Dust Division

MEMORANDUM FOR MICHAEL A. DAVIS
District Manager, Metal and Nonmetal Mine Safety and Health,
Southeastern District, Birmingham, Alabama

THROUGH: EDWARD J. MILLER
Chief, Pittsburgh Safety and Health Technology Center

ROBERT A. HANEY
Chief, Dust Division

FROM: MARK J. SCHULTZ
Chief, Environmental Assessment and Contaminant
Control Branch

SUBJECT: Diesel Particulate Concentrations from DPM Study at the
Black River Mine, Carmeuse Lime and Stone, Inc.
(I.D. No. 15 00062), Butler, Kentucky

Attached is a report of the diesel particulate compliance assistance visit at Black River Mine, Carmeuse Lime and Stone, Inc. (I.D. No. 15 00062), Butler, Kentucky. The study was conducted to evaluate the effect bio-diesel fuel on diesel particulate emissions and personal exposure in an underground nonmetal mine.

If you have any questions regarding this study, please contact this office at (412) 386-6858.

Attachment

bcc: MNM (C. Jones)
TS (L. Zeiler)
MNM (J. Etterer)
TS (E. Miller)
TS (M. Schultz)
TS (K. Fields)
TS (E. Gerbec)
TS (R. Haney)
Chron. Files
Report No. DD-03-316

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UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

Environmental Diesel Particulate Matter Investigation

PS&HTC-DD-03-316

Black River Mine
Carmeuse Lime and Stone, Inc.
Butler, Kentucky
Mine I.D. No. 15 00062

March 18 and 19, 2003,
April 8 and 9, 2003, and
April 29 and 30, 2003

by

Everett J. Gerbec
Mining Engineering Technician

And

Kenneth Fields
Mining Engineer

Objective

To evaluate the effect of a 35% bio-diesel fuel mixture on diesel particulate emissions and personal exposure in an underground nonmetal mine.

Originating Office

Pittsburgh Safety and Health Technology Center
Robert A. Haney
Chief, Dust Division
Cochrans Mill Road, P. O. Box 18233
Pittsburgh, Pennsylvania 15236

INTRODUCTION

At the request of the District Manager, Metal and Nonmetal Mine Safety and Health, Southeastern District, a diesel particulate compliance assistance study was conducted at the Black River Limestone Mine (I.D. No. 15 000062), Butler, Kentucky. The study was jointly conducted by Mine Safety and Health Administration (MSHA) personnel and Carmeuse North America Incorporated personnel. MSHA personnel involved in the study were Kenneth Fields, Mining Engineer, and Everett Gerbec, Mining Engineering Technician, Dust Division, Pittsburgh Safety and Health Technology Center. George Love, Regional Environmental Manager for Carmeuse North America Inc., participated in the surveys for the Black River Limestone Mine.

The purpose of the study was to evaluate the effect of a 35% bio-diesel fuel mixture on diesel particulate emissions and personal exposure in an underground nonmetal mine. Two different bio-diesel fuel mixtures were tested during normal underground mining operations. A standard No. 2 diesel fuel (baseline study) was evaluated on March 18 and 19, 2003, a 35% mixture of recycled vegetable oil (RVO), bio-diesel was evaluated on April 8 and 9, 2003 and a 35% mixture of virgin soy oil (VSO), bio-diesel was evaluated on April 29 and 30, 2003.

BACKGROUND

The Black River Mine, located in Pendleton County, Kentucky, is an underground limestone mine owned and operated by Carmeuse North America, Inc. The Camp Nelson limestone formation is mined. The mine operates two 10-hour production shifts, 4 days per week to produce approximately 2.5 million tons of limestone annually. Mined entries were 30 to 40 feet wide and 24 feet high. The limestone deposit is mined in two benches. The first bench is approximately 22 to 24 feet high and the lower bench is 24 feet. This process resulted in a mine layout consisting of an upper level which eventually was shot down to a lower level. A conventional mining system where the limestone is drilled and blasted was used to mine the limestone deposit. This process consisted of drilling the face or the floor and then loading the drilled holes with ANFO. The blasting sequence was initiated at the end of each shift with a two hour and fifteen minute idle period allowed for the gasses and other contaminants to be removed by the ventilation system. The broken stone was then loaded at the faces by front-end loaders into haulage trucks. The trucks transported the material to a jaw crusher which feeds the mine belt. The conveyor system carried the stone from the crusher area and out of the mine via the exhaust air slope. On the surface, the stone was further crushed and screened. The product was calcined to produce thiosorbic lime; a material used as a scrubbing agent for removing sulfur dioxide from stack gases at coal fired power plants. Other products are quick lime, pulverized lime and lime for water treatment plants and steel mill usage. Reject material was transported back into the mine.

The diesel equipment used to mine limestone included: front-end loaders, haul trucks, scalers, face drills, a roof bolter, a grader, a grease rig, a water truck, service truck, explosives truck, and tractors. A list of all underground diesel equipment is listed in Appendix A.

Primary airflow was induced into the mine at two intake locations. Air was then coursed to the working areas by air walls and auxiliary fans. The freestanding auxiliary fans, which had no ductwork, or tubing, induced additional ventilation to the working panels. This intake air was coursed throughout the mine to two exhaust areas, an exhaust shaft and the belt slope. Airflow varied from 147,000 cubic feet per minute (cfm) to 179,000 cfm exhausting out of the main exhaust shaft during the study and varied from 67,000 cfm to 109,000 cfm exhausting out the slope.

During the studies, blends of 35% bio-diesel to diesel fuel were compared with a baseline of No. 2 low sulfur diesel fuel. One bio-diesel fuel consisted of VSO and the other consisted of RVO. The RVO was supplied by Griffin Industries, Incorporated. The VSO was supplied by Peter Cremer North America. The mine used each bio-diesel fuel for a period of approximately two weeks. During each week of the study, the equipment was given time to adjust to the new type of fuel before particulate samples were collected. Both MSHA personal and Mine personal conducted DPM sampling. This report only discusses MSHA sampling results.

SAMPLING AND ANALYTICAL PROCEDURES

Seven area samples and five personal samples were collected during each day of the three phase study. Area samples were collected at two main intake locations; near the North Intake airshaft and South Intake airshaft. Return samples were also taken at the bottom of the return airshaft and exhaust slope. The North Jaw crusher dump point was also sampled.

In addition to the seven area samples (two at the exhaust shaft, two at the exhaust slope, one at the North intake, one at the South intake, and one at the dump point), five personal samples were collected on each shift. Although individual workers were selected based on availability, the same occupations were sampled for each phase of the study. Occupations sampled were a loader operator, two truck drivers, scaler, and a roof bolter. Smoking was permitted underground in the mine. Since individual workers varied at the occupations during different phases of the test, their smoking and non-smoking designations changed.

Individual area and personal samples were collected with SKC, Inc. diesel particulate sampling cassettes. This cassette includes a submicron impactor and a quartz fiber filter. All sampling units used 10-millimeter nylon preseparator cyclones. Samples were collected using SKC pumps calibrated and operated at 1.7 liters per minute (Lpm) of airflow.

The airborne carbon samples were analyzed by the MSHA Dust Division Laboratory, according to NIOSH Method 5040. Elemental carbon (EC), organic carbon (OC), and total carbon (TC) values were determined from the samples collected. This method uses a thermal/optical carbon analyzer to determine the organic and EC matter per square centimeter of filter surface. Separation of different types of OC is accomplished through temperature ramping over time and controlled atmospheric conditions. Carbonaceous minerals are separated at a temperature of 750^{o}C (fourth OC peak). The carbonaceous mineral content, evolved at the 750^{o}C peak, was subtracted from the OC portion of the analysis, using the software capability of the analytical program. This correction for the carbonaceous mineral content was made because it is associated with mineral dust and is not considered diesel particulate. OC and EC were added together to obtain the TC. A field blank correction was also applied to the carbon measurements. If the field blank correction resulted in a negative carbon measurement, the carbon measurement was defaulted to zero. Concentrations of carbon were calculated from the following formulas:

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

$$TC = OC + EC \text{ or } TC = 1.3 \times EC$$

Where:

C = the corrected OC or EC, concentration measured in the thermal/optical carbon analyzer.
A = the surface area of the filter media used. The surface area of the filters is 8.04 cm^2.

All area concentrations were based on actual sampling time. These results are reported as time weighted averages (TWA). As per Metal and Non-metal protocol, personal samples were collected for the full shift and then time weighted at 480 minutes to obtain shift weighted averages (SWA).

RESULTS AND DISCUSSION

Appendices B and C are the area and personal sample results measured during each of the two day studies. Appendix B is the raw data for the area samples and Appendix C is the raw data for the personal samples. Data from these Appendices was used to compile Tables 1 and 2.

Table 1 contains the summary of the average area DPM sampling results for the three surveys. During the baseline survey, the south intake air concentration averaged 2 $\mu g/m^3$. The north intake concentrations averaged 47 $\mu g/m^3$. The intake TC DPM concentrations indicate the north intake air contributed to the TC DPM levels found in the mine.

The exhaust weighted average concentration was obtained by multiplying the individual return concentrations by the associated airflow then dividing the sum of these two products by the total airflow. Using the TC = EC x 1.3 data, this table shows that the weighted return average DPM for the baseline samples was 693 $\mu g/m^3$. When the 35% RVO bio-diesel mixture was used, the weighted average return concentration was reduced to 480 $\mu g/m^3$. Because the airflow during the baseline and the 35% RVO were similar, an evaluation could be made by comparing DPM concentrations. This comparison shows a 31% DPM reduction when using the 35% RVO bio-diesel fuel mixture.

When the 35% VSO bio-diesel mixture was used, this weighted average return concentration was 707 $\mu g/m^3$. Because of the decrease in airflow due to changes in natural ventilation, a direct comparison of DPM concentrations could not be used to assess the 35% VSO mixture. For this comparison the mass of diesel particulate (airflow times concentration) from the baseline was compared to the mass of diesel particulate from the VSO tests. This resulted in a 16% DPM reduction when using the 35% VSO bio-diesel fuel mixture. When using TC = EC + OC data, similar results were obtained.

Table 2 is a summary of the averages of the personal DPM sampling for all employees sampled. Table 2 is further broken down into employees working inside of cabs and employees working outside of cabs. Since the surveys covered six separate days of sampling with each two day study separated by approximately two weeks, the results of the personal sampling data were affected by numerous variables. Different pieces of equipment were used, different locations were mined, employees sampled varied, and ventilating air quantities changed.

Table 2 shows that the average TC concentration of employees working inside of cabs during the baseline survey was 1611 $\mu g/m^3$. During the 35% RVO bio-diesel survey, this average concentration was reduced to 731 $\mu g/m^3$. During the 35% VSO bio-diesel survey this average concentration was reduced to 967 $\mu g/m^3$. These concentrations correspond to a 55% TC DPM reduction during the 35% RVO bio-diesel survey and a 40% TC DPM reduction during the 35% VSO bio-diesel survey.

Table 3 shows the personal samples that meet or exceed the current and future EC x 1.3 concentration limits of 400 and 160 $\mu g/m^3$, respectively. During the baseline survey, all sampled occupations exceeded both the current and future EC x 1.3 concentration limits. During the 35% RVO survey, the scaler operator was the only occupation to meet the current EC x 1.3 concentration during one of the two sampled shifts. During the 35% VSO survey, the scaler operator was the only occupation to meet the current EC x 1.3 concentration during one of the two sampled shifts. No occupation met the future concentration of 160 $\mu g/m^3$ during the six sampled shifts.

FINDINGS AND CONCLUSIONS

1. The use of 35% RVO bio-diesel fuel resulted in a 31% reduction of TC DPM in the mine exhaust airflow. The use of 35% VSO resulted in a 16% reduction of TC DPM in the mine exhaust airflow.

2. Personal DPM exposures were lowered by use of the RVO bio-diesel fuel; however, only the scaler occupation was below 400 $\mu g/m^3$.

3. Although the RVO bio-diesel fuel reduced DPM in the mine atmosphere, further DPM controls will need to be utilized to reduce DPM to required levels.

Table 1. Average Area Sample Diesel Particulate Matter Concentrations, Black River Mine, March 18-19, 2003, April 8-9, 2003 and April 29-30, 2003

	Baseline				35 % RVO Bio-diesel				35% VSO Bio-diesel			
Location	Airflow cfm	TC EC x 1.3 µg/m³	TC EC + OC µg/m³	Ratio EC/ TC	Airflow cfm	TC EC x 1.3 µg/m³	TC EC + OC µg/m³	Ratio EC/TC	Airflow cfm	TC EC x 1.3 µg/m³	TC EC + OC µg/m³	Ratio EC/TC
South Intake		0	3	0		0	3	0		*	*	*
North Intake		45	47	.74		47	38	.95		58	53	.85
Return Slope	109,000	436	401	.84	77,000	281	263	.82	67 ,000	647	587	.85
Return Shaft	150,000	880	789	.86	179,000	566	514	.85	147 ,000	735	655	.86
Exhaust Weighted Average	259,000	693	626	.85	256,000	480	439	.84	214,000	707	634	.86
Percent Reduction From Baseline						**31%**	**30%**			**16%**	**16%**	

*** South Intake down this part of survey.**

Table 2. Personal Diesel Particulate Matter Concentrations, Black River Mine, March 18-19, April 8-9, and April 29-30, 2003

	Baseline	35 % RVO Biodiesel	35% VSO Biodiesel
Occupation	TC = EC x 1.3 $\mu g/m^3$	TC = EC x 1.3 $\mu g/m^3$	TC = EC x 1.3 $\mu g/m^3$
Average – Workers Inside Cabs	1611	731	967
Percent Reduction From Baseline	-----	55%	40%
Average – Workers Outside Cabs	1369	771	1013
Percent Reduction From Baseline	-----		

Table 3. Personal DPM Samples that Meet or Exceed the Current and Future EC x 1.3 Concentration Limits of 400 and 160 μg/m³, Black River Mine, March 18-19, April 8-9 and April 29-30, 2003

Baseline				35 % RVO Biodiesel				35% VSO Biodiesel			
Date	Above 400 μg/m³	161 to 399 μg/m³	Below 160 μg/m³	Date	Above 400 μg/m³	161 to 399 μg/m³	Below 160 μg/m³	Date	Above 400 μg/m³	161 to 399 μg/m³	Below 160 μg/m³
3/18/03	5	0	0	4/8/03	4	1	0	4/29/03	5	0	0
3/19/03	5	0	0	4/9/03	5	0	0	4/30/03	4	1	0
Totals	10	0	0		9	1	0		9	1	0

Appendix A. Underground Diesel Equipment List, Black River Mine
March 18-19, 2003, April 8-9, 2003 and April 29-30, 2003

Description	Engine Manufacturer	Date of Manufacture	Engine Model	Engine Serial Number	Engine HP
Cannon Drill – 200252	Caterpillar			90U19878	375
Cannon Drill – 200399	Caterpillar			90U19962	375
Cannon Drill – 2000532	Caterpillar			04B27155	165
SCH5000D Gardner Denver Drill	Caterpillar			64Z19902	240
SCH5000D Gardner Denver Drill	Caterpillar			64Z24937	240
Getman Powder Wagon	Caterpillar			04B27207	165
CAT Powder Rig	Caterpillar			48W22630	450
Pony Motor	General Motors			512542-181	100
769C Cat Haul Truck	Caterpillar			48W21183	450
769C Cat Haul Truck	Caterpillar			48W19410	450
769C Cat Haul Truck	Caterpillar			48W18987	450
771C Cat Haul Truck	Caterpillar			48W36157	450
771C Cat Haul Truck	Caterpillar			48W37985	450
771C Cat Haul Truck	Caterpillar			99C01562	450
988B Cat Loader	Caterpillar			48W25048	400
988B Cat Loader	Caterpillar			48W22190	400
988B Cat Loader	Caterpillar			48W29706	400
988B Cat Loader	Caterpillar			48W34587	400
988F Cat Loader	Caterpillar			48W36575	400
966F Cat Loader	Caterpillar			08Z77784	400
Cannon 200415	Caterpillar			02B17964	80
Cannon 200523	Caterpillar			02B17993	80
Cannon 201119	Caterpillar			02B18107	80
Cannon 201119	Caterpillar			02B18190	80

Appendix A. Underground Diesel Equipment List, Black River Mine (Continued)

Description	Engine Manufacturer	Date of Manufacture	Engine Model	Engine Serial Number	Engine HP
315L Cat Scaler	Caterpillar			5XK18627	99
318 Cat Scaler	Caterpillar			4TF65354	140
318 Cat Scaler	Caterpillar			4TF65572	140
320B Cat Scaler	Caterpillar			7JK40061	138
Gradall Scaler	Cummins			60212310	150
Gradall Scaler	Cummins			60207696	150
Maintenance Tractor	Ford			C952318	35
Maintenance Tractor	Ford			D447485	35
Maintenance Tractor	Ford			D006595	35
Maintenance Tractor	Ford			C955560	35
Maintenance Tractor	Ford			C265193	35
Maintenance Tractor	Ford			C265182	35
Maintenance Tractor	Ford			C358452	35
Maintenance Tractor	Ford			C459044	35
Maintenance Tractor	Ford			C468701	35
Engineering Tractor	Ford			D331080	35
Production Tractor	John Deere			422873CD	35
Production Tractor	Ford			C356686	35
Production Tractor	Ford			C421256	35
Blasting Tractor	Ford			BB5423165C21	35
Production Tractor	Kubota			20811	35
Production Tractor	Kubota			20844	35
Production Tractor	Kubota			30091	35
12G Cat Grader	Caterpillar			O8759313	140
Eimco Loader	Caterpillar			C2B17201	80
Integrated Tool Carrier	Caterpillar			2FG07077	100

Appendix A. Underground Diesel Equipment List, Black River Mine (Continued)

Description	Engine Manufacturer	Date of Manufacture	Engine Model	Engine Serial Number	Engine HP
769C Cat Water Truck	Caterpillar			Repair	450
613C Cat Water Truck	Caterpillar			98Z02087	175
JCB	Caterpillar			666389Y	68
P&H Crain	Cummins			45019708	97
Man Lift	Caterpillar			O2B18154	165
Cat RC60 Fork Lift	Caterpillar			LD33649U171079P	35
Grease Rig	Caterpillar			48W24234	450
Water Pump	Deutze			20230011	10
Air Compressor	John Deere			CD4039D155628	35
Welder	Continental			94070635	25

Appendix B. Results of Area Sample Results, Black River Mine,
March 18-19, 2003, April 8-9, and April 29-30, 2003

Location	Baseline				35 % RVO Bio-diesel				35 % VSO Bio-diesel			
	Airflow cfm	TC EC x 1.3 µg/m³	TC EC + OC µg/m³	Ratio EC/TC	Airflow cfm	TC EC x 1.3 µg/m³	TC EC + OC µg/m³	Ratio EC/TC	Airflow cfm	TC EC x 1.3 µg/m³	TC EC + OC µg/m³	Ratio EC/TC
South Int.		0	4	0		0	2	0		*68	*56	.93
South Int.		0	1	0		0	0	0		*54	*60	.70
North Int.		59	62	.73		35	34	.79		61	54	.87
North Int.		31	32	.75		59	42	1.1		48	43	.86
Ret. Slope	109000	400	365	.84	73000	247	242	.79	68000	637	568	.86
Ret. Slope	109000	400	390	.79	73000	250	227	.85	68000	631	576	.84
Ret. Slope	108000	457	415	.85	80000	309	283	.84	66000	**287	**256	.86
Ret. Slope	108000	486	432	.87	80000	316	299	.81	66000	672	617	.84
Average	**109**	**435**	**400**		**77**	**280**	**262**		**67**	**647**	**587**	
Ret. Shaft	146000	807	725	.86	179000	411	377	.84	147000	719	649	.85
Ret. Shaft	146000				179000	429	401	.82	147000	698	638	.84
Ret. Shaft	154000	926	817	.87	178000	730	635	.89	147000	756	661	.88
Ret. Shaft	154000	906	825	.85	178000	692	643	.83	147000	765	673	.87
Average	**150**	**880**	**789**		**179**	**565**	**514**		**147**	**734**	**655**	
Wt,. Avg.	**259**	**693**	**625**		**256**	**479**	**438**		**214**	**706**	**633**	
Percent Reduction						**31.7 %**	**30.7 %**			**15.8 %**	**16.3 %**	
Dump		----	----	----		352	312	.87		870	732	.91
Dump		635	558	.87		376	347	.83		613	540	.87

*** - North Intake samples only this survey, South Intake down.**

Appendix C. Personal Sample Results, Shift Weighted Average, Black River Mine, March 18-19, April 8-9, and April 29-30, 2003

		Baseline		35 % RVO Bio-diesel		35 % VSO Bio-diesel	
Occupation	Cab or No Cab	TC EC x 1.3 $\mu g/m^3$	TC EC + OC $\mu g/m^3$	TC EC x 1.3 $\mu g/m^3$	TC EC + OC $\mu g/m^3$	TC EC x 1.3 $\mu g/m^3$	TC EC + OC $\mu g/m^3$
Bolter	Cab	1553	1438	809	880	1240	1408
Bolter	Cab	1185	1074	733	741	785	815
Scaler	Cab	1202 s	1084	286	294	470	442
Scaler	Cab	1280 s	1175	592	560	325	319
Truck 20, 15	Cab	1613	1426	685	708	1263	1183 s
Truck 20, 15	Cab	1624	1407	606	577	906	933 s
Truck 18	Cab	1584 s	1437	763	776	993	1073
Truck 18	Cab	1500 s	1372	932	859	908	853
Loader 235	Cab	2001	1738	846	786	1227	1314
Loader 235	Cab	2083	1781	1135	1027	1642	1657

S - denotes smoker