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OPACITY AND PARTICULATE MATTER CONCENTRATION

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PATENTED TECHNOLOGY » PROVEN RESULTS » PAYBACK

The property of light extinction, as measured in an exhaust plume, is given by the general form of the Beer-Bouguer-Lambert Law which may be expressed as

$$I/I_o = \exp(-\mu\, l)$$

$$\ln(I/I_o) = -\mu\, l$$

where I = transmitted light intensity; I_o = incident light intensity; l = length of light path through the plume; μ = extinction coefficient (in reciprocal length units).

This extinction law can be written in the following form for cases in which the presence of particulate creates a situation in which there is both significant absorption and scattering:

$$\ln(I/I_o) = -\mu\, l = -C\, l/K\, \rho$$

where C = concentration of particles (e.g., g m^{-3}); ρ = particle density (e.g., g mL^{-3}); K = ratio of specific particle volume to light extinction coefficient (e.g., $cm^3 m^{-2}$). K can be determined from Mie scattering theory and varies with particle size distribution, wavelength of light and particle refractive index. However, for polydisperse systems where the particles are log normally distributed, K is relatively constant over the size range 0.2 to 10 μ m.

APPLICATION TO ENVIRONMENTAL TECHNOLOGY VERIFICATION DATA

Because many of the parameters for the diesel combustion plume are unavailable, rather than use guesstimates for particle parameters, especially K, I have made the assumption that the basic conditions for the baseline and treated cases will be essentially constant. The diesel particulate should be log normally distributed and the average particle density and refractive index should be the same. Using the baseline data from the U.S. Environmental Protection Agency's Environmental Technology Verification (ETV) tests as the reference, it then is possible to calculate the particulate concentration directly from the opacity.

Since (l/K ρ) is treated as constant for the two cases, then, the relationship

$$-\ln(I/I_o) = (l/K\, \rho)C = kC$$

$$C_b/C_t = (\ln I/I_o)_b/(\ln I/I_o)_t$$

where the subscripts b and t denote the baseline and treated cases, respectively. Thus,

$$6.6 \text{ g min}^{-1}(6.0 \text{ min m}^{-3})/C_t = 0.252/0.11 = 39.6 \text{ g m}^{-3}$$

$$C_t = 17.3 \text{ g m}^{-3}$$

Or, alternatively, 6.6 g min^{-1} for the baseline and 2.9 g min^{-1} for the treated fuel case.

However you express it, the reduction in TPM is 56% as measured directly from opacity. The value obtained in our open flame tests of diesel fuel combustion in the laboratory was 55%.

Reference: J.F. Thielke and M.J. Pilat, Atmos. Environ., 12, 2439-2447, 1978.

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