to undertake monitoring ''sufficient'' to verify plan effectiveness, it would be inconclusive on that point. The Agency welcomes comment on this point.

Similarly, the Agency welcomes comment on whether, and how, it should define the term ''reasonably anticipated.'' With respect to coal dust, the Dust Advisory Committee recommended that ''MSHA should define the range of production values which must be maintained during sampling to verify the plan. This value should be sufficiently close to maximum anticipated production'' (MSHA, 1996). For dpm, the equivalent approach might be based on worst-case operating conditions of the diesel equipment—e.g., all equipment is being operated simultaneously with the least ventilation.

Recordkeeping Retention and Access. Pursuant to § 57.5062(b), a copy of the current dpm control plan is to be maintained at the mine site during the duration of the plan and for one year thereafter. Proposed § 57.5062(c) would require that verification sample results be retained for 5 years. Proposed § 57.5062(d) provides that both the control plan and sampling records verifying effectiveness be made available for review, upon request, by the authorized representative of the Secretary, the Secretary of Health and Human Services, and/or the authorized representative of miners. Upon request of the District Manager or the authorized representative of miners, a copy of these records is to be provided by the operator.

Duration. The proposal would require the dpm control plan to remain in effect for three years from the date of the violation resulting in the establishment/modification of the plan. As discussed in Part I of this preamble (Question and Answer 18), MSHA believes operators have sufficient time under the proposed rule to come into compliance with the concentration limits. If a problem exists, maintaining a plan in effect long enough to ensure that daily mine practices really change, is an important safeguard.

Modification During Plan Lifetime. A violation of § 57.5060 would require the mine operator to modify the dpm control plan to reflect changes in mining equipment and/or the mine environment and the operator would be required to demonstrate to MSHA the effectiveness of the modified plan.

Also, proposed § 57.5062(e)(2) would require the mine operator to modify the dpm control plan to reflect changes in mining equipment and/or the mine environment and the operator would be required to demonstrate to MSHA the effectiveness of the modified plan.

Compliance with Plan Requirements. Once an underground metal or nonmetal mine operator adopts a dpm control plan, it will be considered regulation for the mine. Proposed 57.5062(f) specifically provides that MSHA would not need to establish (by sampling) that an operator is currently in violation of the applicable concentration limit under § 57.5060 in order to determine by observation that an operator has failed to comply with any requirement of the mine's dpm control plan.

Section 57.5065 Fueling and idling practices

Fueling Practices. Part II of this preamble contains some background information on fueling practices, together with information about the rules currently applicable in underground coal mines.

Proposed § 57.5065(a) would require underground metal and nonmetal mine operators to use only low-sulfur fuel having a sulfur content of no greater than 0.05 percent. This requirement is identical to that currently required for diesel equipment used in underground coal mines [30 CFR 75.1901(a)]. Both number 1 and number 2 diesel fuel meet the requirement of this proposal.

Sulfur content can have a significant effect on diesel emissions. Use of low sulfur diesel fuel reduces the sulfate fraction of dpm emissions, reduces objectionable odors associated with diesel exhaust, and allows oxidation catalysts to perform properly. A major benefit of using low sulfur fuel is that the reduction of sulfur allows for the use of some aftertreatment devices such as catalytic converters and catalyzed particulate traps which were prohibited with fuels of high sulfur content (greater than 0.05 percent sulfur). MSHA believes the use of these aftertreatment devices is important to the mining industry because they will be necessary to meet the levels specified. The requirement to use low sulfur fuel will allow these devices to be used without additional adverse effects caused by the high sulfur fuel. As noted in Part IV of the PREA, MSHA does not believe such a requirement will add additional cost.

Proposed paragraph (b) of this section would require mine operators to use only diesel fuel additives that have been registered by the Environmental Protection Agency (40 CFR Part 79). Again, this proposed rule is consistent with that currently required for diesel equipment used in underground coal mines [30 CFR 75.1901(c)]. The restricted use of additives would ensure that diesel particulate concentrations would not be inadvertently increased, while also protecting miners against the emission of other toxic contaminants. MSHA issued Program Information Bulletin No. P97–10, on May 5, 1997, that discusses the fuel additives list. The requirements of this paragraph do not place an undue burden on mine operators because operators need only verify with their fuel suppliers or distributors that the additive purchased is included on the EPA registration list.

Idling Practices. Proposed § 57.5065(c) would prohibit idling of mobile-powered diesel equipment, except as required for normal mining operations. The idling requirements being proposed for underground metal and nonmetal mines are consistent with the idling requirements currently required for underground coal mines (§ 75.1916(d)).

MSHA believes that keeping idling to a minimum is very important to reduce pollution in mine atmospheres. Engines operating without a load during idling can produce significant levels of both gaseous and particulate emissions. Even though the concentration emitted from a single idling engine might have little effect on the overall mine environment, a localized, increased exposure of the gaseous and particulate concentrations would occur. In underground operations, an engine idling in an area of minimal ventilation or a ''dead air'' space could cause an excess exposure to the gaseous emissions, especially carbon monoxide, as well as to dpm. Eliminating unnecessary idling would reduce localized exposure to high particulate concentrations.

While the proposed rule is intended to prevent idling except as required for normal mining operations, it does not define normal mining operations. MSHA envisions ''normal mining operations'' to be activities such as idling while waiting for a load to be unhooked, or waiting in line to pick up a load. These types of activities would be permitted. Idling while eating lunch is normally not part of the job and operators would be in violation of the standard. Idling necessary due to very cold weather conditions would be permitted. On the other hand, idling in other weather conditions just to keep balky, older engines running would not be permitted; in such cases, the correct approach is better maintenance. MSHA welcomes comments on whether a more specific definition is necessary, particularly in light of any experience to date under the parallel rule for diesel equipment in underground coal mines.

Section 57.5066 Maintenance Standards

Proposed § 57.5066(a) would place emphasis on the fact that diesel engine emissions are lower from an engine that is properly maintained than from an engine that is not. Part II of the preamble provides more information on this point.

Approved Engines. Proposed § 57.5066(a)(1) would require that mine operators maintain any approved diesel engine in ''approved'' condition. Under MSHA's approval requirements, engine approval is tied to the use of certain parts and engine specifications. When these parts or specifications are changed (i.e., an incorrect part is used, or the engine timing is incorrectly set), the engine is no longer considered by MSHA to be in approved condition.

Often, engine exhaust emissions will deteriorate when this occurs. Maintaining approved engines in their approved condition will ensure near-original performance of an engine, and maximize vehicle productivity and engine life, while keeping exhaust emissions at approved levels. The proposed maintenance requirements for approved engines in this rule are already applicable to underground coal mines, where only approved engines may be utilized (30 CFR 75.1914).

Thus in practice, with respect to approved engines, mine maintenance personnel will have to maintain the following engine systems in near original condition: air intake, cooling, lubrication, fuel injection and exhaust. These systems must be maintained on a regularly scheduled basis to keep the system in its ''approved'' condition and thus, operating at its expected efficiency.

One of the best ways to ensure these standards are observed is to implement a proper maintenance program in the mine—but the proposed rule would not require operators to do this. A good program should include compliance with manufacturers' recommended maintenance schedules, maintenance of accurate records and the use of proper maintenance procedures. MSHA's diesel toolbox provides more information about the practices that should be followed in maintaining diesel engines in mines.

Non-approved Engines. For any non-approved diesel engine, proposed paragraph (a)(2) would require mine operators to maintain the emissions related components to manufacturer specifications.

The term ''emission related components,'' refers to the parts of the engine that directly affect the emission characteristics of the raw exhaust. These are basically the same components which MSHA examines for ''approved'' engines. They are the piston, intake and exhaust valves, cylinder head, injector, fuel injection pump, governor, turbocharger, after cooler, injection timing, and fuel pump calibrator.

It is not MSHA's intent that engines be torn down and the engine components be compared against the specifications in manufacturer maintenance manuals. Primarily, the Agency is interested in ensuring that engines are maintained in accordance with the schedule recommended by the manufacturer. However, if it becomes evident that the engines are not being maintained to the correct specifications or are being rebuilt in a configuration not in line with manufacturers' specifications or approval requirements, an inspector may ask to see the manuals to confirm that the right manuals are being used, or call in MSHA experts to examine an engine to confirm whether basic specifications are being properly observed. MSHA welcomes comment on alternative ways to phrase this requirement so Agency has a basis for ensuring compliance while minimizing the opportunity for over-prescriptiveness.

Emission or Particulate Control Device. Proposed paragraph (a)(3) would require that any emission or particulate control device installed on diesel-powered equipment be maintained in effective operating condition. Depending on the type of devices installed on an engine, this would involve having trained personnel perform such basic tasks as regularly cleaning aftertreatment filters, using methods recommended by the manufacturer for that purpose, or inserting appropriate replacement filters when required, checking for and repairing any exhaust system leaks, and other appropriate actions.

Tagging of Equipment for Noncompliance. Proposed § 57.5066(b)(1) would require underground metal and nonmetal mine operators to authorize and require miners operating diesel powered equipment to affix a visible and dated tag to the equipment at any time the equipment operator detects an emission-related problem.

MSHA believes tagging will provide an effective and efficient method of alerting all mine personnel that a piece of equipment needs to be checked by qualified service personnel. The tag may be affixed because the equipment operator detects a problem through a visual exam conducted before the equipment is started, or because of a problem that comes to the attention of the equipment operator during mining operations, (i.e., black smoke while the equipment is under normal load, rough idling, unusual noises, backfiring, etc.)

MSHA is not proposing that equipment tagged for potential emission problems be automatically taken out of service. The proposal is not, therefore, directly comparable to a ''tag-out'' requirement like OSHA's requirement for automatic powered machinery, nor is it as stringent as MSHA's requirement to remove from service certain equipment ''when defects make continued operation hazardous to persons'' (see 30 CFR 57.14100). The proposed rule is not as stringent as these requirements because, although exposure to dpm emissions does pose a serious health hazard for miners, the existence or scope of an equipment problem cannot be determined until the equipment is examined or tested by a person competent to assess the situation. Moreover, the danger is not as immediate as, for example, an explosive hazard.

Proposed § 57.5066(b)(2) would require that the equipment be ''promptly'' examined by a person authorized by the mine operator to maintain diesel equipment. (The qualifications for those who maintain and service diesel engines are discussed below). The Agency has not tried to define the term ''promptly,'' but welcomes comment on whether it should do so—in terms, for example, of a limited number of shifts. The presence of a tag serves as a caution sign to miners working on or near the equipment, as well as a reminder to mine management, as the equipment moves from task to task throughout the mine. While the equipment is not barred from service, operators would be expected to use common sense and not use it in locations in which diesel particulate concentrations are known to be high.

Proposed paragraph (b)(2) would permit a tag to be removed after the defective equipment has been examined.

The design of the tag is left to the discretion of the mine operator, with the exception that the tag must be able to be marked with a date. Comments are welcome on whether some or all elements of the tag should be standardized to ensure its purpose is met.

Tagged Equipment Log. Proposed § 57.5066(b)(3) would require a log to be retained of all equipment tagged. Moreover, the log must include the date the equipment is tagged, the date the tagged equipment is examined, the name of the person making the examination, and the action taken as a result of the examination. Records in the log about a particular incident must be retained for at least a year after the equipment is tagged.

MSHA does not expect the log to be burdensome to the mine operator or mechanic examining or testing the engine. Based on MSHA's experience, it is common practice to maintain a log when equipment is serviced or repaired, consistent with any good maintenance program. The records of the tagging and servicing, although basic, provide mine operators, miners and MSHA with a history that will help in determining whether a maintenance program is being effectively implemented.

Qualified Person. Proposed paragraph (c) would require that persons who maintain diesel equipment in underground metal and nonmetal mines be ''qualified,'' by virtue of training and experience, to ensure the maintenance standards of proposed § 57.5066(a) are observed. Paragraph (c) also requires that an operator retain appropriate evidence of ''the competence of any person to perform specific maintenance tasks'' in compliance with the requirement's maintenance standards for one year.

The ANPRM requested information concerning specialized training for those persons working on equipment that uses particulate reduction technology and the costs associated with the training. Commenters stated that any equipment modifications will require additional training. The extent and costs would vary widely depending on the type of devices used. MSHA agrees that training should be given when new devices or modifications to machines are made. The training cost will be dependent on the complexity of the control device.

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 (30 CFR 75.1915). The unique conditions in underground coal mines require the use of specialized equipment. Accordingly, the qualifications of the persons who maintain this equipment generally must be appropriately sophisticated.

If repairs and adjustments to diesel engines used in underground metal and nonmetal mines are to be done properly, personnel performing such tasks must be properly trained. MSHA does not believe, however, that the qualifications required to perform this work in underground metal and nonmetal mines necessarily require the same level of training as for similar work in underground coal mines. Under the proposed rule, the training required would be that which is commensurate with the maintenance task involved. If examining and, if necessary, changing a filter or air cleaner is all that is required, a miner who has been shown how to do these tasks would be qualified by virtue of training or experience to do those tasks. For more detailed work, specialized training or additional experience would be required. Training by a manufacturer's representative, completion of a general diesel engine maintenance course, or practical experience performing such repairs could also serve as evidence of having the qualifications to perform the service.

In practice, the results will soon be revealed by performance. If MSHA finds a situation where maintenance appears to be shoddy, where the log indicates an engine has been in for repair with more frequency than should be required, or where repairs have damaged engine approval status or emission control effectiveness, MSHA would ask the operator to provide evidence that the person(s) who worked on the equipment was properly qualified by virtue of training or experience.

It is MSHA's intent that equipment sent off-site for maintenance and repair is also subject to the requirement that the personnel performing the repair be qualified by virtue of training or experience for the task involved. It is not MSHA's intent that a mine operator have to examine the training and experience record of off-site mechanics, but a mine operator will be expected to observe the same kind of caution as one would observe with a personal vehicle—e.g., selecting the proper kind of shop for the nature of the work involved, and considering prior direct experience with the quality of the shop's work.

Section 57.5067 Engines

The proposed rule would require that, with the exception of diesel engines used in ambulances and fire-fighting equipment, any diesel engines added to the fleet of an underground metal or nonmetal mine in the future must be an engine approved by MSHA under Part 7 or Part 36. This requirement would take effect 60 days after the date the rule is promulgated.

The composition of the existing fleet would not be impacted by this part of the proposed rule. However, after the rule's effective date, an operator would not be permitted to bring into underground areas of a mine an unapproved engine from the surface area of the same mine, an area of another mine, or from a non-mining operation. Promoting a gradual turnover of the existing fleet to better engines is an appropriate response to the health risk presented by dpm.

Approval is not something that has to be done by individual mine operators. Approved engines carry an approval plate so they are easy to distinguish. Approval is a process that is handled by engine manufacturers, involving tests by independent laboratories.

MSHA is assuming in the PREA accompanying this proposed rule that this additional requirement will require manufacturers to obtain approval on one additional diesel engine model per year. Some engines currently used in metal and nonmetal mines may have no approval criteria; in such cases, MSHA will work with the manufacturers to develop approval criteria consistent with those MSHA uses for other diesel engines. Based upon preliminary analysis, MSHA has tentatively concluded that any diesel engine meeting current on-highway and non-road EPA emission requirements would meet MSHA's engine approval standards of Part 7, subpart E, category B type engine. (See section 4 of Part II of this preamble for further information about these engines.)

Currently, the EPA non-road test cycle and MSHA's test cycle are the same for determining the gaseous and particulate emissions. MSHA envisions being able to use the EPA test data for engines run on the non-road test cycle for determining the gaseous ventilation rate and particulate index. The engine manufacturer would continue to submit the proper paper work for a specific model diesel engine to receive the MSHA approval. However, engine data run on the EPA on-highway transient test cycle would not as easily be usable to determine the gaseous ventilation and particulate index. Comments on how MSHA can facilitate review of engines not currently approved would be welcome.

Engines in diesel-powered ambulances and fire-fighting equipment would be exempted from these requirements. This exemption is identical with that in the rule for diesel-powered equipment in underground coal mines.

Section 57.5070 Miner Training

Proposed § 57.5070 would require any miner ''who can reasonably be expected to be exposed to diesel emissions'' be trained annually in: (a) The health risks associated with dpm exposure; (b) the methods used in the mine to control dpm concentrations; (c) identification of the personnel responsible for maintaining those controls; and (d) actions miners must take to ensure the controls operate as intended.

The purpose of the proposed requirement is to promote miner awareness. Exposure to diesel particulate is associated with a number of harmful effects as discussed in Part III of this preamble, and the safe level is unknown. Miners who work in mines where they are exposed to this risk ought to be reminded of the hazard often enough to make them active and committed partners in implementing actions that will reduce that risk.

The training need only be provided to miners who can reasonably be expected to be exposed at the mine. The training is to be provided by operators; hence, it is to be without fee to the miner.

The rule places no constraints on the operator as to how to accomplish this training. MSHA believes that the required training can be provided at minimal cost and minimal disruption. The proposal would not require any special qualifications for instructors, nor would it specify the hours of instruction.

Instruction could take place at safety meetings before the shift begins. Devoting one of those meetings to the topic of dpm would be a very easy way to convey the necessary information. Simply providing miners with a copy of MSHA's ''Toolbox'' and, a copy of the plan, if a control plan is in effect for the mine, and reviewing these documents, can cover several of the training requirements. One-on-one discussions that cover the required topics are another approach that can be used.

Operators could also choose to include a discussion on diesel emissions in their Part 48 training, provided the plan is approved by MSHA. There is no existing requirement that Part 48 training include a discussion of the hazards and control of diesel emissions. While mine operators are free to cover additional topics during the Part 48 training sessions, the topics that must be covered during the required time frame may make it impracticable to cover other matters within the prescribed time limits.

Where the time is available in mines using diesel-powered equipment, operators would be free to include the dpm instruction in their Part 48 training plans. The Agency does not believe special language in the proposed rule is required to permit this action under Part 48, but welcomes comment in this regard.

The proposal does not require the mine operator to separately certify the completion of the dpm training, but some evidence that the training took place would have to be produced upon request. A serial log with the employee's signature is an acceptable practice.

To assist mine operators with the proposed training requirement, it is MSHA's intent to develop an instruction outline that mine operators can use as a guide for training personnel. Instruction materials will be provided with the outline.

Section 57.5071 Environmental Monitoring

Operator's Monitoring Responsibility. Proposed § 57.5071(a) would require that mine operators sample their mine environments to evaluate environmental conditions to which miners are exposed. It is proposed that sampling be performed as often as necessary to ''effectively evaluate''—under conditions that can be reasonably anticipated in the mine—(1) Whether the dpm concentration in any area of the mine where miners normally work or travel exceeds the applicable limit; and (2) the average full shift airborne concentration at any position or on any person designated by the Secretary.

There are two important aspects of this proposed operator monitoring requirement. First, it would clarify that it is the responsibility of mine operators to be aware of the concentrations of dpm in all areas of the mine where miners normally work or travel, so as to know whether action is needed to ensure that the concentration is kept below the applicable limit. Secondly, this requirement would ensure special attention to locations or persons known to MSHA to have a significant potential for overexposure to dpm.

The obligation of operators to ''effectively evaluate'' concentrations in a mine is a separate obligation from that to keep dpm levels below the established limit, and can be the basis of a separate citation from MSHA. The proposed rule is performance-oriented in that the regularity and methodology used to make this evaluation are not specified. However, MSHA expects mine operators to sample with such frequency that they and the miners working at the mine site are aware of dpm levels in their work environment. In this regard, MSHA's own measurements will assist the Agency in verifying the effectiveness of an operator's monitoring program. If an operator is ''effectively evaluating'' the concentration of dpm at designated positions, for example, MSHA would not expect to regularly record concentrations above the limit when it samples at that location. If MSHA does find such a problem, it will investigate to determine how frequently an operator is sampling, where the operator is sampling, and what methodology is being used, so as to determine whether the obligation in this section is being fulfilled.

MSHA proposed a performance-oriented operator sampling requirement in its recent proposed rule on noise, and is seeking some consistency of approach in this regard for uniform health standards.

Operator Monitoring Methods. The proposed rule requires that full-shift diesel particulate concentrations be determined during periods of normal production or normal work activity, in areas where miners work or travel. The proposed rule does not specify a particular monitoring method or frequency; rather, the proposal is performance-oriented. Operators may, at their discretion, conduct their monitoring using the same sampling and analytical method as MSHA, or they may use any other method that enables that mine to ''effectively evaluate'' the concentrations of dpm. Monitoring performed to verify the effectiveness of a diesel particulate control plan would probably meet the obligation under proposed § 57.5071 if it is done with enough sufficiency to meet the obligation under proposed § 7.5062(c).

As discussed in connection with proposed § 57.5061, MSHA intends to use NIOSH Method 5040, the sampling and analytical method that NIOSH has developed for accurately determining the concentration of total carbon. Operators are also required to use the TC method for verifying the effectiveness of dpm control plans, as discussed in connection with proposed § 57.5062. But the method may not be necessary to effectively evaluate dpm in some mines. For example, dpm measurements in limestone, potash and salt mines could be determined using the RCD method, since there are no large carbonaceous particles present that would interfere with the analysis. Such estimates can be useful in determining the effectiveness of controls and where more refined measurements may be required.

Of course, mine operators using the RCD, or size-selective methods, to monitor their diesel particulate concentrations would have to convert the results to a TC equivalent to ascertain their exact compliance status. At the present time, MSHA has no conversion tables for this purpose. In most cases, the other methods will provide a good indication of whether controls are working and whether further action is required.

Part II of this preamble provides information on monitoring methods and their constraints, and on laboratory and sampler availability.

Observation of Monitoring. Section 103(c) of the Mine Act requires that:

> The Secretary, in cooperation with the Secretary of Health, Education, and Welfare, shall issue regulations requiring operators to maintain accurate records of employee exposures to potentially toxic materials or harmful physical agents which are required to be monitored or measured under any applicable mandatory health or safety standard promulgated under this Act. Such regulations shall provide miners or their representatives with an opportunity to observe such monitoring or measuring, and to have access to the records thereof.

In accordance with this legal requirement, proposed § 57.5071(b) requires a mining operator to provide affected miners and their representatives with an opportunity to observe exposure monitoring required by this section. Mine operators must give prior notice to affected miners and their representatives of the date and time of intended monitoring.

MSHA has proposed identical language in a supplement to its proposed rule on noise (62 FR 68468).

Corrective Action if Concentration is Exceeded. Proposed § 57.5071(c) provides that if any monitoring performed under this section indicates that the applicable dpm concentration limit has been exceeded, an operator shall initiate corrective action by the next work shift, promptly post a notice of the corrective action being taken and promptly complete such corrective action.

MSHA welcomes comments as to what guidance to provide with respect to the obligations in this regard where an operator is not using the total carbon method. MSHA also welcomes comment as to whether personal notice of corrective action would be more appropriate than posting, given the health risks involved.

The Agency wishes to emphasize that operator monitoring of dpm concentrations would not take the place of MSHA sampling for compliance purposes; rather, this requirement is designed to ensure the operator checks dpm concentrations on a more regular basis than it is possible for MSHA to do.

Proposed paragraph (c) provides that if sampling results indicate the concentration limit has been exceeded in an area of a mine, an operator would initiate corrective action by the next work shift and promptly complete such action.

In certain types of cases (e.g., 30 CFR 75.323), MSHA has required that when monitoring detects a hazardous level of a substance, miners must be immediately withdrawn from an area until abatement action has been completed. Although MSHA has not proposed such action in this case, MSHA would like advice from the mining community on whether such a practice should be required in light of the evidence presented on the various risks posed by exposure to diesel particulate. There is good evidence, for example, that acute short-term increases in exposure can pose significant risks to miner health.

The Agency welcomes comment on whether clarification of this proposed requirement is necessary in light of the fact that operators using more complex analytical procedures (e.g., the total carbon method) may not receive the results for some time period after the sampling has taken place.

Posting of Sample Results. Proposed § 57.5071(d)(1) would require that monitoring results be posted on the mine bulletin board within 15 days of receipt, and remain posted for 30 days. A copy of the results would be provided to the authorized miners' representative. Posting of the results would ensure that miners are kept aware of the hazard so they can actively participate in efforts to control dpm.

Retention of Sample Results. Proposed § 57.5071(d)(2) would require that records of the sampling method and the sample results themselves be retained by operators for five years. This is because the results from a monitoring program can provide insight as to the effectiveness of controls over time and provide a history of occupational exposures at the mine. MSHA would welcome comment on the sample retention period appropriate for the risks involved.

Section 57.5075 Diesel Particulate Records

Various recordkeeping requirements are set forth in provisions of the proposed rule. For the convenience of the mining community, these requirements are also listed in a table entitled ''Diesel Particulate Recordkeeping Requirements,'' which can be found in proposed § 57.5075(a). Each row involves a record that must be kept. The section requiring the record be kept is noted, along with the retention time. MSHA would welcome input from the mining community as to whether it likes this approach or finds it duplicative or confusing.

Location of Records. Proposed § 57.5075(b)(1) would provide that any record which is required to be retained at the mine site may be retained elsewhere if it is immediately accessible from the mine site by electronic transmission. Compliance records need to be where an inspector can view them during the course of an inspection, as the information in the records may determine how the inspection proceeds. If the mine site has a fax machine or computer terminal, there is no reason why the records cannot be maintained elsewhere. MSHA's approach in this regard is consistent with Office of Management and Budget Circular A–130.

MSHA encourages mine operators who store records electronically to provide a mechanism which will allow the continued storage and retrieval of records in the year 2000.

Records Access. Proposed § 57.5075(b) also covers records access. Consistent with the statute, upon request from an authorized representative of the Secretary of Labor, the Secretary of Health and Human Services, or from the authorized representative of miners, mine operators are to promptly provide access to any record listed in the table in this section. A miner, former miner, or, with the miner's or former miner's written consent, a personal representative of a miner, is to have access to any exposure record required to be maintained pursuant to § 57.5071 to the extent the information pertains to the miner or former miner. Upon request, the operator must provide the first copy of such record at no cost. Whenever an operator ceases to do business, that operator would be required to transfer all records required to be maintained by this part to any successor operator.

General Effective Date. The proposed rule provides that unless otherwise specified, its provisions take effect 60 days after the date of promulgation of the final rule. Thus, for example, the requirements to implement certain work practice controls (e.g., fuel type) would go into effect 60 days after the final rule is published.

A number of provisions of the proposed rules contain separate effective dates that provide more time for technical support. For example, the initial concentration limit for underground metal and nonmetal mines would be delayed for 18 months.

A general outline of effective dates is contained in Question and Answer 10 in Part I of this preamble.

V. Adequacy of Protection and Feasibility of Proposed Rule

The Mine Act requires that in promulgating a standard, the Secretary, based on the best available evidence, shall attain the highest degree of health and safety protection for the miner with feasibility a consideration.

Overview

This part begins with a summary of the pertinent legal requirements, followed by a general profile of the economic health and prospects of the metal and nonmetal mining industry.

The discussion then turns to the proposed rule for underground metal and nonmetal mines. MSHA is proposing to establish a concentration limit for dpm, supplemented by monitoring and training requirements. An operator in the metal and nonmetal sector would have the flexibility to choose any type or combination of engineering controls to keep dpm levels at or below the concentration limit. In addition, the proposed rule would require this sector to implement certain work practices that help reduce dpm concentrations—practices similar to those already required in the underground coal mining industry. Miner hazard awareness training would also be required.

This part evaluates the proposed rule for underground metal and nonmetal mines to ascertain if, as required by the statute, it achieves the highest degree of protection for underground metal and nonmetal miners that is feasible, both technologically and economically, for underground metal and nonmetal mine operators to provide. Some significant alternatives to the proposed rule were also reviewed in this regard—for example, reducing the concentration limit or the time permitted to come into compliance with the limit. Based on the best evidence available to MSHA at this time, the Agency has tentatively concluded that the proposed rule for the underground metal and nonmetal sector meets the statutory requirements. The Agency has also tentatively concluded that the alternatives considered are not feasible for underground metal and nonmetal mine operators as a whole—for technological reasons, economic reasons, or both.

An Appendix to this part provides additional information about an approach to simulating the dpm reduction in mines that can be achieved with various types of controls. Some simulations using this model were among the facts considered by MSHA in reaching its tentative conclusions about the feasible concentration limit in underground metal and nonmetal mines.

Pertinent Legal Requirements

Section 101(a)(6)(A) of the Federal Mine Safety and Health Act of 1977 (Mine Act) states that MSHA's promulgation of health standards must:

* * * [A]dequately assure, on the basis of the best available evidence, that no miner will suffer material impairment of health or functional capacity even if such miner has regular exposure to the hazards dealt with by such standard for the period of his working life.

The Mine Act also specifies that the Secretary of Labor (Secretary), in promulgating mandatory standards pertaining to toxic materials or harmful physical agents, base such standards upon:

* * * [R]esearch, demonstrations, experiments, and such other information as may be appropriate. In addition to the attainment of the highest degree of health and safety protection for the miner, other considerations shall be the latest available scientific data in the field, the feasibility of the standards, and experience gained under this and other health and safety laws. Whenever practicable, the mandatory health or safety standard promulgated shall be expressed in terms of objective criteria and of the performance desired. [Section 101(a)(6)(A)].

Thus, the Mine Act requires that the Secretary, in promulgating a standard, based on the best available evidence, attain the highest degree of health and safety protection for the miner with feasibility a consideration.

In relation to feasibility, the legislative history of the Mine Act states that:

* * * This section further provides that ''other considerations'' in the setting of health standards are ''the latest available scientific data in the field, the feasibility of the standards, and experience gained under this and other health and safety laws.'' While feasibility of the standard may be taken into consideration with respect to engineering controls, this factor should have a substantially less significant role. Thus, the Secretary may appropriately consider the state of the engineering art in industry at the time the standard is promulgated. However, as the circuit courts of appeal have recognized, occupational safety and health statutes should be viewed as ''technology-forcing'' legislation, and a proposed health standard should not be rejected as infeasible when the necessary technology looms in today's horizon. *AFL-CIO* v. *Brennan,* 530 F.2d 109 (1975); *Society of the Plastics Industry* v. *OSHA,* 509 F.2d 1301, *cert. denied,* 427 U.S. 992 (1975).

Similarly, information on the economic impact of a health standard which is provided to the Secretary of Labor at a hearing or during the public comment period, may be given weight by the Secretary. In adopting the language of [this section], the Committee wishes to emphasize that it rejects the view that cost benefit ratios alone may be the basis for depriving miners of the health protection which the law was intended to insure. S. Rep. No. 95–181, 95th Cong., 1st Sess. 21 (1977).

Court decisions have clarified the meaning of feasibility. The Supreme Court, in *American Textile Manufacturers' Institute* v. *Donovan* (OSHA Cotton Dust), 452 U.S. 490, 101 S. Ct. 2478 (1981), defined the word ''feasible'' as ''capable of being done, executed, or effected.'' The Court stated that a standard would not be considered economically feasible if an entire industry's competitive structure was threatened. According to the Court, the appropriate inquiry into a standard's economic feasibility is whether the standard is capable of being achieved.

Courts do not expect hard and precise predictions from agencies regarding feasibility. Congress intended for the ''arbitrary and capricious standard'' to be applied in judicial review of MSHA rulemaking (S.Rep. No. 95–181, at 21.) Under this standard, MSHA need only base its predictions on reasonable inferences drawn from the existing facts. MSHA is required to produce reasonable assessment of the likely range of costs that a new standard will have on an industry. The agency must also show that a reasonable probability exists that the typical firm in an industry will be able to develop and install controls that will meet the standard. See, *Citizens to Preserve Overton Park* v. *Volpe,* 401 U.S. 402, 91 S. Ct. 814 (1971); *Baltimore Gas & Electric Co.* v. *NRDC,* 462 U.S. 87 103 S. Ct. 2246, (1983); *Motor Vehicle Manufacturers Assn.* v. *State Farm Mutual Automobile Insurance Co.,* 463 U.S. 29, 103 S. Ct. 2856 (1983); *International Ladies' Garment Workers' Union* v. *Donovan,* 722 F.2d 795, 232 U.S. App. D.C. 309 (1983), *cert. denied,* 469 U.S. 820 (1984); *Bowen* v. *American Hospital Assn.,* 476 U.S. 610, 106 S. Ct. 2101 (1986).

In developing a health standard, MSHA must show that modern technology has at least conceived some industrial strategies or devices that are likely to be capable of meeting the standard, and which industry is generally capable of adopting. *United Steelworkers of America* v. *Marshall,* 647 F.2d 1189, (D.C. Cir. 1980) at 1272. If only the most technologically advanced companies in an industry are capable of meeting the standard, then that would be sufficient demonstration of feasibility (this would be true even if only some of the operations met the standard for some of the time). *American Iron and Steel Institute* v. *OSHA,* 577 F. 2d 825, (3d Cir. 1978); see also, *Industrial Union Department, AFL-CIO* v. *Hodgson,* 499 F. 2d 467 (1974).

Industry profile. The industry profile provides background information describing the structure and economic characteristics of the metal and nonmetal mining industry. This information was considered by MSHA as appropriate in reaching tentative conclusions about the economic feasibility of various regulatory alternatives. MSHA welcomes the submission of additional economic information about the metal and nonmetal mining industry, and about underground mining in particular, that will help it make final determinations about the economic feasibility of the proposed rule.

This profile provides data on the number of mines, their size, the number of employees in each segment, as well as selected market characteristics. It does not provide information about the use of diesel engines in the industry; information in that regard was provided in the first section of part II of this preamble.

Overall mining industry. MSHA divides the mining industry into two major segments based on commodity: The coal industry and the metal and nonmetal (M/NM) mining industry. These major industry segments are further divided based on type of operations (underground mines, surface mines, and independent mills, plants, shops, and yards). MSHA maintains its own data on mine type, size, and employment. MSHA also collects data on the number of contractors and contractor employees.

MSHA categorizes mines as to size based on employment. Over the past 20 years, for rulemaking purposes, MSHA has consistently defined small mines to be those having fewer than 20 employees and large mines to be those having at least 20 employees. For this Preliminary Regulatory Economic Analysis and Initial Regulatory Flexibility Analysis, MSHA will continue to use this small mine definition. However, for the purposes of the Small Business Regulatory Enforcement Fairness Act (SBREFA) amendments to the Regulatory Flexibility Act (RFA), MSHA has also included SBA's definition of small (500 or fewer employees) in the evaluation of impacts.

Table V–1 presents the number of small and large M/NM mines and the corresponding number of miners, excluding contractors, by major industry segment and mine type. Table V–1 uses three size classes: Less than 20 employees (MSHA's definition of small), 20 to 500 employees (also small by SBA's definition, but not by MSHA's), and over 500 employees. Table V–2 presents similar MSHA data on the numbers of independent contractors and the corresponding numbers of employees by the size of the operation, based on employment. Table V–3 shows numbers of M/NM mines and workers by class of commodity produced.

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Table V-1: Distribution of Operations and Employment (excluding contractors) by Mine Type and Size

Mine Type	Size of M/NM Mine						All M/NM Mines	
	Less than 20 Employees		20 to 500* Employees		Over 500* Employees			
	Mines	Miners	Mines	Miners	Mines	Miners	Mines	Miners
Under-ground	130	1,103	124	10,152	7	6,531	261	17,786
Surface	8,781	48,924	1,175	63,753	18	16,723	9,974	129,400
Shop/Yd/ Mill/Plt	284	2,195	212	15,792	4	2,584	500	20,571
Office Workers	-	8,422	-	16,244	-	2,389	-	27,055
Total M/NM	9,195	60,644	1,511	105,941	29	28,227	10,735	194,812

(*) Based on MSHA's traditional definition, large mines include all mines with employees of 20 or greater.

Source: U.S. Department of Labor, Mine Safety and Health Administration, Office of Standards, Regulations, and Variances, based on preliminary 1996 MIS data (quarter 1 - quarter 4, 1996).

Table V-2: Distribution of Contractors and Contractor Employment by Size of Operation

Contractors	Size of Contractor						All Contractors	
	Less than 20 Employees		20 to 500* Employees		Over 500* Employees			
	Mines	Miners	Mines	Miners	Mines	Miners	Mines	Miners
Firms	2,621	13,058	340	18,810	1	897	2,962	32,765
Office Workers	-	691	-	902	-	140	-	1,733
Total Contractors	2,621	13,749	340	19,712	1	1,037	2,962	34,498

(*) Based on MSHA's traditional definition, large contractors include all contractors with employees of 20 or greater.

Source: U.S. Department of Labor, Mine Safety and Health Administration, Office of Standards, Regulations, and Variances, based on preliminary 1996 MIS data (quarter 1 - quarter 4, 1996).

Table V-3: Estimated Distribution of Metal and Nonmetal Mines and Miners by Commodity and Size Category

Commodity	Size of M/NM Mine						All M/NM Mines	
	Less than 20 Employees		20 to 500* Employees		Over 500* Employees			
	Mines	Workers	Mines	Workers	Mines	Workers	Mines	Workers
Metal	175	1,191	167	21,944	25	24,417	367	47,552
Non-Metal	542	3,471	225	21,685	4	3,810	771	28,966
Stone	2,619	22,838	889	53,413	0	0	3,508	76,251
Sand/ Gravel	5,859	33,144	230	8,899	0	0	6,089	42,043
Total	9,195	60,644	1,511	105,941	29	28,227	10,735	194,812

(*) Based on MSHA's traditional definition, large mines include all mines with employees of 20 or greater.

Source: MSHA's Office of Standards, Regulations, and Variances. Employment figures includes office workers.

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Underground M/NM Mines That Use Diesel Powered Equipment

Impacted Mines by Size. A January 1998 count of diesel powered equipment performed by MSHA's Metal and Nonmetal inspectors shows that 203 of the 261 underground M/NM mines (about 78 percent) regularly use diesel powered equipment. Table V–4 shows the 203 underground M/NM mines that use diesel powered equipment, by size and subsector.

Based on MSHA's traditional definition of a small mine (fewer than 20 employees), Table V–4 shows that of the 203 underground M/NM mines, 82 mines (40 percent) are small mines and 121 mines (60 percent) are large mines. Small mines employ about 4 percent of the workforce (849 employees), while large mines employ about 96 percent of the workforce (18,073 employees).

Based on SBA's definition of a small mine (500 or fewer employees), 196 mines (97 percent) are considered small and 7 mines (3 percent) are large. Under this definition, small mines employ 65 percent of the workforce (12,391 employees), while large mines employ 35 percent of the workforce (6,531 employees).

Impacted Mines by Commodity. The M/NM mining industry consists of about 70 different commodities that can be classified into four commodity categories: Metals, nonmetals, stone, and sand and gravel. Some examples of metals mines are gold, silver, and copper, while some examples of nonmetals mines are potash, salt, and trona. Examples of stone mines are limestone, marble, and granite. Table V–4 also presents the numbers of underground mines operators by these four categories.

Table V-4: Number of Underground Metal and Nonmetal Mines and Miners that Use Diesel Powered Equipment by Commodity and Size Category

Commodity	Size of Underground M/NM Mine						Underground M/NM Mines That Use Diesel Equip.	
	Less than 20 Employees		20 to 500* Employees		Over 500* Employees			
	Mines	Workers	Mines	Workers	Mines	Workers	Mines	Workers
Metal	15	103	44	4,691	4	2,517	63	7,311
Non-Metal	15	100	29	4,645	3	4,014	47	8,759
Stone	52	646	41	2,206	0	0	93	2,852
Sand/ Gravel	0	0	0	0	0	0	0	0
Total	82	849	114	11,542	7	6,531	203	18,922

(*) Based on MSHA's traditional definition, large mines include all mines with employees of 20 or greater.

Source: MSHA's Metal and Nonmetal inspectors count of underground Metal and Nonmetal mines that use diesel powered equipment. Includes office workers.

There are no underground mine operators using diesel powered equipment that are classified as sand or gravel. A substantial portion of such small underground mine operators, however, are classified as stone, using either MSHA's definition or SBA's definition of a small mine. Large underground mine operators that use diesel powered equipment are predominantly classified as metal or nonmetal. By MSHA's definition of a large mine (those that employ 20 or more), two thirds (66 percent) of large mines are classified as metal or nonmetal. With respect to SBA's definition of a large mine (those that employ over 500), all large underground mine operators that use diesel powered equipment are classified as either metal or nonmetal.

Structure of Underground M/NM Mining Subsectors

Metal mining. Metal mining in the U.S. consists of about 25 different commodities. Most metal commodities include only one or two mining operations. As is shown in Table V–3, metal mining operations represent 3 percent of the M/NM mines; employ 24 percent of the M/NM miners; and account for 33 percent of the value of M/NM mineral produced in the U.S. (U.S. Geological Survey, 1997, p. 6). By MSHA's definition, 48 percent of the metal mining operations are small. Among underground M/NM mines using diesel powered equipment, Table V–4 shows that metal mining operations represent 31 percent of mines and 39 percent of miners, and (by MSHA's definition) 24 percent are small.

Underground metal mining uses a few basic mining methods, such as stope, room and pillar, and block caving. Larger underground metal mines use more hydraulic drills and track-mounted haulage, whereas smaller underground metal mines use more hand-held pneumatic drills.

Nonmetal Mining (Excluding Stone, Sand and Gravel). For enforcement and statistical purposes, MSHA separates stone mining and sand and gravel mining from other nonmetal mining. There are about 35 different nonmetal commodities, not including stone or sand and gravel. Overall (Table V–3), nonmetal mining operations represent 7 percent of the M/NM mines; employ 15 percent of the M/NM miners; and account for 35 percent of the value of M/NM mineral produced in the U.S. (Ibid., p. 160, 162). By MSHA's definition, 70 percent of the nonmetal mining operations are small. Among underground M/NM mines using diesel powered equipment, Table V–4 shows that nonmetal mining operations represent 23 percent of mines and 46 percent of miners, and (by MSHA's definition) 32 percent are small.

Nonmetal mining uses a wide variety of underground mining methods. For example, potash mines use continuous miners similar to coal mining; oil shale uses in-situ retorting; and gilsonite uses hand-held pneumatic chippers. Some nonmetal commodities use kilns and dryers in ore processing. Others use crushers and mills similar to metal mining. Underground nonmetal mining operations generally use more block caving, room and pillar, and retreat mining methods; less hand-held equipment; and more electrical equipment than metal mining operations.

Stone Mining. There are basically only 8 different stone commodities, of which 7 are further classified as either dimension stone or crushed and broken stone. Overall, stone mining operations represent 33 percent of all M/NM mines; employ 39 percent of the M/NM miners; and account for 19 percent of the value of M/NM mineral produced in the U.S. By MSHA's definition, 75 percent of the stone mining operations are small. Among underground M/NM mines using diesel powered equipment, stone mining operations represent 46 percent of mines and 15 percent of miners, and (by MSHA's definition) 56 percent are small.

Sand and Gravel Mining. Although 57 percent of all M/NM mines are sand and gravel operations, these are all surface mines. No sand and gravel mines will be affected by this regulation.

Economic Characteristics of the M/NM Mining Industry

Overview. The 1996 value of all M/NM mining output was $38 billion (Ibid., p. 6). Metal mining, which includes metals such as aluminum, copper, gold, and iron, contributed $12.5 billion to this total. Nonmetal mining, which includes commodities such as clay, phosphate rock, salt, and soda ash, was valued at $13.3 million. Stone mining contributed $7.4 billion, and sand and gravel contributed $4.8 billion to this total.

The entire M/NM mining industry is markedly diverse, not only in terms of the breadth of minerals but also in terms of each commodity's usage. For example, metals such as iron and aluminum are used to produce vehicles and other heavy duty equipment, as well as consumer goods such as household equipment and beverage cans. Other metals, such as uranium and titanium, have limited uses. Nonmetals like cement are used in construction, while salt is used in a variety of ways, including as a food additive and highway deicing. Soda ash, phosphate rock, and potash also have various commercial uses. Stone and sand and gravel are used in numerous industries including the construction of roads and buildings.

A detailed financial picture of the M/NM mining industry is difficult to develop because most mines either are privately held corporations or sole proprietorships or they are subsidiaries of publicly owned companies. Privately held corporations and sole proprietorships do not make their financial data available to the public; parent companies are not required to separate financial data for subsidiaries in their reports to the Securities and Exchange Commission. As a result, financial data are available for only a few M/NM companies, and these data are not representative of the entire industry. Each commodity has a unique market demand structure. The following discussion focuses on market forces on a few specific commodities of the M/NM industry.

Metal Mining. Historically, the value of metals production has exhibited considerable instability. In the early 1980's, excess capacity, large inventories, and weak demand depressed the international market for metals, while the strong dollar placed U.S. producers at a competitive disadvantage with foreign producers. Reacting to this, many metal mining companies reduced work forces, eliminated marginal facilities, sold non-core businesses, and restructured. At the same time, new mining technologies were developed, and wage increases were restrained. As a result, the metal mining firms now operating are more efficient and have lower break-even prices than those that operated in the 1970's.

Variations in the prices for iron and alloying metals, such as nickel, aluminum, molybdenum, vanadium, platinum, and lead, coincide closely with fluctuations in the market for durable goods, such as vehicles and heavy duty equipment. As a result, the market for these metals is cyclical in nature and is impacted directly by changes in aggregate demand and the economy in general. Both nickel and aluminum have experienced strong price fluctuations over the past few years. With the U.S. and world economies improving, however, demand for such alloys is improving, and prices have begun to recover. It must be noted that primary production of aluminum will continue to be impacted by the push to recycle.

The U.S. market for copper and precious metals, such as gold and silver, is uncertain, which makes consistent production growth in such areas difficult. U.S. gold production in 1996 was estimated at slightly above 1995 levels, which maintains the U.S. position as the world's second largest gold producing nation, after South Africa. U.S. silver production in 1996 increased slightly from 1995 levels to equal the highest production since 1992. U.S. copper production in 1996 continued its modest upward trend, rising to 1.9 million metric tons (Ibid, p. 52).

Overall, the 1996 production from all metal mining is estimated to decrease by about 10 percent from 1995 levels; 1996 estimates put capacity utilization at 84 percent (Ibid., p. 6). MSHA expects that the net result for the metal mining industry may be reduced demand but sustained prices.

Nonmetal Mining. Major commodities in the nonmetal category include salt, clay, phosphate rock, and soda ash. Market demand for these products tends not to vary greatly with fluctuations in aggregate demand. Stone is the leading revenue generator. The U.S. is the largest producer of soda ash and salt. In 1996, the U.S. produced 10.1 million metric tons of soda ash, valued at $778 million, and 40.1 million metric tons of salt, valued at $930 million (Ibid., p. 143). Soda ash is used in the production of glass, soap, detergents, paper, and food. Salt is used in highway deicing, food production, feedstock, and the chemical industry. Phosphate rock is used primarily to manufacture fertilizer. Approximately 42.5 million metric tons of phosphate rock, valued at $900 million, was produced in the U.S. in 1996 (Ibid., p. 124). The remaining nonmetal commodities, which include boron fluorspar, oil shale, and other minerals, are typically produced by a small number of mining operations.

Stone production includes granite, limestone, marble, slate, and other forms of crushed and broken or dimension stone. Sand and gravel products and stone products, including cement, have a cyclical demand structure. As a recession intensifies, demand for these products sharply decreases. Demand for stone, particularly cement, is expected to grow by as much as 3.0 percent, and demand for sand and gravel is expected to grow by as much as 1.2 percent (Ibid., p. 145).

Overall, the 1996 production from nonmetal mining was estimated to increase by 4.5 percent from 1995 levels; 1996 estimates put capacity utilization for stone and earth minerals at about 91 percent (Ibid., p. 6). The net result for the nonmetal mining industry may be higher demand for stone and various other commodities, as well as increased prices.

Adequacy of Miner Protection Provided by Proposed Rule in Underground Metal and Nonmetal Mines. In evaluating the proposed rule, it should be remembered that MSHA has measured dpm concentrations in this sector as high as $5,570_{DPM}$ $\mu g/m^3$—a mean of 830_{DPM} $\mu g/m^3$. See Table III–1 and Figure III–2 in part III of the preamble. As discussed in detail in part III of the preamble, these concentrations place underground metal and nonmetal miners at significant risk of material impairment of their health, and it does not appear there is any lower boundary to the risk. Accordingly, in accordance with the statute, the Agency has to set a standard which reduces these concentrations as much as is both technologically and economically feasible for this sector as a whole.

In this sector, the Agency is proposing a concentration limit on dpm. The proposed concentration limit would be expressed in terms of a restriction on the amount of total carbon because of the measurement system which MSHA proposes to utilize. The proposed limit is 160_{TC} µg/m³—the equivalent of 200_{DPM} µg/m³. This permits concentrations of diesel particulate matter in this sector above those which MSHA hopes to achieve in the underground coal sector with the use of 95% particulate filter technology, as described earlier in this part.

Accordingly, the Agency has explored some significant alternatives to the proposal to ascertain if additional protection can feasibly be provided in this sector.

(1) *Establish a lower concentration limit for underground metal/nonmetal mines.* Based on the Agency's risk assessment, a lower concentration limit would provide more miner protection. The Agency has tentatively concluded, however, that at this time it may not be feasible for the underground metal and nonmetal sector to reach a concentration limit below that proposed. The evidence on this point is somewhat mixed, and comments and specific examples to illustrate them would be most welcome.

Technological feasibility of lower limit. In evaluating whether a lower concentration limit is feasible for this sector, MSHA has considered some examples of real-world situations. As described in more detail in the Appendix to this part, MSHA has developed a simulator or model to estimate the ambient dpm that would remain in a mine section after the application of a particular combination of control technologies. The model uses a spreadsheet template into which data can be entered; the formulae in the spreadsheet (described in the Appendix) instantly make the calculations and display the results. This model is hereinafter referred to as ''The Estimator''.

The examples presented here are based on data from several underground metal and nonmetal mines. The first three have been written up in detail and placed into MSHA's record, with actual mine identifiers removed; the fourth is based on information supplied by inspectors, and all available data is presented here. MSHA had picked these mines because the Agency originally thought the conditions there were such that these mines would have great difficulty in controlling dpm concentrations, but this turned out to not always be the case.

FIGURE V–1.—WORK PLACE EMISSIONS CONTROL ESTIMATOR

[Mine Name: Underground Nonmetal Mine A]

	Column A
1. MEASURED OR ESTIMATED IN MINE DP EXPOSURE (µg/m³)	760 µg/m³
2. VEHICLE EMISSION DATA	
EMISSIONS OUTPUT (gm/hp-hr)	
VEHICLE 1 INDIRECT INJECTION 0.3–0.5 gm/hp-hr FEL	0.3 gm/hp-hr
VEHICLE 2 OLD DIRECT INJECTION 0.5–0.9 gm/hp-hr SCALER	0.3 gm/hp-hr
VEHICLE 3 NEW DIRECT INJECTION 0.1–0.4 gm/hp-hr DRILL	0.3 gm/hp-hr
VEHICLE 4 BOLTER	0.7 gm/hp-hr
VEHICLE OPERATING TIME (hours)	
VEHICLE 1 FEL	6 hours
VEHICLE 2 SCALER	6 hours
VEHICLE 3 DRILL	6 hours
VEHICLE 4 BOLTER	6 hours
VEHICLE HORSEPOWER (hp)	
VEHICLE 1 3 @ 480 FEL	1440 hp
VEHICLE 2 2 @ 250 SCALER	500 hp
VEHICLE 3 2 @ 250 DRILL	500 hp
VEHICLE 4 2 @ 82 BOLTER	164 hp
SHIFT DURATION (hours)	8 hours
AVERAGE TOTAL SHIFT PARTICULATE OUTPUT (gm)	0.13 gm/hp-hr
3. MINE VENTILATION DATA	
FULL SHIFT INTAKE DIESEL PARTICULATE CONCENTRATION	50 µg/m³
SECTION AIR QUANTITY	209000 cfm
AIRFLOW PER HORSEPOWER	80 cfm/hp
4. CALCULATED SWA DP CONCENTRATION WITHOUT CONTROLS	
5. ADJUSTMENTS FOR EMISSION CONTROL TECHNOLOGY	
ADJUSTED SECTION AIR QUANTITY	330000 cfm
VENTILATION FACTOR (INITIAL CFM/FINAL CFM)	0.63
AIRFLOW PER HORSEPOWER	127 cfm/hp
OXIDATION CATALYTIC CONVERTER REDUCTION (%)	
VEHICLE 1	0%
VEHICLE 2 IF USED ENTER 0–20%	0%
VEHICLE 3	0%
VEHICLE 4	0%
NEW ENGINE EMISSION RATE (gm/hp-hr)	
VEHICLE 1	0.1 gm/hp-hr
VEHICLE 2 ENTER NEW ENGINE EMISSION (gm/hp-hr)	0.1 gm/hp-hr
VEHICLE 3	0.1 gm/hp-hr
VEHICLE 4	0.1 gm/hp-hr
AFTERFILTER OR CAB EFFICIENCY (%)	
VEHICLE 1	0%
VEHICLE 2 USE 65–95% FOR AFTERFILTERS	0%
VEHICLE 3 USE 50–80% FOR CABS	0%
VEHICLE 4	0%

FIGURE V–1.—WORK PLACE EMISSIONS CONTROL ESTIMATOR—Continued

[Mine Name: Underground Nonmetal Mine A]

	Column A
6. ESTIMATED FULL SHIFT DP CONCENTRATION	194 µg/m³

The mining community is encouraged to obtain a copy of the Estimator from MSHA and run simulations of its own in individual mines. MSHA would welcome having such examples submitted for the record as part of comments submitted on this proposed rulemaking.

The first example, summarized in Figure V–1, involves a section of an underground salt mine. This section has 9 diesel engines, most of them very heavy duty: three front end loaders of 480 hp each, 2 scalers and 2 drills at 250hp each, and an 82 hp bolter.

Entered in section 1 of the figure is the measured level of dpm, 760_{DPM} µg/m³. This measurement reflects the fact that the equipment was all equipped with oxidation catalytic converters; otherwise, the measurement would have been on the order of 20% higher.

Entered in sections 2 and 3 is information about the engines, operating cycle, horsepower, shift duration, intake dpm concentration, and ventilation currently used in the mine. The entries for engines of a similar type and horsepower were combined. The intake concentration is dpm coming from outside the section, and in the case of these examples has been estimated to be about 50_{DPM} µg/m³. This information is retained by the Estimator as a baseline against which to compare a particular combination of proposed controls.

Sections 2 and 3 of the Estimator also calculate two ratios — the average total shift particulate output, and the airflow per horsepower—that provide useful insights into what controls might be available. For example, in this case, an airflow of 80 cfm/hp is below recommended levels, suggesting that a ventilation increase should be part of the solution to the high dpm concentrations.

The controls to be modeled are entered into section 5 of the Estimator. In this example, the ventilation is increased enough to increase the airflow per horsepower to 127 cfm/hp. Oxidation catalytic converters are already on the equipment, so nothing can be added in that regard. In the example, all 9 engines (grouped into 4 lines by combining those with similar horsepower, as originally entered) would be replaced by newer engines with lower emission rates. No filters or cabs would be used. The calculated result is an ambient dpm concentration of 194_{DPM} µg/m³.

This mine section could actually lower its dpm concentrations more using different combinations of controls. For example, using 80% filters on the three front-end loaders instead of new engines would, according to the Estimator, result in an ambient dpm level of 161_{DPM} µg/m³. If both the 80% filters and new engines were used, the ambient dpm level would be 128_{DPM} µg/m³. Keep in mind that of the amount that remains, 50_{DPM} µg/m³ comes from the intake to the section. The next two studies are of an underground limestone mine that operates in two shifts: one for production, and one for support.

Figure V–2.—Work Place Emissions Control Estimator

[Mine Name: Underground Nonmetal Mine B Production Shift]

	Column A
1. MEASURED OR ESTIMATED IN MINE DP EXPOSURE (µg/m³	330 µg/m³
2. VEHICLE EMISSION DATA	
EMISSIONS OUTPUT (gm/hp-hr)	
VEHICLE 1 INDIRECT INJECTION 0.3–0.5 gm/hp-hr FEL	0.1 gm/hp-hr
VEHICLE 2 OLD DIRECT INJECTION 0.5–0.9 gm/hp-hr Truck 1	0.2 gm/hp-hr
VEHICLE 3 NEW DIRECT INJECTION 0.1–0.4 gm/hp-hr Truck 2	0.1 gm/hp-hr
VEHICLE 4	0.0 gm/hp-hr
VEHICLE OPERATING TIME (hours)	
VEHICLE 1 FEL	9 hours
VEHICLE 2 Truck 1	9 hours
VEHICLE 3 Truck 2	9 hours
VEHICLE 4	0 hours
VEHICLE HORSEPOWER (hp)	
VEHICLE 1 FEL	315 hp
VEHICLE 2 Truck 1	250 hp
VEHICLE 3 Truck 2	330 hp
VEHICLE 4	0 hp
SHIFT DURATION (hours)	10 hours
AVERAGE TOTAL SHIFT PARTICULATE OUTPUT (gm)	0.09 gm/hp-hr
3. MINE VENTILATION DATA	
FULL SHIFT INTAKE DIESEL PARTICULATE CONCENTRATION	50 µg/m³
SECTION AIR QUANTITY	155000 cfm
AIRFLOW PER HORSEPOWER	173 cfm/hp
4. CALCULATED SWA DP CONCENTRATION WITHOUT CONTROLS	
5. ADJUSTMENTS FOR EMISSION CONTROL TECHNOLOGY	

Figure V–2.—Work Place Emissions Control Estimator—Continued

[Mine Name: Underground Nonmetal Mine B Production Shift]

	Column A
ADJUSTED SECTION AIR QUANTITY	155000 cfm
VENTILATION FACTOR (INITIAL CFM/FINAL CFM)	1.00
AIRFLOW PER HORSEPOWER	173 cfm/hp
OXIDATION CATALYTIC CONVERTER REDUCTION (%)	
VEHICLE 1	0%
VEHICLE 2 IF USED ENTER 0–20%	0%
VEHICLE 3	0%
VEHICLE 4	0%
NEW ENGINE EMISSION RATE (gm/hp-hr)	
VEHICLE 1	0.1 gm/hp-hr
VEHICLE 2 ENTER NEW ENGINE EMISSION (gm/hp-hr)	0.2 gm/hp-hr
VEHICLE 3	0.1 gm/hp-hr
VEHICLE 4	0.0 gm/hp-hr
AFTERFILTER OR CAB EFFICIENCY (%)	
VEHICLE 1 CABS	70%
VEHICLE 2 USE 65–95% FOR AFTERFILTERS	70%
VEHICLE 3 USE 50–80% FOR CABS	70%
VEHICLE 4	0%
6. ESTIMATED FULL SHIFT DP CONCENTRATION	134 µg/m^3

Figure V–3.—Work Place Emissions Control Estimator

[Mine Name: Underground Nonmetal Mine B Support Shift]

	Column A
1. MEASURED OR ESTIMATED IN MINE DP EXPOSURE (µg/m3)	600 µg/m^3
2. VEHICLE EMISSION DATA	
EMISSIONS OUTPUT (gm/hp-hr)	
VEHICLE 1 INDIRECT INJECTION 0.3–0.5 gm/hp-hr Drill	0.3 gm/hp-hr
VEHICLE 2 OLD DIRECT INJECTION 0.5–0.9 gm/hp-hr Bolter	0.6 gm/hp-hr
VEHICLE 3 NEW DIRECT INJECTION 0.1–0.4 gm/hp-hr Scaler	0.7 gm/hp-hr
VEHICLE 4 Anfo	0.7 gm/hp-hr
VEHICLE OPERATING TIME (hours)	
VEHICLE 1 Drill	8 hours
VEHICLE 2 Bolter	4 hours
VEHICLE 3 Scaler	8 hours
VEHICLE 4 Anfo	4 hours
VEHICLE HORSEPOWER (hp)	
VEHICLE 1 Drill	116 hp
VEHICLE 2 Bolter	193 hp
VEHICLE 3 Scaler	119 hp
VEHICLE 4 Anfo	86 hp
SHIFT DURATION (hours)	8 hours
AVERAGE TOTAL SHIFT PARTICULATE OUTPUT (gm)	0.39 gm/hp-hr
3. MINE VENTILATION DATA	
FULL SHIFT INTAKE DIESEL PARTICULATE CONCENTRATION	50 µg/m^3
SECTION AIR QUANTITY	155000 cfm
AIRFLOW PER HORSEPOWER	302 cfm/hp
4. CALCULATED SWA DP CONCENTRATION WITHOUT CONTROLS	
5. ADJUSTMENTS FOR EMISSION CONTROL TECHNOLOGY	
ADJUSTED SECTION AIR QUANTITY	155000 cfm
VENTILATION FACTOR (INITIAL CFM/FINAL CFM)	1.00
AIRFLOW PER HORSEPOWER	302 cfm/hp
OXIDATION CATALYTIC CONVERTER REDUCTION (%)	
VEHICLE 1	0%
VEHICLE 2 IF USED ENTER 0–20%	0%
VEHICLE 3	0%
VEHICLE 4	0%
NEW ENGINE EMISSION RATE (gm/hp-hr)	
VEHICLE 1	0.3 gm/hp-hr
VEHICLE 2 ENTER NEW ENGINE EMISSION (gm/hp-hr)	0.6 gm/hp-hr
VEHICLE 3	0.7 gm/hp-hr
VEHICLE 4	0.7 gm/hp-hr
AFTERFILTER OR CAB EFFICIENCY (%)	
VEHICLE 1	80%

Figure V–3.—Work Place Emissions Control Estimator—Continued

[Mine Name: Underground Nonmetal Mine B Support Shift]

	Column A
VEHICLE 2 USE 65–95% FOR AFTERFILTERS	80%
VEHICLE 3 USE 50–80% FOR CABS	80%
VEHICLE 4	80%
6. ESTIMATED FULL SHIFT DP CONCENTRATION	160 μg/m3

The two shifts use completely different types of diesel-powered equipment.

Figure V–2 summarizes the study of the production shift, and Figure V–3 summarizes the study of the support shift.

The production shift already has low-emission engines on the three pieces of equipment present—a front-end loader and two trucks, as well as oxidation catalytic converters on each engine.

Its ventilation provides 173 cfm/hp. Accordingly, the measured dpm for this shift is only about 330_{DPM} μg/m^3 With the addition of a cab on each unit providing roughly 70% effectiveness (see part II of this preamble on cab effectiveness), the ambient concentration (to which the equipment operator would be exposed) can be reduced to 134_{DPM} μg/m^3.

In the case of the support shift, the engines do emit particulate at a high rate; but they all are low horsepower engines, and all have oxidation catalytic converters. The ventilation is the same as on the production shift. Hence the measured dpm is on the order of 600_{DPM} μg/m^3. In the example shown, 80% filtration of each piece of equipment would bring the concentration down to 160_{TC} μg/m^3. If 95% filters were used, the Estimator indicates this concentration could be reduced to 77_{DPM} μg/m^3. Since 50_{DPM} μg/m^3 of this is the estimated intake into the section, the filters and controls already in place appear to be capable of eliminating almost all dpm generated within the section itself.

FIGURE V–4.—WORK PLACE EMISSIONS CONTROLS ESTIMATOR

[Mine Name: Underground Gold Mine]

	Column A
1. MEASURED OR ESTIMATED IN MINE DP EXPOSURE (ug/m3)	1000 us/m^3
2. VEHICLE EMISSION DATA	
EMISSIONS OUTPUT (gm/hp-hr)	
VEHICLE 1 INDIRECT INJECTION 0.3–0.5	
gm/hp-hr FEL	0.7 gm/hp-hr
VEHICLE 2 OLD DIRECT INJECTION 0.5–0.9	
gm/hp-hr Scaler	0.7 gm/hp-hr
VEHICLE 3 NEW DIRECT INJECTION	
0.1–0.4 gm/hp-hr Drill	0.7 gm/hp-hr
VEHICLE 4	0.0 gm/hp-hr
VEHICLE OPERATING TIME (hours)	
VEHICLE 1 FEL	6 hours
VEHICLE 2 Scaler	6 hours
VEHICLE 3 Drill	6 hours
VEHICLE 4	0 hours
VEHICLE HORSEPOWER (hp)	
VEHICLE 1 FEL	315 hp
VEHICLE 2 Scaler	250 hp
VEHICLE 3 Drill	330 hp
VEHICLE 4	0 hp
SHIFT DURATION (hours)	8 hours
AVERAGE TOTAL SHIFT PARTICULATE OUTPUT (gm)	0.44 gm/hr-hr
3. MINE VENTILATION DATA	
FULL SHIFT INTAKE DIESEL PARTICULATE CONCENTRATION	50 ug/m^3
SECTION AIR QUALITY	185000 cfm
AIRFLOW PER HORSEPOWER	207 cfm/hp
4. CALCULATED SWA DP CONCENTRATION WITHOUT CONTROLS	
5. ADJUSTMENTS FOR EMISSION CONTROL TECHNOLOGY	
ADJUSTED SECTION AIR QUANTITY	185000 cfm
VENTILATION FACTOR (INITIAL CFM/FINAL CFM)	1.00
AIRFLOW PER HORSEPOWER	207 cfm/hp
OXIDATION CATALYTIC CONVERTER REDUCTION (%)	
VEHICLE 1	20%
VEHICLE 2 IF USED ENTER 0–20%	20%
VEHICLE 3	20%
VEHICLE 4	0%
NEW ENGINE EMISSION RATE (gm/hp-hr)	
VEHICLE 1	0.7 gm/hp-hr
VEHICLE 2 ENTER NEW ENGINE EMISSION (gm/hp-hr)	0.1 gm/hp-hr
VEHICLE 3	0.1 gm/hp-hr
VEHICLE 4	0.0 gm/hp-hr

FIGURE V–4.—WORK PLACE EMISSIONS CONTROLS ESTIMATOR—Continued

[Mine Name: Underground Gold Mine]

	Column A
AFTERFILTER OR CAB EFFICIENCY (%)	
VEHICLE 1 FILTER	95%
VEHICLE 2 USE 65–95% FOR AFTERFILTERS	0%
VEHICLE 3 USE 50–80% FOR CABS	0%
VEHICLE 4	0%
6. ESTIMATED FULL SHIFT DP CONCENTRATION	134 ug/m^3

The final study, summarized in Figure V–4, involves a multi-level underground gold mine. Each level had one production unit on a separate split of ventilation air. The three engines are large and have a high emission rate, and have no oxidation catalytic converters. The ventilation produces over 200 cfm/hp. In this case, no initial measurement was taken; instead, an initial concentration of 1000_{DPM} µg/m^3 was estimated by taking a percentage of the respirable dust concentration (a method discussed in the Appendix).

By replacing all of the current engines with low-emission engines equipped with catalytic converters, the Estimator calculates that the ambient concentration can be reduced to 159_{DPM} µg/m^3, of which 50_{DPM} µg/m^3 again constitutes the estimated intake to the section. Further reductions could be achieved by adding a filter to the front-end loader and/or drill.

These studies seem to suggest that using a combination of available technologies, even mine sections with significant ambient intake and standard ventilation parameters can reduce dpm concentrations well below the proposed concentration limit.

Economic feasibility of lower concentration limit. MSHA's cost estimates for the proposed concentration limit of 200_{DPM} µg/m^3 for underground metal and nonmetal mines comes to about $19.2 million a year. (See Table I–1, in the response to Question 5 in part I of the preamble). For an average underground metal and nonmetal dieselized mine that uses diesel powered equipment, this amounts to about $94,600 per year to comply with the proposed concentration limits.

The assumptions used in preparing the cost estimates are discussed in detail in the Agency's PREA, and are based on a January 1998 count of diesel powered equipment that regularly operates in the underground metal and nonmetal mines. The count was performed by MSHA's metal and nonmetal inspectors. The assumptions can be summarized as follows: engineering controls, such as low emission engines, ceramic filters, oxidation catalytic converters, and cabs would be needed on certain diesel powered equipment. Most of the engineering controls would be needed on diesel powered equipment used for production, while a small amount of diesel powered equipment that is used for support purposes would need engineering controls. In addition to these controls, MSHA assumed that some underground metal and nonmetal mines would need to make ventilation changes in order to meet the proposed concentration limits.

While the four studies presented here suggest it might be economically feasible for some mines in this sector to reduce dpm concentrations below the concentration level proposed, the Agency is reluctant to conclude on the basis of the examples that most underground metal and nonmetal operators would find it economically feasible to reduce concentrations below the proposed limit of 160_{TC} µg/m^3 (200_{DPM} µg/m^3). The Agency welcomes additional examples and information it can use to make a better assessment of the costs operators would incur to reduce dpm to various concentration limits, as well as other considerations relevant to economic feasibility.

(2) *Shorten the phase-in time to reach the final concentration limit in underground metal/nonmetal mines.* Under the proposed rule, there is a phase-in period for a dpm concentration limit (see proposed § 57.5060). Operators would have 18 months to reduce dpm concentrations in areas of the mine where miners work or travel to 400_{TC} µg/m^3 (500_{DPM} µg/m^3), and up to 60 months in all to reduce dpm concentrations in those areas to 160_{TC} µg/m^3 (200_{DPM} µg/m^3). MSHA established this phase-in period because it has tentatively concluded that it would be infeasible for the underground metal and nonmetal mining industry as a whole to implement the requirements sooner.

With respect to technological feasibility, MSHA notes that many of these mines face unique difficulties in using ventilation to lower dpm concentrations; and high efficiency particulate filters may not yet be commercially available for certain types or sizes of engines and equipment used in this sector. The proposed rule includes a provision for a special time extension to deal with unique situations. Shortening the normal time frame available to this sector could create a situation where special exemptions would become the norm.

The costs of the proposed rule would also increase significantly were the final concentration limit to become effective sooner. As explained in the Agency's PREA, a substantial portion of the costs to implement these provisions were calculated using a 5-year discounting process to reflect the phase-in schedule. Speeding implementation would significantly impact costs.

Accordingly, MSHA has tentatively concluded that, for the underground metal and nonmetal sector as a whole, an accelerated approach may not be feasible.

(3) *In lieu of a concentration limit, require high efficiency filters on certain types of equipment.* In the underground coal sector, MSHA has proposed requiring high efficiency filters on all but light-duty equipment. This appears to be a very effective and feasible way of reducing dpm concentrations in that sector. Accordingly, MSHA considered requiring a similar approach in underground metal and nonmetal mines.

MSHA estimates that to require 95% efficient filters on all diesel engines in underground metal and nonmetal mines after 30 months would cost about $41 million a year. On the other hand, to require that only heavy duty equipment use 95% filters after 30 months would cost about $20 million a year. (''Heavy duty'' equipment here means equipment that moves rock or ore; for costing purposes, MSHA assumed this included production equipment and about five percent of support equipment, which is about 46% of the diesel equipment in underground metal and nonmetal mines).

The estimated costs of complying with the proposed concentration limits and the other provisions of the proposed rule are about $19.2 million a year.

This option is not the equivalent of what is being proposed for underground coal mines. The underground metal and nonmetal equipment that would be left unfiltered pursuant to this option may in some cases, have larger horsepower engines than the equipment that would be left unfiltered pursuant to the proposed rule for underground coal—and there are more pieces of equipment per mine in the underground metal and nonmetal sector (see Table II–1 in part II of this preamble).

Moreover, under the statute, MSHA must take the approach that provides miners with the greatest protection feasible. This option would be less protective than a concentration limit in this sector. Under the option, the only control in underground metal and nonmetal mines would be filters on heavy-duty equipment; by contrast, the controls MSHA has estimated will be necessary to meet the proposed concentration limit are more stringent—all production equipment will need an oxidation catalytic convertor for example, and 85% of production equipment will also need a new engine.

Moreover, the distribution of equipment and miners in underground metal and nonmetal mine areas means that the protection received under this approach—in which only 46% (i.e., the heavy duty equipment) of the equipment is filtered, and no other controls required—would likely be very uneven. Some miners might be reasonably well protected, but many others would not.

There are two other factors that mitigate against such an approach in underground metal and nonmetal mines.

First, it is not clear this approach is technologically feasible. The only filters that are currently available that can produce 95% efficiency in removing particulates are paper filters. Some of the heavy-duty engines are very large, and it may take some time before commercially available designs for filtration of this efficiency will be available to fit all types and sizes of heavy duty equipment—and work effectively without hampering equipment performance. That is why in determining the role filtration might play in this sector, the Agency assumed that replaceable ceramic filters would be used. At this time, such filters are capable of 60–85% efficiency. It is possible, of course, that once a market develops, the manufacturers of such filters might be able to produce a more efficient filter. MSHA solicits information about any such pending developments.

Second, it would appear that in many cases, a new engine and/or cab might be a more effective solution to a localized dpm concentration in an underground metal and nonmetal mine than a filter—and perhaps less expensive for equipment of this size. One of the advantages of a concentration limit is the flexibility it provides.

MSHA has not yet given detailed consideration to requiring all underground metal and nonmetal operators to utilize an oxidation catalytic converter (OCC)—in combination with a concentration limit—but intends to do so. The studies discussed above, and information from MSHA's workshops, suggests that OCCs are already widely utilized in this sector, and can reduce dpm emissions as much as 20%. MSHA assumes that this is the first control to which most operators would turn if a concentration limit were established. Accordingly, the Agency welcomes comment on whether it would be feasible and appropriate to simply require underground metal and nonmetal mining companies to install and maintain OCCs on all diesel engines.

Feasibility of proposed rule for underground metal and nonmetal mining sector. The Agency has carefully considered both the technological and economic feasibility of the proposed rule for the underground metal and nonmetal mining sector as a whole.

There are two separate issues with respect to technological feasibility—(a) the existence of technology that can accurately and reliably measure dpm concentration levels in all types of underground metal and nonmetal mines; and (b) the existence of control mechanisms that can bring dpm concentrations down to the proposed limit in all types of underground metal and nonmetal mines.

Measurement technology. Part II of this preamble contains a detailed discussion of the measurement method which MSHA is proposing to use in this sector, including the evidence MSHA examined in making its determination that this approach provides an accurate and reliable way to measure dpm concentration levels in all types of underground metal and nonmetal mines. Briefly, the method involves the use of a respirable dust sampler to collect particles on a filter, which is then analyzed using a method to detect total carbon validated by the National Institute for Occupational Safety and Health for that purpose. MSHA has concluded that total carbon, is a valid surrogate for dpm in this sector. In fact, to make the concentration limit on dpm easier to use in practice, MSHA is proposing to express that limit in terms of total carbon so that the measurement results can be directly compared with the standard's requirements.

As further explained in part IV, MSHA recognizes that any measurement system has an inherent level of uncertainty. As is its practice with other compliance determinations based on measurement, MSHA would not issue a citation that an underground metal or nonmetal mine has violated the concentration limit unless the measurement exceeds the limit (interim or final) by an amount adequate to ensure a 95% confidence level. While MSHA has not at this time reached a determination of the amount that it deems appropriate to add to the measured concentration to establish such a confidence level, it could be on the order of 11–20% (see part II discussion of measurement for details).

Control technology. The availability of control technology to enable operators to reduce their existing dpm concentrations to the proposed concentration level was discussed earlier in this part [See (1) *Establish a lower concentration limit for underground metal/nonmetal mines*'']. In fact, these studies suggest it is technologically feasible for operators in this sector to reduce their dpm concentrations to an even lower concentration limit. MSHA's publication ''Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—a Toolbox'' summarizes information about the mining community's experience to date with various controls. A copy of this publication is appended at the end of this document.

Although the agency has reached this conclusion, and moreover knows of no mine that cannot accomplish the required reductions in the permitted time, it has nevertheless proposed that any underground metal or nonmetal mine may have up to an additional two years to install the required controls should it find that there are unforseen technological barriers to timely completion. A detailed discussion of the requirements for obtaining approval for such an extension of time to comply is provided in part IV of the preamble. The Agency would particularly welcome comments illustrating situations which warrant further attention in this regard.

Economic Feasibility. MSHA estimates that the proposed rule would cost the underground metal and nonmetal sector about $19.2 million a year even with the extended phase-in time. The costs per underground dieselized metal or nonmetal mine are estimated to be about $94,600 annually.

As explained in the PREA, most ($19.2 million) of the anticipated yearly costs would be investments in equipment to meet the interim and final concentration limits. While operators have complete flexibility as to what controls to use to meet the concentration limits, the Agency based its cost estimates on the assumption that operators will ultimately need the following to get to the final concentration limit: (a) all production equipment will need an oxidation catalytic converter; (b) about 38% of all equipment (production and support) will need a new engine; (c) about 8% of all equipment will need an environmentally conditioned cab; (d) about 34% of all equipment will need a 60–90% replaceable ceramic filter; and (e) 61% of all mines will need some ventilation improvement (16% fan and motor, 45% just motor). The assumptions are based on a January 1998 count of diesel powered equipment that regularly operates in the underground metal and nonmetal mines. The count was performed by MSHA's metal and nonmetal inspectors. This is a conservative estimate; as noted in discussing the possibility of having a lower concentration limit, it does not reflect the possibility that some mines may now be already cleaning up their fleet as they turn over their existing inventory. The cost estimates do reflect some facts noted in part II of this preamble: (a) unlike the coal sector, a large portion of underground metal and nonmetal mines are dieselized; (b) each mine has on average more diesel engines than in the coal sector; and (c) the engines used in these mines are more varied and heavier on average than those used in the coal sector. In addition to the costs to comply with the proposed concentration limit, the costs estimated for this sector include costs for implementing work practice controls that are similar to those already in effect in the underground coal sector.

The Agency is taking a number of steps to mitigate the impact of the rule for the underground metal and nonmetal sector, particularly on the smallest mines in this sector. These are described in detail in the Agency's Initial Regulatory Flexibility Analysis, which the Agency is required to prepare under the Regulatory Flexibility Act in connection with the impact of the rule on small entities. (The regulatory flexibility analysis can be found in part VI of this preamble, or packaged with the Agency's PREA.)

After a careful review of the information about this sector available from the industry economic profile, and the other obligations of this sector under the Mine Act, MSHA has tentatively concluded that a reasonable probability exists that the typical firm in this sector will be able at this time to afford the controls that will be necessary to meet the proposed standard. The Agency endeavored to gather information on examples of how these compliance costs would impact particular companies, and to establish whether existing order plans (e.g. for newer engines) might already contemplate costs which this rule would require, but was unable to find any significant information in this regard. The Agency welcomes information that will provide additional evidence on this important question.

Conclusion: metal and nonmetal mining sector. Based on the best evidence available at this time, the Agency has concluded that the proposed rule for the underground metal and nonmetal sector meets the statutory requirement that the Secretary attain the highest degree of health and safety protection for the miners in that sector, with feasibility a consideration.

Appendix to Part V: Diesel Emission Control Estimator

As noted in the text of this part, MSHA has developed a model that can help it estimate the impact on dpm concentrations of various control variables. The model also permits the estimation of actual dpm concentrations based upon equipment specifications. This model, or simulator, is called the ''Diesel Emission Control Estimator'' (or the ''Estimator'').

The model is capable only of simulating conditions in production or other confined areas of an underground mine. Air flow distribution makes modeling of larger areas more complex. The Estimator can be used in any type of underground mine.

While the calculations involved in this model can be done by hand, use of a computer spreadsheet system facilitates prompt comparison of the results of alternative combinations of controls. Changing a particular entry instantly changes all dependent outputs. Accordingly, MSHA developed the Estimator as a spreadsheet format. It can be used in any standard spreadsheet program.

A paper discussing this model has been presented and published as an SME Preprint (98–146) in March 1998 at the Society for Mining and Exploration Annual Meeting. It was demonstrated at a workshop at the Sixth International Mine Ventilation Congress, Pittsburgh, Pa., in June 1997. The Agency is making available to the mining community the software and instructions necessary to enable it to perform simulations for specific mining situations. Copies may be obtained by contacting: Dust Division, MSHA, Pittsburgh Safety and Health Technology Center, Cochrans Mill Road, P.O. Box 18233, Pittsburgh, Pa., 15236. The Agency welcomes comments on the proposed rule that include information obtained by using the Estimator. The Agency also welcomes comments on the model itself, and suggestions for improvements.

Determining the Current DPM Concentration. The Estimator was designed to provide an indication of what dpm concentration will remain in a production area once a particular combination of controls is applied. Its baseline is the current dpm concentration, which of course reflects actual equipment and work practices.

If the actual ambient dpm concentration is known, this information provides the best baseline for determining the outcome from applying control technologies. Any method that can reliably determine ambient dpm concentrations under the conditions involved can be utilized. A description of various methods available to the mining community is described in part II of this preamble.

If the exact dpm concentration is not known, estimates can be obtained in several ways. One way is to take a percentage of the respirable dust concentration in the area. Studies have shown that dpm can range from 50–90% of the respirable dust concentration, depending on the specific operation, the size distribution of the dust and the level of controls in place. Another method is simply to choose a value of 644 for an underground coal mine, or 830 for an underground metal or nonmetal mine. These values correspond to the average mean concentration which MSHA sampling to date has measured in such underground mines. Or, depending upon mine conditions, some other value from the range of mean mine concentrations displayed in part III of this preamble might be an appropriate baseline — for example, an average similar to that of mine sections like the one for which controls are required.

The Estimator has been designed to automatically compute another estimate of current ambient dpm concentration, and to provide outputs using this estimate even when the actual ambient dpm concentration is available and used in the model. This is done by using emissions data for the engines involved—specific manufacturer emissions data where available, or an average using the known range of emissions for each type of engine being used.

As with other estimates of current ambient dpm concentration, using engine data to derive this baseline measure does not produce the same results as actual dpm measurements. The Agency's experience is that the use of published engine emissions rates provides a good estimate of dpm exposures when the engines involved are used under heavy duty cycle conditions; for light duty cycle equipment, the published emission rates will generally overestimate the ambient particulate exposures. Also, such an approach assumes that the average ambient concentration derived is representative of the workplace where miners actually work or travel.

Columns. An example of a full spreadsheet from the Estimator is displayed as Figure V–5. The example here involves the application of various controls in an underground metal and nonmetal mine. As illustrated in the discussion in this part, the Estimator can be used equally well to ascertain what happens to dpm concentrations in an underground coal mine when the high-efficiency filters required by the proposed rule are used under various ventilation and section dpm intake conditions. Underground coal mine operators who are interested in ascertaining what impact it might have on dpm concentrations in their mines if the proposed rule permitted the use of alternative controls, or required the use of additional controls (e.g. filters on light duty equipment), can use the Estimator for this purpose as well.

FIGURE V–5.—EXAMPLE OF ESTIMATOR SPREADSHEET RESULTS FOR A SECTION OF AN UNDERGROUND METAL AND NONMETAL MINE

[Work Place Diesel Emissions Control Estimator; Mine Name: Underground Metal and Nonmetal]

	Column A	Column B
1. MEASURED OR ESTIMATED IN MINE DP EXPOSURE (µg/m3)	330 µg/m3	
2. VEHICLE EMISSION DATA		
EMISSIONS OUTPUT (gm/hp-hr)		
VEHICLE 1 INDIRECT INJECTION 0.3–0.5 gm/hp-hr FEL	0.1 gm/hp-hr	0.1 gm/hp-hr
VEHICLE 2 OLD DIRECT INJECTION 0.5–0.9 gm/hp-hr Truck 1	0.2 gm/hp-hr	0.2 gm/hp-hr
VEHICLE 3 NEW DIRECT INJECTION 0.1–0.4 gm/hp-hr Truck 2	0.1 gm/hp-hr	0.1 gm/hp-hr
VEHICLE 4	0.0	0.0 gm/hp-hr
VEHICLE OPERATING TIME (hours)		
VEHICLE 1 FEL	9 hours	9 hours
VEHICLE 2 Truck 1	9 hours	9 hours
VEHICLE 3 Truck 2	9 hours	9 hours
VEHICLE 4	0	0 hours
VEHICLE HORSEPOWER (hp)		
VEHICLE 1 FEL	315 hp	315 hp
VEHICLE 2 Truck 1	250 hp	250 hp
VEHICLE 3 Truck 2	330 hp	330 hp
VEHICLE 4	0 hp	0 hp
SHIFT DURATION (hours)	10 hours	10 hours
AVERAGE TOTAL SHIFT PARTICULATE OUTPUT (gm)	0.09 gm/hp-hr	0.12 gm/hp-hr
3. MINE VENTILATION DATA		
FULL SHIFT INTAKE DIESEL PARTICULATE CONCENTRATION	50 µg/m3	50 µg/m3
SECTION AIR QUANTITY	155000 cfm	155000 cfm
AIRFLOW PER HORSEPOWER	173 cfm/hp	73 cfm/hp
4. CALCULATED SWA DP CONCENTRATION WITHOUT CONTROLS		551 µg/m3
5. ADJUSTMENTS FOR EMISSION CONTROL TECHNOLOGY		
ADJUSTED SECTION AIR QUANTITY	155000 cfm	155000 cfm
VENTILATION FACTOR (INITIAL CFM/FINAL CFM)	1.00	1.00
AIRFLOW PER HORSEPOWER	173 cfm/hp	173 cfm/hp
OXIDATION CATALYTIC CONVERTER REDUCTION (%)		
VEHICLE 1	0%	20%
VEHICLE 2 IF USED ENTER 0–20%.	0%	20%
VEHICLE 3	0%	0%
VEHICLE 4	0%	0%
NEW ENGINE EMISSION RATE (gm/hp-hr)		
VEHICLE 1	0.1 gm/hp-hr	0.1 gm/hp-hr
VEHICLE 2 ENTER NEW ENGINE EMISSION (gm/hp-hr).	0.2 gm/hp-hr	0.2 gm/hp-hr
VEHICLE 3	0.1 gm/hp-hr	0.1 gm/hp-hr
VEHICLE 4	0.0 gm/hp-hr	0.0 gm/hp-hr
AFTER FILTER OR CAB EFFICIENCY (%)		
VEHICLE 1 Cabs	60%	60%
VEHICLE 2 USE 65–95% FOR AFTERFILTERS.	60%	60%
VEHICLE 3 USE 50–80% FOR CABS.	60%	60%
VEHICLE 4	0%	0%
6. ESTIMATED FULL SHIFT DP CONCENTRATION	162 µg/m^3	184 µg/m^3

*NOTE: Use of the Estimator does not free operators from the requirements of the rule. It is intended to serve as a guide.

A full spreadsheet from the Estimator has two columns, labeled A and B. Column A displays information on computations where the baseline is the measured ambient dpm concentration, or whose baselines are estimated as a percentage of respirable dust or by using the mean concentration for the sector. Column B displays information on computations in which the baseline itself was derived from engine emission information entered into the Estimator.

Sections. The Estimator spreadsheet is divided into 6 sections. Sections 1 through 4 contain information on the baseline situation in the mine section. Section 5 contains information on proposed new controls, and Section 6 displays the dpm concentration expected to remain after the application of those new controls. Table V–4 summarizes the information in each section of the Estimator.

TABLE V–4.—INFORMATION NEEDED FOR OR PROVIDED BY EACH SECTION OF THE ESTIMATOR MODEL

Speadsheet section	Input/output	Mine information
Section 1	Input	Measured DP Level, µg/m^3.

TABLE V–4.—INFORMATION NEEDED FOR OR PROVIDED BY EACH SECTION OF THE ESTIMATOR MODEL—Continued

Speadsheet section	Input/output	Mine information
Section 2	Input	Engine Emissions, gm/hp-hr. Engine Horsepower, hp. Operation Times, hr. Shift Duration, hr.
Section 3	Input	Section Airflow, cfm Intake DP Level, μg/m³.
Section 4	Output	Current DP Level, μg/m³.
Section 5	Input	DP Controls: Airflow, cfm. Oxid. Cat. Converter, percent. Engine Emissions, gm/hp-hr. after-filters, percent. Cabs, percent.
Section 6	Output	Projected DP Level, μg/m³.

Section 1. This is the place to enter data on baseline dpm concentrations if obtained by actual measurement, estimate based on respirable dust concentration, or mean concentration in the mining sector. Measurements should be entered in terms of whole diesel particulate matter for consistency with engine information. Information need not be entered in this section, in which case only engine-emission derived estimates will be produced by the Estimator (in Column B).

Sections 2 and 3. Section 2 is the place to enter data about the existing engines and engine use, and section 3 is the place to enter data about current ventilation practices. This information is used in two ways. First, the Estimator uses this information to derive an estimated baseline dpm concentration (for column B). Second, by comparing this information with that in section 5 on proposed controls that would change engines, engine use, or ventilation practices, the Estimator calculates the improvement in dpm that would result.

The first information entered in section 2 is the dpm emission rate (in gm/hp-hr) for each vehicle. The Estimator in its current form provides room to enter appropriate identification information for up to four vehicles. However, when multiple engines of the same type are used, the spreadsheet can be simplified and the number of entries conserved by combining the horsepower of these engines. For example, two 97 hp, 0.5 gm/hp-hr engines can be entered as a single 194 hp, 0.5 gm/hp-hr engine. However, if the estimate is to involve the use of different controls for each engine, the data for each engine must be entered separately. In order to account for the duty cycle, the engine operating time for each piece of equipment must then be entered in section 2, along with the length of the shift.

The last item in section 2, the ‘‘average total shift particulate output’’ in grams, is calculated by the Estimator based on the measured concentration entered in section 1 (for column A, or the engine emission rates for column B), the intake concentration, engine horsepower, engine operating time, and airflow. For column A, the average total shift diesel particulate output is calculated from the formula:

$$E(a) = (DPM(m) - I)\times(Q(I)/35200)/[Sum (Hp(I)\times To(I))]$$

Where:

E(a) = Average engine output, gm/hp-hr
DPM(m) = Measured concentration of diesel particulate, μg/m³
Q(I) = Initial section ventilation, cfm
I = Intake concentration, μg/m³
Hp(I) = Individual engine Horsepower, hp
To(I) = Individual engine operating times, hours

For column B, the average total shift diesel particulate output is calculated from the formula:

$$E(a) = [Sum (E(I)\times Hp(I)\times To(I))]/[Sum (Hp(I))]/Ts$$

Where:

E(a) = Average engine output, gm/hp-hr
E(I) = Individual engine emission rates, gm/hp-hr
Hp(I) = Individual engine Horsepower, hp
To(I) = Individual engine operating times, hours
Ts = Shift length, hours

The ‘‘average total shift particulate’’ provides useful information in determining what types of controls would be most useful. If the average output is less than 0.3, controls such as cabs and afterfilters would have a large impact on dpm. If the average output is greater than 0.3, new engines would have a large impact on dpm.

There are two data elements concerning existing ventilation in the section that must be entered into section 3 of the Estimator: the full shift intake dpm concentration, and the section air quantity. The former can be measured, or an estimate can be used. Based upon MSHA measurements to date, an estimate of between 25 and 100 micrograms of dpm per cubic meter would account for the dpm contribution coming into the section from the rest of the mine.

The last item in section 3, the airflow per horsepower, is calculated by the Estimator from the information entered on these two items in sections 2 and 3, as an indication of ventilation system performance. If the value is less than 125 cfm/hp, consideration should be given to increasing the airflow. If the value is greater than 200 cfm/hp, primary consideration would focus on controls other than increased airflow.

Section 4. Section 4 only displays information in Column B. Using the individual engine emissions, horsepower, operating time, section airflow , intake DPM and shift length, the Estimator calculates a presumed dpm concentration. The presumed dpm concentration is calculated by the formula:

$$DPM(a) = \{[[Sum (E(I)\times Hp(I) \times To(I))] \times 35{,}300/Q(I)]+I\}\times[Ts/8]$$

Where:

35,300 is a metric conversion factor
DPM(a) = Shift weighted average concentration of diesel particulate, μg/m³
E(I) = Individual engine emission rates, gm/hp-hr
Hp(I) = Individual engine Horsepower, hp
To(I) = Operating time hours
Ts = Shift length, hours
Q(I) = Initial section ventilation, cfm
I = Intake concentration, μg/m³

Section 5. Information about any combination of controls likely to be used to reduce dpm emissions in underground mines—changes in airflow, the addition of oxygen catalytic converters, the use of an engine that has a lower dpm emission rate, and the addition of either a cab or aftertreatment filter—is entered into Section 5. Information is entered here, however, only if it involves a change to the baseline conditions entered into Sections 2 and 3. Entries are cumulative.

The first possible control would be to increase the system air quantity. The minimum airflow should either be the summation of the Particulate Index (PI) for all heavy duty engines in the area of the mine, or 200 cfm/hp. The spreadsheet displays the ratio between the air quantity in section 5 and that in section 3, and the airflow per horsepower.

The second possible control would be to add an oxidation catalytic converter to one or more engines if not initially present. When such converters are used, a dpm reduction of up to 20 percent can be obtained (as noted in MSHA's Toolbox). The third possible control would be to change one or more engines to newer models to reduce emissions. As noted in part II of this preamble, clean engine technology has emissions as low as 0.1 and 0.2 gm/hp-hr.

Finally, each piece of equipment could be equipped with either a cab and an aftertreatment filter. Since MSHA considers it unlikely an operator would use both controls, the Estimator is designed to assume that no more than one of these two possible controls would be used on a particular engine. Ceramic aftertreatment filters that can reduce emissions by 65–80% are currently on the market; MSHA is soliciting information about the potential for future improvements in ceramic filtration efficiency. Paper filters can remove up to 95% or more of dpm, but these can only be used on equipment whose exhaust is appropriately cooled to avoid igniting the paper (i.e., permissible coal equipment, or other equipment equipped with a water scrubber or other cooling device). Air conditioned cabs can reduce the exposure of the equipment operator by anywhere from 50–80%. (See part II, section 6, for information on filters and cabs). But while the Estimator will produce an estimate of the full shift dpm concentration that includes the effects of using such cabs, it should be remembered that such an estimate is only directly relevant to equipment operators. Thus, cabs are a viable control for sections where the miners are all equipment operators, but they will not impact the dpm concentrations to which other miners are exposed.

Section 6. The Estimator displays in this section an estimated full shift dpm concentration. If a measured baseline dpm concentration was entered in section 1, this information will be displayed in column A. Column B displays an estimate based on the engine emissions data.

Here is how the computations are performed.

The effect of control application is calculated in Section 6, Column A from the following formula:

DPM(c) = {Sum [(To(I) / Ts) × 1000 × [(E(a) / 60) × Hp(I) × (35300 /Q(I)) × (Q(I) / Q(f)) × (1–R(o)) × (1–R(f)) × (1–R(e))]]} + I

Where:

DPM(c) = Diesel particulate concentration after control application/μg/m³,
E(a) = Average engine emission rate, gm/hp-hr,
Hp(I) = Individual engine Horsepower, hp.
To(I) = Operating time hours,
I = Intake DPM concentration, μg/m³,
Q(I) = Initial section ventilation, cfm,
Q(f) = Final section ventilation, cfm,
R(o) = Efficiency of oxidation catalytic converter, decimal
R(f) = Efficiency of after filters or cab, decimal,
R(e) = Reduction for new engine technology, decimal, and
R(e) = (Ei—Ef) / Ei

Where:

R(e) = Reduction for new engine technology, decimal,
E(i) = Initial engine emission rates, gm/hp-hr,
E(f) = New engine emission rates, gm/hp-hr,

The effect of control application is calculated in Section 6, Column B from the following formula:

DPM(c) = {Sum[(E(I) × Hp(I) × To(I)) × (35,300 / Q(I)) × (1–R(o)) × (1–R(f)) × (1–R(e))] × [Q(I) / Q(f)]}+I

Where:

DPM(c) = Diesel particulate concentration after control application/μg/m³,
E(I) = Individual engine emission rates, gm/hp-hr,
Hp(I) = Individual engine Horsepower, hp,
To(I) = Operating time hours,
I = Intake DPM concentration, μg/m³,
Q(I) = Initial section ventilation, cfm,
Q(f) = Final section ventilation, cfm,
R(o) = Efficiency of oxidation catalytic converter, decimal,
R(f) = Efficiency of after filters or cab, decimal,
R(e) = Reduction for new engine technology, decimal, and
R(e) = (Ei—Ef) / Ei

Where:

R(e) = Reduction for new engine technology, decimal,
E(i) = Initial engine emission rates, gm/hp-hr,
E(f) = New engine emission rates, gm/hp-hr.

VI. Impact Analyses

This part of the preamble reviews several impact analyses which the Agency is required to provide in connection with proposed rulemaking. The full text of these analyses can be found in the Agency's PREA.

(A) Costs and Benefits: Executive Order 12866

In accordance with Executive Order 12866, MSHA has prepared a Preliminary Regulatory Economic Analysis (PREA) of the estimated costs and benefits associated with the proposed rule for the underground metal and nonmetal sector.

The key conclusions of the PREA are summarized, together with cost tables, in part I of this preamble (see Question and Answer 5). In addition, a summary of the assumptions made by MSHA about the largest cost component of the proposed rule—the costs for equipment that the underground metal and nonmetal sector will need to comply with the proposed concentration limit—can be found in part V of this preamble, in the discussion of the feasibility of the proposed rule for that sector. The complete PREA is part of the record of this rulemaking, and is available from MSHA.

The Agency considers this rulemaking ''significant'' under section 3(f) of Executive Order 12866, and has so designated the rule in its semiannual regulatory agenda (RIN 1219–AB11). However, based upon the PREA, MSHA has determined that the proposed rule does not constitute an ''economically significant'' regulatory action pursuant to section 3(f)(1) of Executive Order 12866.

(B) Regulatory Flexibility Certification and Initial Regulatory Flexibility Analysis (IRFA)

Introduction. Pursuant to the Regulatory Flexibility Act of 1980, MSHA has analyzed the impact of this rule upon small businesses. MSHA specifically solicits comments on the cost data and assumptions concerning the initial regulatory flexibility analysis for underground metal and nonmetal mine operators.

To facilitate public participation in the rulemaking process, MSHA will mail a copy of the proposed rule and this preamble to every underground metal and nonmetal mine operator. In addition, the entire IRFA is reprinted here.

Definition of Small Mine. Under SBREFA, in analyzing the impact of a proposed rule on small entities, MSHA must use the SBA definition for a small entity or, after consultation with the SBA Office of Advocacy, establish an alternative definition for the mining industry by publishing that definition in the **Federal Register** for notice and comment. MSHA has not taken such an action, and hence is required to use the SBA definition.

The SBA defines a small mining entity as an establishment with 500 employees or less (13 CFR 121.201). MSHA's use of the 500 or less employees includes all employees (miners and office workers). Almost all mines (including underground coal mines) fall into this category and hence, can be viewed as sharing the special regulatory concerns which the RFA was designed to address. That is why MSHA has, for example, committed to providing to all underground metal and nonmetal mine operators a copy of a compliance guide explaining provisions of this rule.

The Agency is concerned, however, that looking only at the impacts of the proposed rule on all the mines in this sector does not provide the Agency with a very complete picture on which to make decisions. Traditionally, the Agency has also looked at the impacts of its proposed rules on what the mining community refers to as ''small mines''—those with fewer than 20 miners. The way these small mines perform mining operations is generally recognized as being different from the way other mines operate which has led to special attention by the Agency and the mining community.

This analysis complies with the legal requirements of the RFA for an analysis of the impacts on ''small entities'' while continuing MSHA's traditional look at ''small mines''.

Underground Metal and Nonmetal Mines: Initial Regulatory Flexibility Analysis. Since MSHA has not recently prepared an initial regulatory flexibility analysis in connection with a proposed rule, the mining community has not had an opportunity to review such an analysis. Accordingly, some background may be helpful.

The requirements for an initial RFA should describe the impact of the proposed rule on small entities. Each initial RFA analysis shall contain:

''(1) A description of the reasons why action by the Agency is being considered;

(2) A succinct statement of the objectives of, and legal basis for, the proposed rule;

(3) A description of and, where feasible, an estimate of the number of small entities to which the proposed rule will apply;

(4) A description of the projected reporting, recordkeeping and other compliance requirements of the proposed rule, including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;

(5) An identification, to the extent practicable, of all relevant Federal rule which may duplicate, overlap or conflict with the proposed rule.''

In addition, ''Each initial regulatory flexibility analysis shall also contain a description of any significant alternatives to the proposed rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the proposed rule on small entities. Consistent with the stated objective of applicable statutes, the analysis shall discuss significant alternatives such as:

(1) The establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities;

(2) The clarification, consolidation, or simplification of compliance and reporting requirements under the rule for such small entities;

(3) The use of performance rather than design standards;

(4) and an exemption from coverage of the rule, or any part thereof, for such entities.''

MSHA would encourage the mining community to structure its comments on these points in a similar manner so that the Agency will be able to clearly respond to them in its final analysis.

MSHA hopes the presentation that follows will provide reviewers enough information to readily grasp the implications of the rule for small entities in particular, but it strongly encourages reviewers to also pursue the referenced discussions of risk, feasibility, historical and other information in the preamble accompanying the proposed rule.

Reasons Why Agency Action is Being Considered. A rule is needed for underground metal and nonmetal mines to assure that a significant risk of material impairment to the health of miners working in these mines is reduced to the extent economically and technologically feasible for this sector as a whole. The risk is created by the presence of diesel engines in the closed environment of underground metal and nonmetal mines which generate in their emissions very high concentrations of particulate matter. These very small particles penetrate to the deepest regions of the lung. As explained in detail in Part III of the preamble accompanying the proposed rule, exposure to high concentrations of diesel particulate matter puts miners at significant risk of material impairment to their health. These elevated risks include, but are not limited to, an increased risk of lung cancer. At the present time, many underground miners, including many miners in underground metal and nonmetal mines, are exposed to levels of diesel particulate matter that far exceed the exposures of any other group of workers in the United States. The reductions in exposure to diesel particulate required in this sector will necessitate changes in mine equipment and practices that are too significant to bring about without regulatory action.

Objectives of the Rule; Legal Basis. MSHA has two related objectives it hopes to accomplish through the rulemaking for underground metal and nonmetal mines. For miners in this sector, it is MSHA's objective that they will no longer be exposed to diesel particulate matter in far greater concentrations than any other group of workers in this country. For mine operators in this sector, it is MSHA's objective to provide each with flexibility as to the controls they may implement to reduce the concentration of diesel particulate matter to the prescribed limit.

The proposed rule won't eliminate the risk of harm, nor even reduce exposures to the level which industry experts are considering establishing as a Threshold Limit Value, but it would reduce miner exposures to levels comparable to those faced by workers in other industries who work around diesel powered equipment. While MSHA has tentatively concluded that there may remain a significant risk to miner health even with this proposed rule, the Agency has also tentatively concluded that: (a) the proposed rule would provide substantial health benefits; and (b) additional controls beyond those provided for in the proposed rule may not be feasible for the underground metal and nonmetal sectors at this time.

Initially, MSHA had an additional objective in this rulemaking: to establish a uniform rule for all mining sectors because uniformity tends to be the most effective solution for worker's health and for industry compliance. After exploring the implications of such an approach, however, the Agency concluded that a uniform approach does not appear to be feasible at this time. MSHA has tentatively concluded that while there is a technological fix available for underground coal mine operators, the best solution for underground metal and nonmetal mine operators will vary considerably. Moreover, while the Agency has confidence that there is a validated method for measuring diesel particulate matter concentrations in underground metal and nonmetal mines, it believes some further work is necessary before recommending that such an approach be used in underground coal mines due to the possibility of contamination of the samples by coal dust. The Agency will reconsider this approach in light of the record in this proceeding before finalizing a rule, but at this point has concluded that it cannot justify proposing a uniform approach to this problem at this time.

MSHA has an obligation under § 101(a)(6)(A) of the Federal Mine Safety and Health Act of 1977 (the ''Mine Act'') which requires the Secretary to set standards which most adequately assure, on the basis of the best available evidence, that no miner will suffer material impairment of health over the miner's working lifetime. The Mine Act makes no distinction between the obligations of operators based on size.

Number and Description of Small Entities Affected. Number and Description of Small Entities Affected

Underground metal and nonmetal mine operators have used diesel-powered equipment for a long time, and they are highly dependent upon such equipment for production. As discussed in detail in part II of the preamble accompanying the proposed rule, a major role of such equipment involves haulage. For example, front-end loaders or load-haul-dump machines remove the metal or mineral deposits from where it was blasted or cut in the mine. However, other types of diesel machinery can also be found in underground metal and nonmetal mines. Examples of some of these other types of diesel powered machines are: roof bolters, jumbo drills, scalers, water trucks, and transport or maintenance vehicles. MSHA's January 1998 count of the number of diesel powered equipment in underground metal and nonmetal mines, shows that of the 261 underground metal and nonmetal mines, there are 203 mines that use diesel powered equipment on a regular basis.

Under MSHA's traditional definition of a small mine (those that employ less than 20), about 40 percent of the 203 underground metal and nonmetal mines that use diesel powered equipment (82 mines) would be considered small underground mines. Approximately 69 percent of these small underground mines (57 mines ÷ mines) are involved in the production of limestone (47 mines) or gold (10 mines). The largest number of small underground mines that are involved in the production of the same commodity are limestone mines. Underground limestone mines account for 57 percent of small mines (47 mines ÷ mines). These 82 small underground mine operators employ approximately 5 percent of all underground metal and nonmetal mine employment, and account for about 15 percent of the diesel powered equipment found in underground metal and nonmetal mines. On average, about 7.5 diesel powered machines are in a small mine, when MSHA's definition of a small mine is used.

Under the SBA definition of a small mine (those that employ 500 or less), about 97 percent of the 203 underground metal and nonmetal mines that use diesel powered equipment (196 mines) would be considered small underground mines. Approximately 68 percent of these small underground mines (134 mines ÷ 196 mines) are involved in the production of: limestone (85 mines), gold (27 mines), Salt (12 mines), and Zinc (10 mines). Again, the largest number of small underground mines that are involved in the production of the same commodity are limestone mines. Underground limestone mines account for 43 percent of small mines (85 mines ÷ 196 mines). These 196 small underground mine operators employ approximately 70 percent of all underground metal and nonmetal mine employment, and account for about 83 percent of the diesel powered equipment found in underground metal and nonmetal mines. On average, about 17 diesel powered machines are in a small mine, when SBA's definition of a small mine is used.

The industry profile in part II of this document provides some further information concerning the characteristics of underground metal and nonmetal mines.

Proposed Rule Requirements. The compliance requirements of the proposed rule for underground metal and nonmetal mine operators are described in detail in the preamble to the rule. The compliance costs to mine operators are described in detail in the PREA. The material following briefly summarizes key elements of the proposed rule.

The proposed rule would require that underground metal and nonmetal mine operators, including small mine operators, observe a set of ''best practices'' underground to reduce engine emissions of diesel particulate matter. (Similar practices are already in effect in underground coal mines as a result of MSHA's diesel equipment rule).

Only low-sulfur diesel fuel and EPA-approved fuel additives would be permitted to be used in diesel-powered equipment in underground areas. Idling of such equipment that is not required for normal mining operations would be prohibited. In addition, diesel engines would have to be maintained in good condition to ensure that deterioration does not lead to emissions increases—approved engines would have to be maintained in approved condition; the emission related components of non-approved engines would have to be maintained in accordance with manufacturer specifications; and any installed emission device would have to be maintained in effective condition. Equipment operators in underground metal and nonmetal mines would be authorized to tag equipment with potential pollution problems, and tagged equipment would have to be ''promptly'' referred for a maintenance check. As an additional safeguard in this regard, maintenance of this equipment would have to be done by persons qualified by virtue of training or experience to perform the maintenance.

The proposed rule would also require that, with the exception of diesel engines used in ambulances and fire-fighting equipment, any diesel engines added to the fleet of an underground metal or nonmetal mine, 60 days after the date the rule is promulgated, must be an engine approved by MSHA under Part 7 or Part 36. The composition of the existing fleet would not be impacted by this part of the proposed rule.

In addition, the proposed rule would establish a limit on the concentration of diesel particulate matter permitted in areas of an underground metal or nonmetal mine where miners normally work or travel.

All underground metal and nonmetal mine operators would be given a full five years to meet this limit. However, starting eighteen months after the rule is published, underground metal and nonmetal mine operators would have to observe an interim limit. No limit at all on the concentration of diesel particulate matter would be applicable for the first eighteen months following promulgation. Instead, this period would be used to provide compliance assistance to the underground metal and nonmetal mining community to ensure it understands how to measure and control diesel particulate matter concentrations in individual operations.

An underground metal and nonmetal mine operator would have to use engineering or work practice controls to keep diesel particulate matter concentrations below the applicable limit. Administrative controls (e.g., the rotation of miners) and personal protective equipment (e.g., respirators) do not reduce the concentration of diesel particulate, and so are not permitted as a means of permanent compliance with this standard. When a mine operator is granted an extension to come into compliance with the concentration limit under the narrow range of circumstances permitted in the rule, MSHA may require the mine operator to utilize personal protective equipment or administrative controls during the duration of the extension period. An underground operator could filter the emissions from diesel-powered equipment, install cleaner-burning engines, increase ventilation, improve fleet management, or use a variety of other readily available controls; the selection of controls would be left to the operator's discretion. MSHA has published a ''toolbox'' of approaches that can be used to reduce diesel particulate matter. MSHA will make available an ''Estimator'' that operators can plug into a standard spreadsheet program to enable them to evaluate the effects of alternative controls in an area of a mine before purchasing and implementation decisions are made.

MSHA has studied a number of metal and nonmetal mines, as described in part V of the preamble accompanying the proposed rule, which the Agency had reason to think might have particular difficulty in controlling diesel particulate matter concentrations. As a result of these studies, the Agency believes that in combination with the required ''best practices,'' engineering and work practice controls are available that can bring diesel particulate matter concentrations in all underground metal and nonmetal mines down to the interim and final concentration limits in a timely manner. Nevertheless, the proposed rule would provide that if an operator of an underground metal or nonmetal mine can demonstrate that there is no combination of controls that can, due to technological constraints, be implemented within that time to reduce the concentration of diesel particulate matter to the limit, MSHA may approve an application for an extension of time to comply with the diesel particulate matter concentration limit. Such a special extension is available only once, and is limited to 2 years.

Sampling to determine compliance with the diesel particulate matter concentration limit would be performed directly by MSHA, rather than relying upon underground metal and nonmetal mine operator samples; however, the proposed rule would also require all underground metal and nonmetal mine operators using diesel-powered equipment to sample as often as necessary to effectively evaluate diesel particulate matter concentrations at the mine.

The proposed rule would require that if an underground metal or nonmetal mine operator is in violation of the applicable limit on the concentration of diesel particulate matter, a diesel particulate matter compliance plan must be established and remain in effect for 3 years. Reflecting practices in this sector, the plan would not have to be preapproved by MSHA, but must be retained at the mine site. The plan would include information about the diesel-powered equipment in the mine and applicable controls. The proposed rule would require operator sampling to verify that the plan is effective in bringing diesel particulate matter levels at or below the applicable limit, with the records kept at the mine site with the plan to facilitate review.

To enhance miner awareness of the hazards involved, underground mine operators using diesel-powered equipment must annually train miners exposed to diesel particulate matter on the hazards associated with that exposure, and in the controls being used by the operator to limit diesel particulate matter concentrations. Underground mine operators may propose to include this training in their existing Part 48 training plans.

Table VI–1 summarizes the compliance costs of the proposed rule, including paperwork costs, to underground metal and nonmetal mine operators. As can be seen in the table, of the approximately $19.2 million per year estimate of total compliance cost for all underground metal and nonmetal mine operators, mines with 19 or fewer miners are estimated to incur approximately $4.6 million per year (an average cost of about $56,100 per year per small mine). When the definition of a small mine operator is 500 or less employees, then nearly all underground metal and nonmetal mine operators would be included (under such a definition, MSHA estimates that approximately $17.2 million of the total $19.2 million would be incurred by small mine entities (an average cost of about $87,800 per year per small mine). A discussion of the benefits of the proposed rule can be found in part I of this preamble (see response to Question 5).

TABLE VI-1
COMPLIANCE COSTS FOR
UNDERGROUND METAL AND NONMETAL MINE OPERATORS
(DOLLARS X 1,000)

	Small Mines With 19 or less miners	All Mines
Detail	Per Year Costs[1]	Per Year Costs[1]
57.5060 (a)	$2,677	$11,046
57.5060 (b)	$1,627	$6,537
57.5060(c)	$2	$12
57.5062	$1	$6
57.5066	$8	$38
57.5067	$121	$852
57.5070	$5	$203
57.5071	$122	$486
57.5075	$1	$4
Total	$4,564	$19,184

1.Per year compliance costs is composed of the addition of annualized and annual compliance costs.

With respect to underground metal and nonmetal mine operators the paperwork requirements include paperwork associated with training for persons maintaining diesel powered equipment, annual training for those miners affected by the hazards of diesel particulate matter, sampling for diesel particulate matter, observation of sampling, and tagging equipment with pollution problems. In addition, there are paperwork requirements for a small portion of underground metal and nonmetal mines that pertain to writing applications to extend the period to comply with the proposed concentration limits, and for writing a diesel particulate control plan.

With a few exceptions, MSHA estimates that all recordkeeping and recording related compliance costs, and all of the other requirements of the standard, will require no special professional background beyond that currently found in the managers of the underground mines in this sector. Based on a small mine definition of less than 20 employees, all small underground metal and nonmetal mine operators, as well as half of the large mines, are assumed to have sampling performed by an independent contractor, because this would be cheaper than setting up their own sampling program and purchasing the required sampling equipment. Also, regardless of what definition is used to define small mines, all underground metal and nonmetal mine operators would have the sample analysis performed by an independent contractor, since the underground mines do not have the expertises or equipment to analyze for diesel particulate matter. Again, no matter what definition is used to define small mines, underground metal and nonmetal mine operators would need to go outside of the mine expertise to receive a portion of their maintenance training.

Based on a small mine definition of less than 20 miners, the total number of annual burden hours to the 82 small underground metal and nonmetal mine operators would be 436. When the definition of a small mine is 500 or less employees, the total number of annual burden hours to 196 small underground metal and nonmetal mine operators would be 3,472.

Impact of Other Federal Rules. There are no other Federal (or for that matter State) rules of which MSHA is aware that would duplicate, overlap or conflict with the proposed rule for underground metal and nonmetal mines.

Significant Alternatives Considered. The Agency considered, and adopted as part of the proposed rule, features designed to minimize the impacts on small entities, and the smallest metal and nonmetal mines in particular, consistent with the stated objectives of the Mine Act. It is important to note in this regard that in implementing the Mine Act's requirement that the Secretary attain the highest degree of safety and health protection, consistent with feasibility, the Agency based its decisions on the technological and economic feasibility of the proposed rule on detailed information about the impacts on mines with 500 or fewer employees and, separately, that segment of these mines with less than 20 employees. Part V of the preamble accompanying the proposed rule reviews the decisions made by the Agency with respect to this statutory obligation.

Under the proposed rule no limit on diesel particulate concentration would be in effect for 18 months, during which time the Agency would provide extensive compliance assistance to the mining community. During this time, MSHA would be working with small underground metal and nonmetal mine operators to provide help concerning the measuring of diesel particulate concentrations. In addition, MSHA would use this time to provide technical assistance about control methods to small mine operators.

In fact, this individualized compliance assistance would supplement general guidance the Agency has already started to provide to the mining industry, and to small mines in particular. In 1995, the Agency held three workshops in various areas of the country to enable the mining community to share ideas on practical ways to control diesel emissions, and made transcripts of these workshops widely available. Subsequently, the Agency published a ''toolbox'' to disseminate this information in a format designed to facilitate use by small mines in particular (appended to the end of this document is a copy of an MSHA publication, ''Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—A Toolbox). Moreover, before the rule goes into effect, the Agency will also develop and distribute a compliance guide, as required by SBREFA, and will provide information to small mines through such other formats as may be suggested by the mining community. For example, MSHA is also considering creating a one page fact sheet or card that can be used by the mining industry to complement training requirements concerning notification of affected miners of the hazards associated with diesel particulate. This can be of particular help to small mine operators who have training resources that may not be as extensive as those found in large mining operations. MSHA will also mail a copy of the proposed rule to every underground mine operator which primarily benefits small operators.

Beyond the initial 18 months the proposed rule would provide for compliance assistance. Also, the proposed rule reflects a preliminary decision by the agency to delay for a full 5 years after promulgation of a final rule the effective date of the requirement which will have the most significant impact on small underground metal and nonmetal mines—the concentration limit for diesel particulate. An interim concentration limit would apply until that date—a limit that should not be at all difficult for small mines to reach, particularly after all of the compliance assistance that precedes it. This extended time for full implementation of the proposed rule ensures that technological issues can be timely resolved prior to the final rule's effective date. It also recognizes that this rule is a significant one for the underground metal and nonmetal sector, that almost all mines in this sector are considered small entities under SBA's definition, and that having adequate time to come into full compliance is of particular importance to the smallest mines in this sector.

Finally, MSHA is including a one-time two-year extension for mines that require additional time to adopt to the final concentration limits.

Other features of the proposed rule also reflect MSHA's recognition of the size distribution of the entities which have to implement any requirements. Special attention was paid to making the rule's requirements comprehensible to the mining community, including the provision of a chart summarizing recordkeeping requirements, and comments in that regard are being solicited. Training and operator sampling requirements were specifically designed to be performance oriented to minimize costs, while at the same time ensure that the important protections that flow from such approaches are included in every mine operator's approach to this health problem.

MSHA did consider a regulatory approach that would have focused on limiting worker exposure rather than limiting particulate concentration. Under such an approach, operators would have been able to use administrative controls (e.g., rotation of personnel) and respiratory protection equipment to reduce diesel particulate exposure. It is generally accepted industrial hygiene practice, however, to eliminate or minimize hazards before resorting to personal protective equipment. Moreover, while rotation of workers may be a perfectly acceptable practice for a hazard like noise (where reducing exposure can allow the ear to recover, thus avoiding any harm), such a practice is generally not considered acceptable in the case of carcinogens since it merely places more workers at risk. Also, allowing use of these practices would not necessarily help the smallest mines, not all small mines can efficiently rotate workers. Accordingly, the agency declined to propose such an approach for this serious health hazard, although it welcomes comments in this regard.

MSHA is proposing dpm concentration limits as the core of the rule. Although the Agency has developed costs in terms of assumptions about the numbers of engineering controls that will be required to meet the standard, design standards are not the point of the regulation. Rather, the Agency has suggested as broad a menu of compliance techniques as is practicable, so that individual mines can select specific techniques that best fit their circumstances.

The Agency has also declined to propose alternatives involving design standards or specific frequency requirements, which it believes would have had a more significant impact on small entities in the underground metal and nonmetal mining sector—although it will certainly take another look at these if the rulemaking record so warrants. Section 101(a)(6)(A) of the Mine Act requires the Secretary when promulgating standards dealing with toxic substances or harmful physical agents to base such mandatory standards on the best available evidence, to most adequately assure that no miner will suffer material impairment of health over his working lifetime. The Act also requires that when promulgating such standards, other factors such as the latest scientific data in the field, the feasibility of the standard and experience gained under the Act and other health and safety laws be considered. Thus, the Mine Act requires that the Secretary, in promulgating a standard, attain the highest degree of health and safety protection for the miner, based on the ''best available evidence'', with feasibility as a consideration.

As a result of this requirement, MSHA seriously considered alternatives that would have significantly increased costs for both large and small mine operators. For example, in light of the health risks involved, and the existing environmental restrictions on particulate matter, the Agency considered proposing for underground metal and nonmetal mine operators a lower limit on the concentration of diesel particulate, and shortening the time frame to get to a final limit. The Agency has tentatively concluded, however, that such approaches would not be feasible for this sector as a whole. The Agency also considered requiring more stringent work practice and engine controls in this sector than those ultimately proposed—i.e., practices exactly like those applicable in the underground coal sector. Such an alternative would have required: (a) weekly emissions tests of diesel powered equipment in underground metal and nonmetal mines instead of just tagging suspect equipment for prompt inspection; (b) requiring these mines to establish training programs for maintenance personnel; and (c) requiring the metal and nonmetal diesel powered fleet to be turned over completely within a few years so as to have only approved engines. The Agency concluded, however, that the concerns which warranted such an approach in underground coal mines had not been established in underground metal and nonmetal mines; and that with respect to the risks created by diesel particulate matter, the approach taken in the proposed rule could provide adequate protection in a cost effective manner.

MSHA also considered other rigorous requirements such as: requiring the installation of a particulate filter on every new piece of diesel powered equipment added to the underground metal and nonmetal diesel powered fleet regardless of the diesel particulate matter concentration level as an added layer of miner protection, establishing a fixed schedule for operator monitoring of the concentration of diesel particulate emissions, and requiring that diesel particulate control plans be preapproved by MSHA before implementation to ensure that their effectiveness had been verified. These approaches were not included in the proposed rule because MSHA concluded that less stringent alternatives could achieve the same level of protection with less adverse impact on underground mining operations, especially small underground mining operations.

MSHA welcomes comments on whether there are significant alternatives it should consider that would accomplish the previously stated purpose and objectives of this rulemaking while reducing the impact on small entities. In this regard, the Agency would also welcome suggestions for alternatives that focus on addressing special concerns on the very smallest mines in this sector—those with less than 20 miners. It is important to remember, however, that under the Mine Act, smaller mines must provide the same level of protection to their workers as larger mines.

As required under the law, MSHA will be consulting with the Chief Counsel for Advocacy on the initial regulatory flexibility analysis for the underground metal and nonmetal mining sector. Consistent with agency practice, notes of any meetings with the Chief Counsel's office on this rule, or any written communications, will be placed in the rulemaking record. The Agency will continue to consult with the Chief Counsel's office as the rulemaking process proceeds.

(C) Unfunded Mandates Reform Act of 1995

MSHA has determined that, for purposes of § 202 of the Unfunded Mandates Reform Act of 1995, this proposed rule does not include any Federal mandate that may result in increased expenditures by State, local, or tribal governments in the aggregate of more than $100 million, or increased expenditures by the private sector of more than $100 million. Moreover, the Agency has determined that for purposes of § 203 of that Act, this proposed rule does not significantly or uniquely affect small governments.

The Unfunded Mandates Reform Act was enacted in 1995. While much of the Act is designed to assist the Congress in determining whether its actions will impose costly new mandates on State, local, and tribal governments, the Act also includes requirements to assist Federal agencies to make this same determination with respect to regulatory actions.

Based on the analysis in the Agency's preliminary Regulatory Economic Statement, the compliance costs of this proposed rule for the underground metal and nonmetal mining industry are about $19.2 million per year. Accordingly, there is no need for further analysis under § 202 of the Unfunded Mandates Reform Act.

MSHA has concluded that small governmental entities are not significantly or uniquely impacted by the proposed regulation. The proposed rule affects only underground metal and nonmetal mines, and MSHA is not aware of any state, local or tribal government ownership interest in underground mines. MSHA seeks comments of any state, local, and tribal government which believes that they may be affected by this rulemaking.

(D) Paperwork Reduction Act of 1995 (PRA)

This proposed rule contains information collections which are subject to review by the Office of Management and Budget (OMB) under the Paperwork Reduction Act of 1995 (PRA95). Tables VI–2 and VI–3 show the estimated annual reporting burden hours associated with each proposed information collection requirement. These burden hour estimates are an approximation of the average time expected to be necessary for a collection of information, and are based on the information currently available to MSHA. Included in these estimates are the time for reviewing instructions, gathering and maintaining the data needed, and completing and reviewing the collection of information.

MSHA invites comments on: (1) Whether any proposed collection of information presented here (and further detailed in the Agency's PREA) is necessary for proper performance of MSHA's functions, including whether the information will have practical utility; (2) the accuracy of MSHA's estimate of the burden of the proposed collection of information, including the validity of the methodology and assumptions used; (3) ways to enhance the quality, utility, and clarity of information to be collected; and (4) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques, when appropriate, and other forms of information technology.

Submission. The Agency has submitted a copy of this proposed rule to OMB for its review and approval of these information collections. Interested persons are requested to send comments regarding this information collection, including suggestions for reducing this burden, to the Office of Information and Regulatory Affairs, OMB New Executive Office Bldg., 725 17th St. NW., Rm. 10235, Washington, DC 20503, Attn: Desk Officer for MSHA. Submit written comments on the information collection not later than December 28, 1998.

The Agency's complete paperwork submission is contained in the PREA/IRFA, and includes the estimated costs and assumptions for each proposed paperwork requirement (these costs are also included in the Agency's cost and benefit analyses for the proposed rule). A copy of the PREA/IRFA is available from the Agency. These paperwork requirements have been submitted to the Office of Management and Budget for review under section 3504(h) of the Paperwork Reduction Act of 1995.

Respondents are not required to respond to any collection of information unless it displays a current valid OMB control number.

Description of Respondents. Those required to provide the information are underground metal and nonmetal mine operators and diesel engine manufacturers.

Description. The proposed rule contains information collection requirements for: underground metal and nonmetal mine operators in §§ 57.5060, 57.5062, 57.5066, 57.5070, 57.5071 and 57.5075; and for diesel engine manufacturers in Part 7, subpart E. Annual burden hours are 3,865 for underground metal and nonmetal mines. There are 36 burden hours related to manufacturers of diesel powered engines which would recur annually.

Tables VI–2 and VI–3 summarize the burden hours for mine operators and manufacturers by section.

TABLE VI–2.—UNDERGROUND METAL AND NONMETAL MINES BURDEN HOURS

Detail	Large	Small	Total
57.5060	306	123	429
57.5062	49	11	60
57.5066	207	76	283
57.5070	136	6	142
57.5071	2,600	213	2,813
57.5075	131	7	138
Total	3,429	436	3,865

TABLE VI–3.—DIESEL ENGINE MANUFACTURERS BURDEN HOURS

Detail	Total
Part 7, Subpart E	36
Total	36

(E) National Environmental Protection Act

The National Environmental Policy Act (NEPA) of 1969 requires each Federal agency to consider the environmental effects of proposed actions and to prepare an Environmental Impact Statement on major actions significantly affecting the quality of the human environment. MSHA has reviewed the proposed standard in accordance with the requirements of the NEPA (42 U.S.C. 4321 et seq.), the regulation of the Council on Environmental Quality (40 CFR Part 1500), and the Department of Labor's NEPA procedures (29 CFR Part 11). As a result of this review, MSHA has preliminarily determined that this proposed standard will have no significant environmental impact.

Commenters are encouraged to submit their comments on this determination.

(F) Executive Order 13045

In accordance with Executive Order 13045, protection of children from environmental health risks and safety risks, MSHA has evaluated the environmental health or safety effects of the proposed rule on children. The Agency has determined that this proposal would not have an adverse impact on children.

Part VII. References

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Supplementary References:

Below is a list of supplemental references that MSHA reviewed and considered in the development of the proposed rule. These documents are not specifically cited in the preamble discussion, but are applicable to MSHA's findings:

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List of Subjects in 30 CFR Part 57

Diesel particulate matter, Metal and nonmetal, Mine safety and health, Underground mines.

Dated: October 16, 1998.

J. Davitt McAteer,

Assistant Secretary for Mine Safety and Health.

It is proposed to amend Chapter I of Title 30 of the Code of Federal Regulations as follows:

PART 57—[AMENDED]

1. The authority citation for Part 57 continues to read as follows:

Authority: 30 U.S.C. 811, 957, 961.

2. The heading of Subpart D of Part 57 is revised to read as follows: ''Subpart D—Air Quality, Radiation, Physical Agents, and Diesel Particulate Matter''

3. Sections 57.5060 through 57.5075, and in undersigned center heading, are added to Subpart D to read as follows:

Subpart D—Air Quality, Radiation, Physical Agents and Diesel Particulate Matter

Diesel Particulate Matter—Underground Only

§ 57.5060 Limit on concentration of diesel particulate matter.

(a) After [the date 18 months after the date of publication of the final rule] and until [the date 5 years after the date of publication of the final rule], any mine operator covered by this part shall limit the concentration of diesel particulate matter to which miners are exposed by restricting the average eight-hour equivalent full shift airborne concentration of total carbon, where miners normally work or travel, to 400 micrograms per cubic meter of air (400_{TC} $\mu g/m^3$).

(b) After [the date 5 years after the date of publication of the final rule], any mine operator covered by this part shall limit the concentration of diesel particulate matter to which miners are exposed in underground areas of a mine by restricting the average eight-hour equivalent full shift airborne concentration of total carbon, where miners normally work or travel, to 160 micrograms per cubic meter of air (160_{TC} $\mu g/m^3$).

(c)(1) If, as a result of technological constraints, a mine requires additional time to come into compliance with the limit specified in paragraph (b) of this section, the operator of the mine may file an application with the Secretary for a special extension.

(2) No mine may be granted more than one special extension, nor may the time otherwise available under this section to a mine to comply with the limit specified in paragraph (b) of this section be extended by more than two years.

(3) The application for a special extension may be approved, and the additional time authorized, only if the application includes information adequate for the Secretary to ascertain:

(i) That diesel-powered equipment was used in the mine prior to October 29, 1998;

(ii) That there is no combination of controls that can, due to technological constraints, bring the mine into full compliance with the limit specified in paragraph (b) of this section within the time otherwise specified in this section;

(iii) The lowest achievable concentration of diesel particulate, as demonstrated by data collected under conditions that are representative of mine conditions using the method specified in § 57.5061(b); and

(iv) The actions the operator will take during the duration of the extension to:

(A) Maintain the lowest concentration of diesel particulate; and

(B) Minimize the exposure of miners to diesel particulate.

(4) An application for a special extension may be approved only if:

(i) The application is filed at least 180 days prior to the date the mine is required by this section to be in full compliance with the limit established by paragraph (b) of this section; and

(ii) The application certifies that one copy of the application has been posted at the mine site for 30 days prior to the date of application, and another copy has been provided to the authorized representative of miners.

(5) A mine operator shall comply with the terms of any approved application for a special extension. A copy of an approved application for a special extension shall be posted at the mine site for the duration of the special extension period.

(d) An operator shall not utilize personal protective equipment, nor shall an operator utilize administrative controls, to comply with the requirements of either paragraph (a) or paragraph (b) of this section.

§ 57.5061 Compliance determinations.

(a) A single sample collected and analyzed by the Secretary in accordance with the procedure set forth in paragraph (b) of this section shall be an adequate basis for a determination of noncompliance with an applicable limit on the concentration of diesel particulate matter pursuant to § 57.5060.

(b) The Secretary will collect and analyze samples of diesel particulate matter by using the method described in NIOSH Analytical Method 5040 and determining the amount of total carbon, or by using any method subsequently determined by NIOSH to provide equal or improved accuracy in mines subject to this part.

§ 57.5062 Diesel particulate matter control plan.

(a) In the event of a violation by the operator of an underground metal or nonmetal mine of the applicable concentration limit established by § 57.5060, the operator, in accordance with the requirements of this section, must—

(1) Establish a diesel particulate matter control plan for the mine if one is not already in effect, or modify the existing diesel particulate matter control plan, and

(2) Demonstrate that the new or modified diesel particulate matter

control plan is effective for controlling the concentration of diesel particulate matter to the applicable concentration limit specified in § 57.5060.

(b) A diesel particulate control plan shall describe the controls the operator will utilize to maintain the concentration of diesel particulate matter to the applicable limit specified by § 57.5060. The plan shall also include a list of diesel-powered units maintained by the mine operator, together with information about any unit's emission control device and the parameters of any other methods used to control the concentration of diesel particulate matter. The plan may be consolidated with the ventilation plan required by § 57.8520. A copy of the current diesel particulate matter control plan shall be retained at the mine site during its duration and for one year thereafter.

(c) An operator shall demonstrate plan effectiveness by monitoring, using the measurement method specified by § 57.5061(b), sufficient to verify that the plan will control the concentration of diesel particulate matter to the applicable limit under conditions that can be reasonably anticipated in the mine. A copy of each verification sample result shall be retained at the mine site for five years. Such operator monitoring shall be in addition to, and not in lieu of, any sampling by the Secretary pursuant to § 57.5061.

(d) The records required by paragraphs (b) and (c) of this section shall be available for review upon request by the authorized representative of the Secretary, the authorized representative of the Secretary of Health and Human Services, or the authorized representative of miners. In addition, upon request by the District Manager or the authorized representative of miners for a copy of any records required to be maintained pursuant to paragraph (b) or (c) of this section, the operator shall provide such copy.

(e)(1) A control plan established as a result of this section shall remain in effect for 3 years from the date of the violation which caused it to be established, except as provided in paragraph (e)(3) of this section.

(2) A control plan modified as a result of this section shall remain in effect, as so modified, for 3 years from the date of the violation which caused the plan to be modified, except as provided in paragraph (e)(3) of this section.

(3) An operator shall modify a diesel particulate matter control plan during its duration as required to reflect changes in mining equipment or circumstances, and shall, upon request from the Secretary, demonstrate the effectiveness of the modified plan by monitoring, using the measurement method specified by § 57.5061(b), sufficient to verify that the plan will control the concentration of diesel particulate matter to the applicable limit under conditions that can be reasonably anticipated in the mine.

(f) Failure of an operator to comply with the provisions of the diesel particulate matter control plan in effect at a mine or to conduct required verification sampling shall be a violation of this part without regard for the concentration of diesel particulate matter that may be present at any time.

§ 57.5065 Fueling and idling practices.

(a) Diesel fuel used to power equipment in underground areas shall not have a sulfur content greater than 0.05 percent. The operator shall retain purchase records evidencing compliance with this requirement for one year after the date of purchase.

(b) Only fuel additives registered by the U.S. Environmental Protection Agency shall be used in diesel powered equipment operated in underground areas.

(c) Idling of mobile diesel-powered equipment in underground areas is prohibited except as required for normal mining operations.

§ 57.5066 Maintenance standards.

(a) Any diesel powered equipment operated at any time in underground areas shall meet the following maintenance standards:

(1) Any approved engine shall be maintained in approved condition;

(2) The emission related components of any non-approved engine shall be maintained to manufacturer specifications; and

(3) Any emission or particulate control device installed on the equipment shall be maintained in effective operating condition.

(b)(1) A mine operator shall authorize and require each miner operating diesel powered equipment covered by paragraph (a) of this section to affix a visible and dated tag to such equipment at any time the miner notes any evidence that the equipment may require maintenance in order to comply with the maintenance standards of paragraph (a) of this section.

(2) A mine operator shall ensure that any equipment tagged pursuant to this section is promptly examined by a person authorized by the mine operator to maintain diesel equipment, and the affixed tag shall not be removed until such examination has been completed.

(3) A mine operator shall retain a log of any equipment tagged pursuant to this section. The log shall include the date the equipment is tagged, the date an examination was made of such equipment, the name of the person making such examination, and any action taken as a result of such examination. The information in the log with respect to any piece of equipment examined as a result of this section shall be retained for one year after the date of examination.

(c) Persons authorized by a mine operator to maintain diesel equipment covered by paragraph (a) of this section must be qualified, by virtue of training or experience, to ensure that the maintenance standards of paragraph (a) of this section are observed. An operator shall retain appropriate evidence of the competence of any person to perform specific maintenance tasks in compliance with those standards for one year after the date of any maintenance, and shall upon request provide such documentation to the authorized representative of the Secretary.

§ 57.5067 Engines.

Any diesel engine introduced into an underground area of a mine covered by this part after [date 60 days after date publication of the final rule], other than an engine in an ambulance or fire fighting equipment which is utilized in accordance with mine fire fighting and evacuation plans, must have affixed a plate evidencing approval of the engine pursuant to subpart E of Part 7 of this title or pursuant to Part 36 of this title.

§ 57.5070 Miner training.

(a) All miners at a mine covered by this part who can reasonably be expected to be exposed to diesel emissions on that property shall be trained annually in—

(1) The health risks associated with exposure to diesel particulate matter;

(2) The methods used in the mine to control diesel particulate matter concentrations;

(3) Identification of the personnel responsible for maintaining those controls; and

(4) Actions miners must take to ensure the controls operate as intended.

(b) An operator shall retain at the mine site a record that the training required by this section has been provided for one year after completion of the training.

§ 57.5071 Environmental monitoring.

(a) Mine operators shall monitor as often as necessary to effectively evaluate, under conditions that can be reasonably anticipated in the mine—

(1) Whether the concentration of diesel particulate matter in any area of

the mine where miners normally work or travel exceeds the applicable limit specified in § 57.5060; and

(2) The average full shift airborne concentration of diesel particulate matter at any position or on any person designated by the Secretary.

(b) The mine operator shall provide affected miners and their representatives with an opportunity to observe exposure monitoring required by this section. Mine operators must give prior notice to affected miners and their representatives of the date and time of intended monitoring.

(c) If any monitoring performed under this section indicates that the applicable concentration limit established by § 57.5060 has been exceeded, an operator shall promptly post notice of the corrective action being taken, initiate corrective action by the next work shift, and promptly complete such corrective action.

(d)(1) The results of monitoring for diesel particulate matter, including any results received by a mine operator from sampling performed by the Secretary, shall be posted on the mine bulletin board within 15 days of receipt and shall remain posted for 30 days, and a copy shall be provided to the authorized representative of miners.

(2) The results of any samples collected by a mine operator as a result of monitoring under this section, and information about the sampling method used for obtaining such samples, shall be retained for five years from the date of the sample.

§ 57.5075 Diesel particulate records.

(a) The table entitled ''Diesel Particulate Recordkeeping Requirements'' lists the records which must be retained by operators pursuant to §§ 57.5060 through 57.5071, and the duration for which particular records need to be retained.

DIESEL PARTICULATE RECORDKEEPING REQUIREMENTS

Record	Section reference	Retention time
Approved application for extension of time to comply with final concentration limit	§ 57.5060(c)	1 year beyond duration of extension.
Control plan	§ 57.5062(b)	1 year beyond duration of plan.
Compliance plan verification sample results	§ 57.5062(c)	5 years from sample date.
Purchase records noting sulfur content of diesel fuel	§ 57.5065(a)	1 year beyond date of purchase.
Maintenance log	§ 57.5066(b)	1 year after date any equipment is tagged.
Evidence of competence to perform maintenance	§ 57.5066(c)	1 year after date maintenance performed.
Annual training provided to potentially exposed miners	§ 57.5070(b)	1 year beyond date training completed.
Sampling method used to effectively evaluate mine particulate concentration, and sample results	§ 57.5071	5 years from sample date.

(b)(1) Any record listed in this section which is required to be retained at the mine site may, notwithstanding such requirement, be retained elsewhere if the record is immediately accessible from the mine site by electronic transmission.

(2) Upon request from an authorized representative of the Secretary of Labor, the Secretary of Health and Human Services, or from the authorized representative of miners, mine operators shall promptly provide access to any record listed in the table in this section.

(3) A miner, former miner, or, with the miner's or former miner's written consent, a personal representative of a miner, shall have access to any record required to be maintained pursuant to § 57.5071 to the extent the information pertains to the miner or former miner. Upon request by such person, the operator shall provide the first copy of such record requested by a person at no cost to that person, and any additional copies requested by that person at reasonable cost.

(c) Whenever an operator ceases to do business, that operator shall transfer all records required to be maintained by this part, or a copy thereof, to any successor operator who shall receive these records and maintain them for the required period.

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Appendix to Preamble—Background Discussion—MSHA's Toolbox

Note: This Appendix will not appear in the Code of Federal Regulations. It is provided here as a guide.

PRACTICAL WAYS TO REDUCE EXPOSURE TO DIESEL EXHAUST IN MINING - - A TOOLBOX

U.S. Department of Labor
Alexis M. Herman, Secretary

Mine Safety and Health Administration
J. Davitt McAteer, Assistant Secretary

Andrea M. Hricko, Deputy Assistant Secretary

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ACKNOWLEDGEMENTS

The Mine Safety and Health Administration (MSHA) held a series of workshops in the fall of 1995 to obtain input from the mining community on ways of reducing miners' exposure to diesel particulate matter from the exhaust of diesel engines.

MSHA thanks those who attended the workshops and willingly shared their ideas on practical ways to reduce exposure to diesel emissions in mining. These practical ideas have been utilized in producing this "Toolbox." A key objective of the toolbox is to facilitate the exchange of practical information on ways to reduce miner exposure to diesel exhaust emissions.

Thanks are also extended to former U.S. Bureau of Mines scientists, from whose diesel-related publications the text of this handbook draws, and to Robert Waytulonis, Associate Director of the University of Minnesota's Center for Diesel Research.

Credit is given to the following MSHA staff for their efforts in organizing the Diesel Exhaust Workshops, their role in selecting pertinent quotations from the workshop transcripts, and in contributing to or reviewing this manual: Kathy Alejandro, Janet Bertinuson, Teresa Carruthers, Jerry Collier, James Custer, George Dvorznak, Guy Fain, Ron Ford, Don Gibson, Hal Glassman, Jerry Lemon, Pamela King, James Kirk, Jon Kogut, Cheryl McGill, William McKinney, Ed Miller, Charlotte Richardson, Bryan Sargeant, Erik Sherer, Pete Turcic, and Sandra Wesdock. Thanks also to Liz Fitch and Mike Doyle for their help in reviewing early drafts, to Todd Taubert for help with the section on lugging, to Reggie McBee and Bria Culp for editorial support, to Anne Masters for graphic design support, and to Bill West for internet conversions.
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In addition, MSHA thanks other segments of the mining industry that provided comments for consideration in the Toolbox.

Andrea Hricko, Deputy Assistant Secretary of MSHA, provided guidance in organizing the Diesel Workshops and worked closely with Winthrop Watts of the University of Minnesota, and Thomas Tomb, Chief of MSHA's Dust Division, as well as with Robert Haney and George Saseen of MSHA's Office of Technical Support, in creating this "Toolbox." Thanks to Peter Galvin for consolidating the final draft while on detail to MSHA from the Office of the Solicitor and to Keith Gaskill for shepherding the "Toolbox" through to publication.

Special thanks to Winthrop F. Watts, Jr., Ph.D., of the University of Minnesota, Center for Diesel Research, for conceptualizing the "Toolbox" and for writing the first drafts of this manual under contract to the Mine Safety and Health Administration.

HOW TO USE THIS PUBLICATION

Who should use this publication?

If your mine uses diesel-powered equipment, or is contemplating its use, you will find this Toolbox to be a useful guide. So too will those who help mine operators select or maintain mining equipment. The Toolbox can be read cover-to-cover as a basic reference, or used as a troubleshooting guide by diesel equipment operators and mechanics. Some knowledge of engines is assumed, although a glossary is provided.

Is this only of interest to underground mines?

No. While some sections are of special interest only to underground mines (e.g., ventilation), most of this publication is of value to surface mines as well.

Is the Toolbox useful in any type of mining?

Yes. The ideas and concepts are just as relevant in metal and nonmetal mines as they are in coal mines, and many of the controls described are available to operators in both sectors.

How can I find what I need quickly?

The Table of Contents on the first page of this handbook can be used to quickly locate a topic of interest. Technical terms or materials are discussed or referenced in appendices.

If I follow the recommendations in the Toolbox, will I be in compliance with MSHA requirements?

This publication is NOT a guide to applicable Federal or State regulations on the use of diesel engines, or the measurement or control of their emissions on mining property. Selection of an approach from the toolbox must be made in light of the need to comply with such requirements. Appendix D references some of the requirements which should be consulted. Please contact your local MSHA office if you have any questions about applicable requirements.

As of the date of this Toolbox printing, MSHA is making final decisions on proposing some additional regulations about diesel emissions. These proposed new rules would help the mining community address the risks created by miner exposure to diesel particulate matter—the very small particles that are part of the diesel exhaust. The Agency expects to publish these proposed rules for comment early in 1998. While the requirements that will ultimately be implemented, and the schedule of implementation, are of course uncertain at this time, MSHA encourages the mining community not to wait to protect miners' health. MSHA is confident that whatever the final requirements may be, the mining community will find this Toolbox information of significant value.

Does MSHA want my input on this subject?

MSHA welcomes your suggestions on how to improve future editions of this Toolbox, and information on your experiences in reducing exposure to diesel emissions. Please direct any comments to: Chief, Pittsburgh Safety and Health Technology Center, Cochrans Mill Road, P.O. Box 18233, Pittsburgh, Pa. 15236. You may also fax them to 412-892-6928, or e-mail them to chiefpshtc @msha.gov.

Special Note on Regulations Involving the Use of Diesel-powered Equipment in Underground Coal Mines

On April 25, 1997, certain key provisions of MSHA's final rule on the use of diesel-powered equipment in underground coal mines went into effect. Other provisions of that rule will go into effect over the next three years. Some of these regulations require the implementation of particular strategies recommended in this Toolbox.

Since the mining community is still becoming familiar with these requirements, some of them are noted in the text at appropriate places, using italics. MSHA hopes this will serve as a useful reminder for underground coal mine operators, without being distracting to the remainder of the mining community.

A compliance guide for the new underground coal mine diesel regulations, in the form of Questions and Answers, has been prepared by MSHA, and is being widely circulated. While this Toolbox is not a substitute for the compliance guide or a copy of the regulations, neither are the compliance guide or the regulations a substitute for this Toolbox—all three documents will be useful for underground coal mine operators and miners.

INTRODUCTION

The Problem

Diesel engines are widely used in mining operations because of their high power output and mobility. Many mine operators prefer diesel-powered machines because they are more powerful than most battery-powered equipment and can be used without electrical trailing cables which can restrict equipment mobility. Underground coal and metal and nonmetal mines currently use approximately 10,000 diesel machines and about 35 percent of these are used for heavy-duty mining production applications. The use of diesel equipment in mining is on the rise, as described by speakers at a series of Workshops on Controlling Diesel Emissions sponsored by MSHA in the fall of 1995:

"In 1985, we had a total mine horsepower of 6,851 horsepower. Today, in 1995, our horsepower has risen to 14,885 horsepower in the mine."

—David Music,
Akzo Nobel Salt's Cleveland Mine

"...Today we have over a hundred pieces of diesel equipment, large and small, anywhere from a Bobcat to large section scoops, generators, welders, compressors, trucks that are used on open highways, and diesel trucks."

—Forrest Addison,
UTAH Coal Miner (UMWA)

The estimated distribution of diesel equip-ment in mining is shown in Table 1. An estimated 30,000 miners work at underground mines using such equipment and approximately 200,000 miners work at surface operations using such equipment.

Table 1. Estimated Distribution of Diesel Equipment

Mines Using Diesel Engines

Type	Underground #Mines	Underground #Engines	Surface #Mines	Surface #Engines
Coal	180	2,950	1,700	22,00
Metal and Nonmetal	250	7,800	10,500	97,000
Totals	430	10,750	12,000	119,000

There is a downside, however, to the use of diesel equipment, especially in the underground mining environment. The problem is the potential acute and long-term health effects of exposure to various constituents of diesel exhaust, which consists of noxious gases and very small particles.

The gases in diesel emissions include carbon monoxide, carbon dioxide, oxides of nitrogen, sulfur dioxide, aromatic hydrocarbons, aldehydes and others. MSHA sets limits on miner exposure to a number of these gases. These limits are specified in Title 30 CFR § 75.322 and § 71.700 for underground and surface coal mines and § 57.5001 and § 56.5001 for underground and surface metal and nonmetal mines.

The particles in diesel emissions are known as "diesel particulate" (DP), or "diesel particulate matter" (DPM). Diesel particulate matter is small enough to be inhaled and retained in the lungs. The particles have hundreds of chemicals from the exhaust adsorbed (attached) onto their surfaces.

The mining community is very familiar with the specific hazards long associated with other particulates of respirable dimensions–like coal mine dust and dust that contains silica. A recent body of evidence, based on studies of air pollution, suggests that exposure to smaller particles (including those present in diesel exhaust) is likewise associated with increased rates of death and disease. Specific evidence has also been accumulating that exposure to high levels of DPM can increase the risk of cancer. In 1988, the National Institute for Occupational Safety and Health recommended that whole diesel exhaust be regarded as a "potential occupational carcinogen," and that reductions in workplace exposure be implemented to reduce cancer risks. In 1989, the International Agency for Research on Cancer declared that "diesel engine exhaust is probably carcinogenic to humans." In 1995, the American Conference of Governmental Industrial Hygienists (ACGIH) added DPM to its "Notice of Intended Changes" for 1995-96, recommending a threshold limit value (TLV®) for a conventional 8-hour work day of 150 micrograms per cubic meter (150 $\mu g/m^3$).

Note on Diesel Particulate Matter Measurements: Microgram v. Milligram

In this Toolbox, measurements of DPM are expressed in micrograms (µg) per cubic meter of air. A microgram is one millionth of a gram. However, in many references, you may see the DPM measurements expressed as milligrams (mg) per cubic meter of air. A milligram is one thousandth of a gram.

1 $\mu g/m^3$=1 milligram per cubic meter of air
1 $\mu g/m^3$=1 microgram per cubic meter of air

1 milligram=1,000 micrograms. So if you want to convert from milligrams to micrograms, multiply by 1000–or move the decimal point three places to the right.

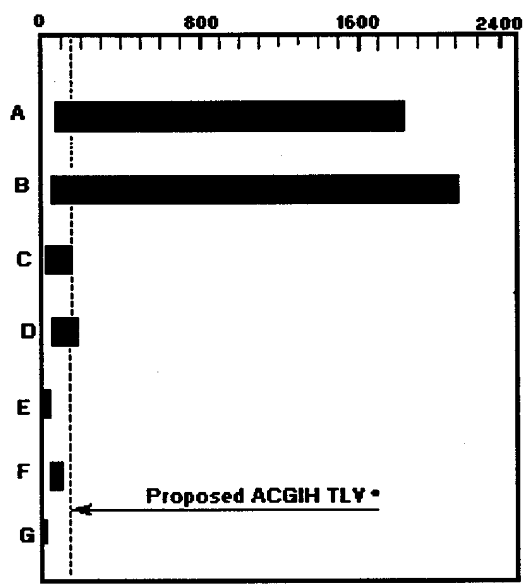
For example, 0.15 mg/m^3=150 $\mu g/m^3$.

Many non-mining workplaces where diesel equipment is used have levels of DPM well below the recommended ACGIH TLV®.In contrast, studies conducted by various scientific researchers demonstrate that exposures to DPM in mining environments can be significantly higher than exposures in the ambient air or in other workplaces.

Figure 1 provides a rough visual picture of the range of DPM exposures of miners, as compared with the range of exposures of other groups of workers who routinely work with diesel-powered equipment. As can be readily seen, the range of exposures in mining environments are significantly higher than in other environments.

Figure 1. Diesel Particulate Exposures in Several Industry Segments

Range of Average DPM Exposures, µg/m³.



A=Underground Metal and Nonmetal Mine
B=Underground Coal Miners
C=Surface Miners
D=Railroad Workers
E=Truck Drivers
F=Dock Workers
G=Ambient Air (Urban)

Table 2 provides additional detail about the levels of exposure in U.S. mines. The higher concentrations in underground mines are typically found in the haulageways and face areas where numerous pieces of diesel equipment are operating, or where insufficient air is available to ventilate the operation. In surface mines, the higher concentrations are typically associated with truck drivers and front-end loader operators.

Table 2. Measured Full-Shift Diesel Particulate Matter Exposure in U.S. Mines

Type	Range of exposure, mg/m^3	Mean exposure, mg/m^3
Surface	9-380	88
Underground Coal	0-3,650	644
Underground Metal and Nonmetal	10-5,570	830

In 1988, MSHA's Advisory Committee on Diesel-Powered Equipment in Underground Coal Mines recognized a number of risks related to the use of diesel-powered equipment in such mines, including the potential risks of exposing miners to diesel emissions. The Committee made recommendations to address its concerns.

Since that time, MSHA has taken several actions relative to diesel exhaust. In 1989, MSHA proposed "air quality" regulations which would, among other things, set stricter limits on some diesel exhaust gases. These regulations remain under review. In 1996, after notice and comment, MSHA issued final regulations for the use of diesel-powered equipment in underground coal mines. These rules will go into effect over a 3-year period. And in response to a specific recommendation of the Advisory Committee that, "The Secretary (of Labor) should set in motion a mechanism whereby a diesel particulate standard can be set…", MSHA is developing a proposed rule toward that end.

There are some cases where alternative power sources (e.g., electricity or batteries) may be the solution. But when diesel engines are used, the mining community needs to understand the potential health risks they present and take steps to reduce the hazards.

"...We're very dependent on diesel engines. At the same time, air quality in the mine is very important to IMC. We realized a long time ago that it affects both miner health and morale, and for us morale and productivity go hand in hand. So beginning in the 1970s we consciously undertook a program of improving our air quality...."

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

"...Of all the health issues that we're dealing with in the mining industry, this issue is at the top of the list...As I travel across this country, I hear more about exposure to diesel exhaust than any other single issue in the mining industry."

—Joe Main,
United Mine Workers of America

Addressing the Problem:

The Experience of the Mining Community

In 1995, MSHA established an internal working group to explore measures to reduce miners' exposure to DPM. This group organized a series of workshops to solicit input from the mining community. The workshops were designed to discuss the potential health risks to miners from exposure to DPM, ways to measure and limit DPM in mine environments, and regulatory or other approaches to ensure a healthful work environment. These workshops provided a useful forum to exchange views and concerns about limiting diesel exhaust exposure. More than 500 members of the mining community attended these workshops, providing evidence that reducing miners' exposure to diesel exhaust emissions, especially in underground mines, is a high priority for the mining industry.

The experience of the mining community appears to support several conclusions:

- The levels of exposure to DPM in mines depend upon engine exhaust emissions, the use of exhaust aftertreatment and its efficiency and, particularly in underground mines, ventilation rate and system design.
- Engine emissions are governed by engine design, work practices, duty cycle, fuel quality and maintenance. Reducing engine emissions will decrease the amount of DPM that needs to be controlled by other means and will reduce the exposure of miners.
- There is no single emission control strategy that is a panacea for the entire mining community.
- Diesel engine maintenance is the cornerstone of a diesel emission control program.

A major objective of this publication is to facilitate the exchange of practical information within the mining community on ways to reduce miners' exposure to diesel exhaust emissions. The Toolbox focuses on currently available methods of control as opposed to methods in the research and development stages. Each of the various technologies presented in the Toolbox will assist in reducing or monitoring worker exposure.

Where possible, the Toolbox quotes specific examples of methods tested or used by the mining industry to reduce exposure to diesel emissions. These quotations are taken directly from public transcripts of the 1995 MSHA workshops, and were selected to provide a representative sample of views expressed. All quotations are offset from the main text in bold lettering. The Toolbox also draws extensively from diesel-related publications prepared by former U.S. Bureau of Mines scientists. Please note that key words and phrases are highlighted in **bold** type for easy reference. [ ] brackets are used to insert explanations not found in the original quotation, "..." are used to indicate that words were removed to make the quote shorter.

MSHA hopes that the mining community will benefit from the exchange of this practical information and will take steps to reduce miners' exposure to diesel emissions, utilizing the variety of techniques described in this publication and other methods as they are developed. The Agency encourages an ongoing exchange of information on strategies to further reduce exposure to diesel emissions and to protect the health of miners.

The quotations cited in this publication do not necessarily represent the views and/or policies of MSHA, nor of the organizations or companies at which the speakers work (or worked). MSHA recognizes that some affiliations have changed since the workshops. Names and affiliations at the time of the workshop are used. Finally, reference to specific manufacturers and/or products does not imply endorsement by MSHA or the U.S. Government.

The Reason for a "Toolbox" Approach

This publication introduces a "toolbox" approach to reducing miners' exposure to diesel exhaust emissions. A toolbox offers a choice of tools, each with a specific purpose. One tool after another may be used to find a solution to a problem or several tools may be tried at the same time.

Reducing exposure to diesel emissions lends itself to a toolbox approach because no single method or approach to reducing exposure may be suitable for every situation. Examples of the "toolbox" approach to reducing exposure to diesel emissions in a mine were described at the 1995 MSHA workshops:

"Since the mid-1980s Homestake has initiated a number of work steps and tests to control the diesel emission components, and these are engine alternatives, maintenance, exhaust aftertreatments, fuels, dilution ventilation and engine type....To summarize our experiences with diesel particulate matter, we've had good luck with respirators, maintenance and fuels. We've had mixed results with diesel particulate filters and with airflows. And results are still pending on engine type. We are going to continue working in all of these areas."

—John Marks,
Homestake Mining Company

"At Galatia a three-point approach is used to ensure safe and healthy diesel operating conditions. First, the mine is designed to provide vast volumes of air to all the active workings... Second, 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, a regularly scheduled emissions test...and...a training program to educate maintenance personnel in the engine operating recommendations and requirements. The third point in our approach is the use of control technology...All permissible vehicles...at Galatia use a wet scrubber for initial particulate reduction. Additionally, 10 Ramcars that are normally assigned to production units have been retrofitted with the pleated paper diesel particulate filter. Additional vehicles are being retrofitted during equipment rebuilds."

—Keith Roberts,

Kerr McGee's Galatia Mine

"...Ventilation is an important control.... Through clean-burning diesel engines, low sulfur fuels, and effective aftertreatment technology, we can reduce emissions at the engine."

—Jeff Duncan,
United Mine Workers of America

The Toolbox is divided into nine sections—

- use of low emission engines
- use of low sulfur fuel, fuel additives and alternative fuels
- use of aftertreatment devices
- use of ventilation
- use of enclosed cabs
- diesel engine maintenance
- work practices and training
- fleet management
- respiratory protective equipment

Each section covers specific methods that are being used to reduce emissions or exposure. Use of these methods will be determined by the specific circumstances found at each mine.

"There is no single control that is a panacea for all the emission problems. Due to differences in the mine design and the mine geology, the equipment types and sizes, and their duty cycles...different types of controls are used."

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

"Because of the interrelationship of the various control technologies on workers' exposures, mine operators often use a combination of controls....These may include

ventilation…reducing engine emissions or utilizing aftertreatment devices."

—Robert Haney,
Mine Safety and Health Administration

The Toolbox

Low Emission Engines

Low emission engines are produced by engine manufacturers to meet increasingly stringent Environmental Protection Agency (EPA) regulations. Mine operators can benefit from discussing the condition of their diesel fleet with diesel manufacturers prior to ordering new diesel engines. Moreover, benefits can be gained by replacing older model engines that require more maintenance with newer engines. In addition, lower emissions and greater machine availability (i.e., the machine does not break down as often) are normally achieved with a newer type engine.

Low-emission engines typically operate at high fuel injection pressures which provide more efficient and complete combustion of fuel. These engines are frequently turbocharged to optimize power, performance, and emissions. After-cooling (cooling intake air that is compressed and heated by the turbocharger prior to induction into the combustion chamber) is used to reduce oxides of nitrogen (NO_x). Electronic engine control is another technological improvement, which optimizes the fuel-to-air ratio resulting in lower emissions.

As a result of EPA regulations in 1988, "on-highway" heavy duty diesel engine emissions have been significantly reduced. Emissions standards have driven particulate emissions levels for such engines from 0.6 grams per horsepower-hour (g/hp-h) in 1988 to less than 0.1 g/hp-h in 1994, and oxides of nitrogen emissions from 10.7 g/hp-h in 1985 to 5.0 g/hp-h in 1991. The EPA regulations provide a schedule for continued improvement. Pursuant to an agreement with the engine industry, the EPA has also proposed a new round of emission reductions in highway engines to begin with models produced in 2004.

In 1996, the EPA established emission regulations for almost all land-based non-road ("off-highway") diesels, such as construction equipment. These regulations specify emission levels that non-road engines must meet depending on the horsepower of the engine. Currently, the regulations affect only non-road engines from 175-750 horsepower. For this category, the 1996 standard reduces particulate emissions from as high as 1.0 g/hp-h to 0.4 g/hp-h and oxides of nitrogen emissions to below 6.9 g/hp-h. The rule phases in limits for other horsepower engines. Modern engines developed for non-road use are expected to provide the mining industry with a greater choice of low emission engines for use underground. It should be noted that diesel engines used in underground coal mines are primarily indirect injection engines (pre-chamber), which in some cases could meet certain EPA non-road requirements. In September 1997, pursuant to an agreement with the engine industry, the EPA proposed a new round of emission reductions in non-road engines to begin with models produced in 1999.

Engines that have been approved or certified by agencies such as MSHA, EPA or the state of California generally have lower emissions. Larger on-highway type engines built after 1988 and non-road engines built after 1996 have been designed to produce lower emissions to meet the stringent on-highway emission standards discussed above. For engines approved under Part 7, subpart E for underground mining applications, MSHA determines a particulate index (PI). The PI indicates the quantity of ventilation air required to dilute particulate emissions from a specific engine operated over a test cycle to a concentration of 1 milligram (1000 micrograms) per cubic meter of air. Mine operators and machine manufacturers of mining equipment can use the PI in selecting and purchasing engines. The lower the PI number, the lower the particulate emissions for the same horsepower engine. Mine operators may also use the PI to roughly estimate each engine's contribution to the mine's levels of total respirable dust in coal mines or the levels of diesel particulate in metal/nonmetal mines. In underground coal mines, all engines must be Msha-approved engines by November 25, 1999.

"...Diesel engines continue to become cleaner; there will be more emission legislation out there in the future.... Diesel engine fuel efficiency has improved at the same time; power density has continued to climb; diesel engine life has steadily increased."

—Peter Woon,
Cummins Engine

"In over the road truck engines, there has been about a 90 percent reduction in just going to cleaner engine technologies, and these are results that apply to well-maintained, new engines..."

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

"Now, this class of engines [modern, low emission engines] has high horsepower, typically from 250 hp up to 500 hp, so they are not suitable for all types of mining equipment.... They have the advantage of producing 80-90 percent less particulate than the conventional naturally-aspirated prechamber engines. They consume on the order of 25 percent less fuel. In the case of the Cat 3306 swirl, it's a drop-in replacement for some of the older 3306 technology."

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

"[Start] with buying a clean engine as opposed to some of these polluting engines that dump out all kinds of NO_x's and carbon monoxide. Buy the cleaner engines..."

—Joe Main,
United Mine Workers of America

"We felt that the problems we had with filters...were so severe and caused so many problems that it was a lot better to clean up the source, and so we got cleaner engines. We are using one manufacturer's engine. We're getting another—in fact, we're getting one of the new...Detroit Diesel engines with electronic controls just for that reason in the next machine we buy.... Utilization of highway-type diesel engines in our replacement engine program is providing us cleaner burning, reliable engines at a lower cost than the regular mining-type engines and a post-combustion device..."

—Ray Ellington,

Morton Salt

USE OF LOW SULFUR FUEL, FUEL ADDITIVES AND ALTERNATE FUELS

In general, emissions can vary from engine to engine and across different engine load conditions, even though all engines are operated using the same basic type of fuel and fuel additive package. Variations occur because the details of the combustion process differ with engine design and methods used to control fuel to the engine as well as with the duty cycle of the engine. Therefore, the following comments on fuel composition and additives should be viewed as generally applicable to an average diesel engine operated over a range of duty cycles.

The quality of the **diesel fuel** influences emissions. Sulfur content, cetane number, aromatic content, density, viscosity, and volatility are interrelated fuel properties which can influence emissions. Sulfur content can have a significant effect on diesel particulate matter emissions. In addition, it affects sulfur oxide (SO_x) emissions, all forms of which are toxic. Moreover, SO_x emissions can poison catalytic converters, and the continued use of high sulfur fuel will contribute to increased piston ring and/or cylinder liner wear.

Cetane number affects all regulated pollutants, and fuel aromatic content affects DPM and nitrogen oxides (NO_x). Therefore, it is important to provide fuel distributors with specific fuel specifications and recommended property limits when purchasing diesel fuel. Table 3 lists recommended property limits for diesel fuel. However, some of the property limits listed may not be commercially available in all areas at this time.

Table 3. Recommended Property Limits for Diesel Fuel

Property	Limit
Cetane number	>48
Aromatic Content	<20%
90% distillation temperature	<600° F
Sulfur content	<0.05% by mass

Use of **low sulfur diesel fuel** (< 0.05 percent sulfur) reduces the sulfate fraction of DPM emissions, reduces objectionable odors associated with diesel use, and allows oxidation catalysts to perform properly. Another benefit from the use of low sulfur fuel is reduced engine wear and maintenance costs. Fuel sulfur content is particularly important when the fuel is used in low emission diesel engines. Low sulfur diesel fuel is available nationwide due to EPA regulations. *As of April 25, 1997, diesel-powered equipment in underground coal mines must use low-sulfur fuel.*

"...There is an ASTM-975-93 specification [on low sulfur fuel] from the EPA. All you have to do is to specify that fuel on your purchase order, and this is the fuel they have to deliver. You just have to insist on it."

—Norbert Paas,
Paas Technology

"...Homestake used a straight No. 2 diesel fuel with up to 0.5 percent fuel sulfur until 1991 when we switched to a premier No. 2 with 0.12 percent fuel sulfur. Since about the start of 1995 we've gone to the 0.05 percent No. 2."

—John Marks,
Homestake Mining Company

"For fuel we use a low sulfur diesel fuel that typically averages 0.041 percent sulfur and a cetane number of 54."

—Bill Olsen,
Mountain Coal Company,
West Elk Mine

The cetane number of U.S. diesel fuel can range between 40 and 57. Increased cetane number and volatility, (as measured by a fuel's distillation temperature characteristics) reduces both hydrocarbon emissions and the tendency to produce white smoke, which occurs when an engine is either cold or under low load. White smoke is mostly water vapor, unburned fuel and a small portion of lube oil. Fuel with a cetane number greater than 48 and a seasonably adjusted cloud point reduces cold-start hydrocarbon emissions, odor, noise, irritant and fuel system wax separation problems.

"...Cetane number is very important—needed for good starting, good combustion and for emission performance of engine.... When cetane number is improved, either by cetane additive or base fuel composition...so that cetane number is improved from 45 to 55, there's a dramatic reduction in hydrocarbons...and...in carbon monoxide...and more than 10 percent reduction in particulates"

—Kashmir Virk,
Texaco, Inc.

Typical No. 2 diesel fuel in the U.S. has an aromatic hydrocarbon content of 20 to 40 percent. Reducing the aromatic hydrocarbon content and the 90 percent distillation temperature of the fuel reduces the soluble organic fraction of DPM and NO_x emissions.

A variety of **fuel additives** are available to reduce emissions. For example, cetane improvers increase the cetane number of the fuel, which may reduce emissions and improve starting. Oxygenated additives increase the availability of oxygen needed to oxidize hydrocarbons in the fuel. Detergents are used primarily to keep the fuel injectors clean. Dispersants or surfactants prevent the formation of thicker compounds that can form deposits on the fuel injectors or plug filters. Lubricity additives are similar to corrosion inhibitors and are frequently added to fuel by petroleum producers. There are also stability additives which prevent the fuel from breaking down when it is stored for long periods of time. Only additives registered by the EPA are recommended for use, to ensure that no harmful agents are introduced into the mine environment. *As of April 25, 1997, only diesel fuel additives that have been registered by the epa may be used in diesel-powered equipment in underground coal mines.*

"...There's a variety of different types of compounds you can add that contain oxygen. Typical diesel fuel doesn't have much oxygen.... [When significant quantities of oxygenates are added to fuel, the oxygen content of the fuel is increased], ...You end up seeing...reductions in particulate emissions, hydrocarbon emissions and CO..., and NO_x levels may increase or decrease slightly depending on the engine and load cycle."

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

"We took a very serious look at metal additives...for on-highway trucks.... We–Caterpillar–and the industry decided not to go that way...[One] concern was [that] these chemicals may actually cause health effects in their own rights..."

—John Amdall,
Caterpillar

"...Detergent-type additives in the fuel primarily prevent coking or fouling [partial plugging] of the injectors. And if you don't use a detergent additive, pretty much all your emissions go up over time... [However] just using a detergent is not going to make up for an engine that's wearing out or isn't properly adjusted or maintained. ...Metals as a group reduce the visible smoke output. ...The problem with metal additives is they show up on the particulate. Metals don't burn up. ...Metals are known to have some biological effects just like diesel particulates would. So I would not recommend that you [use] any of the metal additives for reducing [diesel particulates]."

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

Another promising control technology is **alternative fuel**, especially biodiesel fuels made from methyl esters derived from soybeans, although these are not readily available on the market.

This type of fuel contains about 10 percent oxygen, has a high cetane number, and a much higher flash point. These properties improve combustion, starting, performance and safety characteristics of the fuel. To maximize the reductions in exhaust emissions, it is recommended that biodiesel fuels be used with a diesel oxidation catalyst. EPA has certified a biodiesel brand known as Envirodiesel®, which is being used in combination with diesel oxidation catalyst by urban bus transit operators.

"The Bureau of Mines demonstrated that the combination of methyl soyate fuel and modern diesel exhaust catalyst is a passive control scheme that is very effective.... [In tests conducted at the Homestake Gold Mine], a Wagner load-haul-dump was operated using a 100 percent methyl soyate fuel and a modern catalyst. Compared to baseline emissions, a 70 percent reduction in the ambient levels of [diesel] particulate matter was achieved...."

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

"...Homestake cooperated with the [former]Bureau of Mines to successfully evaluate a soy methyl ester [biodiesel] fuel...miner acceptance was good, and the leftover [biodiesel] fuel was quickly used by our miners."

—John Marks,
Homestake Mining Company

USE OF AFTERTREATMENT DEVICES

Water scrubbers are basically a safety device used on "permissible" equipment in underground mines. Water scrubbers perform three functions: cool exhaust gases to safe temperatures, arrest sparks and arrest flames.

The exhaust airflow from a diesel engine passes through water, making direct contact with the water. This direct contact with the water cools the air and quenches flames and sparks. Although not intended as an emission control device, scrubbers have been shown to remove about 30 percent of DPM from an engine's exhaust stream. Moreover, because water scrubbers cool the exhaust gases, they enable the equipment to be fitted with high efficiency paper filters that reduce DPM. Water scrubbers have no signifcant effect on gaseous emissions.

"The water scrubber...is not an emission control, it's a safety control, but incidentally, it will remove 20 to 30 percent of the particulate.... They require frequent maintenance."

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

"Water scrubbers are not a pollution control, they are a fire control system..., but scrubbers create condensation in the air and increase mine air humidity...and with several pieces of diesel equipment using water scrubbers [on a section], the increased heat effect because of the humidity is a significant concern...."

—Joe Main,
United Mine Workers of America

The **exhaust location** can make a big difference in the concentration of pollution to which equipment operators and nearby miners are exposed. The location should be such that exhaust is directed away from the vehicle operator. The exhaust gas can be directed across the radiator, thus providing immediate dispersal by the radiator fan, or an exhaust extender can be used to **redirect the exhaust away** from the operator or nearby miners. These workers can be exposed to significant concentrations of diesel exhaust constituents before they can be diluted, even at surface mines. **Exhaust dilutors** can also be used in vented headings and tunnels.

"Wouldn't it be nice if we could take that exhaust and put it somewhere else on the vehicle, so then, at the very least, the Ramcar operator is not subject to his own vehicle's emissions?"

—Jan Mutmansky, Ph.D.,
Pennsylvania State University

Exhaust filtration devices capture DPM from the exhaust before it enters the mine atmosphere. Filters used to capture particulate or other exhaust constituents are called **after-treatment devices**.The most commonly used exhaust filtration devices are: **disposable diesel exhaust paper filters and catalyzed or uncatalyzed diesel particulate ceramic filters**.

Particulate control systems using these components typically have removal efficiencies ranging between 50 and 95 percent; that is, they remove 50 to 95 percent of the particulate. It is important to note that an aftertreatment device that is 90 percent efficient is twice as effective for removing DPM as an 80 percent efficient device: only10 percent instead of 20 percent of the particulate would remain in the exhaust.

The **disposable diesel exhaust filter** is similar to the intake air filter used on over-the-road haulage vehicles. It is placed downstream of a water scrubber or a water jacketed heat exchanger, capturing DPM from the exhaust stream. The filter is discarded after being loaded with DPM. Some states such as Pennsylvania require the loaded filters to be bagged and brought to the surface for disposal.

Tests of the disposable diesel exhaust paper filters at two underground coal mines resulted in up to 95 percent reduction in DPM. Utilization of different filtration media and careful application of these filters combined with cleaning and reuse can extend the life of the filters. When used with a water scrubber, proper maintenance of the water level is necessary to eliminate the risk of hot exhaust gases igniting the filter.

"...Disposable paper filters are installed on the Ramcars such that the exhaust first passes through the water scrubber, then through a water trap or baffle system to prevent water droplets from being carried by the exhaust stream to the filter, and then finally through the low-temperature paper filter. There's an exhaust temperature shutdown installed in front of the paper filter to prevent the exhaust gases from reaching 212o F, which is the maximum safe operating temperature of the filter. There's a back pressure gauge mounted in the operator's cab to help them know when the filters need to be changed out."

—Bill Olsen,
Mountain Coal Company,
West Elk Mine

"Today, the best strategy to use on a diesel Ramcar is to use the changeable paper filters that many mining companies are currently using."

—Jan Mutmansky, Ph.D.,
Pennsylvania State University

"...the Ramcar operators quickly accepted the filters and wanted them installed on all the face equipment. We have since installed the disposable diesel exhaust filters on our Wagner 25xs, Teletrams and Petitto Mule.... ...We typically get about six hours off the Ramcar and Petitto Mules. On our Wagner systems we average approximately four hours of service life...."

—Bill Olsen,
Mountain Coal Company,
West Elk Mine

"...In our experience, the lifetime of the filters has varied anywhere from 8 hours to 32 hours–provided that the engine on which the filter is installed is tuned properly so that it is not putting out too much soot. [The actual time between filter changes will vary depending upon the vehicle and engine's state-of-maintenance, duty cycle and other parameters.]"

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

Catalyzed or uncatalyzed ceramic diesel particulate filters currently available can reduce DPM emissions from 60 to 90 percent. Exhaust passes through the ceramic or metallic diesel particulate filter which traps the particulate matter. As exhaust continues to pass through the filter, filtering continues, and the filter slowly becomes clogged with DPM. Clogging increases the exhaust back pressure which can lead to engine damage unless the exhaust back pressure is lowered by cleaning the filter.

Vehicles which have sufficiently high exhaust temperature (at least 325oC, 25 percent of the time) can automatically clean the filter using a process called autoregeneration or self-cleaning. During autoregeneration the high exhaust temperature causes the trapped DPM to ignite and burn, thus reducing the exhaust back pressure on the engine and allowing more DPM to be trapped. For other vehicles, regeneration can be assisted by the application of a catalyst to the filter, which lowers the regeneration temperature, or by the use of on- or off-board regeneration systems.

"There are approximately 1,000 diesel particulate filters presently [being used] on mining vehicles throughout the world."

—Dale McKinnon,
Manufacturers of Emission Control Association

"In 1989 Homestake initiated a test on ceramic wall flow diesel particulate filters. Eight units were tested on a Cat 3306, different loaders from three different suppliers. One failed right away and was replaced by the supplier. Five lasted on the average about 2,000 hours, and two went over 3,000 hours. Miner acceptance was good when the filters were working properly."

—John Marks,
Homestake Mining Company

Although ceramic diesel particulate filters are useful, they may present problems for some users.

"...Number one, while ceramic filters give good results early in their life cycle, they have a relatively short life, are very expensive and unreliable. Number two, other post-combustion devices are not readily available for the larger horsepower production equipment we are currently using. When evaluated for lower horsepower support equipment, they appear to be very costly with no proven reliability..."

—Ray Ellington,
Morton Salt

Oxidation catalytic converters (OCCs) are used to reduce the quantity of carbon monoxide and hydrocarbons (including harmful aldehydes) in diesel exhaust. Oxidation catalytic converters also decrease the soluble organic fraction of DPM as well as gas phase hydrocarbons, which can reduce DPM emissions by up to 50 percent. The soluble organic fraction of the DPM exhaust contains known carcinogenic compounds such as benzo(a)pyrene and other polycyclic aromatic hydrocarbons.

Use of low sulfur fuel (<0.05 percent sulfur) with OCCs is critical because air quality is harmed when fuel containing moderate or high sulfur (>0.1 percent) is used. An OCC oxidizes sulfur dioxide to form sulfates which increase particulate emissions. OCCs can also oxidize nitric oxide to more harmful nitrogen dioxide. Modern catalysts are formulated to minimize the production of sulfate particulate matter and nitrogen dioxide, provided they are used with high quality low sulfur fuel.

The OCC should be located as close as possible to the exhaust manifold to ensure maximum exhaust gas temperature. The catalyst formulation and its operating temperature are critical factors in converter performance. The temperatures required for 50 percent conversion of carbon monoxide and hydrocarbons are typically about 370oF and 500oF , respectively. As higher exhaust gas temperatures are attained, conversion efficiency increases. The use of high sulfur fuel reduces the life of catalytic converters. New catalyst technology and the availability of low sulfur fuel make the use of OCCs on underground mine vehicles an attractive tool for reducing diesel particulate emissions.

“There are also over 10,000 oxidation catalysts that have been put into the mining industry over the years. …Sulfation is key in particulate control; you don’t want a catalyst to cause any oxidation of the sulfur. I remem-ber once I was in India, and there was a complaint that they put a catalyst on and they were saying it caused smoke. And it did, a lot of smoke. I took a fuel sample and the fuel had 2.2 percent sulfur in it, not 0.25 percent. …Engine, fuel and aftertreatment control technology must work together.”

—Dale McKinnon,
Manufacturers of Emission Control Association

“The Homestake Mine has had extensive experience with oxidation catalysts…. We have always had them on our diesel units. And I know there’s been a controversy on whether they might improve the work environment or harm it, but with low sulfur fuel I don’t think there’s any doubt they are a benefit. They oxidize the CO to CO_2, and they burn off some of the unburned hydrocarbons and some of the components of diesel exhaust. We like them. The [modern] catalytic purifiers, to my knowledge, limit the NO-to-NO_2 conversion, and with the low sulfur fuel you don’t get the sulfates coming out. So we think we’re better off with them.”

—John Marks,
Homestake Mining Company

Dry system technology. An alternative to water scrubbers for meeting the exhaust gas cooling, spark arresting, and flame arresting requirements is the Dry System Technology (DST®). With this technology, the exhaust gas does not come into direct contact with cooling water, but is indirectly cooled by a water-cooled heat exchanger such as a tube and shell heat exchanger. This cooling process does not involve the evaporation of water. Spark and flame arrest are provided by mechanical means.

The DST® also includes a water-jacketed oxidation catalytic converter and a disposable diesel exhaust filter to reduce diesel emissions. The oxidation catalytic converter is located upstream of the water-cooled heat exchanger. Exhaust then passes through the water-jacketed heat exchanger, a paper filter and a flame arrestor. This system reduces diesel particulate by 95 to 98 percent. The DST® includes a complete set of diagnostic gauges to monitor system performance. The DST® has been approved by MSHA under 30 CFR Part 36. It can be used in coal or gassy metal and nonmetal mines where permissible equipment is required. In addition, the heat exchanger technology could be applied to nonpermissible engines in order to cool the exhaust gases so that disposable diesel exhaust filters (paper filters) could be used to reduce particulates.

"This system [the DST®], I think, represents, from everything that I've seen, the state-of-art of the industry...the best technology on the market today.... This gives us the ability for the first time in a long time to change direction and try to solve problems [with exposure to diesel exhaust]."

—Joe Main,
United Mine Workers of America

The DST® has been tried on a number of vehicles retrofitted to use it. "...It was a welding truck, at Shoshone. It was put in November, 1992. That's coming up pretty close to three years. Has operated very successfully; have had no problems. There's a 913 scoop; that's at Twenty-Mile since January, 1994.... We retrofitted a 25X Wagner shield hauler...."

—Norbert Paas,
Paas Technology

USE OF VENTILATION

Today the primary means used to reduce exposure to diesel exhaust pollutants underground **is to dilute exhaust pollutants** with fresh air from the mine's ventilation system. The concentration of pollutants is inversely proportional to changes in ventilation air quantity; that is, as the air quantity increases the pollutant concentrations decrease. The mine ventilation system can work in conjunction with the other methods of contaminant control such as maintenance, exhaust treatment, etc. Any control system must then be supplemented with checks to ensure that all aspects are working as designed. One way to check the control system is to conduct periodic sampling of diesel contaminants to detect changes in the system.

Mine ventilation systems where diesel engines are operated generally supply between 100 and 200 cubic feet of air per minute per brake horsepower (cfm/bhp). This air quantity is normally sufficient to dilute gaseous emissions from the diesel equipment to applicable standards for those gases. However, MSHA's experience in underground mines has shown that with these air quantities, DPM levels will still range between 200 μg/m3 and 1,800 μg/m3. As a general reference, about 35,300 cfm of air are required to dilute one gram per minute of DPM to 1,000 $\mu g/m^3$. Therefore, to significantly cause a reduction of DPM concentrations in underground mines through ventilation, it may be necessary to supply air quantities above those currently being used.

There are special ventilation requirements when diesels are used in underground coal mines. When a single piece of diesel equipment is operated, the nameplate airflow must be provided as a minimum airflow requirement. For each individual piece of diesel equipment operating in a coal mine, the approval plate air quantity must be maintained in any working place where the equipment operates, at the section loading point, and in outby entries where the equipment operates. The MSHA regulations also allow the District Manager to add areas where the approval plate air quantity may be required, such as fueling locations. When multiple pieces of diesel equipment are operated, the minimum section airflow is the sum of the nameplate airflows for the individual pieces of equipment. This requirement was developed to reduce the gaseous diesel emissions. However, not all equipment is operated on a continuous basis and some equipment, such as transportation and supply vehicles, may be excluded from this calculation. (Prior to the 1996 diesel powered equipment rule, a 100-75-50 percent guideline was used to establish minimum section air quantity requirements.) Any excluded equipment must be approved by the District Manager and listed in the ventilation plan for the mine. The intent here is to allow for the exclusion of equipment that does not significantly add to the miners' exposure level. These air quantities must be maintained in the last open crosscut of working sections, the intake to longwall sections, and the intake to pillar lines. The multiple unit quantity also applies to the areas where mechanized mining equipment is being installed or removed. Quantities other than the multiple unit formula can be approved by the MSHA District Manager if samples show that such reduced quantity will not result in overexposures.

"...Ventilation can take care, in my opinion, of most diesel equipment in the main haulageway, even in the sub-mains. However, when you approach the face area, you don't have that velocity and that quantity of air; then the control of engine exhaust may be necessary depending on the size of the engine and the concentration."

—Pramod Thakur, Ph.D.,

Consol, Inc.

Metal and nonmetal mines can be ventilated in a variety of ways. In single level mines, working areas are generally ventilated in series. The exhaust of one area becomes the intake for the next area. Multilevel mines may have a separate air split to each level or to several levels. Separation between intake and exhaust air courses is essential to prevent leakage or loss of fresh air. Auxiliary and booster fans should be installed throughout the mine to optimize distribution of workplace airflow.

Changing a mine's ventilation system to reduce pollutant exposure is frequently expensive and may require a long time to implement. Simple changes can include repairing an individual brattice or reducing leaks in an entire brattice line. However, significant improvements in air quality often are achieved only by complex changes such as redesigning the entire mining system to reduce airflow leakage, modifying the main fan installation, or adding a new air shaft.

"The mine ventilation system must be designed to provide and distribute sufficient airflow to areas of the mine where diesel equipment is being used. Typical ventilation rates in metal and nonmetal mines range from 75 to 200 cfm per brake horsepower in use. In coal mines the name plate airflow has been used to determine plan airflow requirements."

—Robert Haney,
Mine Safety and
Health Administration

"Ventilation continues to be an important method of controlling diesel particulate matter concentrations, and our studies have shown that significant reductions can be achieved by changing the ventilation around in the section."

—Jan Mutmansky, Ph.D.,
Pennsylvania State University

"Ventilation still remains the vanguard against diesel emissions. Toward the end of 1992 we reduced overall airflows to cut costs as part of a mine optimization process, and this summer we returned to those airflows. We currently have a mine migration of about 115 cfm/bhp. We designed with the 100 percent rule. We don't use 100 percent, 75 and 50 percent thereafter, although that's the way it sometimes works out. We try and keep all of our diesels on parallel splits as much as possible."

—John Marks,
Homestake Mining Company

"All permissible diesel face equipment is ventilated according to MSHA-required nameplate values. These are usually required to make in excess of 18,000 cfm in the last open break and 40,000 cfm on the section. In normal operation these values are 35,000 cfm in the last open break and 45,000 cfm on the section."

—Chris Pritchard,
Tg Soda Ash Incorporated

"Looking a little closer at ventilation, in one of our larger panels, typically at any one time you'll see three Ramcars at 139 horsepower operating, a roof bolter, a powder wagon and roughly two service vehicles...for more or less a total horsepower of...610. With an air volume of 100,000 cfm, we have an effective air-to-horsepower ratio in an operating panel of 164 cfm. If you look at the entire mine, installed horsepower, the air-to-horsepower ratio is about 95 cfm. New Mexico has a standard of 75 cfm, so we're somewhat better than that."

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

"We control air flow in the mine using air doors and air walls. ...We will shotcrete or gunite some areas to prevent leakage. We build airwalls throughout the mine using waste rock and used conveyor belt. The rock is piled up half to two-thirds of the way to the back and conveyor belt is cut into strips and pinned to the back overlapping by about six inches. This produces a very efficient air wall in the mine."

—Regina Henry,
Dravo Lime Company

"Our stoppings consist of brattice cloth or waste salt piled to within 10 feet of the roof and brattice cloth. We have auxiliary fans located throughout the mine that mix the gases as they come off the sections. Our main intake ventilates all of the sections in B-bed, then returns to the production shaft. Right now our C-bed is on its own split of air, and we continue to keep it that way. Several years ago when our fans were old and running at a maximum capacity, we decided...to see what we needed to do to build a better ventilation system. We conducted several pressure and air quality surveys, and the results were put into a computer simulation model. From this model, we found out that we definitely needed new fans.... We also decided that when we were developing C-bed, that we did not want to continue with the way we were currently ventilating the mine. In other words, we did not want to have one single split ventilating all the sections. So at that time we sat down and we worked out a way to ventilate each section on its own separate split, which is what most coal mines do. We feel that this will give us a better air quality ... and it will help clear the air out faster."

—David Music,
Akzo Nobel Salt's Cleveland Mine

"...We believe mine design and ventilation is an important...control. The fact of the matter

is, though, that... mine ventilation is not a stand alone system [for reducing exposure to diesel emissions].... "Even coupled with the water scrubber exhaust cooling systems that have become the industry standard, we haven't reduced particulate exposure to [what we would consider] an acceptable level...."

—Jeff Duncan,
United Mine Workers of America

USE OF ENCLOSED CABS

Properly designed and maintained environmentally conditioned cabs can reduce equipment operators' exposure to diesel emissions. Cabs should be pressurized and use high-efficiency particulate air (HEPA) filters. Many surface mines are currently using properly designed environmentally conditioned cabs and some efforts are being made to use enclosed cabs on underground mining equipment. The same principles apply to the use of underground booths designed to protect miners.

Question:
"I recently completed a study of a surface coal mine, and they were using pressurized cabs to minimize exposures.... Has this been given some thought in your design [of Ramcars] at Jeffrey?...."

—Robert Wheeler,
Consultant

Response:
"We may be getting very close to that, because just recently we produced the first Ramcar-type of vehicle ever with a cab, with some climate controls. ...One of the problems with exposure in underground mines is not the operator of the machine. Because of the close confines, it's the people around the equipment and, of course, the pressurized cab does not affect them at all."

—John Smith,
Jeffrey Mining Products

DIESEL ENGINE MAINTENANCE

Engine maintenance is an important part of a mine's overall strategy for reducing workers' exposure to diesel emissions. Without proper maintenance, diesel engines will perform poorly, thus reducing the effectiveness of all other emission control strategies.

"It has been definitively proven, that when engine maintenance is neglected [especially if it involves regulating the fuel and air handling systems of engines] the particulate, and carbon monoxide, and hydrocarbons, all skyrocket."

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

"...We had a lack of maintenance on these pieces of diesel equipment. They were running the equipment until they broke down, and they would fix them, and they would run them again until they broke down..."

—Glen Pierson,
Alabama Coal Miner (UMWA)

"We're having problems with respect to maintenance of diesels. We're having problems with untuned diesels. When we go to do longwall moves, we're working in an environment where the blue smoke is so heavy sometimes you can't see. We don't have a good maintenance system. We don't have a good inspection system."

—Joe Main,
United Mine Workers of America

A good preventive maintenance program will maintain near-original performance of an engine, and maximize vehicle productivity and engine life, while keeping exhaust emissions down. Engine maintenance activities which should be performed by mine maintenance personnel include maintenance of the following systems: air intake, cooling, lubrication, fuel injection and exhaust. These systems must be maintained according to manufacturer's specifications and on a regularly scheduled basis to keep the system operating efficiently. Measuring tailpipe CO emissions while the engine is under load provides a good indication when maintenance is required. However, daily checks of engine oil level, coolant, fuel and air filters, water tank, exhaust piping and gauges should be made. *There are very specific requirements for maintenance of diesel equipment in underground coal mines; some are noted below.*

The air intake system removes airborne particles before they enter the engine and cause abrasion of internal engine surfaces. Intake air filters should be replaced when the pressure drop indicator exceeds the manufacturers' specifications, usually 20 to 25 inches of water. *As of November 25, 1997, for diesel-powered equipment used in underground coal mines, intake air filters must be replaced or serviced when the intake air pressure device so indicates, or when the engine manufacturer's maximum allowable air pressure drop level is exceeded.*

"...Maintenance is extremely critical.... It takes two days to screw up the engine in the mine

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.

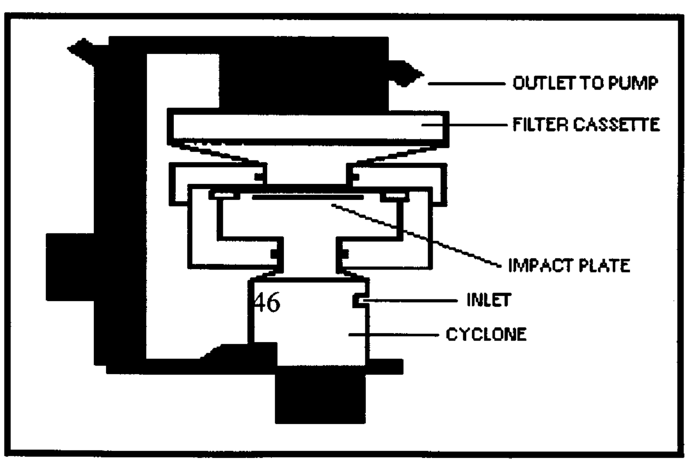
• Measuring the concentration (chemically) of the elemental and organic carbon fractions (total carbon) of either the submicrometer portion of the respirable dust aerosol or of the total respirable dust aerosol.

• 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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