BEHAVIOR OF LATERAL DIFFUSION PARAMETERS

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Data from a number of field experiments have been analyzed to study the behavior of the quantity $S = \sigma_y/x\sigma_\theta$. A previously proposed relation is shown to be valid only under rather restricted circumstances, and significant variations with sampling period, averaging time, and release height are shown.

The determination of the lateral dispersion parameters of a diffusing substance in terms of measurable meteorological variables has been the subject of considerable study. Pasquill[28,29] and Draxler[30] have examined the quantity $S = \sigma_y/x\sigma_\theta$ as measured in a number of field experiments. Despite the considerable scatter in the data, both have found evidence of systematic behavior, either as a function of travel time T or downwind distance x. In particular, Pasquill[31] has suggested that S may be reasonably represented by a universal function of x which is valid independent of terrain roughness, release height, and sampling duration up to one hour.

In the present study, results from nine different field programs were examined in an effort to determine the validity of this suggestion and to gain an understanding of possible deviations from this "universal" behavior.

The application of Taylor's theorem to the turbulent diffusion process may be shown to lead to the following expression for S:

$$S = \frac{[\sigma_y]_{\tau,T}}{x\,[\sigma_\theta]_{\tau,t}} = \left\{ \frac{\int_0^\infty F_L(n)\left(1 - \frac{\sin^2 \pi n\tau}{(\pi n\tau)^2}\right)\frac{\sin^2 \pi nT}{(\pi nT)^2}\,dn}{\int_0^\infty F_E(n)\left(1 - \frac{\sin^2 \pi n\tau}{(\pi n\tau)^2}\right)\frac{\sin^2 \pi nt}{(\pi nt)^2}\,dn} \right\}^{1/2} \quad (1)$$

where $[\sigma_y]_{\tau,T}$ is the lateral dispersion measured over a sampling time τ at a distance downwind x which is reached in time T, and $[\sigma_\theta]_{\tau,t}$ is the variance of the horizontal wind direction measured over a sampling time τ and averaged over a time t. $F_L(n)$ and $F_E(n)$ are the Lagrangian and Eulerian turbulent spectra, respectively, and n is the frequency.

While the precise forms for $F_L(n)$ and $F_E(n)$ are not known, it may also be shown that the qualitative behavior described by (1) is similar for a wide variety of possible spectral shapes. In particular, S should increase as either τ or t increases.

Figure 1.11 shows the variation of S with x for various combinations of τ and t for ground-level releases, as determined from five different field programs. (The Greenglow and 30-Series have been combined.) As may be seen, the values suggested by Pasquill are reasonable for shorter averaging and sampling times, but do not represent the data well for larger values of τ and t.

The effect of release height on the variation of S with x was also found to be important. If the diffusing plume is confined to a plane, then it is not unreasonable that the value of σ_θ measured in that plane would play a role in the dispersal of the material. For elevated releases, however, the situation is considerably more complicated. As the plume descends toward the ground, it encounters turbulent fluctuations which vary with height.[32] It is not at all evident, then, at what elevation σ_θ should be measured to provide useful predictions of diffusion at ground level.

Figure 1.2 shows the results obtained for three release heights, where σ_y and σ_θ are measured near the ground. As can be seen, the curves for the three release heights coincide only at some distance downstream from the source, and the distance to this point increases with increasing height of the release. Near the origin, the variation of σ_θ with height has a clear effect on the behavior of S. Farther downstream, the lateral dispersion is dominated by the crosswind fluctuations near the ground, and the value of σ_θ at the release height is not a governing factor.

This interpretation is borne out by the results shown in Figure 1.13, where S is again plotted as a function of x, but σ_θ has been measured at the release height rather than near the ground. No apparent order can be seen in these curves, indicating that the

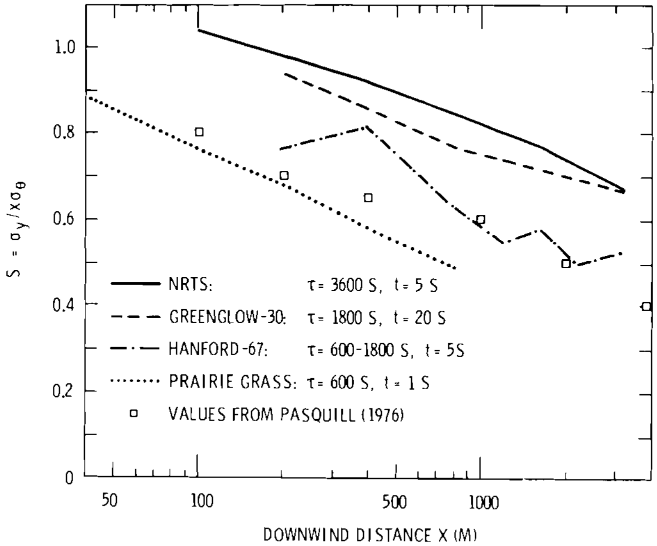

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FIGURE 1.11. Variation of $S = \sigma_y/x\sigma_\theta$ with Distance as Determined from Several Field Programs

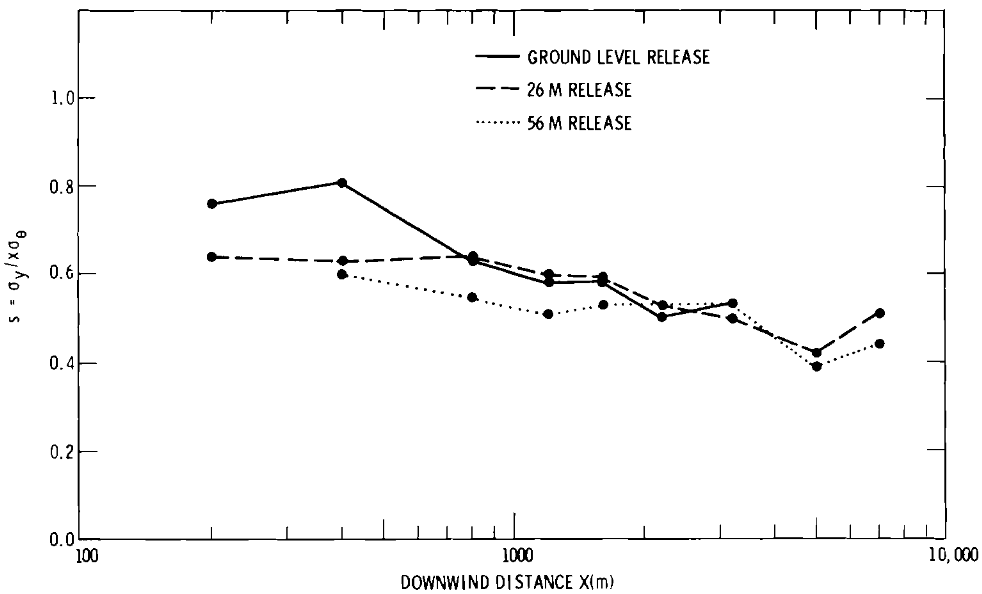

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FIGURE 1.12. Variation of $S = \sigma_y/x\sigma_\theta$ with Downwind Distance for Three Release Heights, Hanford-67 Series. σ_θ was measured at 1.5 m elevation.

value of σ_θ at elevated release points is not a good predictor of the ground-level dispersion. Moreover, the scatter of the data about the mean values is worse than for the analyses described by Figure 1.12, particularly for the 26 m releases.

The variation of S with x was found to be considerably more complicated than suggested by the simple relationship given by Pasquill. While those values suffice for a rough description of diffusion from a ground-level source, they are not very satisfactory for longer sampling and averaging times and are not applicable to the case of elevated releases.