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REPORT OF A STUDY OF THE FATE OF 200-AREA STACK GASES

by

Frank E. Adley

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REPORT OF A STUDY OF THE FATE OF 200-AREA STACK GASES

By Frank E. Adley

The following report contains a discussion of some of the factors which affect the fate of atmospheric contamination following its discharge from the 200-Area stacks.

The normal environmental effects produced by the routine discharge of process stack gases, as exemplified by vegetational radioactivity, has been amplified by the occurrence of unintentional particulate matter or "specks" settling in and around the 200 Areas. To obtain a greater understanding of the implications of such contamination a study has been made of the situation with particular emphasis being placed on the "speck" problem. The findings of this investigation have shown that the fate of such contamination is determined by two factors; the settling characteristics of the contaminant and meteorological conditions.

NATURE OF CONTAMINATION

Present knowledge concerning the physical qualities of the normal gases discharged by the 291 Building stacks indicates that the off-gases contain acid mists, oxides of nitrogen and certain fission products. Since active nitric acid-metal reactions are known to evolve oxides of nitrogen in the form of NO, NO_2, and N_2O_4, it is feasible to anticipate that normal process off-gases may contain such gases, particularly the latter two.

As a result of the acid nature of the air being handled inside the ventilating systems a considerable corrosive action has taken place where metal surfaces such as cell equipment, ductwork, fan housings, and impellors have been exposed to this atmosphere over a period of time. Fine particulate matter has gradually become disassociated from such surfaces and, if sufficiently small, has been conveyed by the ventilation air to the stacks where it was subsequently discharged to the atmosphere. Spectrographic analyses have also shown that in addition to corroded metallic particles there also existed other radioactive particles in relatively small quantities probably originating from painted and/or masonry surfaces inside the ventilating systems.

SETTLING CHARACTERISTICS

Particulate matter when settling in still air accelerates until its terminal velocity is attained after which it assumes its characteristic settling rate. Settling rates of particles can be obtained from Stokes

Law, provided its upper and lower limits are observed. The upper limit is determined by the point at which a particle is of sufficient magnitude to create turbulence in the air as it falls, thus, retarding its rate of settling. The lower limit where Stokes Law ceases to apply is the point where a particle is sufficiently small that it can slip between the molecules of air with less collisions, which results in a diminished resistance to settling. The lower boundary for actual settling occurs at a particle diameter of approximately 0.1μ below which settling ceases and the particle assumes Brownian motion, therein behaving as a gas.

Considering the types of normal particulate matter known to be present in the stack gases their settling rates were calculated, based on assumed values of material densities and particle shapes. The settling rates for nitric acid mists and oxides of nitrogen were calculated and plotted in Figs. 1 and 2, respectively.

The settling rate for "specks" was also calculated and is shown in Fig. 3. In view of the irregular shapes encountered it was thought advisable to check the theoretical settling rate with that which was occurring in practice. This was accomplished by an experimental arrangement utilizing three settling tubes 41 in., 89 in., and 42 ft. in length through which random "specks" were allowed to settle. Close control of individual particles was accomplished where possible by the use of electromagnetic releases and VGM instruments for detecting the termination of settling. Particle thickness was measured as were the major and minor axes and the average of these three dimensions was designated as the "equivalent diameter." The data compiled from this investigation have been superimposed in Fig. 3.

In order to obtain a better evaulation of the data presented in Figs. 1, 2, and 3 the findings contained therein were extended to include other factors pertinent to the problem. It was observed from Project meteorological recordings that the average annual wind velocity in the prevailing direction was approximately 13 mph. Considering this factor and also the stack height, settling rate data were plotted to indicate the distance that stack gas contamination could travel in a wind of 13 mph velocity before reaching the ground. This information is shown in Fig. 4.

Normal environmental contamination is routinely evaluated by the H. I. Division by several types of sampling and analyses. One of these is the sampling of vegetation at designated locations and the subsequent determination of its beta activity. During the period August 1947 to December 1947, 130 analyses were made of vegetation collected at mile intervals from the 200-E Area in a southeast direction or that following the prevailing winds which occur during dissolver runs. The results are shown in Fig. 5.

METEOROLOGICAL

Of equal importance to the settling rate of particulate matter is the influence imposed by meteorological conditions. Variations in atmospheric temperature and wind velocity are characterized by accompanying variations in the pattern of discharged stack gases. These patterns or formations may be divided into three classes; looping, coning, and fanning.[1] Looping implies that stack gases rise and fall periodically with occasional, but not predictable, contact with the ground. This condition is caused by unstable atmospheric conditions when the velocity is approximately the same at the ground and 200-ft levels and is not in excess of 20 mph. Coning is a condition which exists when the discharged gases travel approximately on a horizontal axis and gradually increase in cross section until conical in shape. It has been found that under this type of flow with a 200-ft stack the gases first contact the ground about 1600 to 2000 ft away. Stack discharge is permitted during looping or coning provided that air temperature and wind velocity conditions insure a stack gas dilution of at least 1000/1. Fanning is horizontal, laminar flow which usually exists when the atmospheric temperature differential between the 200-ft and 4-ft levels is positive and the wind velocity does not exceed approximately 15 mph. Under these conditions, which occur mainly at night, dissolver off-gases are discharged into the atmosphere.

In view of a possible difference existing between the overall average annual wind velocity and directional reportings and their component parts, namely the average nocturnal and diurnal recordings, this factor was investigated. An analysis of the diurnal wind velocity and "per cent of time blowing" recordings showed that the prevailing wind during the daytime was from the southwest in contrast to the nighttime prevailing winds which were from the northwest.

Although detailed wind direction and velocity records are maintained by the Project, it was understood that weather reports by surrounding stations usually lack sufficient data pertaining to wind directions. This deficiency eliminates the possibility of tracing wind directions outside of the Project which would be of particular importance in understanding the fate of atmospheric contaminants disseminated in this area.

DISCUSSION

Atmospheric contaminants evolved during the normal 200-Area processing operations and which are picked up by the exhaust ventilating system are thought to consist largely of acid mists and oxides of nitrogen both of which may be radioactive when discharged. Acid mists evolved during active metal-acid reactions, such as picking and stripping, or during dissolving are formed by the release of free hydrogen which physically carries acid in the form of mist from the solution. When freshly produced such mists are microscopic in size, usually below 10μ with the mean size slightly under 5μ in diameter. Oxides of nitrogen are not usually visible individually but collectively the visible components are NO_2 and N_2O_4 fume which are recognizable at the stack discharge by their brown and yellow colors, respectively.

Reference to the settling rates of the normal contaminants, as shown in Figs. 1 and 2, indicates that insignificant settling should occur from this source. However, acid mists after being in suspension for a short period and subjected to the turbulence typical of the airstream in ventilating systems are subject to considerable coalescing. In view of this, it is thought that the average and maximum droplet size is considerably increased with an accompanying increase in the rate of settling by the time the air is emitted by the stack.

The mist and fume which does not coalesce remains sufficiently small to have the same properties as smoke and gases which have minimal settling qualities and are influenced mainly by atmospheric conditions. Previous studies[2,3] have shown that the maximum ground level concentration is usually expected to occur at a distance equivalent to approximately 10 times the height of the stack and that after 50 stack heights the atmospheric concentration varies as the inverse square of the distance. An examination of available data of vegetation activity within 200-E Area indicated that the maximum concentration occurred at approximately 10 stack heights distance. Further evaluation of the beta analyses as shown in Fig. 5 manifests that the ground contamination occurring in the path of the prevailing winds during that period varied inversely as the (distance)$^{0.75}$. The disparity between these findings and those resulting from previous investigations is thought to be attributed to the higher mean wind velocities common to this area and the type of contamination investigated.

"Specks" that were examined and studied in a random manner were found to be mostly magnetic and to have a density about the same as iron. Settling characteristics, within the limits of this study, followed the same slope as that derived from Stokes Law, although a slower rate was indicated. This was apparently due to the irregular shapes of the "specks" encountered in this problem.

The maximum size available for study was approximately 1000μ in equivalent diameter which would settle to the ground in about 4000 ft from the stack if discharged during a 13-mph wind. It can also be seen from extrapolation of the data collected that particles of an equivalent diameter of 20μ might travel as far as 100 miles.

In view of the lack of beneficial weather station reporting of wind directions outside of but in the immediate vicinity of the Project, additional information should be obtained on this phase of the problem. One method of accomplishing this would be by the routine liberation of no-lift theodolite balloons from the 200 Areas. The present theodolite balloons and equipment could be utilized with the addition of some form of individual balloon identification and tagging to permit the finder to return the desired data. Although this method of tracing air currents has acknowledged deficiencies the results would possibly indicate whether certain areas are located in a concentration of winds from the Project.

RECOMMENDATIONS

As a result of the findings of this investigation the following recommendations are offered to permit a more extensive interpretation of the data contained herein.

1. A qualitative study of stack gases, as discharged, should be conducted.
2. A particle size distribution study should be made of the 200-Area stack gases, as discharged.
3. Supplemental wind direction data should be obtained to permit coursing of winds leaving the Project.

REFERENCES

1. "Characteristics of Mixing and the Dilution of Waste Stack Gases in the Atmosphere" by Phil Church and C. A. Gosline, Jr.
2. "Effectiveness of High Stacks in Overcoming Objectionable Concentrations of Gases at Ground Level" by G. R. Hill, M. D. Thomas, and J. N. Abersold.
3. Transactions of the Faraday Society: 1249-1264 (April, 1936).

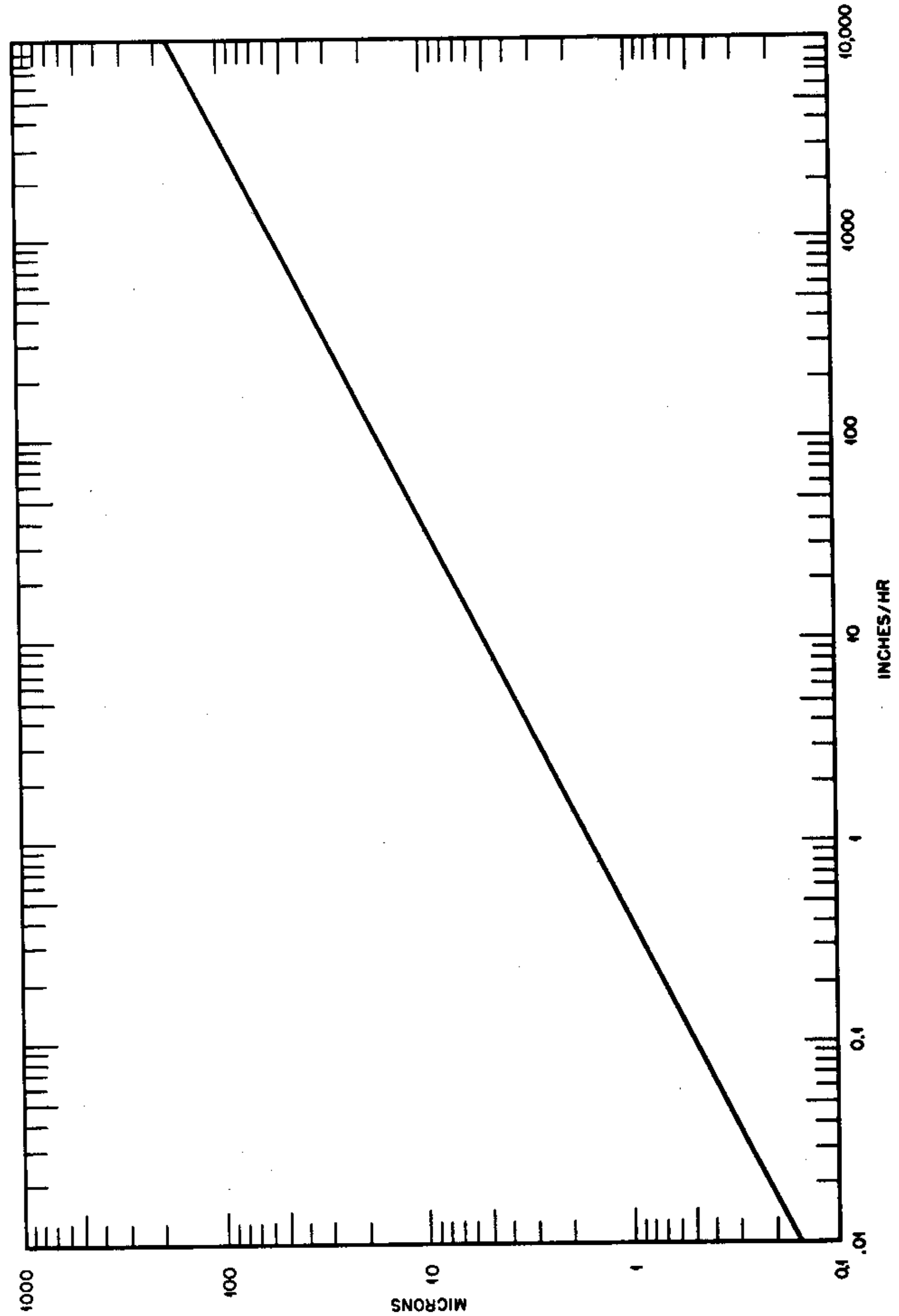

Fig. 1--Settling rate--nitric acid mist.

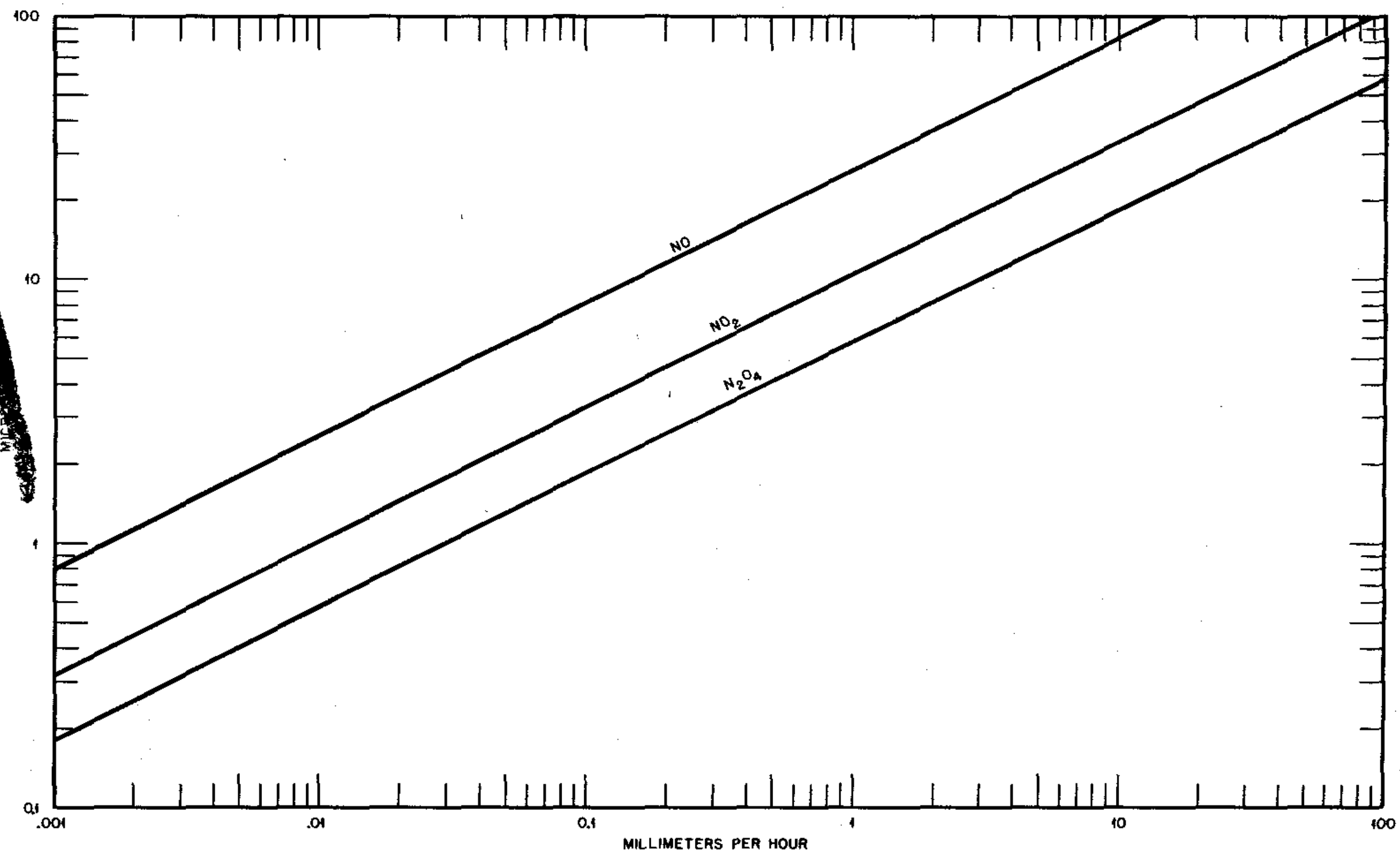

Fig. 2--Settling rate--oxides of nitrogen.

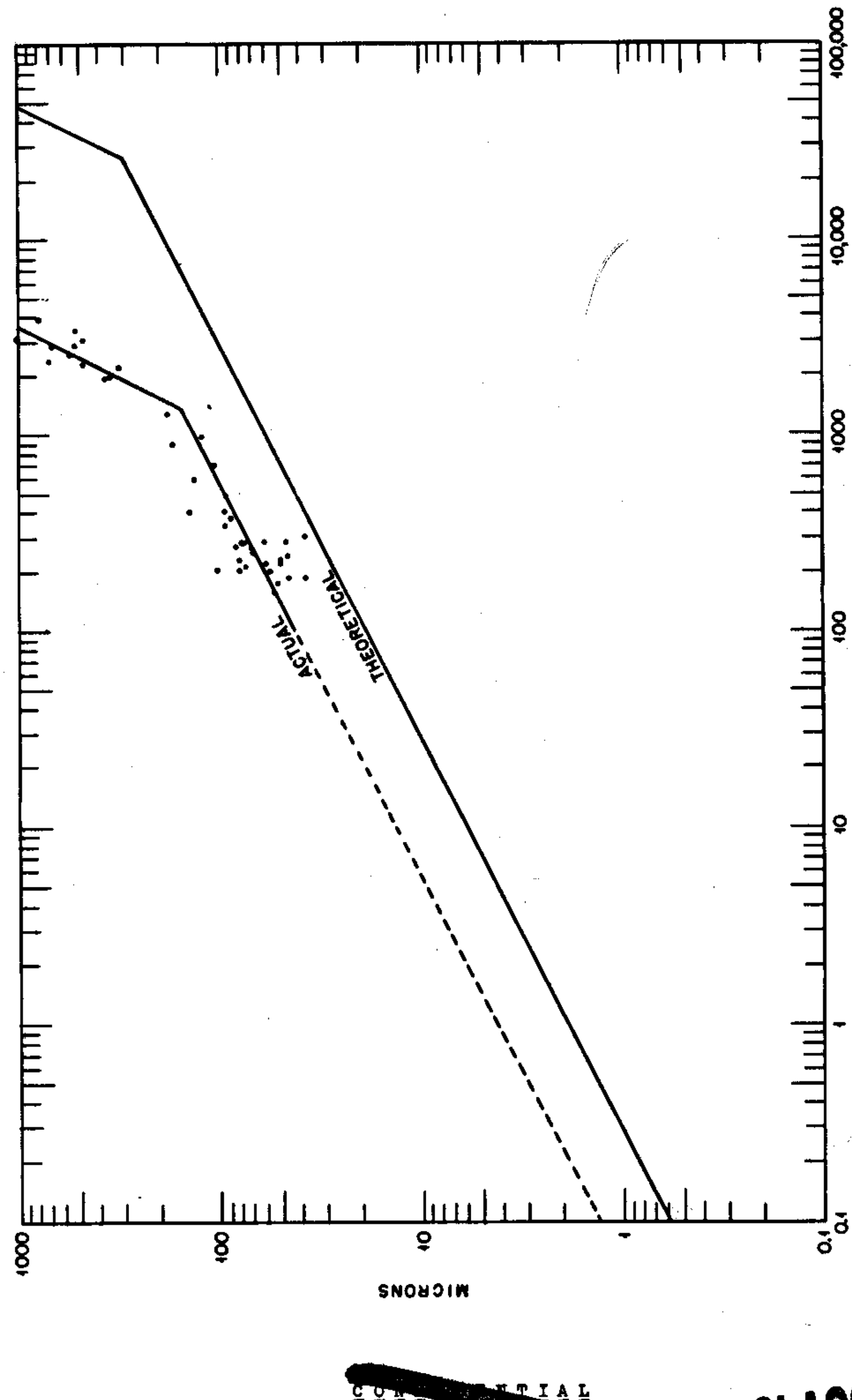

Fig. 3--Settling rate--"specks."

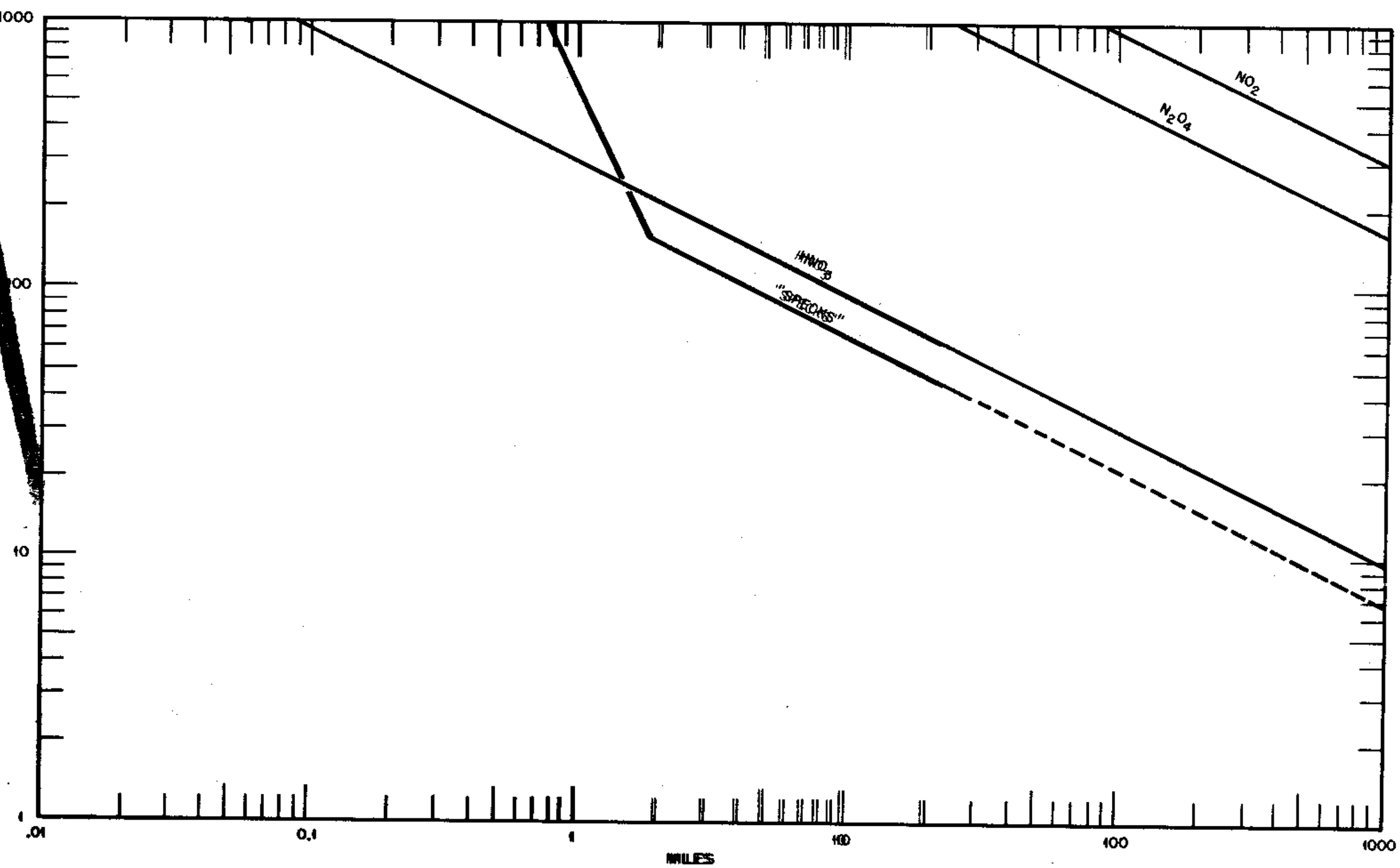

Fig. 4—Travel contaminants before settling (15-mph wind).

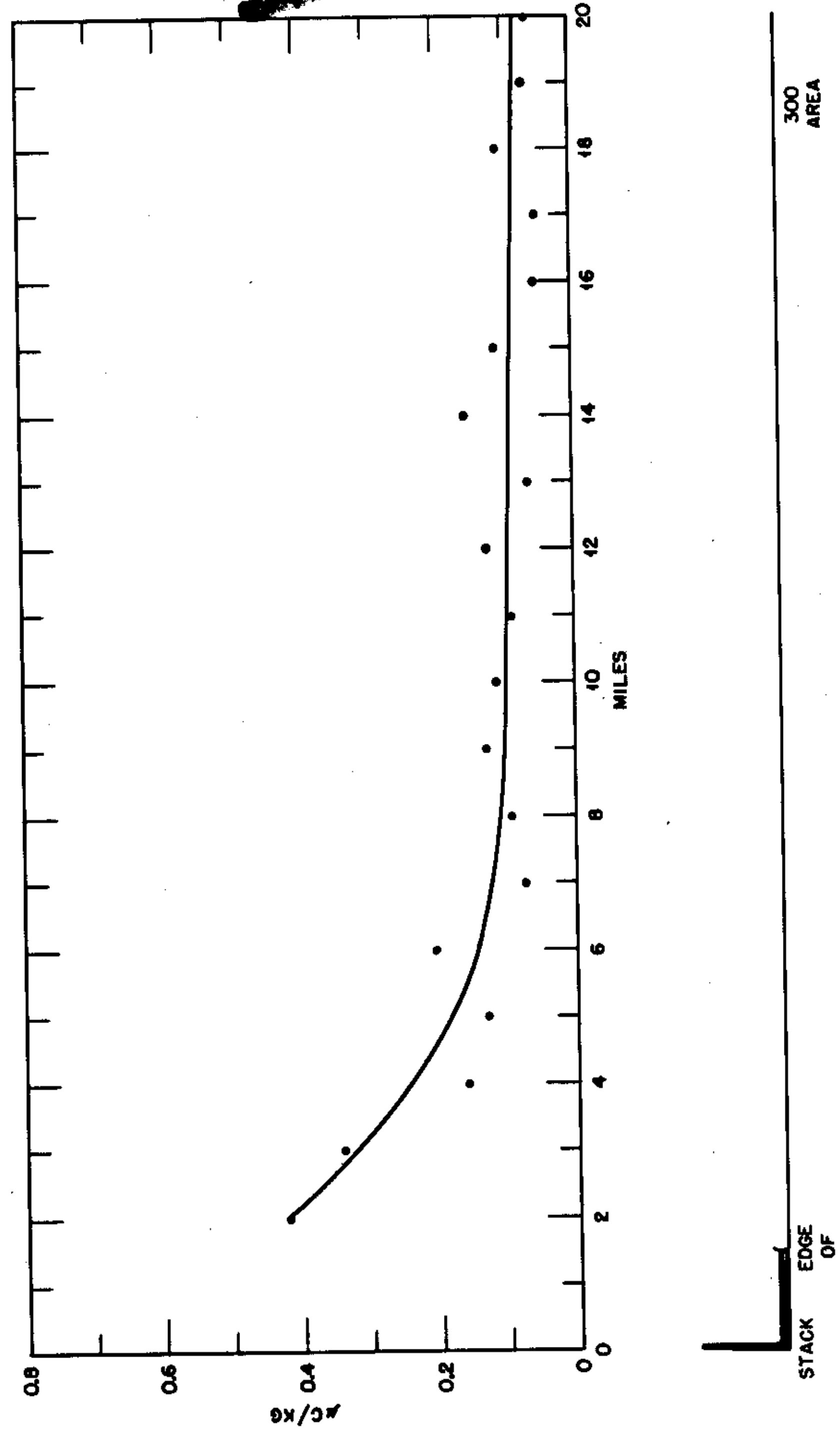

Fig. 5--Beta activity--vegetation, southeast from 200-E Area.