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Project Summary

Filter Media for Collecting Diesel Particulate Matter

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Certification of particulate emissions from diesel motor vehicles involves filtration of measured aliquots of the total air diluted exhaust. Seven commercially available filter media were examined for this purpose. The media included a variety of PTFE membrane filters, glass fiber filters, and PTFE coated glass fiber filters. Relative flow resistance (pressure drop), collection efficiency, and gas phase adsorption were examined. Filter structural differences, which influence particulate collection mechanisms, sample flow rates and pressure drops, were studied microscopically. Two media, a membrane and a fiber filter, were also examined microscopically with varying levels of particulate load to determine the role of collected particles in the filtration of subsequent particles.

The results obtained indicate that under the defined test conditions the membrane filters yield low gram per mile emissions rates due to difficulties with collection of Federal Test Procedure phase 1 emissions, and the Gelman A-E glass fiber filter high rates due to adsorption of gas phase emissions. The mechanics of particle collection are similar for both membrane and fiber filters as applied. Diffusion deposition is important with fiber filters for about 5 percent of the collected particulate matter, the remaining 95 percent collected primarily by direct interception. With the membrane filters direct interception is the dominate process.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

On March 5, 1980, the U.S. Environmental Protection Agency published rules and regulations concerning the control of particulate emissions from light duty passenger cars and trucks. Included were procedures for sampling and analyzing emissions to determine the gram per mile (g/mi) emission rate of total particulate matter from this category of motor vehicles. The recommended sampling apparatus is illustrated in Figure 1. Particulate emission rates are determined by filtration of a measured aliquot of air-diluted exhaust. Samples are collected during each of three phases of the Federal Test Procedure (FTP). Primary and back-up filters are used to establish acceptable levels of collection efficiency. If the back-up filter weight gain during testing is less than 5 percent of the total weight gain of the primary and back-up filters, only the primary weight need be used in the emission rate calculation, otherwise, the total weight gain of both the primary and back-up filters is used in the calculation.

During this investigation a variety of commercially available filter media were examined for the purpose of collecting particulate matter from diesels in the light-duty certification practice Two primary filter types, membrane and

fiber, are commonly used for this purpose. The mechanisms of particle collection are similar for both and have been studied for many years. Three major factors are important to the study of aerosol filtration: the dispersed particles, the dispersion medium (air for the case of interest), and the porous filtration medium. Important characteristics of the particles include their size or size distribution, shape, mass or density, electrical charge, chemical composition, and concentration. The gas flow is characterized by velocity, density, temperature, viscosity, and humidity; the porous filtration medium is characterized by surface area, thickness, size of structural units (e.g. thickness of fibers in fibrous filters), porosity, and electrical charge Two major considerations in using filters for particulate collection are filtration efficiency and flow resistance or pressure drop. Both depend on the particle, gas flow, and filter characteristics previously mentioned.

Seven filter media, two PTFE membrane filters, two PTFE coated glass fiber filters, and three standard glass fiber filters were tested for collecting diesel exhaust particulate matter using the procedures required for emissions certification. Particle composition, size distribution, concentration, and velocity at the filter face were held constant as were the dispersion medium composition, temperature and humidity, while the filter medium composition, thickness and porosity were varied. Pressure drops and relative collection efficiencies were determined for each of the media Relative adsorption characteristics were also examined. Structural differences and collection mechanics were studied microscopically. With all of the examined media, greater than 95 percent of the collected particulate matter was located on the primary filter of a standard 2 filter set (see Figure 1). However, with the membrane filters the g/mi emission rates were somewhat low because of difficulties associated with collection of emissions during test phase 1 of the FTP and with one of the fiber filters high rates were obtained because of adsorption of gaseous components of the exhaust.

Conclusions

Particulate emission rates were determined for a light-duty diesel passen-

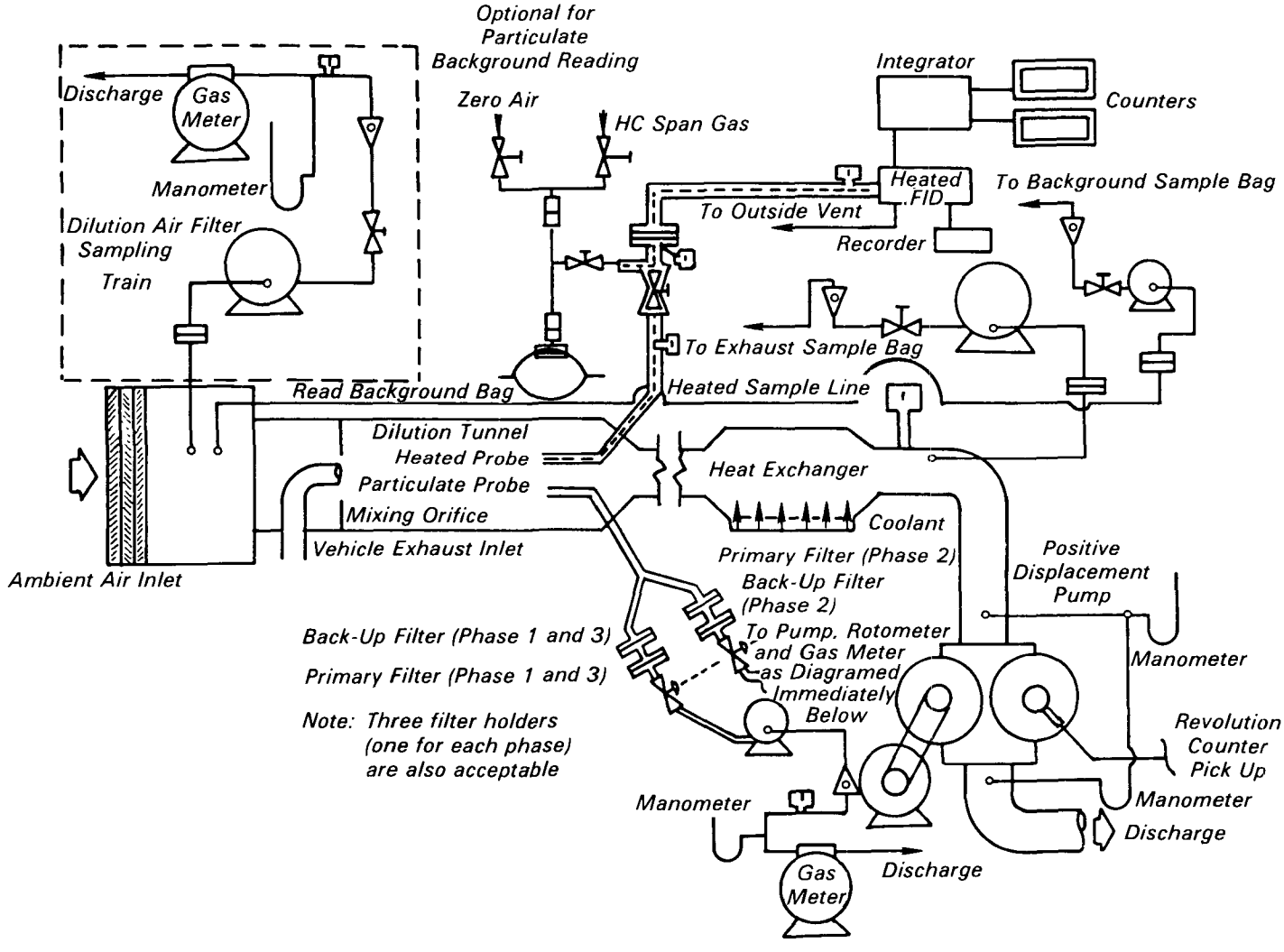

Figure 1. *Federal emissions certification sampling system.*

ger car under FTP cyclic driving conditions using seven commercially available filter media. Rates obtained with 1μ PTFE membrane filters were low owing to difficulties experienced with collection of FTP test phase 1 emissions. The rate obtained with the Gelman A-E glass fiber filter was high owing to apparent adsorption of gaseous emission components. All of the examined media collected greater than 95 percent of the sample aerosol on the primary filter of a standard two filter collection set as determined by comparison of primary to primary plus secondary weights (Federal Register procedure).

Microscopic study of the media revealed significant structural differences. The glass fiber filters had different densities and fiber sizes, resulting in different pressure drops during sampling and slightly different collection efficiencies. Two of the examined glass fiber filters, Pallflex T60A20 and TX40HI, were PTFE coated. The TX40HI had significantly larger amounts of PTFE in the fiber system and also was backed with a PTFE coated glass fiber "cloth" improving the filter strength. The PTFE membrane filters had average pore sizes about 1μ, nearly an order-of-magnitude smaller than the glass fiber filters. The membrane had a "quasi-fiber" structure with PTFE filaments about 0.2μ in diameter. The membrane filters had coarse backing materials so that the membrane itself could be as thin as possible to minimize sampling pressure drops, which still exceeded all of examined glass fiber filters. The Fluoropore filter used a polyethylene "ribbon" matrix for backing, while the Zefluor filter had a coarse PTFE "webbing." Microscopic examination also revealed the particle loads at which the gas flow passages become clogged, a condition important to the mechanics of deposition and collection efficiency. Under the FTP test conditions used, more than 95 percent of particulate collection occurred under "clogged" filter conditions.

Recommendations

The two filtration problems identified in the reported program were collection of FTP test phase 1μ (transient cold start) emissions with membrane filters and adsorption of gaseous exhaust components with Gelman A-E glass fiber filters. Available resources would not permit comprehensive examination of either phenomenon. Further study is indicated, particularly of the collection of test phase 1 emissions. Comparison of test phase 1 data from the various filters showed scatter exceeding that of the other test phases. Further, several parameters important to deposition of particles on filters, for example particle velocity at the filter face, temperature and concentration, were not studied with the membrane or other media. Were the observations sensitive to particulate composition? Would similar results have been obtained with other motor vehicles and sampling conditions?

This study emphasized the accuracy with which total particulate mass emission rates can be determined with various filtration media. However, procedures defined for determining mass rates are commonly applied to collect samples of exhaust particulate matter for chemical analysis and assessment of potential health effects using various bioassay techniques. There are many possible physical and chemical phenomena associated with the laboratory sampling practice that could seriously bias results and estimates of the potential environmental impact of the emissions. Obviously, exhaust cannot be diluted in the laboratory exactly as it is on the roadway. The importance of dilution to mass has been examined in many studies and the laboratory procedures give reasonably accurate results. However, chemical changes occurring at low dilution are not well understood. Chemical kinetics would suggest that any process resulting in abnormally high concentrations of reactant compounds can affect composition. Further, it is possible that sampling system components, including the filter medium, can catalyze reactions. Substantial further study is indicated to determine the adequacy of certification procedures for collecting diesel particulate matter for determinations other than total mass.

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The complete report, entitled "Filter Media for Collecting Diesel Particulate Matter," (Order No. PB 81-197 774; Cost: $6.50, subject to change) will be available only from:

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