Capabilities at the Diesel Engine Test Facility for Measuring Gas-Phase and Particulate Emissions

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Description of the test facility

The combustion research laboratory has a variety of capabilities for measuring and characterizing emissions produced from the test diesel engine. For particulate matter, the combustion laboratory has a TSI Scanning Mobility Particle Sizer (SMPS) that measures particle size distributions from 7 nm to 300 nm, and a Lasair 310 optical particle counter (OPC) that measures particle counts in seven size ranges from 0.3 µm to 10 µm. In addition, the laboratory can measure real-time PAH (polycyclic aromatic hydrocarbon)-laden particles and elemental carbon on particles (with a PAS 2000 and photoacoustic instrument developed by Desert Research Institute). The photoacoustic analyzer and the PAS 2000 are relatively new instruments, and details of these two instruments can be found below. The laboratory also has a high volume particulate matter sampler (developed by Graseby Andersen, Inc.) for collecting large quantities of particulate matter with a diameter less than 10 µm. For gas-phase emissions, the laboratory has the capabilities to measure CO, CO_2, NO_x, CO_2 and total hydrocarbons. CO_2 and CO can be analyzed with a California Analytical infrared analyzer model ZRH (CO) and model 200 (CO_2), respectively. The infrared gas analyzer measures gas concentration using the unique absorption spectra of the gas in the infrared region. A Thermo Environmental Instruments NO-NO_2-NOx analyzer model 42C is used to measure NOx concentration, and the instrument operates based on the principle that nitric oxide (NO) and ozone (O_3) react to produce a characteristic luminescence with an intensity linearly proportional to the NO concentration and infrared light emission results when electronically excited NO_2 molecules decay to lower energy state. For CO_2 concentration, a ZA8 (Yokogawa Electric Corporation) zirconia oxygen analyzer averaging converter system is employed, which can perform multipoint oxygen concentration measurements. For gas-phase hydrocarbons, a AVS-GC/MS (HP5971) can be used, and the AVS (direct Atmospheric Vapor Sampling unit) was developed by the center for Micro Analysis and Reaction Chemistry, University of Utah, for real-time, continuous, online analytical measurements.

Photoelectric aerosol sensor

Figure 1 shows a schematic of the PAS. Details about the PAS can be found in EPA (1997) and Burtscher (1992). Briefly, an aerosol sample passes through the PAS instrument at a constant flow of 2 l/min. As the sample passes through the examiner lamp ionization region, the particle-bound PAH molecules are ionized, and the electron that is stripped from the PAH molecule has a probability of escaping the particle that is dependent on the particle size and composition. The photon energy of the lamp is chosen so that no gas-phase molecules are ionized. The photoelectric ionization and subsequent electron loss leaves the particle with a net positive charge that is detected by measuring the charge that collects on an isolated filter element. Because this charge is exceedingly small, an electrometer is used to detect the change in potential from the filter element to ground. The change in potential can be attributed to a charge and is integrated over time to give the photoelectric current (in femto or pico amps). This current should be proportional to a specific loading of PAH on a particle and related to a specific PAH mass/volume of surrounding gas.

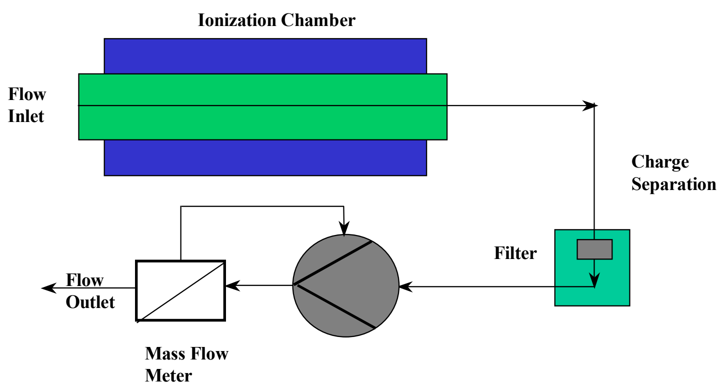

Figure 1. Schematic of the PAS.

Photoacoustic analyzer

The Desert Research Institute (DRI) PA detects and quantifies black carbon (soot) particles in real time. Detailed instrument description is in Arnott et al. (1999), and calibration is in Arnott et al. (2000). Briefly, the instrument measures light absorption at a laser wavelength of 1047 nm. Black carbon absorbs very strongly at this wavelength, in contrast to other aerosols and gases. Sample air is pulled continuously through an acoustical waveguide, and the laser also passes through the waveguide. The laser power is modulated at the resonance frequency of the waveguide. Now when soot absorbs light, it is heated. This heat transfers very rapidly to the surrounding air, in a time that is much shorter than the period of the laser beam modulation, so all of the heat from light absorption comes out of the particles during each acoustic cycle. Upon receiving heat, the surrounding air expands, generating a pressure disturbance (i.e. an acoustical signal) that is measured with a microphone attached to the waveguide. Since black carbon aerosols absorb light throughout the entire particle volume, the light absorption measurement is also a measure of black carbon mass concentration. This is the reason that light absorption can be used as a measure of black carbon mass concentration. The PA measures particles in a flowing air stream without the need to collect the particles on a filter, and the PA has a very large dynamic range (130 dB), making it suitable for use on a wide range of exhausts.

Specifications for the Diesel Engine

The diesel engine is a two-cylinder Kubota model Z482B, with 482 cc displacement. Its torque curve is consistent from 1800 to 3400 rpm, and it consumes between 0.8 – 2.2 l/hr of fuel. The dynamometer is a Land and Sea water-break dynamometer with torque load control. The dynamometer absorbs load through entire torque range. In addition, the engine system has speed control and automated computer data acquisition.

References

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