Measurement of Soot Extinction Coefficients

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ABSTRACT

An experimental apparatus used to obtain soot extinction coefficients in the infrared portion of the electromagnetic spectrum will be presented. Numerous experimental measurements of soot extinction coefficients have been previously obtained at visible wavelengths. However, such measurements have not been reported at infrared wavelengths relevant to radiation transport in fires (approximately 2 μm to 5 μm). There is a need for such data to quantify accurately the effect of combustion generated particulates on the transport of infrared radiation in fire scenarios, and in particular for the development of fire dynamics models.

The experimental apparatus consists of a flow control system, a soot generation source, an optical flow cell, a blackbody radiation source, and an infrared spectrograph to characterize the optical extinction. The flow cell, which was fitted with CaF_2 windows transparent to infrared radiation, provided a homogeneous, isothermal environment for the extinction measurements. A well-characterized Burke-Schumann flame burning ethylene at various global equivalence ratios was used to generate the soot. The gaseous combustion products from the flame and inert dilution gas carried the soot into the flow cell, where the soot extinction coefficient was determined as a function of wavelength using a unique infrared spectrograph. A sedimentation cell located upstream of the optical cell was used to eliminate the largest soot agglomerates and reduce the amount of soot lost in the tubing of the apparatus. The spectrograph, which contains a cooled 320 × 244 element PtSi CCD array and appropriate optics, images a line approximately 35 mm long and provides intensity measurements over the wavelength range from 2500 nm to 5000 nm. Soot samples obtained with filters upstream and downstream of the optical cell, combined with the extinction data from the infrared spectrograph, were used to calculate the mass specific extinction coefficient as a function of wavelength.

The experimental data are compared to predictions using Rayleigh's theory for particles that are small compared to the wavelength of light. Refractive index values from literature were used for the theoretical predictions. Data obtained at four global equivalence ratios will be presented, and discrepancies between the theoretical predictions and the experimental measurements will be discussed.

KEYWORDS: Soot, extinction coefficient, infrared radiation, fire models