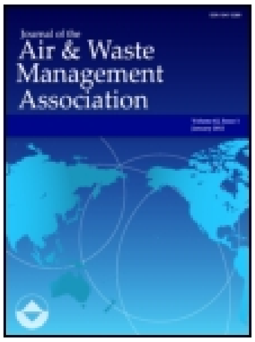

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Electrostatic Precipitator Efficiency Calculations

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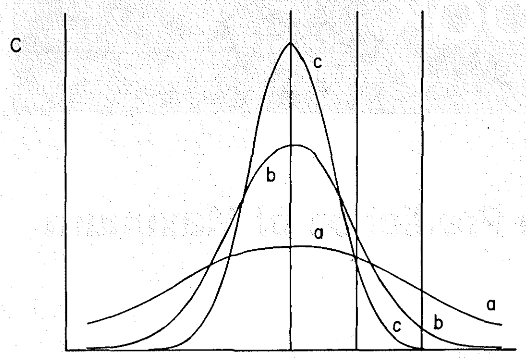

Figure 1. The Gaussian concentration curves for a given set of conditions (x,H,u,Q,σ_z) and three stability classes *a, b,* and *c* (in order of increasing stability and decreasing standard deviation in the *y* direction) are illustrated. The vertical axis represents the predicted concentration; the figure shows that at y_1, curve *b* represents the worst possible case because it produces the highest concentration. The standard deviation of curve *b* equals y_1. Similarly at y_2, curve *a* represents the worst possible case.

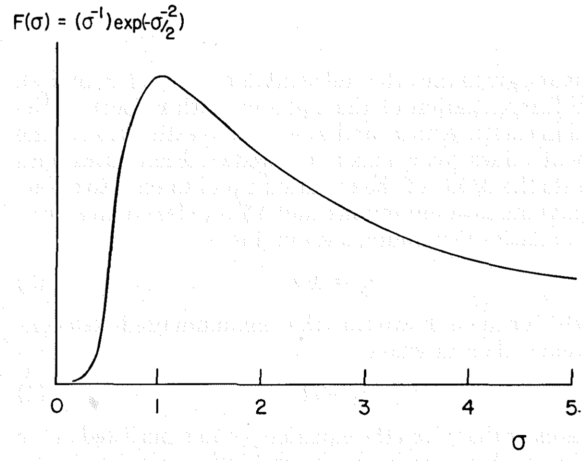

Figure 2. This curve of the normalized Gaussian function $F(\sigma) = 1/\sigma \exp(-\frac{1}{2}\sigma^{-2})$ shows a maximum at $\sigma = 1$, which corresponds to $\sigma = \pm y$ or H for the Gaussian plume model. Note the slope of the curve is much steeper for $\sigma < 1$ than $\sigma > 1$; this shows it is better to overestimate than to underestimate the dispersion parameter when approximating worst possible case conditions.

from the ground, as given by Turner[9] can also be maximized with respect to σ_z; the solutions for σ_z are unique to each z and H combination, and thus have not been included in this note. If $z = 0$, a special case arises where the largest σ_z is the worst possible case.

Substitution of the coefficients with their values for maximum concentration gives the concentration predicted by each equation. The usual Gaussian, Cramer, and Sutton equations give:

$$C(x,y,0;H) = Q/(\pi u e y H) \tag{6}$$

while the Bosanquet and Pearson equation gives:

$$C(x,y,0;H) = Q \exp(-3/2)/Huy\sqrt{2\pi} \tag{7}$$

Thus the Bosanquet and Pearson equation will predict concentrations 76% of the other equations, for the worst possible conditions.

The results presented in this note are intended to be a guide to those who are using the Gaussian type of plume equation to predict pollutant concentrations; these workers should note that the equation has analytical maxima with respect to dispersion coefficients.

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Electrostatic Precipitator Efficiency Calculations

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Electrostatic precipitator (ESP) collection efficiency has long been calculated by the Deutsch equation;[1]

$$\eta = 1 - q = 1 - \exp(-wA/Q), \tag{1}$$

where η = efficiency of collection, q = penetration, w = migration velocity for particles, and A/Q = specific collecting area = area of collecting electrodes/gas flow rate. The fact that this equation does not fit ESP data very well is becoming quite apparent as ESP's are designed for ultra high efficiencies. The many methods being used to adapt the Deutsch equation include putting in "effective" migration velocities from applications experience[2,3] and employing factors that downgrade the calculated efficiency, such as "sneakage."[4] An approach that appears to work quite well is presented here—the Hazen short-circuiting formula.

The laminar flow efficiency equation,

$$\eta = wA/Q, \ [\text{for } \eta \leq 1] \tag{2}$$

leads to the Deutsch equation when it is assumed that the particles are uniformly distributed over the section by turbulence and are randomly removed upon entry into a boundary layer on the collecting electrode. ESP performance may be considered analogous to the performance of a sedimentation basin, cyclone, or other particle removal device where the laminar flow equation leads to the exponential for turbulent flow.

Fair and Geyer[5] derive an equation based on a concept of Hazen;[6] it is

$$\eta = 1 - \left[1 + \frac{1}{n}\frac{wA}{Q}\right]^{-n} \tag{3}$$

where n = number of turbulence damping cells in basin (arrived at empirically). The behavior of this function is shown in Figure 1 for the range of $n = 1$ to $n = \infty$. For $n = \infty$ Eq. 3 reaches the limiting form, which is the exponential (Eq. 1).

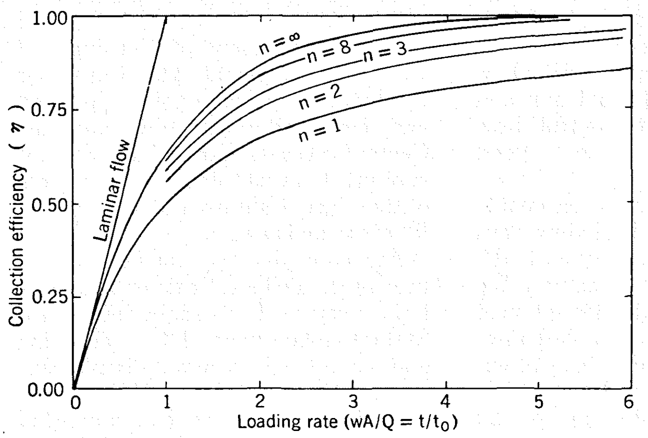

Figure 1. Short-circuiting function of Hazen.

The value of n will vary with different designs and constructions from 2 to 8; however, n = 3–5 seems to fit most ESP data, including the data for both hot-side and cold-side fly ash collection.

Figure 2 shows hot-side ESP performance on fly ash applications. If it is estimated that the theoretical migration velocity (w) would be 20 cm/sec for each of the two curves and for the curve midway between these two, the Hazen equation does quite well in fitting the curves with an n of 4.65 for the upper, 3.75 for the lower, and 4.00 for the curve midway between the upper and the lower.

That equipment efficiency falls short of the theoretical efficiency is a well-known fact. The Hazen approach does a good job of predicting this shortfall. Moreover, it is a well-established formulation that has been with us a long time and it is explained in a rational manner in the past literature.

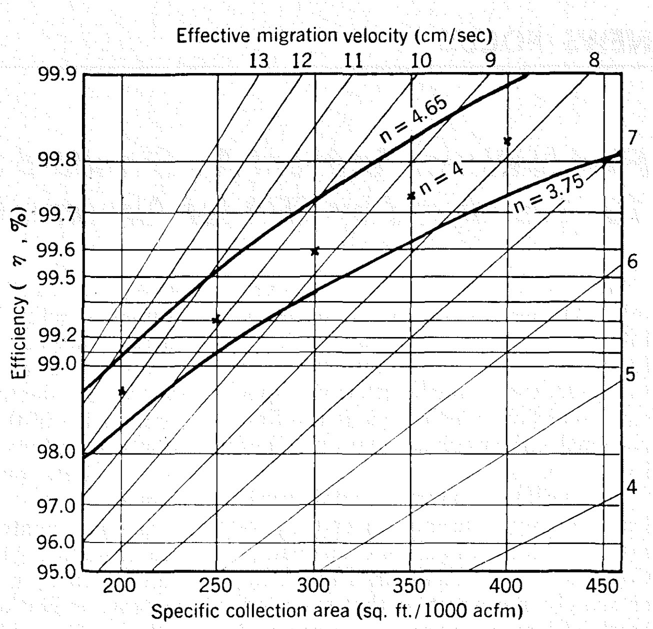

Figure 2. Efficiency versus specific collection area.

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