Testing of Diesel Emissions Control Technologies in Isolated Zone

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CDC Workplace Safety and Health

Objectives of the study

- Measure the effects of six diesel particulate matter filtration systems (DPFs) on the concentrations of PM and gases in mine air
  - Engelhard DPX, model 9308,
  - DCL BlueSky, model 3211-SA-6CG1-21,
  - DCL MineX, model 5C5711,
  - ECS CatTrap, model CT28,
  - CleanAir Systems, model FPA158 W, and
  - Donaldson high-temperature disposable filter elements, model P604516
- Measure the effects of diesel oxidation catalytic converter/muffler (DOC) on the concentrations of PM and gases in mine air
- Measure the effects of fuel formulation on the concentrations of PM and gases in mine air
  - Biodiesel blends B20 and B50 (B100 from Griffin Industries, KY, G3000)
  - Diesel D1 vs. diesel D2 (Cenex, Billings, MT)
  - Fuel additive (CDT Platinum Plus) in conjunction with CleanAir Systems DPF

Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health

Methodology - Study Site

- The study was conducted at Stillwater Nye mine:
  - Nye, Montana
  - Precious metals mine (palladium, platinum, gold, silver,…)
  - Vein mining
  - Large inventory of diesel-powered equipment (~ 400 units)
  - Relatively small and low-power equipment
  - Main portal at 5000 feet above see level with production between 2900-7000 ft
- Tests were conducted in a two-week period in May and June 2003

Methodology

- **Isolated zone tests**
  - Direct in-situ assessment of the effects of control technologies on quality of ambient air downwind of working equipment
  - Vehicles operated over a simulated transient production cycle
  - Interaction between vehicle, engine, and control technology
  - Complements laboratory evaluations
- **Tailpipe emissions measurements**
  - Complemented the isolated zone testing
  - Limited to small number of steady-state vehicle/engine operating conditions
  - Go, no-go tests for isolated zone testing

Test Vehicles

- **Criteria for selection of the vehicles and DPFs**
  - Select the vehicles which typify the mine fleet
  - Are significant PM source in workplace (horsepower-hours)
  - Are ones most suitable for passive DPF systems
  - System potentially could fit on vehicle but temporary installations were used to expedite testing

Vehicle Number	Equipment Type	Engine Type
#92128	MTI 1604 Haulage Truck	Deutz BF6M1013 ECP
#92133	MTI 1604 Haulage Truck	Deutz BF6M1013C
#92506	MTI 350 LHD	Deutz BF4M1013
#92526	Elphinstone R1300 LHD	Caterpillar 3306 DITA
#99942	Elphinstone R1500 LHD	Caterpillar 3306 DITA

Filtration Systems

Engelhard DPX on #92128
cordierite monolith
platinum coated

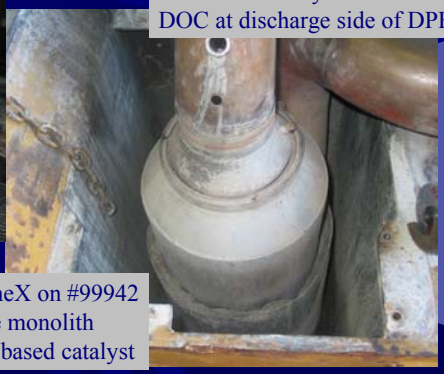
CleanAIR Systems on #92133
cordierite monolith
platinum coated (light)
CDT Platinum Plus fuel additive

DCL BlueSky on #92506
silicon carbide monolith
on-board electrical regen.

Filtration Systems

ECS CatTrap on #92526
cordierite monolith
base metal catalyst
DOC at discharge side of DPF

Donaldson on #99506
two high-temperature
disposable filter elements



DCL MineX on #99942
cordierite monolith
platinum based catalyst

Diesel Oxidation Catalytic Converter/ Muffler

DOC/muffler on #92526

Fuel Formulations

Biodiesel blends B20 and B50 - B100 "yellow grease" biodiesel blended with diesel D2

CDT Platinum Plus additive - Additive blended directly in the fuel tank (30 ounces for 125 gallons)

Fuel Analysis

Type of analysis		Method	Units	SwRI			Cenex		Griffin
				D2	B20	B50	D1	D2	B100
1		2	3	4	5	6	7	8	9
Cetane Number		ASTM D613	N/A	43.2	47.6	51.5	42.8	43.2	53.5
Hydrocarbon Type	Aromatics	ASTM D1319	Vol%	30.9	N/A	N/A	N/A	N/A	N/A
	Olefins		Vol%	2.1	N/A	N/A	N/A	N/A	N/A
	Saturates		Vol%	67	N/A	N/A	N/A	N/A	N/A
Density		ASTM D4052	g/ml	0.85	N/A	N/A	0.82	0.85	N/A
Sulfur Content		ASTM D5453	ppm	299	238	159	125	366	25
Nitrogen Content		ASTM D4629	ppm	28	36.3	43.4	N/A	N/A	N/A
Oxygen		By difference	% wt.	NA	2.49	5.56	N/A	N/A	N/A*
Heat of Combustion		ASTM D240	BTU/ lb	18335	17853	17164	N/A	N/A	N/A
Flash Point		ASTM D93	°C	71.1	73.3	78.9	57.2	66.1	>120
Viscosity, 40 °C		ASTM D445	mm^2/s	NA	2.61	3.25	N/A	N/A	4.65

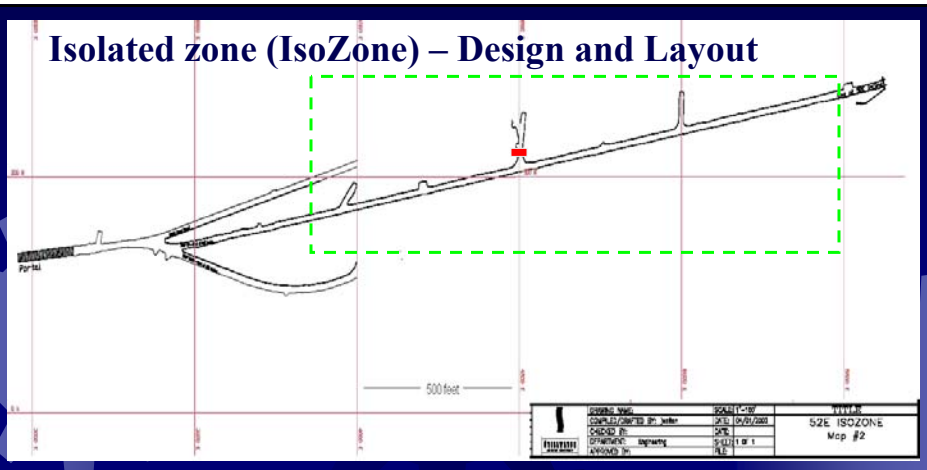
* B100 Biodiesel is normally about 11% oxygen.

Fuel Used for Testing

Vehicle	Test	Exhaust System Configuration	Date	Fuel
#92128	Baseline	Muffler	5/26/2003	D1(27.5%)/D2(72.5%)
	DPF	Engelhard DPX	5/26/2003	D1(47.3%)/D2 (52.7%)
#92133	Baseline	Muffler	5/22/2003	D1(19.1%)/D2(80.9%)
	DPF	CleanAir Systems	5/22/2003	D1(31.4%)/D2(68.6%)
#92506	Baseline D1	Muffler	5/23/2003	D1(10.4%)/D2(89.6%)
	Baseline D2	Muffler	5/23/2003	D2(100%)
	DPF	DCL BlueSky	5/21/2003	D1(75.0%)/D2(25.0%)
	Disposable DPF	Donaldson P604516	5/23/2003	D1(14.7%)/D2(85.3%)
#92526	Baseline D1	Muffler	5/27/2003	D1(74.1%)/D2(25.9%)
	Baseline/ DOC	DOC and muffler	5/27/2003	D1(52.2%)/D2(47.8%)
	DPF	ECS Cattrap	5/24/2003	D1(94.8%)/D2(5.2%)
	Biodiesel B20	DOC and muffler	5/28/2003	D2(80.0%)/Bio(20%)
	Biodiesel B50	DOC and muffler	5/28/2003	D2(50%)/Bio(50%)
#99942	Baseline D1	Muffler	5/29/2003	D1
	Baseline D2	Muffler	5/30/2003	D2
	DPF	DCL MineX	5/29/2003	D1

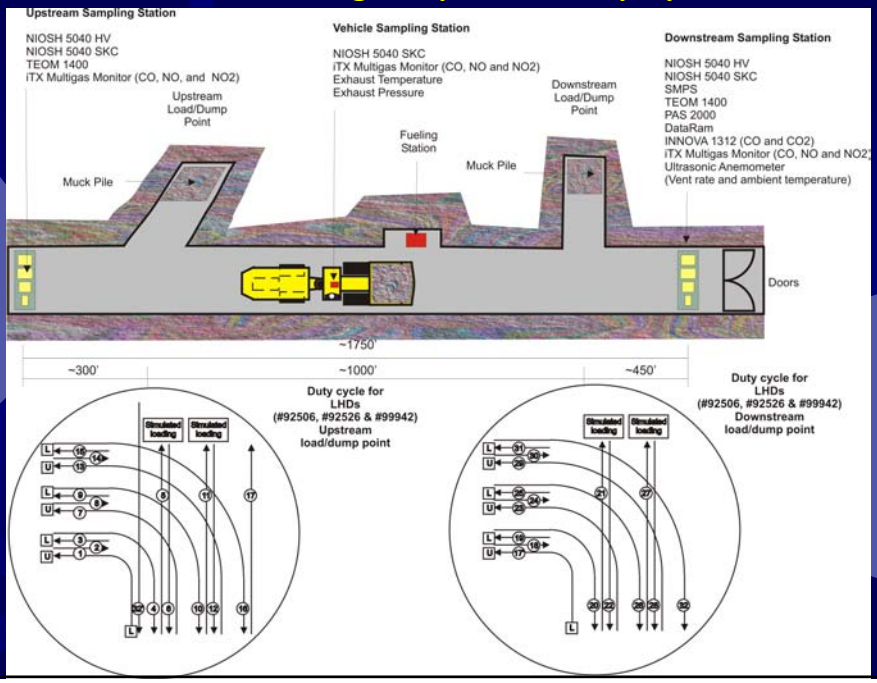
Isozone fuel top-off reservoir

Isolated zone (IsoZone) – Design and Layout

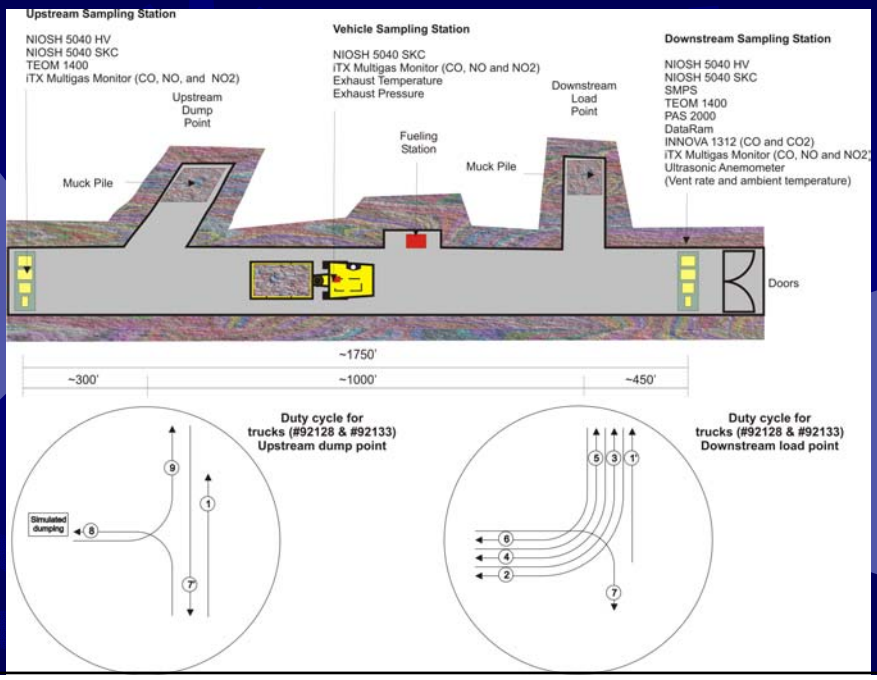


- ~1750 ft (533 m) long
- ~1000 ft (305 m) from portal
- 9% grade rising downstream
- ventilated with fresh air

LHDs in IsoZone: Design, Layout and Duty Cycle



Haulage Trucks in IsoZone: Design, Layout and Duty Cycle



Sampling Methodology and Instrumentation Used in IsoZone Tests

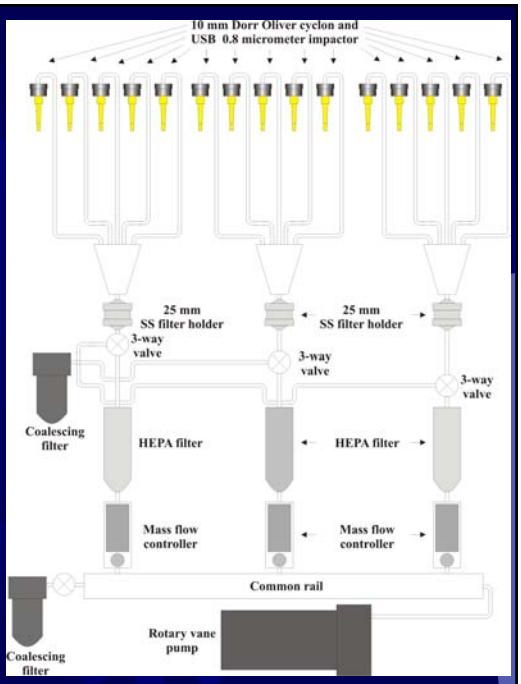
- Three sampling locations were:
  - Upstream sampling station, ~ 300 ft (91 m) upstream of the upstream load/dump point
  - Downstream sampling station, ~ 450 ft (137 m) downstream of the upstream load/dump point
  - On-vehicle, ~ 6 ft (1.8 m) from the operator
- Contribution from the vehicles obtained by subtracting upstream from downstream concentrations. (As a rule, upstream concentrations were found to be negligible for every substance measured except CO_2 whose background was measured over night.)

Sampling Methodology and Instrumentation Used in Isolated Zone Tests

- Concentrations of particles were measured using:
  - TEOM 1400 (real-time total PM with D_{50} under 800 nm)
  - SMPS (size distribution and number concentrations of aerosols with D_{50} between 10 and 400 nm)
- Filter samples for NIOSH 5040 carbon analysis (elemental carbon with D_{50} under ~800 nm) were collected using:
  - Standard sampling train (10mm Dorr Oliver cyclone, SKC impactor, pump) at upstream, downstream, and on-vehicle sampling locations
  - High volume sampling train at upstream and downstream sampling station
- Concentrations of CO, NO, and NO_2 in mine air at upstream, downstream, and vehicle sampling station were continuously measured using:
  - Industrial Scientific iTX multigas monitors
- Concentrations of CO and CO_2 in mine air at downstream sampling station were continuously measured using:
  - INNOVA 1312

High-volume Sampling Train

- High expected DPF efficiencies and limited sampling times demanded high-volume sampling
  - Increased sampling flow to 8.5 lpm vs. 1.7 lpm
  - Reduced filter area to 25 mm vs. 37 mm tissue quartz filter
  - Outcome: ~10 times more sample for the same sampling time

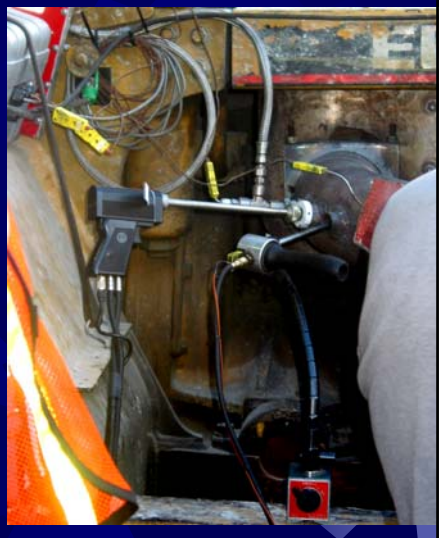


Instrumentation at Downstream Sampling Station

Sampling Grid at Downstream Sampling Station

Methodology- Tailpipe Emissions Measurements

- **Engine operating conditions**
  - Torque converter stall (TCS)
  - High idle (HI)
  - Low idle (LI)
- **DPM emissions were measured using ECOM KL to collect:**
  - Filter smoke spots for Bacharach number
  - Filter samples for NIOSH 5040 elemental carbon analysis
- **Gaseous emissions (CO, NO, and NO_2)**
  - Steady-state (ECOM KL)
  - Quasi- transient (Enerac 400)

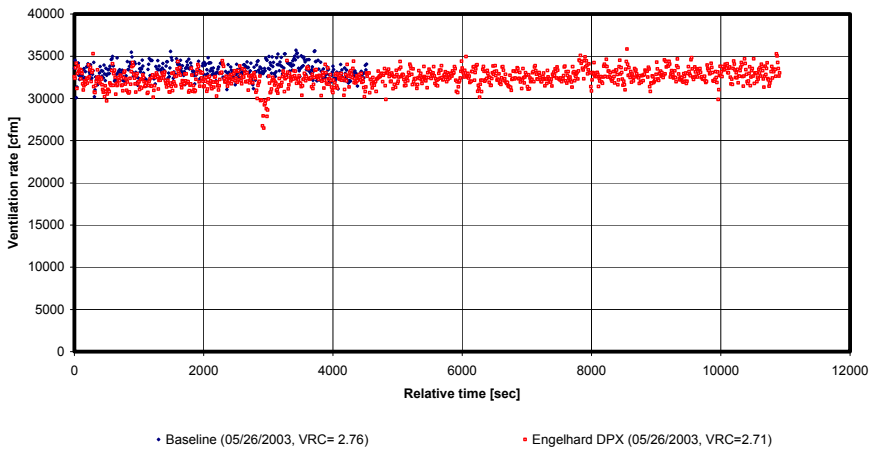


Results and Discussion

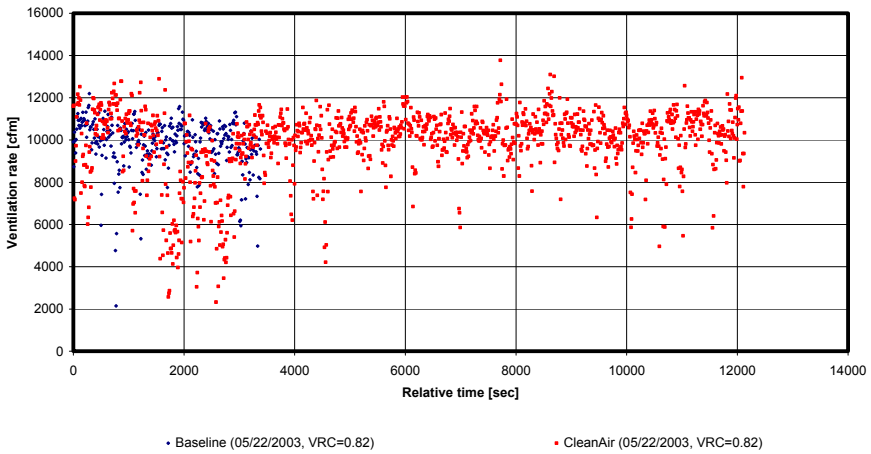
- Ventilation rates
- Effects of diesel particulate filters (DPFs) on:
  - mass concentrations of elemental carbon particles under 800 nm
  - mass concentrations of total particulate matter under 800 nm
  - number concentrations and size distribution of aerosols between 10 and 400 nm
- Effects of different fuel formulations on:
  - mass concentrations of elemental carbon particles under 800 nm
  - mass concentrations of total particulate matter under 800 nm
  - number concentrations and size distribution of aerosols between 10 and 400 nm

Results and Discussion: Ventilation Rates

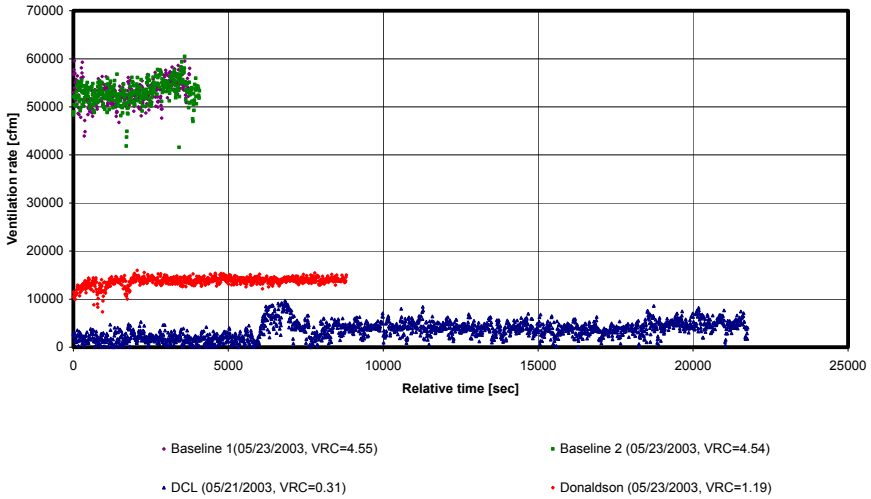
#92128



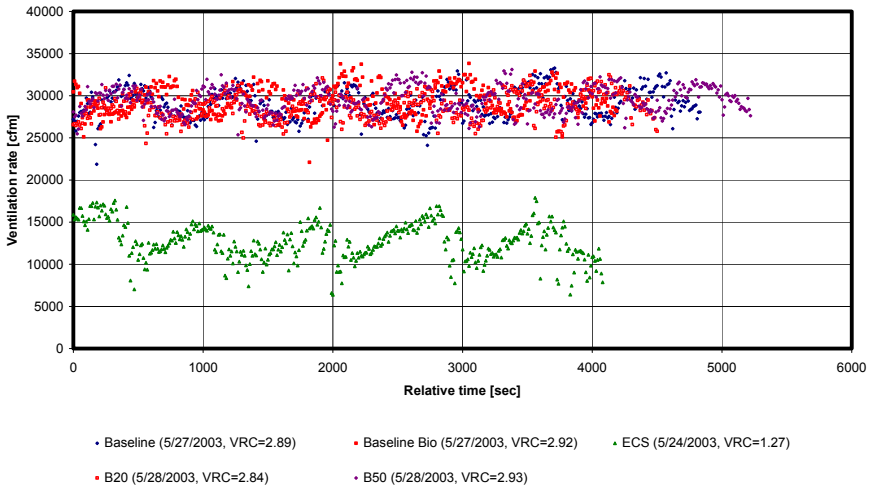
Results and Discussion: Ventilation Rates **#92133**



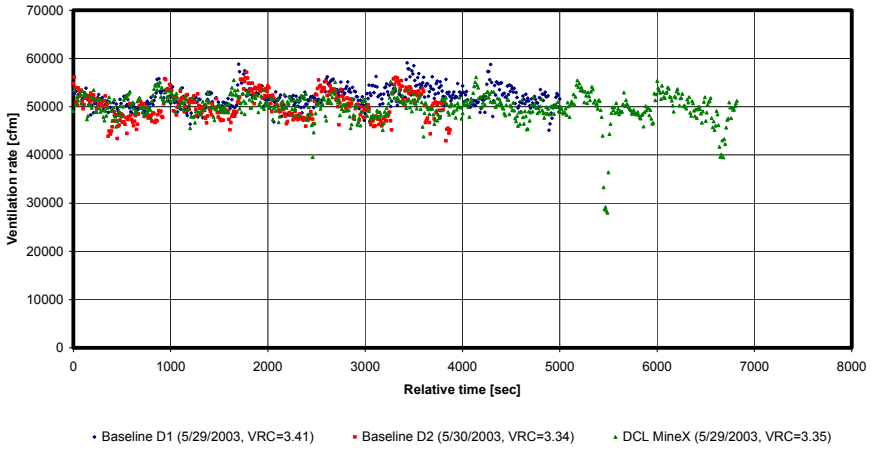
Results and Discussion: Ventilation Rates **#92506**



Results and Discussion: Ventilation Rates **#92526**



Results and Discussion: Ventilation Rates **#99942**



Results and Discussion: Ventilation Rates

- Problems with tests conducted at lower ventilation rates:
  - Downstream concentrations of CO_2 and NO_x were significantly lower for the tests with lower ventilation rate coefficients (VRC = average VR of test divided by MSHA VR for engine)
  - And baseline VR greater than DPF test VR precluded comparison
- The results of those tests are not discussed.
- Exception: #92133 where VR for baseline and DPF were the same.

Test Type	VR Coefficient	VRC Average CO2 Concentrations INNOVA [ppm]	VRC Average NOx Concentrations ITX [ppm]
#92128 Haul Truck, MSHA ventilation rate 12000 cfm			
Baseline	2.7676	3630.2	17.5
Engelhard DPX	2.7064	3363.5	14.6
#92133 Haul Truck, MSHA ventilation rate 12000 cfm			
Baseline	0.8193	1553.8	6.2
Clean Air	0.8241	1667.9	7.3
#92506 LHD, MSHA ventilation rate 11500 cfm			
Baseline D1	4.5560	3510.8	4.9
Baseline D2	4.5363	3594.0	5.4
DCL BlueSky	1.0000	2203.5	5.7
Donaldson	1.1902	1838.1	8.4
#92526 LHD, MSHA ventilation rate 10000 cfm			
Baseline	2.8916	4234.4	17.7
Baseline/PTX	2.9226	4563.3	19.4
ECS CATTRAP	1.2685	2919.4	12.6
Biodiesel B20/PTX	2.8395	4531.6	20.3
Biodiesel B50/PTX	2.9349	4018.8	22.3
#99942 LHD, MSHA ventilation rate 15000 cfm			
Baseline/D1	3.4123	3896.6	14.4
Baseline/D2	3.3368	3793.8	13.9
DCL MineX	3.3516	3672.4	12.8

Effects of Selected Diesel Particulate Filters (DPFs) and Diesel Oxidation Catalytic Converter (DOC) on Concentrations of Particulate Matter and Gases in Mine Air

Mass Concentrations of Elemental Carbon (EC)

Test type	EC		Reductions normalized by vent. rate
	[µg/m^3]	CV [%]	[%]
#92128 Haul Truck, MSHA vent rate 12000 cfm			
Baseline	1182	5.3	
Engelhard DPX	51	3.2	96
#92526 LHD, MSHA vent rate 10000 cfm			
Baseline	1328	1.6	
DOC	1365	2	-3
#99942 LHD, MSHA vent rate 15000 cfm			
Baseline, D1	1112	7.7	
DCL MineX	149	2.6	88

- Tested DPFs reduced concentrations of EC bellow current standards (308 µg/m^3).
  - It was also estimated that CleanAir Systems DPF reduced concentrations of EC by app. 99%.
- Tested DOC did not significantly affect EC concentrations.

Mass Concentrations of Total Particulate Matter (TPM)

Test Type	Concentrations of TPM [µg/m3]		Reductions [%]
	Ave.	Max.	Ave.
#92128 Haul Truck, MSHA ventilation rate 12000 cfm			
Baseline	1343.9	1536.3	--
Engelhard DPX	341.7	411.6	75
#92526 LHD, MSHA ventilation rate 10000 cfm			
Baseline	1631.9	2083.0	--
DOC	1874.6	2324.6	-15
#99942 LHD, MSHA ventilation rate 15000 cfm			
Baseline D1	1433.6	2140.2	--
DCL MineX	369.6	588.1	74

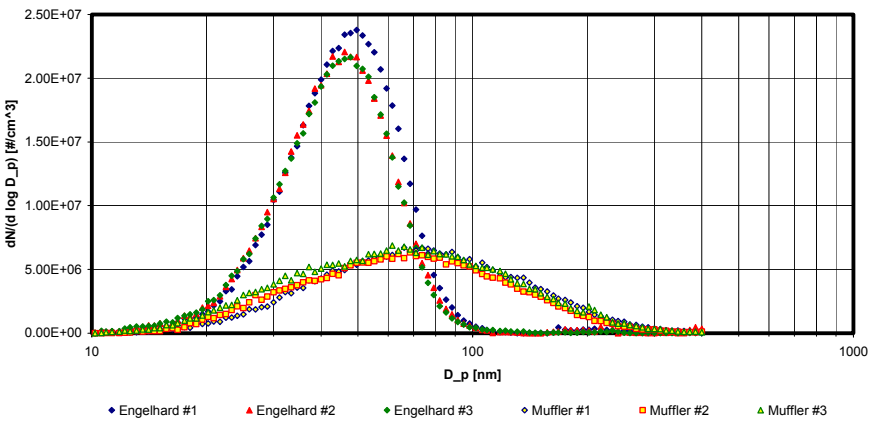
- Tested DPFs reduced concentrations of TPM somewhat less efficiently than concentrations of EC (sulfate or other artifact?)
  - It was also estimated that CleanAir Systems DPF reduced concentrations of TPM by app. 89%.
- Tested DOC increased slightly concentrations of TPM in mine air possibly as a result of a sulfate artifact.

Concentrations of Aerosols with Electrical Mobility Diameter Between 10 and 400 nm in Mine Air

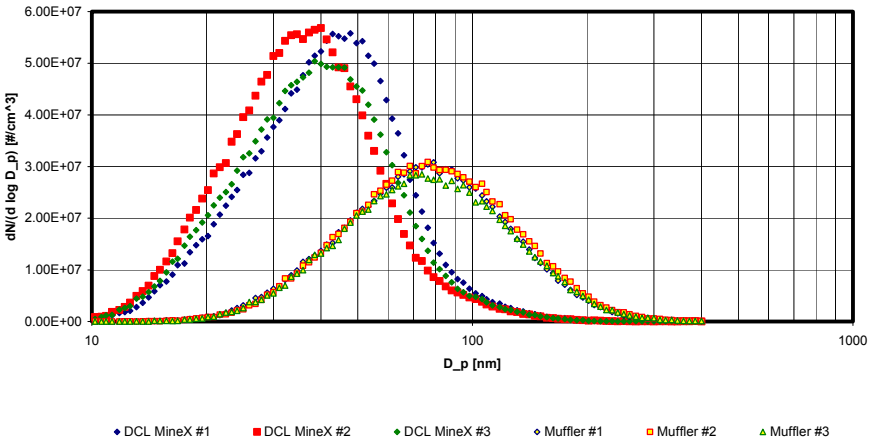
Test Type	Geo. Mean [nm]	Geo. Std. Dev.	Average Geometric Mean [nm]	Average Total Particle Conc. @	Change in Total Particle Conc. [%]
#92128 Haul Truck, MSHA vent rate 12000 cfm					
Baseline (Muffler)	71.6	1.83	67.3	2.88E+08	N/A
	65.8	1.83			
	64.4	1.90			
Engelhard DPX	45.1	1.44	43.7	5.17E+08	79.6
	43.5	1.47			
	42.6	1.44			
#92526 LHD, MSHA vent rate 10000 cfm					
Baseline (Muffler)	85.1	1.68	85.7	6.82E+07	N/A
	86.4	1.67			
Baseline (DOC)	72.2	1.75	72.4	7.32E+07	7.4
	72.6	1.74			
#99942 LHD, MSHA vent rate 15000 cfm					
Baseline D1 (Muffler)	74.4	1.64	75.4	3.97E+07	N/A
	76.6	1.65			
	75.2	1.65			
DCL MineX	40.7	1.58	38.1	7.09E+07	78.7
	35.5	1.57			
	38.0	1.59			

- Tested DPFs significantly increased the aerosol number concentration.
- Tested DPFs reduced D_{50} of the aerosols.
- Tested DOC slightly increased aerosol number conc.
- Tested DOC slightly reduced D_{50} of the aerosols.

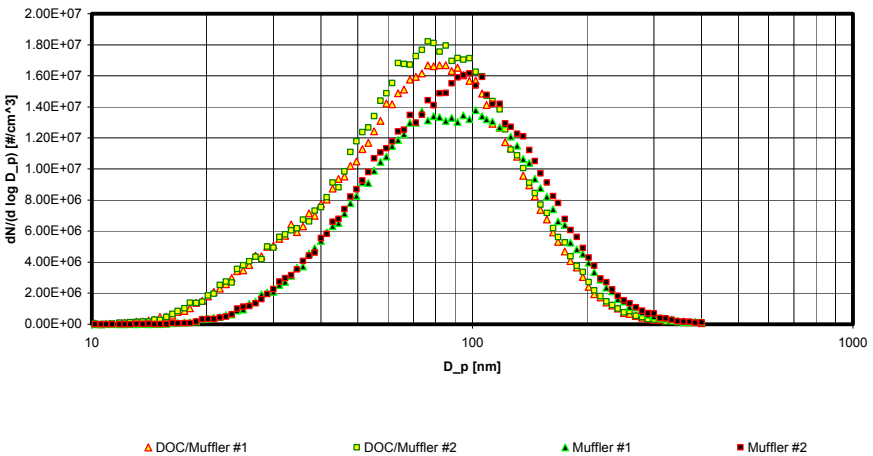
Size distribution of aerosols in mine air
Truck #92128: Engelhard DPX DPF vs. Muffler



Size distribution of aerosols in mine air
LHD #99942 - DCL MineX vs. Muffler



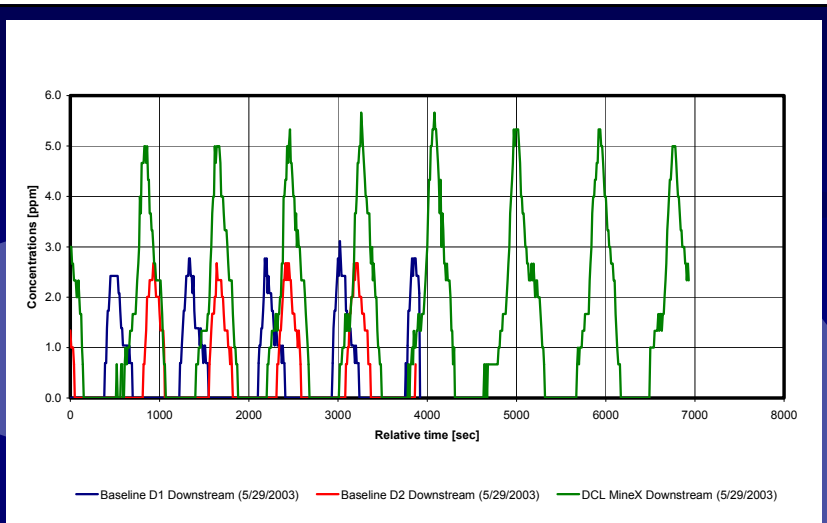
Size distribution of aerosols in mine air
LHD #92526 –DOC/Muffler vs. Muffler



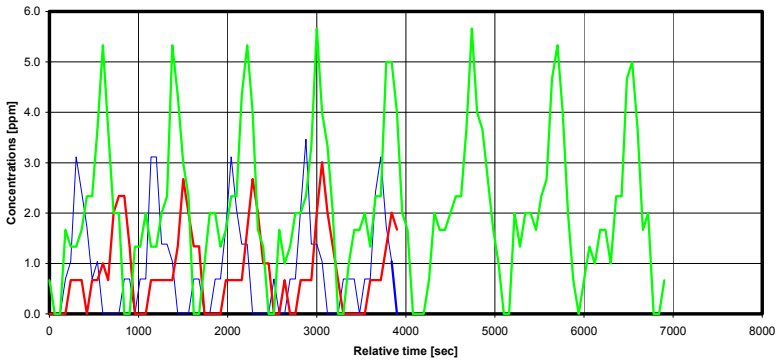
Concentrations of Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitric Oxide (NO), and Nitrogen Dioxide (NO_2)

Test Type	CO [ppm]		CO2 [ppm]		NO [ppm]		NO2 [ppm]	
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.
#92128 Haul Truck, MSHA ventilation rate 12000 cfm								
Baseline	11.1	6.7	3834	2924	22.2	16.9	1.1	0.6
Engelhard DPX	0.0	0.0	3793	2718	18.9	12.5	3.2	2.1
#92526 LHD, MSHA ventilation rate 10000 cfm								
Baseline	17.5	6.4	7820	3699	40.8	17.0	2.6	0.9
DOC	0.0	0.0	7622	3821	41.3	18.6	2.9	1.0
#99942 LHD, MSHA ventilation rate 15000 cfm								
Baseline, D1	24.2	4.5	8740	2849	50.2	13.5	3.1	0.6
DCL MineX	0.0	0.0	8656	2713	43.3	11.2	5.7	1.5

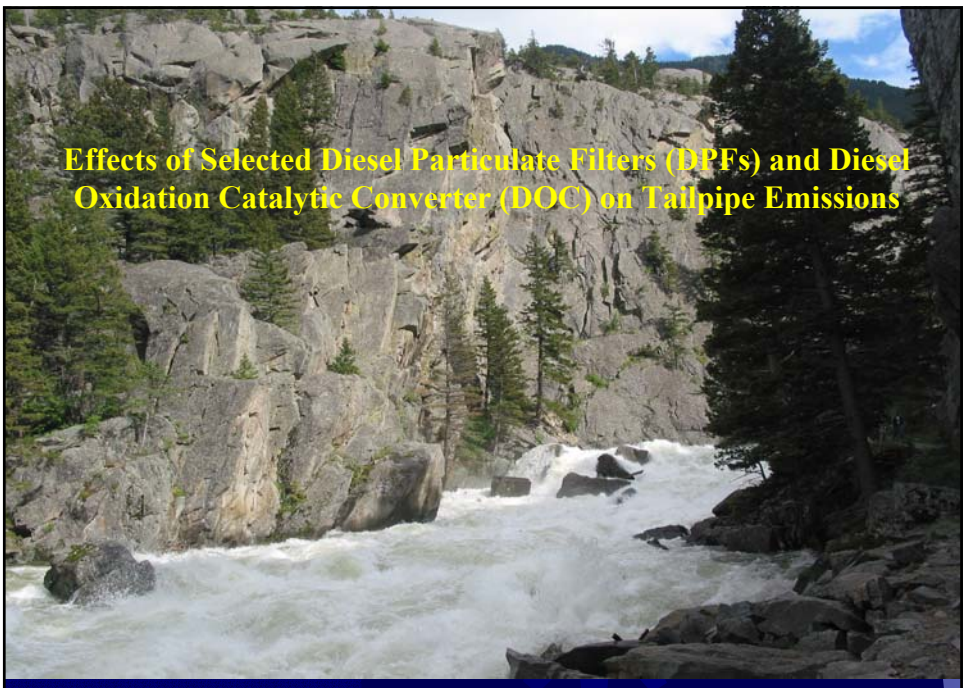
- CO concentrations were not measurable in the mine air when vehicles used platinum catalyzed DPFs and DOCs.
- Average concentrations of CO_2 were almost identical for baseline and controls tests.
- Average NO_X concentrations were found to be somewhat lower for the DPF than for the baseline tests.
- Significant increase in ambient concentrations of NO_2 was observed when vehicles used platinum coated DPFs.
- Tested DOC did not significantly affect ambient concentrations of NO_2.



Ventilation-normalized NO_2 concentrations at downstream sampling station observed during the tests with LHD #99942



Ventilation-normalized NO_2 concentrations at vehicle sampling station observed during the tests with LHD #99942



Effects of Selected Diesel Particulate Filters (DPFs) and Diesel Oxidation Catalytic Converter (DOC) on Tailpipe Emissions

Elemental Carbon (EC) Emissions and Bacharach Smoke Number

Test Type	EC [µg/m3] HI		EC [µg/m3] TCS		Reduction of EC [%]	
	Upstream	Downstream	Upstream	Downstream	HI	TCS
#92128 Haul Truck						
Engelhard DPX	2369	< 920	18230	< 920	> 61	> 95
#92133 Haul Truck						
CleanAir Systems	6043	< 920	33537	< 920	> 85	> 97
#92506 LHD						
DCL BlueSky	5282	1055	23316	< 920	80	> 96
Donaldson	3353	< 920	18230	1748	> 72	90
#92526 LHD						
ECS Cattrap	8898	< 920	8254	< 920	> 90	> 89
DOC	16049	11529	8230	6712	28	18
#99942 LHD						
DCL MineX	40838	< 920	16417	< 920	> 98	> 94

Test Type	Bacharach smoke number HI		Bacharach smoke number TCS	
	Upstream	Downstream	Upstream	Downstream
#92128 Haul Truck				
Engelhard DPX	3	0	7	0
#92133 Haul Truck				
CleanAir Systems	3	0	4	0
#99942 LHD				
DCL MineX	9	0	8	0

Carbon Monoxide (CO)

Test Type	CO [ppm] HI		CO [ppm] LI		CO [ppm] TCS		Instrument
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
#92128 Haul Truck							
Engelhard DPX	217	0	197	0	136	0	ECOM
	204	0	170	0	131	0	Enerac
#92133 Haul Truck							
CleanAir	314	2	100	0	114	0	ECOM
Systems	301	0	110	0	109	11	Enerac
#92506 LHD							
DCL BlueSky	2437	1329	168	3	386	3	ECOM
	2207	910	208	0	460	0	Enerac
Donaldson	N/A	N/A	N/A	N/A	N/A	N/A	ECOM
	2960	1359	248	79	268	210	Enerac
#92526 LHD							
ECS Cattrap	278	2	N/A	N/A	106	1	ECOM
	238	0	168	0	98	0	Enerac
Biodiesel B20,	187	18	158	1	71	1	ECOM
DOC	167	16	173	0	74	4	Enerac
Biodiesel B50,	203	22	N/A	N/A	75	6	ECOM
DOC	174	21	159	0	76	13	Enerac
#99942 LHD							
DCL MineX	376	0	N/A	N/A	229	0	ECOM
	343	0	125	0	215	0	Enerac

Nitrogen Dioxide (NO_2)

Test Type	NO2 [ppm] HI		NO2 [ppm] LI		NO2 [ppm] TCS		Instrument
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
#92128 Haul Truck							
Engelhard DPX	58	98	73	-	25	89	ECOM
	87	121	72	170	23	101	Enerac
#92133 Haul Truck							
CleanAir Systems	51	12	21	43	25	39	ECOM
	51	8	10	38	11	7	Enerac
#92506 LHD							
DCL BlueSky	83	6	40	50	16	16	ECOM
	48	0	51	65	2	14	Enerac
Donaldson	-	-	-	-	-	-	ECOM
	28	1	61	0	0	1	Enerac
#92526 LHD							
ECS Cattrap	34	59	55	-	17	121	ECOM
	31	81	68	177	31	163	Enerac
Biodiesel B20, DOC	22	16	34	36	16	36	ECOM
	-	-	-	-	-	-	Enerac
Biodiesel B50, DOC	21	21	18	-	12	40	ECOM
	6	3	43	41	6	8	Enerac
#99942 LHD							
DCL MineX	28	68	-	-	18	90	ECOM
	10	85	29	190	10	45	Enerac

Effects of Tested Fuel Formulations on Concentrations of Particulate Matter and Gases Mine Air

Mass Concentrations of Elemental Carbon (EC)

Test type	EC		Reductions normalized by vent. rate
	[µg/m^3]	CV [%]	[%]
#92526 LHD, MSHA vent rate 10000 cfm			
Baseline / DOC	1365	2	
Biodiesel B20 / DOC	1015	4.7	26
Biodiesel B50 / DOC	703	4.3	48
#99942 LHD, MSHA vent rate 15000 cfm			
Baseline, D1	1112	7.7	
Baseline, D2	1222	4	-10

- Biodiesel ('yellow grease") blended with diesel D2, B20 and B50 reduced concentrations of EC in mine air by 26 and 48 %, respectively.
- Fueling #99942 with diesel D2 resulted in 10% increase in EC concentrations in mine air over the baseline case established when the same vehicle was fueled with diesel D1. Changes of this magnitude are not statistically significant.

Mass Concentrations of Total Particulate Matter (TPM) in Mine Air

Test Type	Concentrations of TPM		Reductions
	[µg/m3]		[%]
	Ave.	Max.	Ave.
#92526 LHD, MSHA ventilation rate 10000 cfm			
Baseline / DOC	1874.6	2324.6	--
Biodiesel B20 / DOC	1698.8	2084.8	9
Biodiesel B50 / DOC	1416.6	1800.7	24
#99942 LHD, MSHA ventilation rate 15000 cfm			
Baseline D1	1433.6	2140.2	--
Baseline D2	1735.1	2739.2	-21

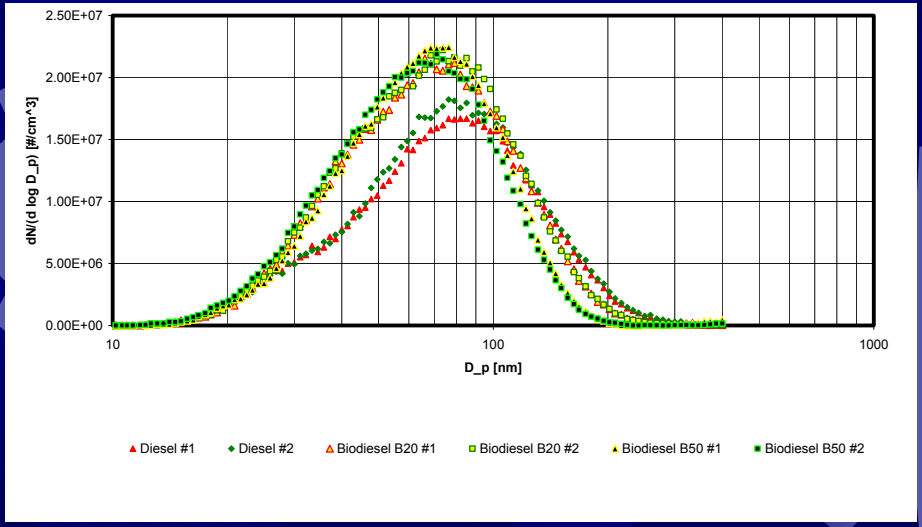
- Biodiesel blended with diesel D2, B20 and B50 reduced concentrations of TPM in mine air by 9 and 24 % respectively.
- Fueling #99942 with diesel D2 resulted in 21% increase in TPM concentrations in mine air over the baseline case established when the same vehicle was fueled with diesel D1.

Concentration of Aerosols with Electrical Mobility Diameter Between 10 and 400 nm in Mine Air

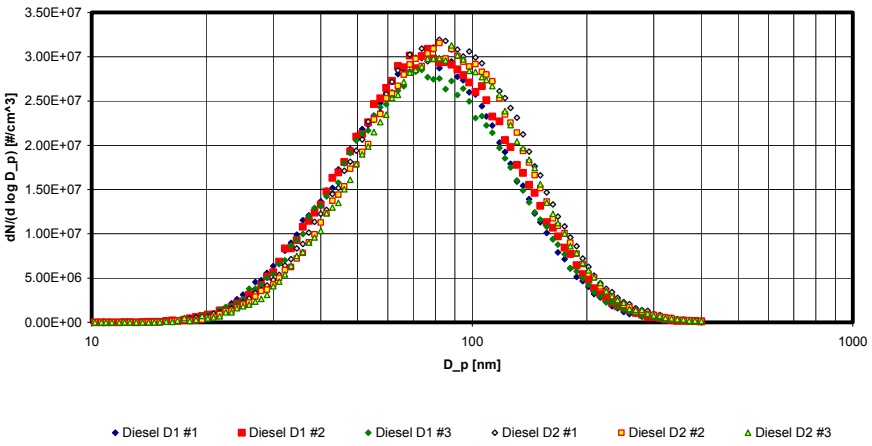
Test Type	Geo. Mean [nm]	Geo. Std. Dev.	Average Geometric Mean [nm]	Average Total Particle Conc. @	Change in Total Particle Conc. [%]
#92526 LHD, MSHA vent rate 10000 cfm					
Baseline (DOC)	72.2	1.75	72.4	7.32E+07	N/A
	72.6	1.74			
Biodiesel B20 (DOC)	65.8	1.66	65.9	9.72E+07	32.7
	66.0	1.65			
Biodiesel B50 (DOC)	63.3	1.60	61.8	9.11E+07	24.4
	60.2	1.61			
#99942 LHD, MSHA vent rate 15000 cfm					
Baseline D1 (Muffler)	74.4	1.64	75.4	3.97E+07	N/A
	76.6	1.65			
	75.2	1.65			
Baseline D2 (Muffler)	81.6	1.65	81.9	4.85E+07	22.2
	81.7	1.63			
	82.5	1.63			

- Fueling with B20 and B50 instead with diesel D2 resulted in an increase in number concentrations and lower D_{50} of measured aerosols.
- Fueling with diesel D2 instead with diesel D1 resulted in increase in number concentrations and higher D_{50} of measured aerosols.

Size distribution of aerosols in mine air
LHD #92526 with DOC and muffler: Diesel vs. Biodiesel B20 vs. Biodiesel B50



Size distribution of aerosols in mine air
LHD #99942 equipped with muffler: Diesel D1 vs. Diesel D2



Concentrations of Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitric Oxide (NO), and Nitrogen Dioxide (NO_2)

Test Type	CO [ppm]		CO2 [ppm]		NO [ppm]		NO2 [ppm]	
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.
#92526 LHD, MSHA ventilation rate 10000 cfm								
Baseline / DOC	0.0	0.0	7622	3821	41.3	18.6	2.9	1.0
Biodiesel B20 / DOC	0.0	0.0	7450	3826	40.1	19.3	2.9	1.1
Biodiesel B50 / DOC	0.0	0.0	7622	3855	44.2	21.1	3.5	1.3
#99942 LHD, MSHA ventilation rate 15000 cfm								
Baseline, D1	24.2	4.5	8740	2849	50.2	13.5	3.1	0.6
Baseline, D2	23.4	4.4	9028	2861	43.3	11.2	2.7	0.5

- CO concentrations were not measurable in the mine air when vehicles using a DOC were tested in the zone while fueled with regular diesel or biodiesel blends.
- Concentrations of CO were not significantly different between tests with diesel D1 and D2.
- Average concentrations of CO_2 were almost identical between tests with different tested fuels.
- Average NO_X concentrations were found to be somewhat higher when biodiesel blends were supplied to the engine instead of diesel D2.
- Average NO_X concentrations were found to be somewhat lower when #99942 was fueled with diesel D2 instead of diesel D1.

Elemental Carbon (EC) Emissions

#92526 LHD	Test Type	HI		TCS	
EC [µg/m3]	Diesel D2, DOC	16049		8230	
	Biodiesel B20, DOC	13798	-	5641	-
	Biodiesel B50, DOC	-	9890	-	4537
Reduction of EC [%]		**14**	**38**	**31**	**45**

Emissions of Nitric Oxides (NO_x)

#92526 LHD	Test Type	HI		LI		TCS	
NOx [ppm]	Diesel D2, DOC	221		300		444	
	Biodiesel B20, DOC	211	-	274	-	508	-
	Biodiesel B50, DOC	-	182	-	243	-	461
Reductions [%]		**5**	**18**	**9**	**19**	**-14**	**-4**

Conclusions

- Tested DPF systems offered excellent reduction in concentrations of elemental carbon and total particulate matter in mine air.
- But some of the tested DPF systems significantly increased concentrations of NO_2 in mine air.
- And, the size distributions of aerosols generated by some of the vehicles equipped with DPF systems were found to be characterized with significantly larger number of particles, smaller size, and higher peak concentrations than the size distributions of aerosols generated by the sane vehicles when equipped with mufflers.

Conclusions (continued)

- Using tested biodiesel blends in a place of neat diesel D2 fuel appears to be viable option for controlling concentrations of elemental carbon and total DPM:
  - Tested biodiesel blends offered significant reductions in the elemental carbon and total carbon emissions.
  - But, fueling vehicle with biodiesel blends instead with regular diesel resulted in the size distributions of aerosols characterized with somewhat larger total number, smaller size, and higher peak concentrations of aerosols.
  - Biodiesel blends increased slightly concentrations of NO_x in mine air.

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Questions???

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