Journal of the Air Pollution Control Association

ISSN: 0002-2470 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uawm16

The Change of Concentration Standard Deviations with Distance

Robert W. McMullen

The Change of Concentration Standard Deviations with Distance

Robert W. McMullen
California Air Resources Board, Sacramento, CA

Calculations of pollutant concentrations at various downwind and crosswind distances from an elevated point source are frequently based on diffusion models and parameter values contained in Turner's *Workbook of Atmospheric Dispersion Estimates.*[1] These calculations can be made much more speedily on a computer or on a current-generation, programmable desk calculator, if the values of the horizontal and vertical standard deviations of plume concentrations distributions are stated explicitly as a mathematical function of downwind distance. The alternative is to read the values from Turner's Figures 3-2 and 3-3 and input them into the calculation for each individual value of downwind distance.

The values of the standard deviations for the horizontal and vertical distributions can be satisfactorily approximated by the following model:

$$\sigma = \exp\left[I + J(\ln x) + K(\ln x)^2\right] \quad (1)$$

where σ = Standard deviation of the concentration in the horizontal (σ_y) or in the vertical (σ_z), meters.
$\ln x$ = Natural log of downwind distance expressed in kilometers.
I, J, K = Empirical constants for a given stability condition, for each type of σ.

Table I. Values of the constants I, J, and K, for σ_y as a function of downwind distance, for six stability conditions.

Stability condition*	I	J	K
A	5.357	0.8828	−0.0076
B	5.058	0.9024	−0.0096
C	4.651	0.9181	−0.0076
D	4.230	0.9222	−0.0087
E	3.922	0.9222	−0.0064
F	3.533	0.9181	−0.0070

* As defined in Table 3-1, p. 6, Turner.[1]

Table II. Values of the constants I, J, and K, for σ_z as a function of downwind distance, for six stability conditions.

Stability condition*	I	J	K
A	6.035	2.1097	0.2770
B	4.694	1.0629	0.0136
C	4.110	0.9201	−0.0020
D	3.414	0.7371	−0.0316
E	3.057	0.6794	−0.0450
F	2.621	0.6564	−0.0540

* As defined in Table 3-1, p. 6, Turner.[1]

Values of I, J, and K associated with the six atmospheric stability categories are presented in Table I for σ_y, and in Table II for σ_z. These constants were derived by fitting the mathematical function by the method of least squares to visually read values from each of Turner's curves. A weighting process was used in fitting the function with the major weights being applied in the downwind range from 1 to 10 km.

As an example, for stability category "D", the appropriate equations would be:

$$\sigma_y = \exp\left[4.230 + 0.9222(\ln x) - 0.0087(\ln x)^2\right] \quad (2)$$

and

$$\sigma_z = \exp\left[3.414 + 0.7371(\ln x) - 0.0316(\ln x)^2\right]. \quad (3)$$

For a downwind distance of say, 2 km, the value of $\ln x$ is 0.693, for which:

$$\sigma_y = \exp[4.865] = 130 \text{ m}$$

and

$$\sigma_z = \exp[3.910] = 50 \text{ m}$$

The adequacy of the approximation is demonstrated by the relatively small departure of values obtained through the mathematical function from values read visually from Turner's Figures 3-2 and 3-3. For the horizontal standard deviation, the departure is generally less than 2% and averages less than 1%. For the vertical standard deviation, the departure is generally less than 4% and averages less than 2%. Departures of this magnitude are trivial compared to other uncertainties in the calculations of pollutant concentrations. The significance of such departures may be put in perspective by noting that the wider segments of the curves from which visual readings are made, are about 4% wide. Thus, any error introduced by using the mathematical function is of about the magnitude of the variability to be expected from different people extracting the values visually.

References

1. D. B. Turner, *Workbook of Atmospheric Dispersion Estimates*, U. S. Department Health, Education and Welfare, Rev. 1969.

Mr. McMullen is senior meteorologist with the State of California Air Resources Board, 1709–11th Street, Sacramento, CA 95814.

Trace Metal Samples Collected in the Front and Back Halves of the E.P.A. Stack Sampling Train

Robert B. Jacko, David W. Neuendorf, and Kenneth J. Yost
Purdue University, West Lafayette, IN

A Purdue University industrial source sampling team has been involved since 1972 with a number of industrial and municipal collaborators, in order to characterize the flow of trace metals into the atmosphere. The plants involved in this cooperative research effort include the East Chicago municipal incinerator, rated at 450 ton/day of residential and commercial solid waste; a multiple furnace open hearth shop at a Northwest Indiana steel mill producing approximately 8 million ton/yr of steel; a coker and sinter plant serving a 100,000 ton/yr vertical retort zinc production facility; and the Purdue University coal fired power plant equipped with 250,000 lb/hr steam boilers. At each of these facilities a number of stack samples have been obtained using the standard E.P.A. train. Analysis of the probe, filter, and impinger catch showed that in each case the front half of the E.P.A. Method 5[1] sampling train was highly efficient for collection of trace metal particulate.

The E.P.A. sampling train (Figure 1), manufactured by Joy, Western Precipitation Division, was modified in each case by the use of 5% nitric acid in the first two impingers in order to trap particulate containing Cd, Pb, Zn, Cu, Fe, and Ni, which are soluble in dilute acid. The probe backwash, glass fiber filter, and impinger contents were analyzed separately for the metals, using a Perkin-Elmer atomic absorption spectrometer equipped with deuterium background corrector. The impinger contents were not evaporated to dryness for determination of condensible fraction, since the formation of nitrate salts would bias the mass of condensible particulate captured in the impingers.

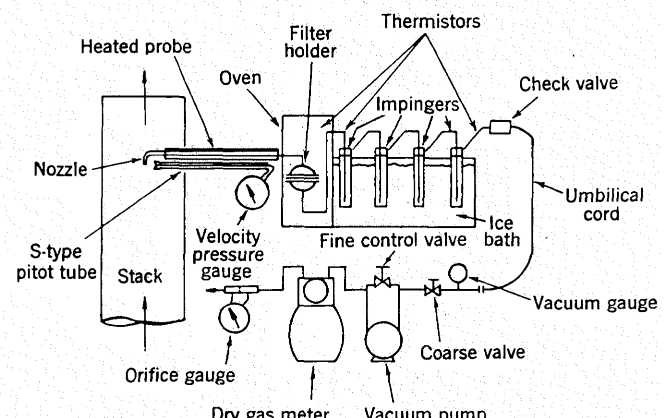

Figure 1. Purdue's E.P.A. stack sampling train utilizing 5% nitric acid in impingers 1 and 2.