

Sampling and Interferences For Diesel Particulate Matter in Underground Metal and Nonmetal Mines

Robert A. Haney, Supervisory Mining Engineer, P. E.
U. S Department of Labor
Mine Safety and Health Administration
Pittsburgh, Pennsylvania, USA

ABSTRACT

The United States Mine Safety and Health Administration, has proposed an exposure standard for diesel particulate matter for underground metal and nonmetal mining operations. These limits are in terms of total carbon as determined by the National Institute of Occupational Safety and Health (NIOSH) Method 5040. Method 5040 is a thermal optical procedure for determining elemental and organic carbon content of an airborne sample. Elemental and organic carbon content of the sample are added to obtain the total carbon concentration.

Mining industry comments and concerns on the proposed regulation included: the applicability of Method 5040 to diesel particulate measurements, the sample collection system and the impact various interferences may have on diesel particulate measurements. Concerns on Method 5040 included accuracy, calibration of the instrumentation and calculation of the total carbon concentration. Sample collection issues addressed sample collection method (total dust (open face), respirable dust or submicron particulate). Potential interferences included: sample blanks, carbonaceous minerals (including carbonates), graphitic minerals, oil mist and cigarette smoke.

In order to address these concerns, MSHA reviewed the analytical method, and conducted studies to verify the magnitude of the interferences. The sampling and analytical procedures and the results of the supporting tests are described in this paper.

KEY WORDS

Diesel particulate, air sampling, total carbon, elemental carbon, organic carbon, mineral interferences.

INTRODUCTION

On October 29, 1998, the Mine Safety and Health Administration, U. S. Department of Labor proposed regulations to reduce diesel particulate exposures in underground metal and nonmetal mines (U. S. Department of Labor, 1998). These regulations included an exposure standard which would be implemented in two stages. The first stage would be a $400 \mu\text{g}/\text{m}^3$ diesel particulate limit which would be effective 18 months after the final regulation goes into effect. The second stage called for a $160 \mu\text{g}/\text{m}^3$ exposure limit to go into effect 60 months after the final regulation goes into

In the United States, following the publication of a

effect. These limits were in terms of total carbon as determined by the National Institute of Occupational Safety and Health (NIOSH) Method 5040. Method 5040 is a thermal optical procedure for determining elemental and organic carbon content of an airborne samples. The elemental and organic carbon content of the sample are added to obtain a total carbon concentration. Total carbon is being considered a surrogate for diesel particulate matter. Under the proposed rule, the ratio of total carbon to diesel particulate is assumed to be 0.80. The proposed regulation also allows for personal or area sampling to determine compliance with the standard.

proposed regulation, the regulatory agency holds public

hearings and solicits comment from interested parties on the proposed regulations. The Agency then considers these comments and responds to them in developing the final regulation. During the public hearings and comment period, mining industry representatives expressed concerns about the proposed methods for sampling and analysis of diesel particulate matter. These concerns included the applicability of Method 5040 to diesel particulate matter measurements in underground metal and nonmetal mines; the sample collection system and the impact various interferences may have on diesel particulate measurements. Concerns relative to Method 5040 included accuracy and calibration of the instrumentation; sample acidification to remove carbonate; the calculation of the total carbon concentration and the use of blank (control) filters. Sample collection issues included which sample collection method should be used: total dust (open face), respirable dust or submicron particulate sampling. Interferences that were addressed included: sample blanks, carbonaceous minerals (including carbonates), graphitic minerals, oil mist, organic vapors and cigarette smoke. Graphitic minerals could potentially interfere with the elemental carbon determination. Other interferences could potentially interfere with the organic carbon determination.

In order to address the mining industry's concerns, MSHA reviewed the analytical method, conducted tests on the different sampling methods and conducted field and laboratory studies to verify the magnitude of the interferences. This paper presents a detailed review of the sampling issues and the results of the MSHA tests to verify the magnitude of the potential sample interferences.

SAMPLING AND ANALYTICAL TECHNIQUES

Sampling Methods

There are three methods by which airborne diesel particulate samples can be collected. These methods include total dust samples (open face or cassette without a preclassifier), respirable dust (collected with a respirable preclassifier), and submicron dust (collected with both a respirable preclassifier and a submicron impactor). The choice of sample collection method considers the cost and the potential interferences that can result from the method. Regardless of the sampling method, the sampling media (filter) must be one that does not interfere with the analysis. For this reason a pre-fired quartz fiber filter has been chosen. The quartz fiber filter is capable of withstanding the temperatures from the analytical procedure. The filter is pre-fired to remove residual carbon, attached to the

filter during manufacturing.

Total dust sampling: Total dust sampling is the least expensive method to collect an airborne dust sample. It is commonly used to collect a sample that is representative of all the dust in the environment; i.e., the particles are not preclassified during the collection process. Total dust sampling can be performed using a filter cassette that allows the whole face of the filter to be exposed during collection of the sample (open face) or using a filter cassette with a small inlet opening (referred to as a closed face filter cassette). The latter method is used by MSHA for compliance sampling for total dust in the metal and nonmetal sector. Because the sample collected is representative of all the particulate matter in the environment, there is the potential for interference from mineral contaminants containing organic and elemental carbon when sampling for diesel particulate matter. While in many cases the analytical results can be corrected for these interferences, in some instances the interferences may be so large that they can not be quantified with the analytical procedure, thus preventing the analytical result to be corrected for the interference.

Additionally, MSHA has noted that in some cases when using the total dust sampler with the small inlet hole, distribution of the collected sample on the filter is not uniform. The distribution of sample is concentrated in the center of the filter. This can result in the effect of an interference being magnified. As a result, while total dust sampling may be suitable for general industry diesel particulate samples, it is not considered an appropriate sampling method for the mining industry to use when sampling diesel particulate matter.

Respirable dust sampling: Respirable dust sampling is commonly used when the dust being collected is to represent the fraction of dust deposited in the lungs. The mining industry is familiar with respirable dust sampling for the collection of dust samples in coal mines and for the collection of respirable silica samples in metal and nonmetal mines. For respirable dust sampling MSHA uses a 10-millimeter, Dorr Oliver nylon cyclone as a particle preclassifier to separate the respirable fraction of the aerosol from the total aerosol sampled. The use of this particle classifier is also suitable when sampling diesel particulate, provided significant amounts of interfering minerals are not present. If a dust contains carbonaceous minerals, an interference in either the elemental or organic carbon determination can occur. While in many cases, the interferences from these minerals could be removed during the analytical procedures, the analytical procedures alone can not be assured of removing the interferences when large amounts of mineral dust are present.

Additionally, MSHA has observed that in some sampling equipment the cyclone outlet hole has been reduced when interfacing it with the filter capsule. MSHA has further observed that where this has occurred, the distribution of sample on the collection filter may not be uniform. In this circumstance the sample is also concentrated in the center of the filter which can result in the effect of a mineral interference being magnified. As a result, respirable dust sampling is not a universally applicable sampling method for the mining industry to use for sampling diesel particulate matter.

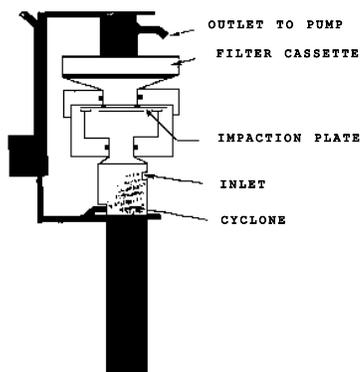


Figure 1 Schematic of the submicron sampler.

Submicron dust sampling: Since only a small fraction of the mass of a mineral dust aerosol is less than 1 micrometer in size, a submicrometer impactor (Cantrell and Rubow, 1992) was developed to permit the sampling of diesel particulate without sampling potential mineral interferences. The submicrometer impactor was initially developed to remove the interference from coal mine dust when sampling diesel particulate in coal mines. It was designed to remove the

particles that are greater than 0.8 micrometer in size. As a result the use of a submicrometer impactor will minimize or eliminate potential interference when sampling for diesel particulate in the presence of mineral dust containing carbonaceous compounds. A schematic of the submicron sampler is shown in figure 1.

Analytical Method

NIOSH Method 5040 is an analytical method that is used to determine the elemental and organic carbon content of a sample collected on a quartz fiber filter (NIOSH, 1999). It is more versatile than other carbon analytical methods in that it differentiates the carbon into its organic and elemental carbon components. The method accomplishes this through a thermal optical process. A portion of the filter, (approximately 2 square centimeters in area) is placed into the carbon analyzer oven. The temperature of the oven is increased in increments. At certain oven temperature and atmospheric conditions (helium, helium-oxygen), carbon on the filter is oxidized into carbon dioxide. The carbon dioxide gas is then passed over a catalyst and reduced to methane. The methane concentration is measured and carbon content is determined. Five separate sucrose standards ranging between 10 and 100 $\mu\text{g}/\text{cm}^2$ carbon are initially analyzed to check the linearity of the internal calibration. Four individual peaks are identified in the organic carbon portion of the analysis.

A laser is used to differentiate the organic carbon from the elemental carbon. The laser penetrates the filter and when the laser transmittance reaches its initial value this determines when elemental carbon begins to evolve. The computer software supplied with the instrumentation indicates this separation by a vertical line. The separation point can be manually adjusted by the analyst. As a result, there may be small differences in the determination of organic and elemental carbon between analysts, but the total carbon (sum of elemental and organic carbon) does not change.

The software also allows the analyst to identify and quantify the different types carbon using individual peaks. This permits the mathematical subtraction of a particular carbon peak. This feature is particularly useful in removing contributions from carbonates or other carbonaceous minerals. In other methods that measure only total carbon, samples have to be acidified to remove carbonate interference. While acidification of samples will remove carbonate interferences, it may not completely remove interferences caused by other carbonaceous minerals.

The method will be used in mining applications to determine total carbon contamination where the diesel particulate concentration will be limited to 400 TC µg/m³ and 160 TC µg/m³. NIOSH has reported that the lower limit of detection for the method is 0.1 µg/cm² elemental carbon for an oven pre-fired filter portion and 0.5 µg/cm² organic carbon for an oven pre-fired filter portion. For a full shift sample, this detection limit represents approximately 1 and 10 µg/m³ of elemental and organic carbon, respectively. Additionally, NIOSH has conducted a round robin program to assess interlaboratory variability of the method. This study indicated a relative standard deviation for total carbon, of less than 15 percent.

Diesel particulate Matter Concentration Calculations

The concentration of organic and elemental carbon (in µg per square centimeter) are separately determined from the sample analysis and added together to determine the amount of total carbon. The interference from carbonate or mineral dust quantified by the fourth organic carbon peak is subtracted from the organic carbon results. The field blank correction is then subtracted from the organic analysis (the blank does not typically contain elemental carbon). A 1.7 Lpm flow rate is used in accordance with metal and nonmetal mine aerosol sampling procedures. This results in an impactor cut point of 0.9 micrometers.

Time weighted average concentrations (TWA) of carbon are calculated from the following equation 1.

$$TWA = \frac{C(\mu\text{g}/\text{cm}^2) * A(\text{cm}^2) * 1,000 \text{ L}/\text{m}^3}{1.7 \text{ Lpm} * \text{time (min)}} \tag{1}$$

Where:

C= The Organic Carbon (OC) or Elemental Carbon (EC) concentration, in µg/m³, measured in the thermal/optical carbon analyzer (corrected for carbonate and field blank).

A= The surface area of the filter media used. The surface areas of the filters are: quartz fiber filter without aluminum cover is 8.55 cm²; filter with aluminum cover is 8.04 cm².

Field and Laboratory Tests Sampling Protocol

The field and laboratory tests were designed to isolate potential interferences, evaluate various sampling methods and to quantify the potential magnitude of the interference. For mineral dust interferences, samples

were collected on the surface near crushing and sample preparation facilities and in a laboratory dust chamber. For oil mists and cigarette smoke, samples were collected underground. In the underground tests, samples were collected upwind of the interfering source, at the interfering source and downwind of the interfering source. Airflow measurements were taken upwind or down wind of the interfering source as well as in the stope or heading where work operations were taking place.

Figure2. Schematic of a underground test station.

A combination of total, respirable and submicron samples were collected. For each test control (blank)

samples were collected. These samples were used to adjust organic and elemental carbon concentrations for residual carbon attached to the sample filters. Figure 2 shows a schematic of a typical underground test station. Following the testing at the surface crusher it became apparent that excessive mineral dust interference could occur with total dust samples. Therefore, the total dust sampling method was considered not appropriate for mining and consequently discontinued. .

In all, twelve sets of tests were run: five tests for mineral dust interference at crushing or sample preparation facilities; two sets of tests for smoking interference; three sets of tests for oil mist interference; and two dust chamber test directed specifically to assess carbonate interference. These tests were conducted at four mining operations, an underground test mine and a laboratory dust chamber.

Thermogram

A typical diesel particulate thermogram is shown in Figure 3. The thermogram generally contains five or six carbon peaks, one for each temperature ramp on the analyzer. The first four peaks (occurring during heating in a helium atmosphere at temperatures ranging from of 210°C to 870°C) are associated with organic carbon determination and the fifth and/or sixth peak (occurring during heating in a helium/oxygen atmosphere at temperatures ranging from 610°C to 890°C) provides the elemental carbon determination.

The fourth peak (which occurs at ~750°C) is where carbonate and other carbonaceous minerals are evolved. For a diesel particulate sample without mineral interferences present, this fourth peak is usually minimal as it is attributed to heavy distillate organics not normally associated with diesel operations in underground mining applications. If this peak is due to carbonate, the carbonate interference can be verified by analyzing a second portion of the sample after acidification as described in the NIOSH 5040 method. If the fourth peak is caused by some other carbonaceous mineral, the acidification process may not completely remove the interference and may, on occasion, cause a positive bias to the elemental carbon determination.

Sample Blanks

Each set of samples collected to measure the diesel particulate concentration of a mine environment, was accompanied by a field blank (a filter cassette that is treated and handled in the same manner as filters used to collect the samples) when submitted for analysis. The amount of total carbon determined from the analysis of the blank sample must be applied to (subtracted from) the carbon analysis of each individual sample. The field blank correction is applied to account for non-sampled carbon that attaches to the filter media. The blank correction is applied to the organic fraction as, typically, no elemental carbon is found on the blank filters.

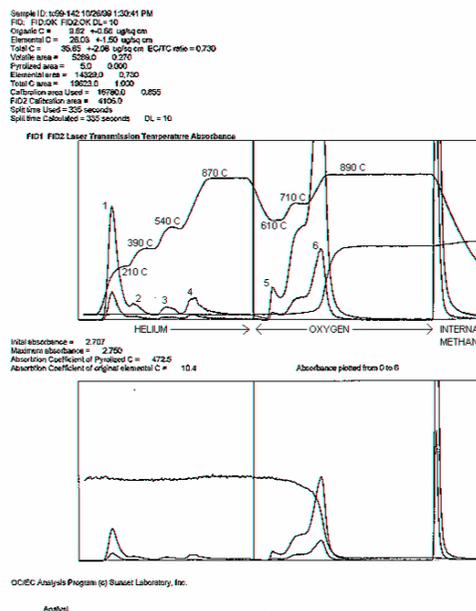
Failure to adjust for the blanks can lead to incorrect results. Typically the carbon content on the field blanks ranged from 2 to 3 µg/square centimeter of filter area. For a one-hour sample, not using a blank correction of this magnitude, could result in an overestimate of 250 µg/m³ of dpm ($3 \times 8.55 \times 1000 / (1.7 \times 60) = 250$). For an eight-hour sample, the overestimate of total carbon by not using a blank correction, would be reduced to 30 µg/m³ of dpm ($3 \times 8.55 \times 1000 / (1.7 \times 480) = 30$).

Figure 3. Thermogram From Respirable Diesel

Particulate Sample.

Mineral Dust Interference

There are two potential types of mineral interference - graphitic minerals that may effect the elemental carbon



determinations; and carbonaceous minerals that may effect the organic carbon determinations. Both laboratory and field tests were conducted to assess the impact of these two interferences.

Graphitic minerals: Several ores, including those associated with gold mines, may contain graphitic carbon. This carbon may show up as elemental carbon in an airborne dust sample. MSHA has collected samples of this ore and has found that in fact this is true (MSHA, PS&HTC-DD-505, PS&HTC-DD-509, PS&HTC-DD-510, 1999).

The field measurements consisted of simultaneous respirable and submicron dust samples were collected near crushing operations and ore sample preparation areas where there was no diesel equipment operating. For the field measurements, the samples were analyzed for carbon using NIOSH Method 5040. Results of analysis of these samples showed that for respirable dust samples, several µg/m³ of elemental carbon could be present in the sample. Typical results of samples collected during these tests are given in Table 1.

These results show that the magnitude of this interference in a respirable dust sample is small, and can be reduced still further through the use of the submicron impactor. The highest elemental carbon content of the ores was less than 5 percent of the total carbon content. These ores also contain at least 20 percent respirable silica, as determined from samples collected near crushers where diesel particulate was not present. Based on a 20 percent respirable silica content in the dust in the environment, the allowable respirable dust exposure would be limited to 0.45 mg/m^3 ($\text{PEL} = 10 / (\% \text{quartz} + 2)$). Based on a 5 percent elemental carbon content in the sample, this sample could contain $23 \text{ } \mu\text{g/m}^3$ of elemental carbon. Typically 10 percent by mass of mineral dust is less than one micron. By using the submicron impactor, the interference from graphitic carbon in the ore would be less than $3 \text{ } \mu\text{g/m}^3$. Samples collected by MSHA, near crushing operations, using submicron impactors, did not contain elemental carbon. A submicron impactor can be used to minimize or remove graphitic carbon interference through field measurements.

Carbonates and carbonaceous minerals:

As noted in the discussion of the analytical method (NIOSH Method 5040), carbonates have been known to cause an interference when determining the total carbon content of a diesel particulate sample. Carbonates are generally in two forms - carbonates (such as limestone and dolomite) and bicarbonate which is associated with trona (soda ash). Other carbonaceous minerals, especially associated with gold ores can also interfere with a diesel particulate sample. The HCl acidification process described in Method 5040 removes carbonate from a diesel particulate sample.

A series of tests were conducted in a laboratory test chamber at various sample loadings of carbonate and diesel particulate (MSHA, PS&HTC-DD-00-523, 2000). Results of samples collected during these tests are given in Table 2. For respirable samples, acidification removed the carbonate. Acidification did not produce elemental carbon. Carbonate was evolved in the forth peak of the organic portion of the analysis. The carbon evolved by the analysis was approximately 10 percent of the carbonate collected on the gravimetric sample, roughly equating to 12 percent carbon contained in calcium carbonate tested (limestone). The expected ratio of evolved carbon from the carbonate to carbonate (C/CaCO_3) would be $0.12 \times (12 / (40 + 12 + 48))$. Sampling with the submicron impactor removed the carbonate from the sample.

Sample results from the laboratory tests further indicated that the total carbon masses determined for the respirable diesel particulate samples were approximately 95 percent of the diesel particulate mass determined gravimetrically and the total carbon masses determined from the impactor diesel particulate samples was approximately 82 percent of the respirable value. Use of the impactor reduced the amounts of carbonate collected on the sample by 90 percent.

The difference between the respirable total carbon determinations and the gravimetric diesel particulate can be attributed to sulfates or other noncarbonaceous impurities in the diesel particulate. The difference between the submicron total carbon and the respirable total carbon determinations is attributed to the removal of diesel particulate particles that are greater than 0.9 micrometers in size.

Results of the field tests further showed that the acidification procedure, may not remove all of the other carbonaceous minerals from a respirable diesel particulate sample. In fact in some cases, the acidification process may cause a positive bias to the elemental carbon measurement. The interference from carbonaceous mineral can be reduced by collecting the sample with a submicron impactor and/or eliminated by subtracting the forth organic peak from the thermogram using the software supplied with the analytical instrumentation. Because bicarbonate is evolved over several temperature ranges, subtraction of only one peak does not remove all of the interference from bicarbonate. As a result, the sample needs to be acidified to remove the bicarbonate interference.

Oil Mist Interference

Because oil mist contains organic carbon, it could be a potential source of interference on a diesel particulate samples. To verify the existence and extent of this interference, MSHA collected samples at stoper drilling, jack leg drilling and face drilling operations. The stoper drill and jack leg drill were pneumatic. The face drill was electrohydraulic. Respirable and submicron samples were collected in the stope, the intake air to the stope and the exhaust air from the stope. Interference in the form of elevated organic carbon, from drill oil mist was observed for both the stoper drill and jack leg drill operations (MSHA, PS&HTC-DD-505, PS&HTC-DD-511, 1999). Interference from drill oil mist was not found in submicron samples collected on the electrohydraulic face drill (MSHA, PS&HTC-DD-505, 1999).

Results of samples collected during these tests are given in Table 3. The oil mist interference for the stoper drill

was confined to the drill location due to the use of a high viscosity lube grease. The amount of interference in the stope on a submicron sample for the stoper drill was $4.5 \mu\text{g}/\text{m}^3$ per hour of drilling. The interference from the oil mist on the jack leg operation extended throughout the mining stope area, but it did not extend into the main ventilation heading. The amount of interference in the stope on a submicron sample for the jack leg drill was 9 to $11 \mu\text{g}/\text{m}^3$ per hour of drilling. While not measured, similar interferences could occur when miners are working near organic solvents.

This potential interference can be avoided by not sampling near the source of the interference. When collecting diesel particulate samples on drilling operations that produce an oil mist, or where organic solvents are used, rather than collecting personal samples, an area sample could be collected, upwind of the driller or organic solvent source.

Cigarette Smoke Interference

Cigarette smoke is a form of organic carbon. As a result cigarette smoke could interfere with a diesel particulate measurement when total carbon is used as the indicator of dpm. To verify the existence and the extent of any such interference, MSHA collected samples in an underground mine where controlled smoking took place. A test site was chosen in the NIOSH, PRL, Experimental Mine. The site consisted of approximately 75 feet of straight entry. The entry was approximately 18.5 feet wide and 6.2 feet high (115 square feet area). Two series of cigarette tests were conducted. In the first test, the airflow rate through the test area was 6,000 cfm and 4 cigarettes were smoked over a 120 minute period. In the second test, the airflow was 3,000 cfm and 28 cigarettes were smoked over a 210 minute period. A control filter was used to adjust for organic carbon present on the filter media. MSHA collected samples on the smokers, twenty-five feet upwind of the smokers, twenty-five feet downwind of the smokers and fifty feet downwind of the smokers.

Results of samples collected during the underground cigarette smoking tests are given in Table 4. These tests did verify that smoking could be an interference on a dpm measurement. Analysis of the thermogram from the smoking test showed that cigarette smoke showed

up only in the organic portion of the analysis. In the test with the cigarette smoke, a fifth organic peak was observed. This peak contributed approximately $0.5 \mu\text{g}/\text{cm}^2$ to the analysis. This would be equivalent to an 8 hour full shift concentration of $5 \mu\text{g}/\text{m}^3$. The thermogram otherwise is not distinguishable from the organic portion of a thermogram for a diesel particulate sample. Analysis of the thermogram indicated that 30 percent of the organic carbon appeared in the first organic peak, 15 percent appeared in the second organic peak, 10 percent appeared in the third organic peak, 25 percent of the cigarette smoke appeared in the fourth organic peak, and 20 percent of the cigarette smoke appeared in the fifth organic peak. While the amount of carbon identified by the fourth and fifth organic peak can be quantified and mathematically subtracted from the amount of total carbon measured, the remaining three peaks, representing 55 percent of the total carbon associated with smoking, would be an interference to the diesel particulate matter measurement.

The effect of cigarette smoke was localized to the smoker. Twenty five feet upwind of the smoker, no carbon attributed to cigarette smoke was detected. For the smoker, each cigarette smoked would add 5 to $10 \mu\text{g}/\text{m}^3$ to the exposure, depending on the airflow. Smoking 10 cigarettes would add 50 to $100 \mu\text{g}/\text{m}^3$ to a worker's exposure. At both twenty five feet and fifty feet downwind of the smoker, after mixing with the ventilating air, the contribution of carbon attributed to smoking was reduced to $0.3 \mu\text{g}/\text{m}^3$ for each cigarette smoked. Sampling twenty-five to fifty feet down wind of a worker smoking 10 cigarettes per day would add approximately $3 \mu\text{g}/\text{m}^3$ to the worker's exposure (MSHA, PS&HTC-DD-518, 2000). The air velocities in this test (30 to 60 feet per minute) were relatively low compared to typical mine air velocities. The interference would be even less at the higher air velocities normally found in mines.

Bases on these sample results, miners will be requested not to smoke while being sampled for diesel particulate. If a miner does want to smoke while being sampled, and is not prohibited from doing so by the mine operator, an area sample a minimum of twenty-five feet upwind or downwind of the smoker could be collected to minimize interference from cigarette smoke.

carbon measurements.

SUMMARY OF TEST RESULTS

1. As specified in NIOSH Method 5040, it is essential to use a blank to correct organic
2. Contamination (interference) from carbonate and carbonaceous minerals is evolved in the fourth organic peak of the thermogram.
3. Interference from graphitic minerals may appear in the elemental carbon portion of the analysis.

- | | | |
|-----|--|---|
| 4. | Interference from cigarette smoke and oil mist from pneumatic drills appears in several peaks of the organic analysis. | 00055, Lead, South Dakota, (PS&HTC-DD-00-505), 1999. |
| 5. | Use of the submicron impactor removes the mineral interference from carbonate, carbonaceous minerals and graphitic minerals. | MSHA, Sampling for Diesel Particulate Interferences Barrick Goldstrike Mines, Incorporated, Mine I.D. No. 26 01089, Elko, Nevada, (PS&HTC-DD-00-509), 1999. |
| 6. | Acidification is required to remove the interference from bicarbonate which maybe evolved in several of the organic peaks. | MSHA, Diesel Particulate Evaluation at a Crusher and Sample Preparation Room South Area, Newmont Mining Corporation, Mine I.D. No. 26 00500, Carlin, Nevada, (PS&HTC-DD-00-510), 1999. |
| 7. | Subtraction of the fourth organic peak by software integration can be used to correct for interference from carbonaceous minerals. | MSHA, Jackleg Drill Diesel Particulate Evaluation Carlin Mine, Newmont Mining Corporation, Mine I.D. No. 26 02271, Carlin, Nevada, (PS&HTC-DD-00-511), 1999. |
| 8. | Interference from cigarette smoke and oil mist from pneumatic drills is localized. It can be avoided by sampling upwind or downwind of the interfering source. | MSHA, Results of Tests to Determine Interference on Diesel Particulate Matter Measurements from Cigarette Smoke, (PS&HTC-DD-00-518), 2000. |
| 9. | Total carbon from cigarettes smoke and oil mist are small compared to emissions from a diesel engine. | MSHA, Results of Tests to Determine Interference on Diesel Particulate Matter Measurements from Carbonate Dust, (PS&HTC-DD-00-523), 2000. |
| 10. | Sampling can be conducted down wind of the interfering source after the contaminated air current has been diluted with another air current. | NIOSH, Elemental Carbon (Diesel Exhaust) 5040. NIOSH Manual of Analytical Methods (NMAM), Fifth Edition, January 1, 1999, as revised in Issue 3 (Interim), September 30, 1999, 8 p. |
| 11. | The magnitude of interferences measured during the verifications were small compared to the levels of total carbon measured in underground mines. | U.S. Department of Labor, Mine Safety and Health Administration, <u>Practical Ways to Reduce Exposure to Diesel Exhaust in Mining - - A Toolbox</u> , 1997.

<u>U. S. Department of Labor, Mine Safety and Health Administration, Diesel Particulate Mater Exposure of Underground Metal and Nonmetal Miners; Proposed Rule, 30 CFR, Part 57, Federal Register, October 29, 1998.</u> |

REFERENCES

Birch, M. E. and Cary, R. A., "Elemental Carbon-Based Method for Monitoring Occupational Exposures to Particulate Diesel Exhaust," Aerosol Science and Technology, 25:221-241, 1996.

Cantrell, B. and Rubow, K., "Diesel Exhaust Aerosol Measurements In Underground Metal and Nonmetal Mines," U. S. Bureau of Mines Informational Circular 9324, pp. 18 - 23, 1992.

MSHA, Diesel Particulate Study at the Homestake Mine, Homestake Mining Company, Mine I.D. No. 39

Table 1. Results of Carbon Analysis (Diesel Particulate) on Samples Collected at Surface Crushing and Ore Sample Preparation Operations.

Type and Location of Sample	Organic Carbon, (OC) $\mu\text{g}/\text{m}^3$	Carbonate Carbon (CC) $\mu\text{g}/\text{m}^3$	Elemental Carbon (EC) $\mu\text{g}/\text{m}^3$	Total Carbon (EC + OC) $\mu\text{g}/\text{m}^3$	Gravimetric Concentration mg/m^3	Percent Silica
Crusher 1 Impactor	0	0	2	2	--	--
Crusher 1 Respirable	8	25	14	22	1.28	33.8
Crusher 2 Impactor	0	0	7	7	--	--
Crusher 2 Respirable	0	54	29	29	2.22	30

Table 2. Typical Results of Carbon and Gravimetric Analysis Of Diesel Particulate and Limestone Dust Collected in NIOSH Dust Chamber.

TEST			IMPACTOR				RESPIRABLE			
Set	DPM	CC	OC μg	CC μg	EC μg	TC μg	OC μg	CC μg	EC μg	TC μg
1	L	M	50	8	114	164	62	66	129	191
1-A	L	M	49	6	122	171	48	6	136	184
2	L	H	57	9	126	183	76	105	129	205
2-A	L	H	51	10	121	172	54	7	142	196
3	M	0	64	6	254	318	58	6	270	329
3-A	M	0	47	6	317	364	57	6	367	425
4	M	L	35	6	142	177	79	46	268	346
4-A	M	L	48	6	144	192	71	6	268	338

OC - Organic Carbon EC - Elemental Carbon DPM - Diesel Particulate Mater
 CC - Carbonate Carbon TC - Total Carbon L - Low, M - Medium, H - High
 A - Indicates sample was acidified.

Table 3. Results of Carbon Analysis (Diesel Particulate) on Samples Collected on Drills.

Stoper Drill

Type and Location of Sample	Organic Carbon (OC) $\mu\text{g}/\text{m}^3$	Carbonate Carbon (CC) $\mu\text{g}/\text{m}^3$	Elemental Carbon (EC) $\mu\text{g}/\text{m}^3$	Total Carbon (EC + OC) $\mu\text{g}/\text{m}^3$
Intake Respirable	28	0	107	135
Face Impactor	53	0	85	138
Face Respirable	88	1	88	176

Jackleg Drill - Stope Intake

Type and Location of Sample	Organic Carbon (OC) $\mu\text{g}/\text{m}^3$	Carbonate Carbon (CC) $\mu\text{g}/\text{m}^3$	Elemental Carbon (EC) $\mu\text{g}/\text{m}^3$	Total Carbon (EC + OC) $\mu\text{g}/\text{m}^3$
Intake Impactor	0	0	74	74
Intake Respirable	56	16	154	209
Face Impactor	75	32	167	243
Face Respirable	139	35	175	313

Table 4. Average Results of Carbon Analysis (Diesel Particulate) on Samples Collected During Cigarette Smoking, NIOSH, PRL Experimental Mine, Pittsburgh, PA, NIOSH Method 5040.

Location of Sample	Respirable	Impactor
	Organic Carbon (OC) $\mu\text{g}/\text{m}^3$	Organic Carbon (OC) $\mu\text{g}/\text{m}^3$
Smoking Station	109	90
25' Downwind	24	10
50' Downwind	8	10