# Technology News

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# Apparatus for Sampling and Measuring Diesel Tailpipe Emissions

## Objective

Develop a portable emissions measurement apparatus to sample and measure tailpipe concentrations of diesel particulate matter (DPM), carbon monoxide (CO), carbon dioxide ($CO_2$), nitric oxide (NO), and nitrogen dioxide ($NO_2$) under steady-state engine load and speed conditions during a 1-minute test.

## Background

The U.S. Bureau of Mines (USBM) has a comprehensive research program to develop ways to reduce exposure of miners to diesel exhaust pollutants. Engine maintenance has been shown to have important effects on such exposure.

Accurate measurements of tailpipe emissions are becoming an essential part of a good maintenance program for underground mines that use diesel-powered vehicles. Past studies of particulates in U.S. underground coal mines have shown that DPM alone may be present at concentrations greater than 1 milligram per cubic meter ($mg/m^3$), half the 2-$mg/m^3$ limit for respirable coal mine dust. A poorly tuned (smoking) diesel engine may be the sole cause for respirable dust concentrations exceeding the limit. Although there is currently no standard specifically for DPM in U.S. mines, regulatory steps are underway, and significant reductions of DPM levels in both coal and metal mines will most likely be required.

Tailpipe emission measurements can provide diagnostic information to identify engine malfunctions such as clogged air cleaners, faulty injectors, or incorrect injection timing. In some cases, mine vehicle tailpipe DPM concentrations have been reduced up to 50 percent by engine maintenance and adjustments.

An accurate measuring instrument would also be useful for determining the effects of exhaust control devices on tailpipe emissions. Little information is currently available about the overall effectiveness of exhaust controls after long-term use. Raw exhaust concentrations with and without the control device can be measured in underground mines, and from these data a control efficiency can be calculated. Knowledge of the effectiveness of exhaust control devices over time is needed to make intelligent decisions on how to use and maintain these devices, and when to replace them.

## Approach

The design and development of the emissions measurement apparatus was undertaken by Michigan Technological University, under sponsorship by the USBM.[1] The apparatus consists of (1) a dilution system, (2) a sampling system with a particulate filter to collect DPM and a gas-sampling bag to collect gaseous emissions, and (3) a measurement system consisting of portable gas instruments, a DPM filter conditioning chamber, and a balance to weigh the particulate filters.


[1]This research has been supported by the U.S. Department of the Interior's Mineral Institute Program, administered by the USBM through a subcontract from the Pennsylvania State University's Generic Mineral Technology Center for Respirable Dust under grant G1115142.

## How It Works

The emissions measurement apparatus (fig. 1) contains an ejector that dilutes and cools a portion of the exhaust with nitrogen and passes the mixture through a preweighed particulate filter, where a weighable quantity of DPM is collected. A portion of the filtered exhaust is collected in a gas-sampling bag. The concentrations of CO, $CO_2$, NO, and $NO_2$ in the bag are analyzed by portable gas instruments. The DPM mass collected is determined by conditioning and weighing the filter before and after sampling. The DPM concentration is then calculated from the mass, the volume of exhaust flowing through the filter, and the dilution ratio.

The emissions measurement apparatus is designed to be used only during a stationary test of an underground mine vehicle. In-mine tests are conducted by operating the mine vehicle engine under high load at a single speed with the vehicle in a safe condition. This condition, representing the torque stall condition, is attained by depressing the vehicle's brake, engaging the transmission in high gear, and pressing the accelerator pedal to the floor. Loading the engine in this manner is necessary to attain a fuel-to-air ratio (determined by $CO_2$ concentration) that produces higher CO and DPM concentrations than lighter load conditions. Engine faults increase these pollutant concentrations at this condition and allow the emissions measurement apparatus to make meaningful measurements.

## Testing the Design

Comparisons were made between the emissions measurement apparatus and laboratory instruments at the USBM Diesel Emission Research Laboratory. Current measurement accuracy and precision are adequate, but attempts are still being made toward simplifying and automating the emissions measurement apparatus for ease of use. The apparatus has been used to measure the tailpipe concentrations of diesel-powered vehicles in a number of U.S. underground coal and noncoal mines, and plans are being made to integrate it into periodic maintenance of engines and vehicles at these mines.

## Future Applications

The emissions measurement apparatus is applicable to underground mine vehicles and to other diesel-powered equipment such as railroad locomotives, ships, off-highway vehicles, and heavy-duty trucks. Michigan Technological University is currently seeking a partner to enter into a cooperative agreement to develop the emissions measurement apparatus into a commercial product.

## For More Information

More information is available in USBM Report of Investigations 9422, "Apparatus for Measuring Diesel Tailpipe Emissions in Underground Mines." For answers to technical questions or for additional information, contact Todd Taubert, U.S. Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Avenue South, Minneapolis, MN 55417-3099, (612) 725-4766; or John H. Johnson, Presidential Professor, Mechanical Engineering, Engineering Mechanics Department, Michigan Technological University, Houghton, MI 49931, (906) 487-2576.

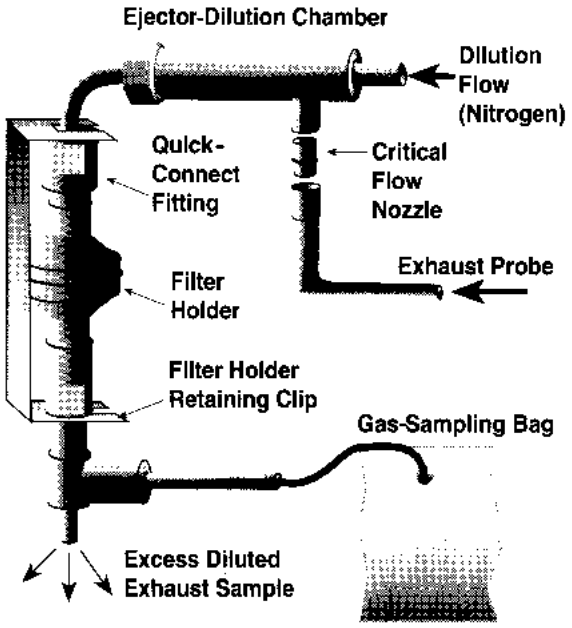


**Figure 1.—Emissions measurement apparatus.**