Fuel borne catalysts and diesel aerosols emissions

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INTRODUCTION

The results of long-term evaluation tests and field and laboratory emission tests showed that the Mann+Hummel SMF-AR® system (currently marketed by HJS) is potentially a viable control technology that can be used to substantially reduce the exposure of underground miners to aerosols emitted by light-duty underground mining diesel-powered vehicles.

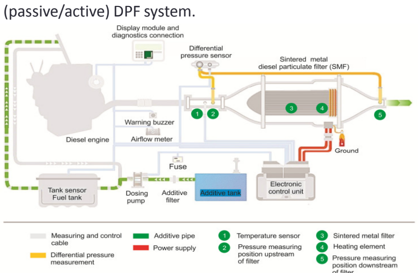
The operation of the SMF-AR® system requires the use of fuel additives containing iron-based fuel borne catalysts (FBCs).

Potential emissions of nano-sized metallic aerosols with high surface reactivity and toxicity and their potentially adverse effects in underground environments is of concern.

The NIOSH and Vale conducted a laboratory study to characterize the effects of selected fuel additives on the emission of aerosols and criteria gases emitted by a diesel engine equipped with the SMF-AR® system.

BACKGROUND

The system evaluated in this study is a hybrid (passive/active) DPF system.



The filter element was made of sintered metal plates with 10-µm mean pore size, 45% porosity, and 0.38-mm wall thickness. When needed, the electrical heater mounted at the back of the filter element is used to actively regenerate the system. The additive plays an important role in the regeneration process and operation of the system.

The emissions were assessed for three fuels:

- Ultralow sulfur diesel (ULSD);
- ULSD doped with Satacene® (Innospec Ltd., Cheshire, U.K.) and marketed under name DT8i;
- ULSD doped with Eolys Powerflex®, (Rhodia, La Rochelle Cedes, France) marketed as DT9.

Both additives introduced approximately 30 ppm of iron in the fuels.

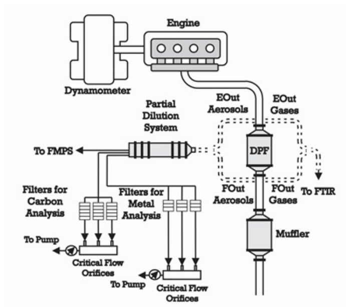
OBJECTIVES

The objective of this study was to evaluate the effects of the system and fuel additives on:

- Integrated mass concentrations of total carbon (TC) and elemental carbon (EC);
- Aerosol number concentrations;
- Aerosol size distributions;
- Integrated total mass concentrations of Fe;

METHODS

The testing took place at the Diesel Laboratory at NIOSH OMSHR, Pittsburgh, PA.



The system was evaluated using Isuzu C240 engine coupled to eddy-current dynamometer. The engine was operated at four steady-state (R50, R100, I50, and I100) and one transient cycle (Inco LHD cycle).

The aerosol sampling and measurements were conducted in the exhaust diluted approximately 30 times using partial dilution system (Dekati FPS 4000).

The effects on mass concentrations of elemental carbon (EC) and total carbon (TC) were determined using the results of thermal optical transmittance-evolve gas analysis (TOT-EGA) performed on the filter samples of the diluted exhaust collected upstream (EOut) and downstream (FOut) of the system.

Number concentrations and size distributions of aerosols were measured in EOut and FOut diluted exhaust using Fast Mobility Particle Sizer (TSI, Model 3091 FMPS).

The effects on Fe concentrations were determined using results of the inductively coupled plasma - atomic emission spectroscopy (ICP-AES) analysis performed on the samples collected on 37 mm diameter, 0.8 µm pore, mixed cellulose ester (MCE) filters.

The effects of the systems on the concentrations of the NO_2 were determined using the results of measurements made in undiluted exhaust using the Fourier Transform Infrared (FTIR) analyzer (Gasmet, Model 4000).

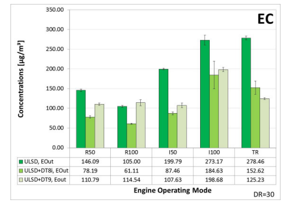
RESULTS

The system dramatically reduced TC and EC concentrations in diluted exhaust (TC results shown below). Since the FOut TC and EC concentrations were at or below the limit of quantification of the TOT-EGA analysis., the efficiency of the system in reducing TC and EC concentrations was estimated to be better than 99%.

	R50	R100	I50	I100	TR
ULSD, EOut	178.2	124.6	238.8	343.6	362.9
ULSD+DT8i, EOut	113.1	79.3	143.9	334.0	214.6
ULSD+DT9, Eout	179.0	168.1	168.2	288.2	213.2
ULSD, FOut	0.1	2.2	0.3	1.0	1.2
ULSD+DT8i, FOut	0.9	1.0	0.4	0.1	2.0
ULSD+DT9, FOut	1.1	1.4	0.3	1.6	1.6

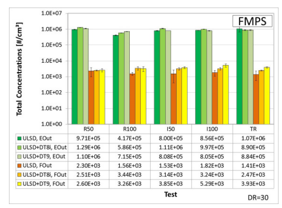
The effects of the additives on TC and EC concentrations were found to be function of engine operating conditions . In the cases of R50, I50, I100, and TR tests, the EOut TC and EC concentrations were substantially lower when fuels treated with ULSD+DT8i and ULSD+DT9 were used in place of neat ULSD. In the cases of R100, the EOut TC and EC concentrations were lower when ULSD+DT8i was used, but not when ULSD+DT9 was used in place of neat ULSD.

RESULTS



	R50	R100	I50	I100	TR
ULSD, EOut	146.09	105.00	199.79	273.17	278.46
ULSD+DT8i, EOut	78.19	61.11	87.46	184.63	152.62
ULSD+DT9, Eout	110.79	114.54	107.63	198.68	125.23

For all studied cases, the FMPS results showed that the system filtered more than 99% of aerosols by number. With the exception of a couple test conditions, the evaluated additives slightly increased EOut total number concentrations. The fuels with additives consistently produced higher FOut concentrations of aerosols.

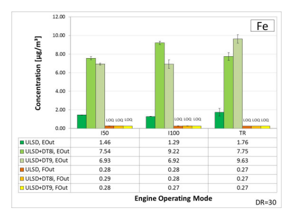


	R50	R100	I50	I100	TR
ULSD, EOut	9.71E+05	4.17E+05	8.00E+05	8.56E+05	1.07E+06
ULSD+DT8i, EOut	1.29E+06	5.86E+05	1.11E+06	9.97E+05	8.90E+05
ULSD+DT9, EOut	1.10E+06	7.15E+05	8.08E+05	8.05E+05	8.84E+05
ULSD, FOut	2.30E+03	1.56E+03	1.53E+03	1.82E+03	1.41E+03
ULSD+DT8i, FOut	2.51E+03	3.44E+03	3.14E+03	3.24E+03	2.47E+03
ULSD+DT9, FOut	2.60E+03	3.26E+03	3.85E+03	5.29E+03	3.93E+03

The EOut aerosols were generally distributed in single accumulation mode with count median diameters (CMDs) between 51 and 67 nm. Depending on test conditions, the FOut size distributions were single modal or bimodal. The CMDs of FOut aerosols in accumulation modes ranged between 63 and 93 nm and the CMDs of FOut aerosols in nucleation modes ranged between 13 and 36 nm.

The ICP-AES analysis on the filter samples showed that the system was very effective in trapping iron (Fe). For all test conditions, Fe introduced with the additives substantially increased the Fe concentration in the EOut aerosols samples. In all cases, the Fe concentrations in the FOut samples were below LOQ of the applied method. Importantly, the FOut Fe concentrations were much lower than ULSD EOut concentrations.

For the majority of the test conditions, the NO_2 concentrations were lower downstream than upstream of the system.



	I50	I100	TR
ULSD, EOut	1.46	1.29	1.76
ULSD+DT8i, EOut	7.54	9.22	7.75
ULSD+DT9, EOut	6.93	6.92	9.63
ULSD, FOut	0.28	0.28	0.27
ULSD+DT8i, FOut	0.29	0.28	0.27
ULSD+DT9, FOut	0.28	0.27	0.27

CONCLUSIONS

- The tests showed that the evaluated system was very effective in reducing EC, TC, and total number concentrations of aerosols.
- With the exception of a couple test conditions, the evaluated additives slightly increased EOut total number concentrations.
- The fuels with additives consistently produced slightly higher FOut number concentrations of aerosols.
- In some cases, substantial fractions of FOut aerosols were found in pronounced nucleation modes.
- For all test conditions, Fe introduced with the additives substantially increased the Fe concentration in the EOut aerosol samples.
- However, the ULSD+DT8i and ULSD+DT9 FOut Fe concentrations were much lower than ULSD EOut concentrations.

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DISCLAIMER

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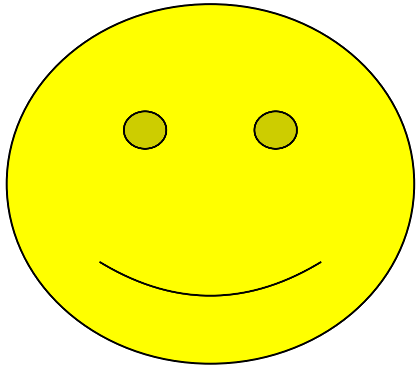

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