

Study to Assess the Performance of Ceramic Diesel Particulate Filters for Reducing Diesel Emissions

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Overview

- The MSHA and a base metal mining company participated in a collaborative study to verify the performance of catalyzed ceramic diesel particulate filters for reducing diesel emissions.
- Tests were conducted in a stope with a loader and two trucks.
- Tests were conducted with and without catalyzed ceramic filters installed on all vehicles.

Specific Objectives

1. Assess effect on personal exposures.
 - Compare worker full shift Dpm exposures with and without filters (3 samples)
2. Assess effect on emissions during mining.
 - Compare difference between stope intake and return Dpm concentration with and without filters. (6 main intake, 6 main return samples; 2 stope intake and 2 stope return samples)

Test Design

- Difference of 15 % at 400 ug/m³
– 60 ug/m³
- Variation of 15 %
– 60 ug/m³
- 95 % confidence – “t” value of 2.50
- $n = \frac{t^2 \times (s)^2}{(xi - xo)^2}$ or $\frac{2.5^2 \times (60)^2}{(400 - 340)^2} \sim 6$

Specific Objectives

3. Assess effectiveness of environmental cab.
 - Compare area samples inside and outside cab. (1 inside/1 outside samples).
4. Assess effect on tail pipe emissions.
 - ECON analyzer with and without filters.

Exposure Sampling

- Approximately 21 DPM samples were collected on each shift for six shifts.
- Both area and personal samples were collected with SKC, Inc. diesel particulate sampling cassettes.
- Diesel particulate samples were analyzed at the MSHA Pittsburgh lab using NIOSH Method 5040.
- Stain tubes were used to assess CO and NO₂

Equipment Used

- Tests were conducted on a production unit when the ceramic filters were in use and on the same or similar production unit when the filters were not in use. Where possible, the same production equipment was used for both test configurations.

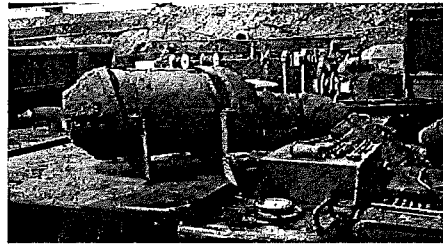
DPM Sampling Locations

- Area samples were collected for three stope-loading cycles utilizing ceramic filters and three stope-loading cycles without ceramic filters.
- Personal samples were collected for three full shifts utilizing ceramic filters and three full shifts without ceramic filters.

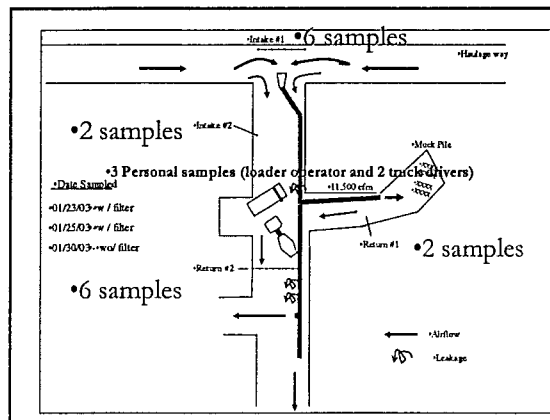
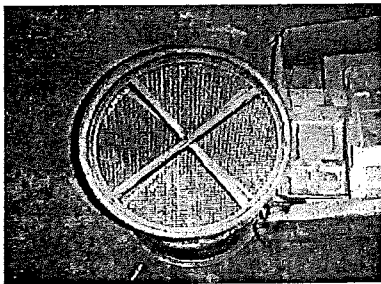
Equipment Specifications

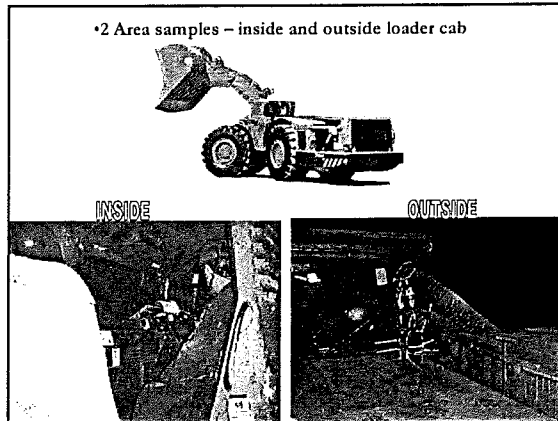
- 1 LHD and 2 or 3 Haul Trucks
- 300/475 hp, Detroit Diesel, Series 60, DDEC Engines
- Gaseous Ventilation Rate – 20,000 / 28,000 cfm
- Particulate Index – 5,800 / 8,500 cfm
- 15 x 15 Engelhard Platinum Catalyzed Ceramic Filter

All of the haul trucks and the loader utilized in the stopes where sampling occurred were equipped with working Engelhard DPM filters during the first three days of the study.



The Engelhard DPM filters installed on the machines were based on a Corning cordierite filtration media that is wash coated with a platinum catalyst.



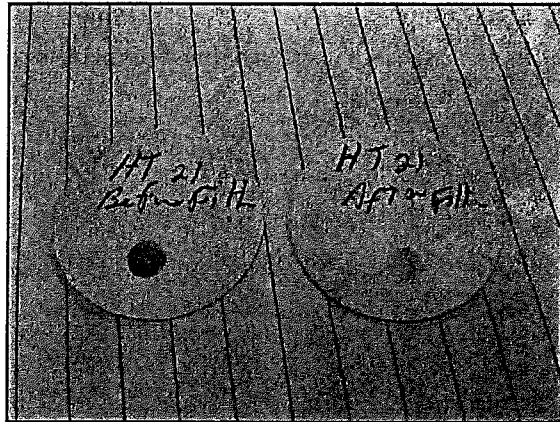


Additional Data Collected.

- Airflow in the stope,
- CO and NO₂ measurements,
- Engine and emission data,
- Filter data,
- Time and motion data.

Tail Pipe Emission Test

- Run with repeatable engine load test procedure to determine the raw gaseous and particulate emissions before and after the catalyzed ceramic filter.
- The test was conducted using MSHA's ECOM multi-gas analyzer.
- CO, CO₂, NO, NO₂ and smoke number were measured.



Study Results

- Personal Exposures:
- Without Filters –
 - DPM - 222 to 309 µg/m³
 - CO - 5 to 14 ppm
 - NO₂ - 0 to 1.3 ppm
- With Filters –
 - DPM - 70 to 133 µg/m³
 - CO - 3 to 4 ppm
 - NO₂ - 1 to 3.5 ppm

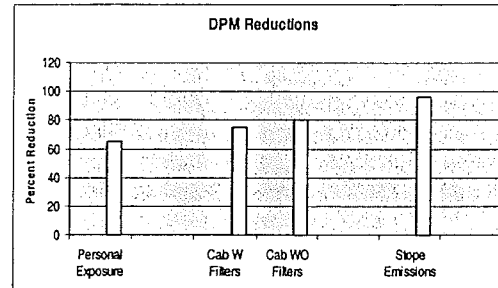
Study Results

- Engine Emissions = $(C_R - C_I) \times Q$
- Without Filters –
 - Intake DPM - 322 µg/m³
 - Return DPM - 623 µg/m³
 - Emissions - 22.5 gm/hr
- With Filters –
 - Intake DPM - 165 µg/m³
 - Return DPM - 173 µg/m³
 - Emissions - 0.8 gm/hr

Study Results

- Cab Performance
- Without Filters –
 - DPM out cab - 1351 $\mu\text{g}/\text{m}^3$
 - DPM inside cab - 271 $\mu\text{g}/\text{m}^3$
- With Filters –
 - DPM outside cab - 193 $\mu\text{g}/\text{m}^3$
 - DPM inside cab - 49 $\mu\text{g}/\text{m}^3$

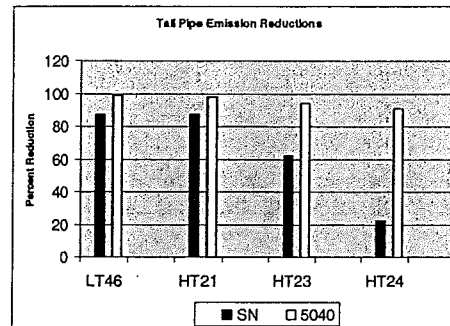
Study Results



Study Results

- Tail Pipe Emissions:
- Without Filters –
 - DPM Smoke Number - 8 to 9
 - DPM 5040 - 6000 to 31,000 $\mu\text{g}/\text{m}^3$
- With Filters –
 - DPM Smoke Number - 1 to 7
 - DPM 5040 - 122 to 2300 $\mu\text{g}/\text{m}^3$

Study Results



Findings and Conclusions

- Personal Exposure
- Equipment Emissions During Mining
- Cab Performance
- Tail Pipe Emissions
- Mine Worthiness
- Company Concerns

FINDING AND CONCLUSIONS

Personal Exposures

- Personal DPM exposures were reduced by 60 to 68 percent when after-filters were used.
- Reduction in personal exposure includes other factors such as ventilation, up wind equipment use and cabs.

FINDINGS AND CONCLUSIONS
DPM Emissions During Mining

- The use of ceramic after-filters reduced average engine emissions by 96 percent.

FINDINGS AND CONCLUSIONS
Gaseous Emissions During Mining

- CO levels decreased by up to one-half when the catalyzed filters were being used.
- There was a small increase in NO₂ when catalyzed filters were used, however, it was unclear whether this increase was due to data variability, changes in ventilation rate or the use of the catalyzed filters.

FINDINGS AND CONCLUSIONS
Cabs

- The cabs reduced DPM concentrations by 75 percent when after-filters were used and by 80 percent when after-filters were not in use.

FINDINGS AND CONCLUSIONS
Tail Pipe Emissions

- The results of the raw exhaust gas measurements conducted during the study indicated that the engines were operating properly.
- The Bosch smoke test provides an indication of filter deterioration.
 - Colorization method does not quantify the results. White or gray is good. Black is poor.

FINDINGS AND CONCLUSIONS
Mine Worthiness

- The ceramic filters installed on the machines used in this study did not adversely effect the machine operation.
- Observed filter deterioration after up to 5000 hours of use.
- Even with some apparent visual cracking from the rotation of the filter media, the ceramic filters effectively removed DPM.
- The filters passively regenerated during machine operation.

FINDINGS AND CONCLUSIONS
Company Concerns

- Truck filters passively regenerated due to heavy duty cycle.
- Identical loader filter did not consistently passively regenerate.
- Company is reluctant to have active regeneration for production equipment.