DRY DEPOSITION OF ATMOSPHERIC OZONE

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The dry removal processes of pollutants associated with emissions from fossil-fuel-fired power plants were studied in field tests. Results of ozone dry deposition tests using both an eddy flux method and a profile method are given. These data are needed as input for modeling long-range transport of atmospheric pollutants.

Ozone was selected for study because of its importance as an atmospheric pollutant. The availability of fast response ozone monitors allows direct measurement of the ozone Reynolds flux as well as concentration profiles. The high sensitivity of such instruments allows study of ozone at background concentrations of ozone.

The concentration gradient $\partial C/\partial z$ may be determined as a function of height from measurements of the concentration profile. If an eddy transport coefficient is then assumed, the aerodynamic resistance to transport may be calculated and the surface resistance term determined (Droppo 1976; Garland 1976). The surface resistance may also be determined directly from measurements of the Reynolds flux, $w'C'$, of the pollutant and the pollutant concentration near the surface (Desjardins and Lemon 1974; Wesely et al. 1977). The ratio of $w'C'$ and $\partial C/\partial t$ then provides a value for the eddy diffusivity K_C. While some evidence exists that the diffusivity for heat, K_H, is more appropriate than that for momentum, K_M, the question has not been totally resolved (Dyer and Hicks 1970; Galbally 1971).

Measurements were taken at two sites: one in western Washington and one in eastern Washington. The experimental techniques and procedures were developed at the former site, but the availability of additional apparatus and superior fetch at the latter site made it a more attractive choice.

The terrain at the eastern Washington site was a relatively flat, uniform desert with sparse sagebrush and various grasses being the main vegetation. An acceptable fetch was available in most directions for several kilometers, and a roughness length of $\sim$4.5 cm was estimated from a number of wind and temperature profiles. Winds were determined using three-component Gill anemometers located at heights of 1.22, 4.72 and 18.3 m. Thermistor temperature probes were located at the same heights.

As many as three chemiluminescent ozone monitors were used simultaneously during data collection periods. A factory modified instrument, with a response time of approximately one second, was used to record ozone fluctuations at the top of an 18.3-m tower. Air was drawn in at that height through a teflon line connected to a pump. A double tee arrangement (Figure 1.21) enabled the ozone in the line to be sampled by the monitor that was located near the pump. Reynolds fluxes of ozone were computed from fluctuations in concentration and vertical wind speed at the 18.3-m level.

Two roving sample lines were used to record the ozone concentration profiles. The lines were positioned so that one inlet was located at a height of 0.76 m when the other was at 15.2 m. The intake lines switched positions periodically to compensate for possible systematic errors. The relative calibration of the two instruments

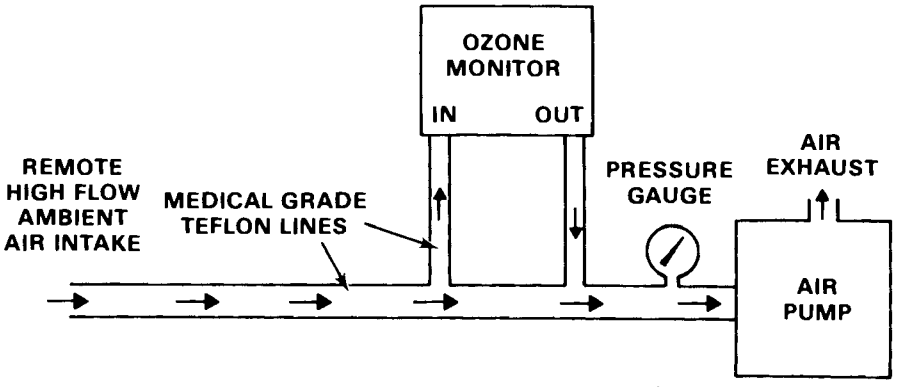

FIGURE 1.21. Schematic Diagram of Ozone Monitor Intake Systems

was checked before and after each data period (∿1 hr) by moving the two intakes to the same height and recording concentrations for several minutes.

Examples of the measured wind, temperature and ozone concentration profiles are shown in Figure 1.22 for slightly unstable conditions and in Figure 1.23 for moderately unstable conditions.

In determining surface resistances to ozone transport, several assumptions are made. First, the roughness length for momentum flux, z_0, is an appropriate height at which to determine the resistance for ozone. Second, the surface and atmospheric resistance terms may be added in series so that the total resistance is given by the sum of these two contributions, $R_T = R_a + R_s$. The surface term, R_s, is simply treated as a residual after the atmospheric contribution, R_a, has been removed. Thus, R_s used here may contain a stomatal resistance contribution as well as any resistance to transfer across the surface layer of air in contact with a vegetative surface (Wesely and Hicks 1977).

From measurements over the semi-arid terrain of eastern Washington, a surface resistance value for ozone of 290 ± 150 s/m was found. This agreed well with results from measurements over a grassy field in western Washington, where the surface resistance was found to be 270 ± 160 s/m.

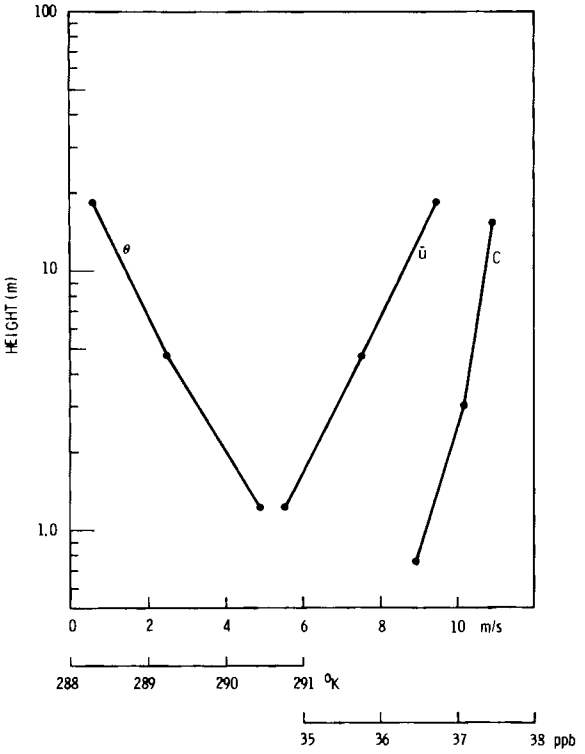

FIGURE 1.22. Measured Ozone Concentrations, Wind and Temperature Profiles in Slightly Unstable Conditions

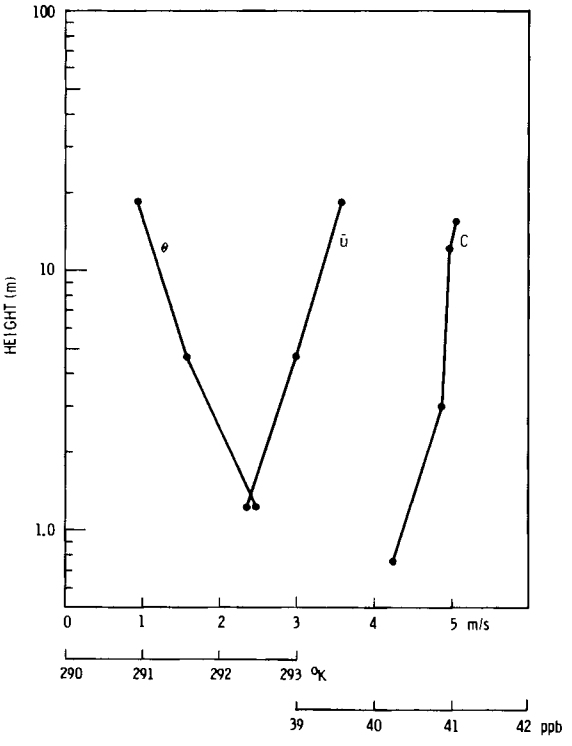

FIGURE 1.23. Measured Ozone Concentrations, Wind and Temperature Profiles in Moderately Unstable Conditions

The eddy diffusivity for any quantity is defined as the ratio of the flux to the concentration gradient. Determining ozone eddy diffusivity requires accurate specification of the very small ozone concentration gradients to allow comparison with values for heat and momentum.

A straight line of the form $C = a + b \ln z$ was fitted to the ozone profiles, and similar fits were made to the velocity and temperature profiles as well. An estimate of $\partial C/\partial z$ at z = 10 m is then given by b/10, and $K_C \approx \text{Flux}(O_3)/(\partial C/\partial z)$. Similar calculations were carried out for velocity and temperature, and some results are summarized in Table 1.11.

TABLE 1.11. Estimated Values of Momentum (K_M), Diffusivity for Heat (K_H) and Eddy Diffusivity (K_C) at 10 m.

Run	K_M, m²/sec	K_H, m²/sec	K_C, m²/sec
1	3.29	3.87	3.63
2	3.32	3.58	4.42
3	1.90	2.99	3.80
4	1.73	2.27	4.65
5	1.48	4.31	2.59

From these values, the ratio K_C/K_M is found to be 1.77 ± 0.62 while K_C/K_H = 1.22 ± 0.54. A value of unity would be expected for one of these ratios if the transport mechanisms for ozone were identical with that for momentum or heat. The significantly better agreement with the eddy diffusivity for heat suggests that it is the more appropriate value.

Surface resistance values for ozone have been measured at two sites and were found to agree well with each other. The combined measurement of concentration profiles and eddy fluxes is a useful technique in transport and resistance studies. Results obtained from these indicate that the eddy diffusivity for ozone is more similar to that for heat than to that for momentum.

PROFILE MEASUREMENTS OF AEROSOL DEPOSITION

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A field test program, which assesses the accuracy of the gradient profile method of determining deposition velocities, is described.

The gradient method of deposition velocities has proved useful in the study of dry removal of gases, such as SO_2 and O_3 (e.g., Garland 1976). Measurements of particulate deposition by this technique are considerably more difficult, but reported results (Droppo 1977) suggest that the approach is feasible. One of the major objections to this method is that the expected small values of deposition velocity would result in exceedingly small gradients that would not be sufficiently well resolved by available measuring and analysis procedures. However, recent results (Wesely et al. 1977; Hicks and Wesely 1978) indicate that deposition velocities for small particles may be higher than previously anticipated; thus, the gradient method becomes more attractive.

Critical to the successful application of this method is the relative accuracy with which concentration differences between various heights can be measured. A careful study of this aspect of the problem has, therefore, been undertaken.

A 12.2-m tower was erected and used to mount the holder and filters that sample the ambient air. Eight filters were mounted on the tower, and they were divided into two groups of four. Each filter in a group was connected to a common pressure manifold by 1.9-cm I.D. flexible tubing. The manifold was used to equalize the pressure in each of the lines so that identical flow conditions for each filter might be established. In actual practice, minor variations in the filter holder geometries resulted in different flow rates. These rates, however, were monitored by Roots meters located at the manifold, which ensured that the meter readings were recorded at the same pressure for each line. This made pressure corrections unnecessary. The manifold itself was attached to three pumps, which were used to draw air through the lines. An independent set of pumps, meters and manifold were connected to the second group of filters. Figure 1.24 shows a schematic diagram of the arrangement.