DIFFUSION-DEPOSITION MEASUREMENTS AND MODELING

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1. INTRODUCTION

Continuous point source dispersion from an elevated release is generally described by a gaussian plume model but no great abundance of experimental data exists to give confidence in elevated plume variances which are usually extrapolated from surface release descriptions. This is of particular concern for the vertical dimensions of the plume since the turbulence spectrum for the vertical velocity component changes with height systematically.

If, in addition, the dispersing pollutant of interest interacts with the surface, it is important to account for material removed from the plume and to quantify its effect on airborne concentration distributions. The uncertainty in describing this process further detracts from the reliability of existing elevated point source dispersion models.

Furthermore, attempts to evaluate this effect with dispersion experiments or observations involving depositing materials are severely limited without the ability to more realistically describe the vertical diffusion accompanying the deposition.

Studies at Battelle, PNL have attempted to improve gaussian plume dispersion descriptions by including recent advances in atmospheric turbulence and allowing for the turbulent flux of material to the surface by incorporating the deposition velocity. A diffusion-deposition model was assembled and then compared with data from elevated source particulate tracer experiments conducted over the Hanford diffusion grid in neutral through very stable conditions and the deposition velocity was evaluated for the various conditions of the experiments.

2. DESCRIPTION OF THE MODEL

The model utilized predicts groundlevel crosswind integrated exposures from an elevated source by assuming a gaussian distribution in the vertical for either a depositing or a nondepositing tracer. The CIE is given by

$$CIE(x) = \sqrt{\frac{2}{\pi}} \frac{Q}{U_c \sigma_z(x)} \exp \left[-\frac{1}{2} \frac{H^2}{\sigma_z^2(x)} \right] \quad (1)$$

where Q is a tracer mass released at height H, x

is the downwind distance from the foot of the tower of release, $\bar{U}$ is the mean wind speed at a characteristic height, and σ_z is the vertical standard deviation of the plume.

The σ_z values are determined by applying the Hay-Pasquill equation (Pasquill, 1962) to the vertical dispersion. This equation is

$$\sigma_z^2 = T^2 \int_0^\infty n S_w(n) \left[\frac{\sin \pi n T / \beta_w}{\pi n T / \beta_w} \right]^2 d \left[\ln(n) \right] \quad (2)$$

where T is the travel time $x/\bar{U}$, n is frequency, $n S_w(n)$ is the logarithmic power spectrum for the vertical velocity component and β_w is the ratio of the Lagrangian to the Eulerian time scales for the vertical component. The value of β_w used is the empirical result suggested by Pasquill (1971)

$$\beta_w = \frac{0.44 \bar{U}_c}{\sigma_w} \quad (3)$$

The power spectral model used is one developed from analysis of Hanford turbulence data (Elderkin, et al., 1971). This spectrum compares favorably with other models (Busch and Panofsky, 1968 and Kaimal, et al., 1972) differing at most 20% in magnitude. It reads:

$$\frac{n S_w(n)}{u_*^2} = \frac{1.15 F}{1 + 1.5 F^{5/3}} \quad (4)$$

where u_* is the friction velocity and F is a dimensionless frequency. F is given by

$$F = \frac{n z_c}{0.46 \psi \bar{U}_c} \quad (5)$$

where z_c is the characteristic height at which $\bar{U}_c$ applies, and 0.46ψ is the dimensionless frequency of maximum spectral energy. The value of ψ tentatively used is based on partial analysis of neutral and stable turbulence data collected on the site.

$$\psi = 1 + 0.3 (z_c/L) \quad (6)$$

where L is the Monin-Obukhov stability length.

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The integral of this spectrum provides the value of σ_w required for Equation (3).

In the absence of turbulence measurements u_* and z/L are calculated from observations of mean wind speed and temperature at two heights, 2.2 m and 15 m, using profile theory for neutral and stable conditions (Businger, et al. 1971).

The characteristic height z_c is the height for which the spectrum is scaled. The present analysis uses the height of release as the characteristic height.

Of the several parts of the model, the power spectrum and the value of β_w have been verified independently by local experiments and the dependability of u_* , z/L , and σ_w estimates from profiles of wind and temperature are supported by comparisons with direct measurements.

If the source material is a depositing particulate, the ratio of Q to the original source mass Q_0 is given by

$$\ln \frac{Q}{Q_0} = -\sqrt{\frac{2}{\pi}} \frac{V_d}{u_*} \int_0^x \sigma_z(x)^{-1} \exp \left[-\frac{1}{2} \frac{H^2}{\sigma_z^2(x)} \right] dx \quad (7)$$

where V_d is a deposition velocity (see Meteorology and Atomic Energy, 1968).

To specify the deposition velocity, the transfer of particulates can be considered to take place through two regions: one, the canopy of vegetation extending to a height z_1 and the other, the layer of turbulent air above extending to z_2 , the height at which exposure measurements were taken. If the diffusivities in the air above the canopy are equal for the turbulent transfer of momentum and particulates,

$$\frac{\bar{u}_2 - \bar{u}_1}{u_*^2} = \frac{x_2 - x_1}{f} = \frac{1}{V_d} - r_1 \quad (8)$$

or

$$V_d = \frac{1}{\frac{\bar{u}_2 - \bar{u}_1}{u_*^2} + r_1} \quad (9)$$

where r_1 , the concentration at the top of the canopy layer divided by f , the flux into the canopy, can be considered as the resistance of the canopy layer. Considerable wind tunnel investigation of this resistance to particle transfer has been carried out by Sehmel, et al. (1973), for a limited number of surface types, demonstrating particle size dependence as well as roughness and shear stress dependence. No detailed experimental evaluations of the deposition have yet been performed for the type of vegetated surface of interest here, however. If the resistance of the canopy is small compared to that offered by the atmospheric surface layer, we can estimate Equation (9) to be

$$V_d = \frac{u_*^2}{\bar{u}_2} \quad (10)$$

assuming a logarithmic wind profile. This form

has been evaluated earlier by Chamberlain (1953) and more elaborate expressions have been found more precise. However, for simplicity it will be used here and the most appropriate value of the constant c determined for the set of dispersion data available.

If, on the other hand r_1 is larger than $(\bar{u}_2 - \bar{u}_1)/u_*^2$ and relatively independent of variations in atmospheric variables, V_d may be best represented as a constant for the type of surface and particle sizes involved here.

3. THE FIELD EXPERIMENTS

Two series of field experiments conducted on the USAEC's Hanford, Washington field diffusion grid were employed as guides in specification of model parameters during assembly and verification of the diffusion-deposition model. The first test series consisted of 24 experiments, 19 of which were of sufficient quality to warrant analysis. Tracer release was at an elevation of 26 meters from a 125-meter tower. The field sampling grid consists of a series of 14 sampling arcs concentric about the centrally located 125-meter tower. Radii of the sampling arcs used in this test series ranged from 0.2 km for the innermost to 12.8 km for the outermost arc.

Arcs are instrumented at the 1.5-meter elevation with vacuum fittings at more than 900 locations for inserting filters to collect particulate tracers. Depending on distance from the central tower (tracer release location), the sampling arcs used in this series embraced azimuths ranging from 190 to 60 degrees. Samplers were spaced at 2-degree increments at the near-source locations. Spacing narrowed to 1-degree increments at the outer sampling arcs.

The tracer employed was a fluorescent zinc sulfide (U. S. Radium FP 2210). This particulate has a mass median diameter of about 5 microns with a specific gravity of about 4. Collection was on 47 mm diameter membrane filters (Gelman VM-1), and assay was accomplished on the Rankin counter--a Hanford-developed device employing an alpha-induced scintillation of the FP as a measure of the mass of tracer on a filter.

Meteorological measurements during the test series were made on two towers at or near the tracer release point. Relatively coarse measurements were made of wind speed, wind direction and temperature at 15-meter elevation increments on the 125-meter tower. The wind sensors were Aerovanes. Supplementary more detailed speed, direction and temperature measurements were made on a 24-meter tower with instrument booms spaced logarithmically. Wind speed sensors employed here were Beckman and Whitley 3-cup anemometers.

The second test series consisted of eight field experiments where, in addition to collecting data to calculate surface CIEs for comparison with modeled values, measurements were simultaneously made to independently evaluate the various segments of the model. To date, only one of these experiments, test V6, has been analyzed in sufficient detail for inclusion in this report.

During this second test series, additional tracer and meteorological measurements were made. The 1.5-meter elevation (ground level) tracer measurements were supplemented by measurements on an array of 20 towers placed on arcs at 0.2, 0.8, 1.6 and 3.2 km from the source point. Tower heights ranged from 33 meters on the 0.2-km arc to 62 meters on the 3.2 km arc. A total of 345 filter sampling locations were employed on these towers.

Further, an inert gas (krypton) tracer system was employed on three of the six sampling arcs used during this test. Although the cost of each sampler on the more sophisticated krypton grid precluded matching the particulate filter samplers on a one-to-one basis, Geiger-Müller detectors were employed at 67 ground level and 60-tower locations. Krypton was released from the same location as the particulate tracer with the intent of comparing differences in downwind concentrations of the two tracers as an indicator of the amount of deposition of the particulate tracer.

During test V6, turbulence measurements also were made on an L-shaped grid of eight towers located within the confines of the tracer sampling grid. The major axis of the L aligned with the prevailing wind direction. Gill 3-component anemometers were employed on these towers. In addition to providing turbulence spectra for comparison with modeled spectra, turbulence correlations in space and time permit the Lagrangian turbulence correlations to be estimated, and values of β_w to be compared to those produced by the model.

4. RESULTS

The crosswind integrated exposures measured at the surface in the first series of 19 experiments showed significant irregularities and yet some expected characteristics were also clearly present. Because nonstationarities and inhomogeneities are often found during stable conditions over the 13 km sampling distance, distributions were not smooth and multiple peaks in CIE vs. x frequently occurred. The data were separated into 4 stability groups for inspection, even though the model permits comparisons as a continuous function of Richardson number. Five tests fell into Group 1 at $0 < Ri < 0.03$, six tests into Group 2 at $0.04 < Ri < 0.06$, four tests into Group 3 at $0.07 < Ri < 0.09$, and four tests into Group 4 at $0.10 < Ri < 0.15$. The maximum CIE was found at increasing distance from the source with increasing stability except for Group 4. Peaks for Group 1 occurred at 800 to 1200 meters, for Group 2 at 1200 to 1600 meters, and for Group 3 at 1600 meters--except for the most stable case in that group which, with a Richardson number of 0.09, peaked at 3200 meters from the source, the greatest distance to maximum CIE observed in the test series. For Group 4, however, the peak retreated, occurring as close as 800 meters from the source in the most stable conditions. It is possible that nonstationarity becomes quite significant in these very stable conditions and intermittent bursts of turbulence bring concentrations to the ground at close distances from the source for short intervals of time.

The magnitudes of the peak CIE values

for the first three stability groups were also consistent with expectations for gaussian plumes, where Equation (1) reaches a maximum normalized value of $CIE \bar{U}/Q = 0.0186$ at a distance from the source where $\sigma_z = H$. The observed peak values (generally from 0.0102 to 0.0237) were relatively close to the expected peak value of 0.0186, and were found at distances where the model-estimated σ_z values (19 meters $< \sigma_z < 30$ meters) did not deviate seriously from the expected σ_z of 26 meters. One normalized peak value, 0.0388, was noticeably too large and, as mentioned earlier, the Group 4 plumes reach the surface much earlier than expected and the peak normalized CIE values were also more variable for that group.

Comparisons of the measured CIEs at all distances with predicted values when a wind dependent deposition velocity function was employed were made to determine the best constant c in Equation (10).

Measured data were compared with modeled CIE by forming the ratio, R , of calculated to observed CIE for each arc in each experiment. The geometric mean of all ratios in a given stability group and the standard deviation about that mean were then determined. These are listed in Table 1.

Table 1

		Stability Group			
		1	2	3	4
c	R_i	0.00 to 0.03	0.04 to 0.06	0.07 to 0.09	0.10 to 0.15
3.0	g.m.	1.24	1.15	1.05	0.61
	s.d.	1.99	1.92	1.91	4.80
2.5	g.m.	1.39	1.26	1.15	0.63
	s.d.	1.95	1.93	1.97	4.94
2.0	g.m.	1.57	1.38	1.25	0.65
	s.d.	1.95	1.98	2.06	5.10
1.5	g.m.	1.77	1.56	1.37	0.68
	s.d.	2.00	2.05	2.18	5.27
1.0	g.m.	2.00	1.64	1.50	0.71
	s.d.	2.10	2.18	2.33	5.46

gm: geometric mean; s.d.: standard deviation

Ignoring the last stability group, which was not adequately described by the model, both $C = 3.0$ and $C = 2.5$ gave reasonable results.

It is most necessary that the geometric means of R calculated for each arc remain relatively constant with distance, particularly beyond the point of maximum where the plume concentrations at ground level are no longer on the tail of the vertical distribution. For $c > 3.0$, the arcwise means of R became noticeably lower at the greatest distances than in the vicinity of the peak CIE, indicating that the deposition was being overestimated in the model. Similarly, at $c = 1.0$ and $c = 0$, the ratios at the greatest distances are significantly too large, indicating deposition was being underestimated. For each stability group, the range of arcwise geometric means is slightly better for $c = 2.5$ than for $c = 3.0$, although the difference between the overall geometric means for each stability group is seen to be less for $c = 3.0$. The arcwise geometric mean ratios and their standard deviations are given in

Table 2 for $c = 2.5$. For stability groups 1 through 3 at distances beyond the peak CIE, the arcwise ratios are within a factor of 2 to 3.

Table 2

X (m)	Stability Group							
	1		2		3		4	
	g.m.	s.d.	g.m.	s.d.	g.m.	s.d.	g.m.	s.d.
400	0.77	1.29	1.03	1.79	0.55	3.12	0.06	1.00
800	0.98	1.44	0.76	1.38	0.54	1.00	0.13	2.18
1200	1.53	1.30	1.34	1.62	1.16	1.35	0.18	2.43
1600	1.21	1.45	0.79	1.11	0.90	1.06	0.74	1.00
2200	2.18	1.25	2.06	2.57	2.19	1.50	2.52	1.82
3200	1.25	1.72	0.88	1.21	1.04	1.39	1.42	1.25
5000	2.41	1.79	2.22	1.66	1.82	1.46	3.68	1.20
7000	1.54	2.68	0.87	1.04	1.52	1.56	1.38	1.22
12800	0.91	3.47	2.33	1.92	1.67	1.00	1.54	1.00

In Table 1, standard deviations are smallest and less than 2 for $c = 2.5$ and $c = 3.0$. Also, in Table 3 below for $c = 2.5$, it is seen that roughly two-thirds of the predicted CIEs are within a factor of two of the observed values for Groups 1 through 3 and that 90% or more of the model predictions are within a factor of four of the observations.

Table 3

Stability group	% of ratios <2	% of ratios <4
1	64	90
2	70	90
3	72	96
4	48	61

Again, Group 4 is shown to be inadequately described by the model.

The deposition velocities for each experiment, considering $V_d = 2.5 u_*^2 / U_2$, are given in Table 4.

Table 4

Test	R1 (2-15m)	L (m)	$\bar{U}_{26m}$ (m/sec)	$\bar{U}_{2m}$ (m/sec)	u_* (cm/sec)	V_d (cm/sec)
Group 1						
78	0.005	785	6.0	3.7	35	8.2
62	0.01	389	8.0	5.4	45	9.4
70	0.01	389	7.2	4.3	41	9.6
61	0.02	187	7.8	5.0	42	8.8
76	0.03	119	6.0	3.7	31	6.3
Group 2						
63	0.04	85	5.8	3.0	28	6.7
65	0.04	85	5.2	3.2	26	5.1
73	0.04	85	4.9	2.4	24	5.9
67	0.06	51	4.5	2.7	19	3.5
69	0.06	51	4.8	2.6	21	4.3
77	0.06	51	3.4	1.4	15	3.9
Group 3						
68	0.07	41	4.8	2.3	20	4.2
74	0.07	41	4.8	1.7	20	5.7
79	0.08	33	4.8	1.6	18	5.2
72	0.09	27	4.7	1.7	17	4.2
Group 4						
83	0.13	13	5.8	1.1	14	4.7
71	0.14	11	4.3	1.5	9.4	1.5
64	0.15	8.6	4.9	1.0	9.5	2.2
82	0.15	8.6	4.9	0.6	9.5	3.7

The fact that the geometric mean is somewhat greater than unity is not serious. In Equation (7), the assumed proportionate spread of the deposition deficit over the complete vertical concentration distribution is a simplification which overestimates the surface concentration and causes the ratio of calculated to observed CIE to be slightly larger than unity. When the deposition deficit is diffused from the surface upward through the plume, Horst (1974) determined the ratio of the source depletion model (proportionate vertical spread of deposition deficit) to his surface depletion model (deposition deficit diffused from the surface) for various stabilities and source heights. His work shows that it would not be unusual to find the source depletion model exceeding the surface depletion model by as much as a factor of 2. Thus, for the meteorological conditions applicable to Tables 1 and 2, ratios greater than unity might well be expected.

Considering next that deposition velocity is constant, i.e., the canopy resistance is dominant and relatively independent of meteorological variables, Table 5 shows averages and deviations of calculated to observed CIE ratios for each stability group when calculations were made using deposition velocities of 1.0 through 9.0 cm/sec.

Table 5

V_d (cm/sec)	Stability Group			
	1	2	3	4
	R1 (2-15m)	0.00 to 0.03	0.04 to 0.06	0.07 to 0.09
9.0	g.m. 1.38 s.d. 1.90	0.93 1.92	0.80 1.91	0.47 4.23
7.0	g.m. 1.58 s.d. 1.92	1.09 1.87	0.96 1.88	0.52 4.41
5.0	g.m. 1.81 s.d. 1.99	1.29 1.91	1.15 1.99	0.58 4.72
3.0	g.m. 2.07 s.d. 2.13	1.52 2.06	1.37 2.19	0.65 5.10
1.0	g.m. 2.37 s.d. 2.32	1.80 2.34	1.64 2.53	0.73 5.60

g.m.: geometric mean; s.d.: standard deviation

A deposition velocity of 7 cm/sec appears to be the best single value since the standard deviation is smallest overall. For the first stability group, a deposition velocity of 9.0 cm/sec would appear to be slightly better. Rather than reflecting stability dependence, this is more likely associated with the stronger turbulence for that group where the five largest u_* values of the test series are found, producing a comparable average wind dependent deposition velocity of 8.5 cm/sec.

The arcwise average ratios of calculated to observed CIE also are the most constant with distance beyond the peak, where deposition is occurring. The arcwise averages and deviations for each stability group are given in Table 6.

Table 6

X (m)	Stability Group							
	1		2		3		4	
	g.m.	s.d.	g.m.	s.d.	g.m.	s.d.	g.m.	s.d.
400	0.77	1.28	1.02	1.79	0.54	3.12	0.06	1.00
800	0.99	1.42	0.75	1.36	0.54	1.00	0.13	2.17
1200	1.57	1.30	1.27	1.62	1.12	1.36	0.17	2.43
1600	1.26	1.42	0.77	1.09	0.86	1.05	0.72	1.00
2200	2.32	1.25	1.75	2.79	1.93	1.55	2.37	1.84
3200	1.43	1.67	0.77	1.20	0.85	1.45	1.28	1.25
5000	2.96	1.75	1.79	1.63	1.33	1.33	2.76	1.25
7000	2.03	2.50	0.65	1.28	0.97	1.63	0.82	1.23
12800	1.46	3.18	1.16	1.39	0.82	1.00	0.46	1.00

Comparing Table 5 and Table 1, it can be seen that although the mean values are not as consistent between stability groups for a constant deposition velocity of 7.0 cm/sec as for wind dependent deposition velocities, the standard deviations are noticeably less. Rather than the deposition being limited strictly by either the canopy resistance or the atmospheric transfer resistance, most likely both should be accounted for in the best description of the deposition to be developed in future studies.

In a recent wind tunnel study by Sehmel (1974), results have been organized for deposition velocities over a variety of surfaces of relatively low roughness. He modeled and extrapolated to the greater roughness of $z_0 = 3.0$ cm, comparable to that of the dispersion grid utilized in the experiments discussed here. After consideration of tracer particle diameter and density, the modeled deposition velocities, which are dependent on particle size and friction velocity as well as roughness, agree well with those determined from the field experiments. Sehmel's model estimates that V_d would fall between 7 and 10 cm/sec for Stability Group 1, between 3 and 7 cm/sec for Stability Group 2, between 3-1/2 and 4-1/2 for Stability Group 3, and between 2 and 3 cm/sec for Stability Group 4. These estimates compare favorably with the wind dependent deposition velocity estimates of Table 4.

A tracer with another particle size was also used in the second series of experiments which have yet to be fully analyzed. It is clear, however, that particle size dependence must be reflected in Equation (9) before future field evaluations of deposition. Otherwise, a degraded agreement can be expected between Sehmel's results and field tests utilizing other particulate tracers.

The second series of experiments provide independent field evaluations of the segments of the model while simultaneously providing the concentration data necessary for overall model verification. The turbulence was measured directly so that the true spectrum of vertical velocity would be provided. A line of turbulence measurements along the mean wind direction gave the quasi-Lagrangian time scale (Gifford 1967) as well as the Eulerian scale for β_w estimates. Depositing (zinc sulfide FP particulates) and nondepositing (Krypton-85 gas) tracers were simultaneously released for direct determination of the FP tracer loss from the plume and thus of the deposition. One of these experiments, test V6, is discussed

here and comparisons are made between measured and modeled results.

Comparisons were made between the turbulence characteristics generated by the model and those measured at the release height of 26 m. The model used with wind and temperature profile data produced $u_* = 0.26$ and $\sigma_w = 0.35$, which compared very well with the directly measured values of $u_* = 0.23$ and $\sigma_w = 0.34$. The vertical velocity turbulence spectrum generated by the model compared well with the measured spectrum with the exception that at high frequencies the measured spectrum falls off more rapidly than the -2/3 slope of the model spectrum.

The above modeled σ_w and the measured $\bar{U}_{26} = 6.2$ m/sec provide the turbulence intensity input to the model resulting in a calculated $\beta_w = 7.9$. The value of β_w estimated from correlations of turbulence measurements spaced along the mean wind in this test was about 6, however. The method of determining β_w was that followed by Elderkin and Powell (1972). It has been noted by N. Z. Ariel and E. K. Bytner (1966) however that variability in both speed and wind direction about the mean values tends to reduce the quasi-Lagrangian correlation coefficient estimated in this manner because of the dispersal of trajectory end points for a given time lag, about the mean position where the turbulence data were measured. To evaluate this effect, shorter time increments were selected where this dispersion was reduced. As shown in Table 7, β_w for the vertical wind component was largest when determined over the shortest time increment of 7 min, ranging from 6 to 10.

Table 7

Time Interval (min)	$\rho_{3,4}(\tau_m)$	τ_m (sec)	w_3	τ_{Em}	w_4	$\beta_w = \tau_m / \tau_{Em}$
45-99	0.282	7.2	1.33	1.27	5.41	5.67
45-72	0.264	7.2	1.42	1.11	5.07	6.49
59-72	0.325	7.4	1.00	1.00	7.4	7.4
59-65	0.281	7.2	1.24	1.20	5.81	6.0
66-72	0.385	7.4	0.72	0.84	10.3	8.8

In the table, w_3 and w_4 are w' measured at the third and fourth towers of the turbulence array; $\rho_{3,4}(\tau_m)$ is the maximum cross-correlation value between w_3 and w_4 ; τ_m is the time lag at which the maximum cross-correlation occurs; τ_{Em} is the time lag at which this same cross-correlation value occurs on the Eulerian autocorrelation functions of w_3 and w_4 , as indicated. A more reasonable estimate of β_w than the average value of 6 would appear to be $\beta_w = 8$, an average value for the 7-min calculations. This agrees with the value calculated by the model.

The modeled vertical velocity spectrum and the modeled β_w value serve as inputs to σ_z as it is determined by the Hay-Pasquill technique which, in the gaussian diffusion equation without the deposition function, can be compared with Krypton-85 CIEs to evaluate the vertical diffusion segment of the model. This comparison is made in Figure 1 where the Krypton data is seen to agree with the model curve.

Figure 1. Crosswind integrated exposure vs. distance for field test V6

When deposition is included in the model using $c = 2.5$ and the resultant $V_d = 5.9$ cm/sec, the calculated CIE can also be compared in Figure 1 with the depositing particulate tracer measurements shown. The data are seen to conform to the shape of the model curve (with deposition) but are roughly a factor of two larger in magnitude. This appears to have resulted from the vertical distribution of the particulate plume being non-gaussian and a lobe occurring below the height of release which was not found in the Krypton distribution raising the surface values somewhat.

The data point at the first arc is noted to be especially high compared with the model value but the surface measurements were on the tails of the vertical distributions, the surface exposure being less than 2% of the elevated centerline exposure at 200 m. At 800 m and beyond, the plume had significantly intersected the surface, with exposures at 800 m being more than 25% of the elevated centerline value. At 800 m and beyond, the ratio of calculated to observed exposures was consistently near 0.5.

Along-wind mass fluxes of the particulates calculated through cross sections of the plume, reported by Nickola and Clark (1974a) for test V6, offer support to the results of the deposition segment of the model. Table 8 shows estimates of the tracer remaining in the plume at each sampling distance.

Table 8

x (m)	200	842	1647	3248
Per cent remaining	73	62	96	45

The estimates for the first two distances are obviously low, most likely due to the narrow horizontal spread of the plume causing peaks between sampling towers to be ill-defined. The model-

estimated remainder of mass in the plume of 64% at 3200 m is consistent with the very gross estimate from cross-section analysis of 45%. Also, by comparison of zinc sulfide and Krypton profiles near the ground, Nickola and Clark (1974b) are able to estimate that the fraction of the plume lost at 800-m distance from the source is 3% to 6% of the quantity released in test V6. The model estimates that 3% has been lost at this distance, agreeing reasonably well with observation.

These analysis results offer some confidence that the segments of the diffusion-deposition model are appropriately described. It is considered that evaluation of deposition occurring in the first series of experiments was reasonable and that future experiment-model comparisons would be useful for other aerosol particle sizes and other meteorological conditions.

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