THE HANFORD 67-SERIES: ATMOSPHERIC FIELD DIFFUSION MEASUREMENTS
Micrometeorological and Tracer Data Archive
Set 003 Documentation Report

by

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ABSTRACT

An archive for micrometeorological and tracer dispersion data has been developed by Battelle, Pacific Northwest Laboratories for the U.S. Environmental Protection Agency. The archive is designed to make the results of extensive field tests readily accessible to EPA for model testing, development, and verification efforts.

This report provides documentation for one volume of data sets, the Hanford 67-Series Atmospheric Dispersion Experiments. The entries in this documentation report are as follows: data set fact summary, narrative description of experiment and data, special information, references, description of archive data files, contacts (names, addresses, and phone numbers) and standard experiment summary table.

CONTENTS

ACKNOWLEDGMENT

This archive volume is dedicated to the memory of Paul Nickola. These were his experiments, and these are his data. Without the efforts of Paul Nickola, these data would not exist.

The author also wishes to acknowledge the foresight of the U.S. Environmental Protection Agency's Atmospheric Sciences Research Laboratory in initiating a project with the intent of preserving valuable data bases in a form that is readily available to the technical community. John S. Irwin's contribution in conceiving and guiding the effort as Project Officer is gratefully acknowledged.

SECTION 1

INTRODUCTION

The Meteorology and Assessment Division of the U.S. Environmental Protection Agency's (EPA's) Atmospheric Sciences Research Laboratory has initiated a project to develop and establish an archive of original experimental data and documentation for use by atmospheric dispersion and boundary layer researchers. The archive of data sets will be useful for evaluating and improving dispersion models, ensuring the retention of these data for the future, and making the data more readily available to the research community.

This report documents the micrometeorological and tracer (M&T) data archive for the Hanford 67-Series atmospheric field dispersion experiments. Section 2 provides listings of the data set documentation entries, which are also provided in ASCII text files on the data archive tape.

The archive includes both documentation and data. A data set documentation report is prepared for each archived data set. The archive is contained in five or more files on magnetic tape. These files consist of a header file, three documentation files, and one or more data files.

The data are entered into the archive in as close to original form as possible to maintain a clear link with original records. The archived data are contained within a well-defined structure called a data map. The data map allows data to be entered in original formats, while providing the user with a machine-readable pathway for accessing the diverse data formats.

Detailed information that the user will find helpful, if not essential, is contained in the data archive introduction report, "Introduction to Micrometeorological and Tracer Data Archive Procedures" (Droppo and Watson, 1985). That report provides an overview of the archive and specific guidance for using it. In addition, that report provides a brief summary of all the data sets in the archive.

Questions about the archive that are not answered by this report or the data introduction report (Droppo and Watson, 1985) should be directed to:

U.S. Environmental Protection Agency
Atmospheric Sciences Research Laboratory
Meteorology Assessment Division
Research Triangle Park, North Carolina 27711

SECTION 2

DATA SET DOCUMENTATION ENTRIES

The data set documentation entries for the Hanford 67-Series atmospheric field diffusion measurements are given below.

DATA SET FACT SUMMARY

Archive Set Title: M&T DATA ARCHIVE 003

Experiment Type: Atmospheric dispersion, tracer, planetary boundary layer

Name: Hanford 67-Series

Purpose: To examine the dispersion of various tracers under stable atmospheric conditions

Location: Southeastern Washington State, on the U.S. Government's Hanford Reservation

Time: 1967 to 1973

Number of Tests: 104 tracer releases during 54 release periods

Nature of Experiment: Tracer dispersion experiments were conducted over relatively flat terrain. Multitracer releases (generally from different elevations) were made during most experimental periods. Release heights varied from ground level to an elevation of 111 m. Tracers were sampled simultaneously on as many as 10 arcs at distances of up to 12.8 km from the tracer release point. As few as 63 and as many as 718 field sampling locations were employed during some of the experiments. Vertical profiles of concentration were monitored on towers during 23 of the 54 release periods.

Meteorological Conditions: Tracer releases under both daytime unstable conditions and nighttime with generally stable atmospheric conditions.

Meteorological Measurements: Wind speed and direction, the standard deviation of the wind direction, and temperature were all measured at eight levels on a 121.9-m (400-ft) tower.

Measurement Methods: For particulate tracers (zinc sulfide fluorescent particulate 2210, fluorescein, and rhodamine B), filter samplers were deployed

on the arcs at 1.5 m above ground level and on sampling towers at various heights. Krypton-85 was monitored using Geiger-Muller tubes (Model 18546) manufactured by Amperex Electronic Corporation, Hicksville, New York.

NARRATIVE DESCRIPTION OF EXPERIMENT AND DATA

The Hanford-67 Series experiments were conducted on what is now the U.S. Department of Energy's Hanford site. Hanford is located in a 40-km-wide basin in southeastern Washington State (latitude 46 deg. 34'N, longitude 119 deg. 36'W, elevation 733 feet). The site is bordered on the north and east by the Columbia River and on the west and south by the Rattlesnake Hills and the Yakima River. The climate of the region is semiarid. The experiments were conducted on the relatively flat Hanford Dispersion Grid at an elevation of roughly 200 m above sea level. The vegetation on the grid is composed primarily of steppe grasses and sagebrush. A typical roughness length for the area is 3 cm.

Four different tracers were released during the Hanford-67 Series. The particulate tracers used in the Hanford-67 Series were zinc sulfide fluorescent particulate 2210, fluorescein, and rhodamine B. The fourth tracer was krypton-85, an inert gas whose radioactivity could be monitored.

To determine concentrations, the three particulate tracers were collected on membrane filters for subsequent laboratory analysis. Krypton-85 was monitored using Geiger-Muller tubes.

The reported data include data for both unstable and stable atmospheric conditions. Tracer concentrations normalized by dividing by the release rate are provided on a series of progressively more distant surface arcs. In some tests, vertical profiles of normalized tracer concentrations are given. The table for each set of concentration data contains the run name, tracer name, date, start time and stop time, release height, arc distance, and wind speed at (or near) the release height. Following the concentration tables, meteorological data are given. These meteorological tables contain vertical profiles of temperature, wind speed, wind direction, and wind direction standard deviation over the time of release for each test.

The following detailed description of the Hanford-67 Series field studies is provided from documentation given by Nickola (1977). To avoid inadvertent changes in meaning, only minimal changes from the original text have been made. These changes are indicated by text enclosed in square brackets. The requirement that this archive documentation report be a machine-printable copy precluded inclusion of figures - the reader is directed to the original sources for the figures (Nickola, 1977 or, alternatively, Nickola et al., 1983; Ramsdell, Glantz, and Kerns, 1985). The references for this section have been incorporated into the reference list for this data archive documentation report.

Introduction

During the period 1959 to 1973, more than 300 atmospheric field diffusion experiments have been conducted at the Hanford reservation near Richland, Washington. This volume documents 103 of the more recent of these experiments. Both diffusion and current meteorological data are presented in, hopefully, user-oriented format.

Prior to this volume [Nickola, 1977], some of the earlier of the 300 experiments have been described in reports or journal articles. The 1959 experiments, dubbed the Green Glow diffusion program, were documented by Barad and Fuquay (1962). They included detailed diffusion and meteorological data for the 27 Green Glow field tests. Green Glow tracer releases were from an elevation of 2 to 3 meters. Sampling included both ground-level and tower arrays.

These near ground-level tracer releases with both horizontal and vertical sampling arrays continued at Hanford with a series of 42 field experiments in 1960, 1961, and 1962 known as the Hanford 30-Series. Selected ground-level diffusion data and meteorological data from both the Green Glow and 30-Series experiments were tabulated by Fuquay, Simpson and Hinds (1962) in a journal article. Only the more "reliable" tests were considered in the journal article--16 Green Glow and 30 Series-30 experiments.

Concurrent with the 30-Series, another group of field experiments began at Hanford. These more than 200 tracer releases, beginning in the fall of 1960, were primarily elevated source experiments. The individual experiments (or subgroups of experiments) in this total of 200 were designed to investigate a variety of specific areas in the more general realm of diffusion. Results of these investigations have been presented in a variety of forums--including annual reports (Hales, 1977) to the sponsors, the Atomic Energy Commission and more recently the Environmental Research and Development Administration. However, measurements made during these field experiments have pertinence in areas beyond the narrower original objectives. It is with this thought in mind that this current data volume is published.

The diffusion experiments documented in this volume are the portion of those described in the preceding paragraph which were carried out at Hanford since July 1967. These have been rather arbitrarily labeled the Hanford 67-Series. Following publication of this report, there remain approximately 100 Hanford field diffusion experiments (carried out between 1960 and June 1967) which have not been documented in a fashion convenient for general research use. The experiments considered in the 67-Series have been selected primarily on the basis of being more recent, and hence having pertinent diffusion/meteorology data more readily accessible to the author than the pre-July 1967 experiments.

The 103 tracer releases of the Hanford 67-Series were carried out during 54 different experimental periods. Multitracer releases (generally

from two different elevations) account for the fact that the number of tracer releases is greater than the number of experimental periods. Meteorological measurements made during the tracer releases include vertical profiles of wind speed, wind direction, and temperature. Release duration was generally 30 minutes. As few as 63 and as many as 718 field locations were employed in sampling tracer concentration during a given release. In 32 of the 103 releases, ten or more towers were employed downwind of the source in an attempt to define vertical concentration distributions. Tower height varied from 27 m to 62 m. As few as two and as many as ten sampling arcs, concentric about the release point, were used in the deployment of tracer samplers. The radii of these arcs varied from 0.2 km to 12.8 km from the source. Tracer was released at an elevation of 1 m, 2 m, 26 m, 56 m, or 111 m. Details of the meteorology and of tracer dispersal and sampling for each experiment follow in the body and appendices of this report.

The Field Grid

The Hanford reservation is located in a semiarid region in the southeast of the state of Washington. The natural vegetation in the area is sagebrush 1 to 2 m in height interspersed with steppe grasses. Figures 1, 2, 3, and 4 [in Nickola (1977)] give some idea of the nature and density of the vegetation.

The center of the reservation is about 200 m above mean sea level. Although the reservation is nearly surrounded by hills or bluffs on all sides (some reaching as high as 1,000 m msl), the field diffusion grids are located near the center of this approximately 40-km-diameter basin.

Figure 5 [in Nickola (1977), also published as Figure 1 in Ramsdell, Glantz, and Kerns (1985)] shows the diffusion sampling grids superimposed on a contour map. The bulk of the sampling arcs are located on a relatively flat area where the extremes in elevation range from 200 m to 230 m msl. The most distant tracer sampling arc, 12.8 km from the source, is at an elevation about 35 m lower than the nearer-source sampling arcs.

The primary or "ground-level" sampling on the Hanford diffusion grids is done at an elevation of 1.5 m, an elevation that approximates the breathing height of man. About 1,000 ground-level sampling locations are instrumented with vacuum sources.

Power for field vacuum pumps is supplied by hundreds of gasoline- or propane-fueled internal combustion engines. A single engine/pump assembly draws vacuum for one to nine sampling stations, with the number depending on the flow rate required at the stations. Flow at each sampling station is controlled by inserting a critical flow orifice in the vacuum line just downstream of the filter-filter holder assembly upon which the particulate tracers are collected. Flow through each sampler is constant as long as the pressure drop across the control orifice is greater than half an atmosphere. This pressure drop is monitored for each engine/pump assembly

by inserting a vacuum gauge in the vacuum line immediately downstream of the orifice at the most remote sampler serviced by that assembly.

The ground-level sampling can be supplemented by 365 tower-mounted sampling stations. The towers, as tall as 62 m and as far removed as 3.2 km from the tracer release point, are discussed in more detail later in this section. Vacuum and flow control to the towers are accomplished in a manner similar to that already described for the ground-level sampling.

The vacuum/filter field system described in the preceding paragraphs is employed in the collection of particulate tracers. A much less extensive but more sophisticated sampling network was also deployed on portions of the Hanford field grids during the 67-Series. This system (Ludwick et al., 1968; Nickola, Ludwick and Ramsdell, 1970; Nickola, 1971) employed Geiger-Muller tubes at up to 127 field locations to monitor the concentration of the inert gas krypton-85 during nine field experiments. Although the inert gas system recorded the real-time history of tracer concentration at all Geiger tube locations, only the time-integrated concentrations (exposures) are reported in this volume. An earlier data volume (Nickola, Ramsdell, and Ludwick, 1970) reported real-time concentration measurements for five of the nine krypton releases summarized in the current volume.

The sampling grid(s) used during the 67-Series evolved from grids laid out in 1959 and 1960. The grids were designated the "U" and the "S" grids because their original use was restricted to either thermally unstable (U) or thermally stable (S) atmospheres. The U-grid is laid out in a series of arcs of circles concentric about a 122-m tower. This configuration is evident in Figures 2 and 3 [in Nickola (1977)]. Several arcs concentric about the U-source on these figures are labeled with the letter "U" followed by the radial distance in meters from source to arc. The arcs of the U-grid actually used in one or more of the 67-Series experiments, the crosswind extent of those arcs and other grid design specifications are given in Table 1 [in Nickola (1977)]. The intent is not to imply that all arcs or even the complete angular extent of a selected arc were employed during each field experiment. Experimental objectives, meteorological conditions, and manpower available all were factored into decisions as to which samplers should be activated.

The S-grid source, used with only near ground-level tracer releases, is located 100 m due south of the U-grid source. This location was selected so as to minimize the wake effect of buildings at the base of the 122-m tower. Figure 4 [in Nickola (1977)] is a view looking "upwind" from the S-source. The S-source is also indicated on Figures 2 and 3 [in Nickola (1977)]. Fewer concentric arcs were instrumented about the S-source. The three arcs closest to the S-source are darkened and labeled on Figure 3 [in Nickola (1977)]. S-grid arcs used during the 67-Series were S200, S800, S1600, S3200 and radial distance in meters from S-source to sampling arc. Further detail on the S-grid is given in Table 1 [in Nickola (1977)].

Two more "arcs" of opportunity were laid out with azimuths related to the U-source. These so-called arcs were not arcs of circles, but were merely tracer sampling stations set out along existing roads or trails. They were dubbed the U5000 and U7000 arcs in correspondence with the approximate source-to-sampler distances involved. The specific source-to-sampler distance is tabled in Appendix A [in Nickola (1977)] each time a U5000 or U7000 sampler intercepted tracer. Figure 5 [in Nickola (1977)] shows the configuration of the U5000 and U7000 arcs.

For reasons of economy, efficiency or experimental design, it frequently became advantageous to activate parts of the S- and U-grids simultaneously. (For instance, a wider range of acceptable experiment wind directions was possible.) However, tracer sampling stations located at a constant distance and evenly spaced in azimuth on, say, the S-course, were at varying distances and azimuth spacing with respect to the U-source. This nonconcentric effect is most significant at distances close to the source, as is evident in comparing locations of the U200 and S200 arcs on Figures 2 and 3 [in Nickola (1977)]. U and S sampling arcs become more nearly congruent at greater distances as is exemplified by the U1600 and S1600 arcs in Figure 3 [in Nickola (1977)]. When displacement of the tracer release source from the center of the employed sampling grid occurred, it was considered in the azimuths and distances reported--with the exception of the sampling at the S12800 arc. Even when release was from the U-source, the S12800 diffusion data were reported without correction since the 100-meter maximum error in distance and the less than one-half degree maximum error in stated azimuth were deemed of minimal importance.

Twenty towers were instrumented for tracer sampling on the S-grid. These towers were placed at azimuths of 98 degrees, 106 degrees, 114 degrees, 122 degrees, and 130 degrees on the S200, S800, S1600, and S3200 arcs. Tower heights were 27, 42, 62 and 62 m at the S200, S800, S1600 and S3200 arcs, respectively.

The 100-m separation of the S- and U-sources caused some complication when vertical sampling was desired with an elevated release. Elevated release was not possible from the S-source, and the geometry of the field grids was such that a release of tracer at the U-source could likely not be sampled on both the S200 towers and the more distant S-grid towers. A curved trajectory would have been necessary. The problem was solved to a great extent by the erection of five towers on the U200 arc. These towers at azimuths of 102 degrees, 110 degrees, 118 degrees, 126 degrees, and 134 degrees align reasonably well on a radial from the U-source through the S-tower arrays at the greater distances. The U200 towers, 33 m in height, were used in only the eight "V" experiments conducted after the summer of 1972.

Tracer Release, Sampling and Assay

Four different tracers were released during the Hanford 67-Series. Small particulate tracers employed were zinc sulfide fluorescent powder

(ZnS FP), fluorescein, and rhodamine B. The fourth tracer, krypton-85, is an inert gas. The three particulate tracers were collected on membrane filters, and the concentrations determined in laboratory procedures which depended upon the fluorescent properties of the tracers. Assessment techniques were discriminatory to the extent that collection of ZnS and fluorescein or ZnS and rhodamine on a common filter proved no problem. Krypton-85, by virtue of its radioactivity, was monitored in situ by Geiger-Muller tubes.

Zinc Sulfide Fluorescent Particulate 2210

Use of fluorescent paint pigment (FP) as an atmospheric tracer was initiated in 1946 and documented in 1955 (Leighton, 1955) at Stanford University under the auspices of the U.S. Army Chemical Corps. The Hanford meteorology group began investigation of the use of such fluorescent pigments in 1952, and made use of FP field techniques on a relatively modest scale through 1958. The development in 1958 of an optical-electronic device (Barad and Fuquay, 1962; Rankin, 1958) (which obviated the need for a tedious "man-and-microscope" sample assay procedure) facilitated the laboratory assay of the large number of FP samples collected during the Green Glow and through subsequent Hanford field diffusion programs.

The FP selected for use in the Hanford technique is Helecon Fluorescent Pigment 2210 manufactured by U.S. Radium Corp., Morristown, New Jersey. It is ZnS with an activator placed interstitially in its crystalline structure. These particulates have a specific gravity of 4.1. Based on optical microscope sizings at 1000X magnification, the number median (geometric mean) diameter of FP 2210 is about 2.1 um. Using methods detailed by Green and Lane (1957), the geometric standard deviation (sigma-g) and the mass median diameter can be computed. (Sigma-g is defined as the standard deviation of the logarithms of the particle radii about the mean. The mass and number sigma-g values are identical for log normal size distributions.) The mass median diameter and sigma-g for the FP 2210 used in the 67-Series are 4.1 um [the um is used to represent micro-meters] and 1.6 um, respectively. Presuming Stokes' law for spheres applies, the number and mass diameters translate to terminal fall velocities of 1.9 m/hr and 7.6 m/hr, respectively.

The ZnS tracer was dispersed to the atmosphere through a commercial insecticidal sprayer. Two of these dispersal devices are shown on Figure 4 [in Nickola, 1977]. A measured quantity of the tracer (generally about 1 to 4 kg) was added to a known volume of the liquid carrier (generally about 150 L). ZnS is insoluble in the liquid carrier. The tracer was maintained in suspension by insertion of a heavy-duty industrial propeller into the approximately 200 L cylindrical tank (Figure 4) in which the tracer-liquid carrier was mixed. The tracer-carrier suspension was drawn directly from the cylindrical tank by the commercial sprayer unit. In the sprayer, the suspension was pumped to a nozzle assembly where it was atomized by mixing with a jet of heated air and dispersed to the

atmosphere. The total tracer dispersed was determined by measuring the liquid level in the cylindrical tank before and after tracer dispersal.

The temperature of the air used in the atomization was approximately 400 degrees C. This high temperature was instrumental in producing a spray that was sensibly dry a few meters from the generator nozzle. The evaporation of the liquid carrier aided in the dissipation of heat so that the effluent from the generator felt dry and thermally comfortable to the hand within 1 to 2 m from the nozzle.

In the early years of use of this Hanford tracer dispersal technique, the liquid carrier used was water. Some concern developed over the possibility that, under high humidity conditions, the evaporation of the water carrier in the nozzle spray might take place so slowly that there would be a significant gravitational settling. Therefore, a more volatile carrier, trichloroethane (CH_3CCl_3), was frequently employed as the liquid carrier in many of the later experiments. The difficulty in use of trichloroethane was that it did not act as a lubricant (as water apparently did) in the insecticidal sprayer. Many more mechanical difficulties or failures of the tracer dispersal equipment occurred when trichloroethane was used. Although it is difficult to assess any field differences that might be due to a difference in carrier used, it can be qualitatively stated that at Hanford there was no obvious effect attributable to the carrier used in the dispersal process.

In the 67-Series, trichloroethane was used in the dispersal of ZnS in all experiments except four. In tests V5, V6 and V7, water was used as the carrier. In the final test of the series, V8, a commercially available dry FP tracer dispenser was used.

This dry dispenser, manufactured by Metronics Associates, Incorporated, of Palo Alto, California, is described by Leighton et al. in a journal article (Leighton et al., 1965). This device evolved from the early Stanford University work with FP. In the early 1950s, a Hanford dry dispenser was built from prints obtained from the Stanford group. Hanford personnel were unable to obtain a constant tracer dispersal rate with this early model dry dispenser. This problem led to the more cumbersome wet dispersal technique which has already been described. A constant dispersal rate was demonstrated with the wet dispersal technique. Further details of the dispersal rate determination--and of the wet dispersal technique--are given in Chapter V of the Green Glow documentation (Barad and Fuquay, 1962).

The possibility was considered that the wet dispersal technique would result in a significant agglomeration of individual tracer particles. However, in the years preceding development of a semi-automated device for assessment of FP 2210 at Hanford, a great number of filters were examined and particles were visually counted with the aid of a microscope and ultraviolet illumination. Very few agglomerates were observed during these microscopic examinations. The wet dispersal technique was in use at that time.

A comment should be made regarding the high temperatures to which the ZnS fluorescent particulates were subjected during the dispersal process. There was concern that the 400 degrees C temperature might alter the fluorescent properties of the tracer even though the high temperature was experienced for only a fraction of a second. Nickola (1963) subjected samples of FP 2210 to temperatures of 1000 degrees C for periods up to 20 sec without discernible changes between the pre-heated and post-heated masses indicated when the samples were assayed on the soon-to-be-discussed Rankin counter assay device.

It was also demonstrated by Nickola and Scoggins (1964) that FP 2210 was not affected by exposure to bright sunlight--as has been observed (Eggleton and Thompson, 1961) for other fluorescent powders. Filters were selected from a field experiment in which tracer dispersal, field sampling and filter retrieval from the field all occurred during hours of darkness. The filters were stored in an opaque box until they were assayed for FP 2210. Subsequent to the original assessment, the filters were exposed to bright sunlight for more than 7 hours before reassessment. (The Rankin counter assessment used does not destroy or alter the field samples.) There was no reduction in the measured mass of FP on the filters.

The filter employed in collecting particulate tracers was a polyvinyl chloride membrane filter designated type VM-1 by the manufacturer, the Gelman Instrument Company of Ann Arbor, Michigan. This filter offers a compromise between the opposing requirements of minimal restriction to flow through the filter and of a flat surface upon which to retain the sampled ZnS. (The latter requirement is germane to the ZnS assay procedure which will be discussed presently.)

The 47-mm-diameter filter is inserted into a polyethylene filter holder assembly which leaves a circular arc 41 mm in diameter exposed for tracer collection. Figure 6 [in Nickola (1977)] shows several of these assemblies in place in the turntables of the assay device (Rankin counter). Between the counters, two of the filter assemblies are shown turned face down to display the ribbed nozzle which can be inserted in a neoprene grommet at each field sampling location. A dust cap (as on the assembly marked "a-122" on Figure 6) is placed over the filter-filter holder assembly during handling and storage. In order to minimize tracer contamination from experiment to experiment, all filter-filter holder assemblies are used only once before being discarded.

Membrane filters from the field were assayed for ZnS FP2210 by the Rankin counting method (Barad and Fuquay, 1962; Rankin, 1958) developed at Hanford in 1958. An assembled Rankin counter is shown at the right in Figure 6. A Rankin counter with top removed to expose a turntable is shown at the left. After the dust cap is removed from a field sampler, the remaining filter-filter holder assembly is inserted into a circular cavity in the turntable. Several filters can be seen in these cavities on Figure 6 [in Nickola (1977)]. The exposed filter is rotated until it lies directly below a multiplier phototube. Here a 200-microcurie plutonium source, in the shape of an annulus about the face of the

phototube, bombards the face of the filter with alpha particles. If there is any FP on the filter face, it is excited to fluorescence by the alpha bombardment, and the scintillations are monitored by the phototube, amplified and counted by a scaler. The VM-1 filter, which retains the bulk of the FP on its surface rather than allowing deeper penetration, enhances the probability of the short-range alpha particles reaching the FP and of the resulting scintillations being seen by the photomultiplier. The Rankin counter calibration is specific for the type of filter employed.

Design of the counting pig permits the operator to insert or remove a filter from the turntable at the same time another filter is being counted under the phototube. This procedure was a significant time saver in view of the large number of filters assayed for each experiment.

Normal counting time employed during the 67-Series was one minute for each filter. The count rate on unexposed filters was generally zero. Field exposed background filter count rates were from 0 to about 6 counts/min due, presumably, to some foreign fluorescent material in the ambient atmosphere. Despite precautions, infrequently there was strong evidence of contamination of some exposed filters with the ZnS tracer. This contamination was generally associated with tower samples where it was more difficult to minimize the handling of filter assemblies during field deployment and collection.

The Rankin counter underwent a primary calibration against a series of filters of well established mass several times during the Hanford 67-Series. The calibration in effect at the end of the series was

$$M = (2.06 \times 10^{-10})\ C\ ,$$

where M is mass of ZnS FP 2210 in grams and C is Rankin/counts min. If the level of detection with confidence is considered as 20 counts/min (about 3 times the maximum field background) the corresponding mass was about 4×10^{-9} grams. Count rate reproducibility is good with the Rankin counter, particularly at the higher count rates. The ratio of count rate standard deviation to mean count rates of 100, 1000, 10,000, and 100,000 counts/min are 0.16, 0.048, 0.038 and 0.012, respectively.

The Rankin counter was also checked (and tuned electronically, if necessary) against a standard filter left continually in one of the twelve turntable cavities. Inasmuch as the standard filter was counted each time it passed beneath the photomultiplier, this secondary calibration occurred once for each 10 field filters assayed. (A background filter occupied the twelfth turntable cavity.)

One difficulty with the Rankin counting technique is the atmospheric dust--or carbon from the internal combustion engines associated with the field vacuum system--can collect on the filter face and degrade the scintillations monitored by the photomultiplier. Accordingly, a series of previously assayed filters with ZnS thereon, but which had a clean appearance, were intentionally subjected to tracer-free but dust-laden

air. The filters were ranked subjectively from 1 (clean) to 10 (extremely heavy dust load) according to their post-dust visual appearance. It was found that assay of filters with dust nomenclature of 4 or less was essentially unaffected by the dust. With successively higher dust nomenclature, increasingly greater count rate degradation was observed. Therefore, in the exposures for ZnS listed in Appendix A of this report [(Nickola, 1977)], dust nomenclature is indicated for filters graded 5 or greater. This point will be discussed further in the section entitled "The Experiments."

Perhaps it should be pointed out that a liquid scintillation counting technique (Barad and Fuquay, 1962; Ludwick and Perkins, 1961) is available which to a large extent overcomes the ZnS assay problems caused by dust-laden filters. However, the laboratory procedure is a much more tedious "wet" procedure than the simple Rankin counting approach. This fact, plus the relatively few dusty filters encountered during the 67-Series, led to the decision not to employ this more elaborate assay technique.

In order for a filter to sample particles carried in a fluid stream properly, the fluid velocity at the filter face should equal the ambient fluid stream velocity. In this isokinetic flow situation, the fluid streamlines neither diverge nor converge at the filter. Therefore, the particles imbedded in the fluid are sampled properly. However, if the face velocity at the filter is substantially greater or less than the ambient fluid velocity, the particles carried by the fluid will not (by virtue of their greater density than the fluid) faithfully follow the fluid streamlines in the vicinity of the filter. In the case of the Hanford field vacuum grid, the filter face velocities were essentially always less than ambient wind speed, resulting in subisokinetic sampling.

Sehmel (1966), in a wind tunnel study, investigated nonisokinetic sampling effects using ZnS FP 2210 and the standard Hanford field filter. He derived corrections for nonisokinetic flow which are functions of wind speed and filter flow rate. Sehmel's corrections have been applied to all the ZnS data presented in this report.

Fluorescein

An atmospheric tracer technique using uranine dye, the sodium salt of fluorescein, was reported by Robinson, et al. (1959) The possibility of using this dye as a tracer to complement the existing ZnS FP 2210 technique was first investigated at Hanford in (Ludwick, 1961) with early field results reported by Nickola (1965) and by Ludwick (1966). The term fluorescein, rather than the specific salt, uranine, has been applied to the dye in Hanford nomenclature. This dye is available through industry chemical suppliers.

The fluorescein used during the Hanford 67-Series was labeled "Uranine Conc., Code 1801" by the vendor, Allied Chemical Company, San Francisco, California. These particulates have a specific gravity of 1.53. Based

on microscope sizing at 1000X magnification, the specific batch of fluorescein used had a number median diameter of 1.4 um, a mass medium diameter of 18.6 um and a sigma-g of 2.5. The number and mass median diameters translate to terminal fall velocities of about 0.4 and 64 m/hr if Stokes' law is applied.

As with the ZnS, dispersal of fluorescein was by means of a commercial insecticidal sprayer. The liquid carrier used in the dispersal tank was trichloroethane. Fluorescein is insoluble in this liquid. The dispersal process used in all but two 67-Series fluorescein releases was as described for the ZnS releases.

During Tests U91 and U92, the fluorescein dispersal technique was altered. In these two tests, the liquid in the mixing tank was water. Fluorescein was added to give an approximate 2.6% solution of fluorescein in water. This solution was dispersed to the atmosphere at a rate of about 95 L/hr. Although no particle-size measurements were made during field tests U91 and U92, the manufacturer specifications on the insecticidal sprayer indicate that a droplet size of about 25 um diameter should be generated with the sprayer control settings employed and the liquid consumption rate observed. Stein et al. (1966) measured the density of fluorescein particles generated through nebulization as 0.58 g/cc. Presuming this density and the parent droplet size of 25 um apply, the resultant diameter of the dry fluorescein particle during Tests U91 and U92 was 8.8 um with an associated Stokes' terminal velocity of 5.0 m/hr. The lack of a measured size distribution of particles or droplets precludes further detail.

The filter employed for collection of the fluorescein tracer has already been described in the discussion of the ZnS tracer. In the cases where both ZnS and fluorescein were dispersed and sampled, the ZnS assay on the dry filter was carried out first. The filters were then placed individually in glass vials. Distilled water was added to dissolve the fluorescein particulates on the filter, leaving the insoluble ZnS imbedded on the filter. The fluorescing solution was then assayed with a previously calibrated spectrophotofluorometer with excitation and emission wavelengths tuned for optimum performance. The fluorometer employed was model number 4-8202 manufactured by the American Instrument Company of Silver Spring, Maryland, The analytical technique is explained in greater detail by Ludwick (1961, 1966).

Although less than 1×10^{-11} gram of fluorescein was detectable under laboratory conditions, field pollutants and filter-to-filter background variance resulted in a more realistic field-detection limit of about 5×10^{-9} grams. The greater variance in background made definition of the tails of crosswind or vertical tracer distributions less certain with fluorescein than with ZnS.

In contrast to the deleterious effect that the dust-ZnS combination displayed with the ZnS assay, the laboratory assessment of the fluorescein in solution was minimally affected by dust.

Although no laboratory tests were made to directly investigate the possible effects of the subjection of fluorescein to high temperatures during dispersal, Nickola (1965) found that ZnS and fluorescein released from the same location gave compatible downwind field concentrations. Reduction of fluorescence due to mixture for a fraction of a second with air at 400 degrees C caused no obvious problems in these 1964 field tests.

No corrections have been attempted for nonisokinetic sampling of fluorescein on field filters.

Rhodamine B

Use of another soluble fluorescent dye, Rhodamine B, began at Hanford in 1968 (Wolf and Dana, 1969). This dye, dissolved in methanol, was dispersed in only six of the Hanford 67-Series experiments. The 1% rhodamine solution was dispersed to the atmosphere by means of a pari or ultrasonic nozzles. This technique, described by Dana (1971) generates particles of small diameter. No heat was supplied during the dispersal process.

Measurements made during Tests V1, V2 and V3 with Anderson cascade impactors revealed a mass median particle size of about 1 um and a sigma-g of 3.2. Although no measurement of the specific gravity of the ultrasonically generated particles was made, the specific gravity of the parent powder particulate (before solution) was 1.38. This contrasts with the specific gravity of 1.53 of the fluorescein parent particulate. Assuming the 1.38 specific gravity is applicable to the 1-um particles, and that Stokes' law applies (electron micrography displayed spherical particles), the terminal velocity of the mass median rhodamine particles was 0.14 m/hr. If it is presumed that the density of the nebulized particles is only 38% of the parent powder (as was the case with fluorescein), the 1-um rhodamine particle should have a Stokes' fall velocity of 0.05 m/hr. In either event, the terminal velocity of the rhodamine tracer particles should be negligibly small.

Rhodamine was sampled on the same filter as was ZnS. The assessment procedure for rhodamine was essentially identical to the procedure employed for fluorescein. Since fluorescein and rhodamine were not paired in field release, no tracer discrimination was required from the fluorometer.

As with fluorescein, the detection limit for rhodamine under ideal laboratory conditions was much lower than for field exposed filters. The respective laboratory and field detection limits were approximately 5×10^{-11} and 2×10^{-8} g. Again, as with fluorescein, specification of the tails of field tracer distributions was more difficult with rhodamine than with ZnS.

Also, as with fluorescein, dust collected on field samples offered no obvious assay problem with rhodamine.

No corrections for nonisokinetic flow were applied to the masses of rhodamine collected on field filters. However, the small particle size would have made such corrections minimal in any event.

To some degree with all the particulate tracers, there are opposing objectives in dispersal. On the one hand, there is the desire to disperse large masses of tracer to the atmosphere so that downwind sampling problems will be minimized. On the other hand, the desire is to disperse the particulate as individual small particles and avoid effects due to dispersal technique (as opposed to effects due to atmospheric turbulence and diffusion). The dispersal of rhodamine B as 1-um [micron] particles tended to minimize dispersal problems and to maximize field detection problems. About 100 g of rhodamine were released during each test, whereas typical ZnS or fluorescein releases were from 1000 g to 3000 g.

Krypton-85

A field system for measuring atmospheric concentrations of the inert radioactive gas krypton-85 was developed and deployed in the field at Hanford in 1967. Ludwick et al. (1968) and Nickola et al. (1970b) have described this system in reasonable detail. A data volume including time-histories of concentration at 63 field locations for eight instantaneous (puff) releases and for five continuous releases (Tests C1 to C5 of the 67-Series) has been published (Nickola et al., 1970a).

Among the advantages of this noble gas tracer technique are that krypton has minimal interaction with structures and vegetation, and will not react with other atmospheric constituents. And although only "continuous" releases are considered in this report, the field technique does include the capability of releasing instantaneous puffs by the simple procedure of dropping a brick on a quartz vial.of the gaseous tracer.

Among the disadvantages of this tracer technique are the cost of each field sampling unit and the necessity of running a signal cable from each sampler to a central signal processing station.

During the five experiments of the 67-Series prefixed with the letter "C," krypton was released from a pressurized cylinder. A minimal volume of krypton-85 had been inserted into the argon carrier in the cylinder. Release rate of the krypton was about 1 Ci/min. The rate of the krypton/carrier gas dispersal was monitored by a rotameter, and valving was manually adjusted to maintain a nearly constant rate of release.

During the six krypton-release experiments prefixed with the letter "V", the flow rate from the pressurized source cylinder was automatically held to a constant rate by an electronic mass flow control device. Dispersal rate during the V-tests was about 0.6 Ci/min.

Airborne krypton concentration was monitored by Geiger-Muller tubes (Model 18546) manufactured by Amperex Electronic Corporation, Hicksville, New York. These detectors are of the end window type with a window

diameter of greater than 50 mm. These field detectors were calibrated by a procedure involving support of the detector inside a large meteorological balloon into which a known amount of krypton-85 had been inserted. The Geiger counters were calibrated in two modes. In the mode where the open face of the detector was exposed to the atmosphere, a krypton concentration of 1 uCi/m^3 corresponded to a count rate of 9.7 counts/sec. In a mode where a remote control valve was open, a concentration of 1 uCi/m^3 resulted in a count rate of 5.5 counts/sec. (The weatherproof valves were used primarily on tower-mounted tubes where manual removal of between-experiment protective covers was impractical.)

During the prefix C experiments, a total of 63 detectors were deployed on portions of arcs S200 and S800. Three S200 towers were instrumented to elevations of 10.7 m, and three S800 towers were instrumented to elevations of 21.3 m. A series of 38.4-sec end-to-end concentration measurements was made.

During the prefix V experiments, a total of 127 detectors were deployed on portions of the U200, S800 and S1600 arcs. All ten towers on the U200 and S800 arcs were instrumented to their tops--32.8 m and 42.0 m at S200 and S800, respectively. The time increment for which short-period concentrations were recorded during the V-tests was 10.0 sec.

Description of Experiments and Data

The Hanford 67-Series experiments were carried out during 54 separate days. During most of the experiments, two or more tracers were released--generally from different elevations above the same point. Zinc sulfide tracer was released on 50 occasions. Fluorescein, rhodamine B, and krypton-85 were released on 38, 6, and 9 occasions, respectively. Tracer sampling equipment was activated before tracer dispersal began and was continued for a period deemed long enough for the bulk of the tracer to pass before deactivation. (The deactivation time was based on the wind speed at 15 meters. A time period 2-1/2 times as long as necessary for uninhibited transport to the sampling arc of interest was generally allowed.)

The cataloging of the field diffusion and meteorological measurements in this volume [Nickola (1977)] follows (with three exceptions) the chronological sequence of experiments. Table 2 [in Nickola (1977)] introduces the 54 experiments/103 releases of the 67-Series in the near chronological order. [The data in this table is given in the first data subset in the archived data.] This table identifies the tracer release point, the type tracer, the release elevation, several pertinent meteorological measurement, and the extent of sampling during each test.

Tables 2 to 5 and Tables/Figures C-1 to C-4 [in Nickola (1977)] are intended to be largely self-explanatory. The intent of these tables and figures is to enable a researcher to conveniently pinpoint the specific experiments in the appendices that are pertinent to his area of interest.

If these tables and figures do their intended job, much of the narrative in this section can be considered of minimal importance.

Tables 3 and 4 [in Nickola (1977)] give the frequency of releases from various elevations and show the number of times sampling was attempted at various distances. These tables also place a qualitative specification on the overall sampling results for specific locations.

Table 5 [in Nickola (1977)] is divided into four parts on the basis of tracer release height. These four tables give some detail on the location and quality of sampling for each field tracer release. The symbols indicating the degree of success at each sampling arc are based on slightly less severe standards than are the symbols which are associated with the quantitative summaries listed in Appendix B [in Nickola (1977)].

For reasons which will be pointed out later, there are many instances when it was felt that estimates should be supplied for "bad" or missing data. However, no effort has been made to change the general character of the observations merely because the observed data were unexplainable. For instance, consider field test D4. Both fluorescein and ZnS were released from the same point. Yet on three of the towers at a distance of 200 m, complete vertical distributions of ZnS were observed, but no fluorescein was detected at all.

As has been mentioned in the section describing the ZnS tracer technique, sampling of particulates on filters opens the door to nonisokinetic sampling errors. Even though corrections have been applied to the ZnS data in an attempt to compensate for this error, it is felt that the wind tunnel-determined empirical corrections do not always perform an adequate adjustment. Furthermore, no isokinetic corrections are attempted with the fluorescein or rhodamine assessments. The result can be a "roller-coaster" effect in the situation where arcs of relatively low flow rate are interspersed with those of higher flow rate. Both ZnS and (especially) fluorescein for field test U83 offer such an example. The U400 (high flow rate), S800 (low flow rate), U1200 (high), S3200 (low), U2200 (high) sequence of sampling results in normalized measured concentrations at these arcs which appear to be low, high, low, high and low, respectively. Let it be stressed that flow rate has been factored into the calculations.

The uncertainty as to which values of concentration are most proper is disconcerting. (It is the author's opinion that inasmuch as the higher flow rates required a smaller correction, they generate more nearly correct values.) In defense of what may seem to be poor field technique, the roller coaster effect would never have been observed had the same flow rate been used at all sampling arcs--or had a higher flow rate been used at each succeeding arc. Such flow arrangements would not necessarily have made the measured concentrations any closer to the correct values, but merely would have given results more pleasing to the eye.

Before proceeding with the description of the method of presentation of the individual field experiments, a mention of near-source wake effects

seems in order. Although the ideal experiment would entail a point source release into an undisturbed ambient atmosphere, such releases are impossible. Perhaps the experiments with the least disturbance in the upwind fetch were the four prefix D experiments. Figure 4 [in Nickola (1977)] shows the upwind fetch for these four experiments. During the C experiments, the particulate dispersal equipment shown in Figure 4 was placed on a low, flatbed trailer about 6 m in length which was parked about 4 m upwind of the source. The ZnS during Test C5 was dispersed from this trailer. The krypton during the C experiments was released from the cement pad shown in Figure 4, and thus had the trailer and associated equipment forming a lattice-like cross section of about 8 to 10 m^2 in the upwind fetch.

All elevated releases were undoubtedly affected to some degree by the wake induced by the 122-m tower from which release took place. This tower is a rather sturdy structure, triangular in cross section, and about 3.6 m on each side. Some idea of the appearance of this structure can be gained by examination of Figure 2 [in Nickola (1977)].

The near ground-level releases from the U-source (Tests U56 to U70) were subjected to perhaps the worst wake situation. First, the dispersal equipment (Figure 4 [in Nickola (1977)]) was mounted on a small trailer; secondly, the wake of the 12-m tower a few meters away no doubt added to the turbulence; and third, a small 4 m x 4 m x 3 m building stood near the base of the tower. (The bulk of the building complex shown in Figure 4 at the base of the tower was dismantled prior to the start of the 67-Series.)

The Appendix A Diffusion Data

Appendix A [in Nickola (1977)] gives the individual field diffusion measurements. These data form the bulk of this data volume [and comprise the data contained in the archive subsets 2,3,4, and 5]. The 54 experiments are presented in the order given in Table 2 [in Nickola (1977) and in the standard experiment summary given below]. Dual tracer release data are presented side-by-side. Some general comments pertinent to each field experiment precede listing of the individual field measurements. The date and time of release height are included in a heading preceding each arc or tower of measurements.

The body of the Appendix A tables gives AZIMUTH with respect to the source in the first column, and DISTANCE from the source in the last column. In instances where S-grid arcs combined with portions of U-grid arcs) were employed with U-source releases, the nonuniformity of the samplers with respect to these sources is reflected in these first and last columns. For example, during field test U71 fluorescein indicates that all sampling at the 400-m arc was actually done on the U-grid inasmuch as azimuths increment evenly by 4 degrees, and all distances are listed as 400 m. However, on the 800m arc, the samplers exposed between 61.0 degrees and 97.0 degrees were on the U-grid (3-degree increments and 800 m distance), while those exposed between 97.1 degrees and 110.7 degrees

were on the S-grid (uneven azimuth increments and distances not 800 m). As mentioned earlier in the description of the grid, the data from the S12800 arc are not "corrected" for the variation in distance and direction resulting from release from the U-source. The 100-m separation of U- and S-sources is considered of minimal importance at this distance.

The second column in the Appendix A tables lists EXPOSURE. (For towers, a column specifying sampling HEIGHT precedes the EXPOSURE column.) The EXPOSURE data for particulate tracers evolves from division of the mass of tracer measured on each filter by the flow rate through the filter (Table 1 [in Nickola (1977)]). Inasmuch as no normalization to source strength is made in the EXPOSURE column, the magnitude of the individual numbers are directly related to the mass of tracer collected on each filter, and are therefore related to the confidence that can be placed in each sample. For the krypton tracer, the EXPOSURE column is the integral of concentrations measured over all the shorter time increments. Magnitude here is also related to the confidence that can be placed in an individual sample.

The EXPOSURE column has been left in digital format (as opposed to scientific notation as in the subsequent 2 columns) in order to give an analog appearance to concentration distribution across an arc (or up a tower). In most cases the shape of the crosswind (or vertical) distribution is relatively obvious with a glance at the column.

In the column headed E/Q, exposure has been normalized by dividing by the total mass emitted (or total curies in the case of the krypton emissions).

EU/Q is the exposure normalized to both unit emission and unit wind speed. The mean wind speed (U) used in this normalization is that listed in the heading immediately preceding each arc (tower) of data. It is the mean wind speed at the release height during the period of release. (In the cases where more than one tracer was released at the same time but release periods differed, the U used in the EU/Q column resulted from measurements over the longer release period.)

In many cases, a one-character symbol precedes the azimuth column in Appendix A. These symbols indicate that something less than ideal was associated with the sample. A detailed explanation of the alphabetical symbols is given at the beginning of Appendix A. The numerical symbols were mentioned earlier in the subsection entitled "Zinc Sulfide Fluorescent Particulate 2210." It was stated that filters with visual dust nomenclature of 4 or less appeared to give no problems. However, the indicated mass of zinc sulfide on a filter was reduced when a visual dust rating of 5 or more was observed. The experiment upon which this conclusion was based was severe, however. It involved collecting tracer on a filter followed by the collection of dust. If the dust had been collected first, leaving the tracer "on top" of the dust, the degrad$ion of the zinc sulfide assessment might not have been as severe. In any event, the observation of a 5 or greater dust loading can be associated with a reduction in indicated ZnS, but it is not necessarily so in all

cases. It should be pointed out that in many cases dust nomenclature of less than 5 is indicated on the Appendix A data. These are vestiges of laboratory assessment notes made before the mentioned dust loading experiments were made, and can thus be ignored.

Since each 1.5-m sample was used in the computation of CROSSWIND INTEGRATED concentrations following each arc of data (and in other statistics to be found in Appendix B), it was deemed wiser to substitute a reasonable estimate for an obviously erroneous sample than to have an erroneous number go into computations. These estimates are frequently merely interpolations or extrapolations of data collected on the same arc. At times it was necessary to plot areal distributions of tracer to interpolate concentrations on a mid arc from arcs closer to or farther from the source than the arc in question.

In some instances, the amount or quality of data on an arc is so low that no estimations were attempted. Also, since no vertical moments or vertical crosswind sums were computed, the incentive to supply estimates for poor tower samples was not as great as it was for the poor 1.5-m samples. Thus the poorer tower measurements are frequently reported directly with an accompanying remark symbol other than "E" for "estimate".

The Appendix B Diffusion Summaries

Appendix B [in Nickola (1977)] summarizes the ground-level data for each of the 103 releases. [These summary data are not contained in the archive.] Presented first is a repeat of the specific experiment remarks from Appendix A. A heading then identifies the specific tracer and gives pertinent release information.

The first column of the tabular data indicates DISTANCE FROM SOURCE. The next four columns give statistics relating to the CROSSWIND DISTRIBUTION. The first of these columns gives the location of the MEAN of the crosswind distribution. The STANDARD DEVIATION (sigma-y) and COEFFICIENT of SKEWNESS and KURTOSIS for the crosswind distribution follow.

The next three columns give the AZIMUTH and the magnitude of the three largest exposures measured at each arc. E/Q is exposure normalized to source strength, and EU/Q is exposure further normalized to wind speed, U, at tracer release height. Three values of exposure are given in order to reduce the change of considering a "sport" or somehow erroneous measurement as representative of plume centerline.

The last two columns give CROSSWIND INTEGRATED values for the source and source/wind speed-normalized EXPOSURES.

Tabulated data followed by the symbol "?" indicate some uncertainty in the data. The uncertainty may involve estimates in the Appendix A data. Perhaps there was some question on the performance of the laboratory assay equipment. The symbol is intended to alert a user of the data to the fact that something not completely routine went into the generation

of the associated number. An examination of the remarks preceding the table or scanning of the appropriate Appendix A field data should display the reason for the symbol. Where estimates of missing data were on the tails of a distribution, or where a broad distribution made one large estimate of minimal consequence, a "?" may not have been appended in the Appendix B data. Admittedly some subjectivity went into the decision as to whether to append the symbol or not, and a second review of the data would not result in precisely the same tagging. The symbol is intended primarily as a convenience to the data user.

Appending of the symbol "X" to Appendix B data symbolizes a much more serious difficulty with the data. The data are either incomplete or invalid. For instance, the computation of a mean, sigma-y, skewness, kurtosis and crosswind integrated exposure from a badly truncated distribution lacks significance. An "X" is then appended. (However, if the truncated distribution is such that there is little doubt that the plume centerline was observed, no "X" is appended in the MAXIMUM EXPOSURE columns.)

The qualification for a "clean bill of health" in Appendix B was a bit more strict than was the case in Table 5 [in Nickola 1977)]. Thus a "?" may be found in Appendix B whereas a "C," indicating no problems, may have been listed for the same data in Table 5.

The Appendix C Meteorological Data

[The data in Appendix C of Nickola (1977) are contained in the sixth subset of the archived data.] Vertical profiles of temperature, wind speed and wind direction were measured on the 122-m tower at the U-source during the Hanford 67-Series. In addition, wind speed and direction were measured on a second tower--also generally near the tracer release point.

Temperature measurements on the 122-m tower were made by Foxboro thermohms. The aspirated thermohms were exposed at elevations of 0.9, 15.2, 30.5, 45.7, 61.0, 76.2, 91.4 and 122 m (3, 50, 100, 150, 200, 250, 300 and 400 ft). During the eight prefix-V tests, an additional thermohm was exposed at an elevation of 6.1 m (20 ft). Recording was a series of points on a strip chart. About 3-1/2 min were required to cycle through all temperature sensors. Inasmuch as most field tests were 30 min in duration, eight on nine measurements were available to compute the mean temperature for a given elevation as presented in Table C-1 and Figure C-1 of Appendix C [in Nickola 1977].

Wind speed and direction on the 122-m tower were measured by seven Aerovane anemometers mounted at elevations of 2.1, 15.2, 30.5, 45.7, 61.0, 91.4, and 122 m (7, 50, 100, 150, 200, 300, and 400 ft). The starting speed for Aerovane propellers is approximately 1 m/sec. The Aerovane is a rather large streamlined vane/anemometer assembly about 80 cm in length. The assembly has a distance constant of about 4.5 m for speed and about 10 m for direction.

The Aerovane outputs were recorded on strip charts moving at the rate of 7.6 cm/min (3 inches/min). The strip chart traces were averaged (means) by eye for 20-sec increments, and the resulting digitized data were used in computing mean speeds, mean directions, and standard deviations of wind direction for the period of tracer release.

For the bulk of the field tests, wind speed and direction were measured at six levels on a 25-m tower located about 25 m west of the S-source. (During Tests U84 to U92, these sensors were mounted on the tower at 106 degrees on arc S1600.) The system for measuring and recording winds on this tower has been described by Ratcliffe and Sheen. The wind speed sensors were Beckman and Whitley Model M1564 three-cup anemometers. These cups have a startling threshold of less than 0.4 m/sec and a distance constant of about 1.5 m. Circuitry was arranged to permit accumulation of an integrated wind speed for 3.5 sec, after which 1.5 sec were consumed in signal processing and recording. In each minute, 12 such recorded segments of wind speed were accumulated for each anemometer.

Wind direction transducers employed on the 25-m tower were Beckman and Whitley Model M1565 vanes. These vanes respond to winds of less than 0.4 m/sec and have a distance constant of about 1.5 m. The output signals from these light-weight vanes were smoothed by a filter having a 5-sec time constant. The filter output was sampled for 60 msec once each 5 sec, digitized and recorded. The digitized data were used for computing mean directions and standard deviations of direction, sigma-theta.

The Beckman and Whitley cups and vanes were mounted at elevations of 0.76, 1.5, 3.0, 6.1, 12.2, and 24.4 m (2.5, 5, 10, 20, 40, and 80 ft) during most of the field experiments. During Tests U84 to U92 they were mounted at elevations of 2, 4, 8, 16, 32, and 36 m. Thus, the spacing between wind sensors on the shorter towers was closer than was the spacing between Aerovanes on the 122-m tower. Wind speeds indicated by the Beckman and Whitley cups frequently averaged slightly higher than those computed from the Aerovanes, although the shapes of the profiles in the area of common measurement were in excellent agreement. The wind speeds reported on Table C-2 and Figure C-2 [in Nickola 1977] of Appendix C are based primarily on the cup measurements at the lower elevations, and on the Aerovane measurements above the measurements level of the cups.

The sets of wind direction and wind direction standard deviation (sigma-theta) data were developed. One set is based on the Aerovane measurements, and one set follows the Beckman and Whitley vane measurements. These measurements are found in Tables C-3 and C-4 of Appendix C, and are graphed in Figures C-3 and C-4 [in Nickola 1977]. With a few exceptions during light wind cases, these data show that agreement between Aerovane and Beckman and Whitley data is reasonably good. The agreement in mean direction profiles is rather expected. However, in view of the difference in physical characteristics of the large Aerovane and the relatively lightweight Beckman and Whitley vane, and the difference in the method of digitizing direction, the agreement in profiles is more surprising.

It has been the author's experience that the orientation of a wind vane is not a simple matter. If only one vane is exposed, one may feel confidence in the orientation. Exposure of a second vane at an elevation differing form the first essentially always results in a difference in mean direction that can logically be explained by wind direction shear with height. However, addition of a third, a fourth, and more vanes at additional elevations seems to inevitably lead to mean direction profiles that have repetitive kinks that should not logically be there. This observation is made as a partial or likely explanation of some of the similarly shaped wind profiles observed at times in the 67-Series. Aerovane direction profiles for the upper elevations during Tests U84, U85 and U86 are an example (Figure C-3) [in Nickola 1977].

The data presented on Tables C-1 to C-4 and Figures C-1 to C-4 are based on measurements made during tracer release. In the event that two or more tracers were released during the same experiment and the periods of release did not coincide, the meteorological data apply to the longer tracer release period.

Note that on Figure C-1, which depicts vertical profiles of temperature, the vertical scale is linear. On the companion Figures C-2, C-3 and C-4 [in Nickola 1977], the vertical scale is logarithmic. Heights of tracer release are indicated on all these figures by the symbols F, K, R and Z for fluorescein, krypton-85, rhodamine B and zinc sulfide, respectively. It is recognized that use of Figures C-1 to C-4 [in Nickola 1977] in a quantitative sense would be difficult. However, the intent of these figures is to aid in picking out features in the vertical profiles that otherwise might not be obvious. Once a characteristic of interest is observed on the analogs of Figures C-1 to C-4, absolute values can be obtained from Tables C-1 to C-4.

SPECIAL INFORMATION

The main reference for the archived data is Nickola (1977). For further information on these and other experiments on the Hanford Dispersion Grid, see Nickola et al. (1983), Barad and Fuquay (1962), Nickola, Ramsdell and Ludwick (1970), Hinds (1967 and 1969) and Nickola et al. (1983), Ramsdell, Glantz and Kerns (1985).

The question of tracer deposition in the early Hanford data was considered by Simpson (1961) and discussed by Irwin (1983). The tracer release methods were improved over the course of the Hanford studies, and the question of tracer deposition should be treated on a study-by-study basis.

DOCUMENTATION - Hanford 67-Series

This section provides a list of related documents for the Hanford 67-Series data. References cited in this report may not be included in the following documentation list, but they will be included in the reference list at the end of the report.

The main reference for the data and documentation of the Hanford 67-Series is:

Nickola, P. W. "The Hanford 67-Series: A Volume of Atmospheric Diffusion Measurements." PNL-2433, Pacific Northwest Laboratory, Richland, Washington, 1977. [This document is the published source of all the data contained in Micrometeorological and Tracer Data Archive Sets 003, 004, 005, and 006.]

Other related documents of interest are:

Barad, M. L. and J. J. Fuquay (Eds.), The Green Glow Diffusion Program. Geophysical Research Papers No. 73, Vols. I and II, AFCRL-62-251 (I and II), Air Force Cambridge Research Laboratories, Bedford, MA, [also as HW-71400 (I and II), Hanford Laboratories, General Electric Co., Richland, Washington], (I) Jan. and (II) Apr. 1962.

Dana, M. T., "Calibration of an Ultrasonic Nozzle for Aerosol Generation." In: Pacific Northwest Laboratory Annual Report for 1970 to the USAEC Division of Biology and Medicine, Vol. II: Physical Sciences, Part I, Atmospheric Sciences. BNWL-1551, Vol. II, Part 1: 98-101, Pacific Northwest Laboratory, Richland, Washington, June 1971.

Eggleton, A. E. J. and N. Thompson, "Loss of Fluorescent Particles in Atmospheric Diffusion Experiments by Comparison with Radio-xenon Tracer." Nature 192:935-936, Dec. 1961.

Fuquay, J. J., and C. L. Simpson and W. T. Hinds, "Prediction of Environmental Exposures from Sources Near the Ground Based on Hanford Experimental Data." J. of Appl. Meteorol. 3(6):761-770, Dec. 1962.

Glantz, C. S., R. K. Woodruff, J. G. Droppo, "The Hanford 1964 Atmospheric Boundary Layer Experiment, Micrometeorological and Tracer Set 002 Documentation Report." EPA 600/3-85/055, 1985.

Green, H. L. and W. R. Lane, "Particulate Clouds: Dusts, Smokes and Mists." E. & F. N. Spon, Ltd., London, England, 1957.

Hales, J. M. and Staff, Pacific Northwest Laboratory Annual Report for 1976, to the ERDA Assistant Administrator for Environment and Safety, Part 3, Atmospheric Sciences. BNWL-2100 PT3, Pacific Northwest Laboratory, Richland, Washington, August 1977. Pertinent reports previously issued in this series are as follows:

Annual Report for

1975 BNWL-2000, PT 3
1974 BNWL-1950, PT 3
1973 BNWL-1850, PT 3
1972 BNWL-1751, Vol. II, PT 1
1971 BNWL-1651, Vol. II, PT 1
1970 BNWL-1551, Vol. II, PT 1
1969 BNWL-1307, Vol. II, PT 1
1968 BNWL-1051, Vol.II, PT 1
1967 BNWL-715, Vol. II, PT 3
1966 BNWL-481, Vol. II, PT 1
1965 BNWL-235, Vol. I
1964 BNWL-36-I
1963 HW-81746
1962 HW-77609
1961 HW-73337
1960 HW-70050

Hinds, W. T., "On The Variance of Concentration in Plumes And Wakes." BNWL-SA-1435, Pacific Northwest Laboratory, Richland, Washington, 1967.

Hinds, W. T., "Peak-to-Mean Concentration Ratios from Ground Level Sources in Building Wakes." Atmos. Environ., 3:145-156, 1969.

Irwin, J. S., "Estimating Plume Dispersion - A Comparison of Sigma Schemes." J. of Climate and Appl. Meteor., 22:92-114, 1983.

Leighton, P. A., "The Stanford Fluorescent-Particle Tracer Technique." [Defense Documentation Center, AD 91-94], Dept. of Chemistry, Stanford University, Palo Alto, California, June 1955.

Leighton, P. A., W. A. Perkins, S. W. Grinnell and F. X. Webster, "The Fluorescent Particle Atmospheric Tracer." J. Appl. Meteorol. 4(3):334-348, June 1965.

Ludwick, J. D. and R. W. Perkins, "Liquid Scintillation Techniques Applied to Counting Phosphorescence Emission." Anal. Chem. 33(9):1230-1235, 1961.

Ludwick, J. D., "Dual Atmospheric Tracer Techniques for Diffusion Studies Using Phosphorescence - Fluorescence Analysis." HW-70892, Hanford Atomic Products Operation, General Electric Co., Richland, Washington, March 1961.

Ludwick, J. D., "Atmospheric Diffusion Studies with Fluorescein and Zinc Sulfide Particles as Dual Tracers." J Geophys. Res. 71(6):1553-1558, Mar. 1966.

Ludwick, J. D., J. J. Lashock, R. E. Connally and P. W. Nickola, "Automatic Real Time Air Monitoring of 85Kr Utilizing the 4096 Memory of a Multiparameter Analyzer." Rev. Sci. Inst. 39(6):853-859, June 1968.

Nickola, P. W. and M. F. Scoggins, "Atmospheric Tracer Technology." In: Hanford Radiological Sciences Research and Development Annual Report for 1963, HW-81746: 1.43-1.51, Hanford Atomic Products Operation, General Electric Co., Richland, Washington, Jan. 1964.

Nickola, P. W., "Field Testing of a Fluorescein-Zinc Sulfide Dual Atmospheric Tracer Technique." BNWL-103, Pacific Northwest Laboratory, Richland, Washington, Aug. 1965.

Nickola, P. W., J. V. Ramsdell, Jr., and J. D. Ludwick, "Detailed Time-Histories of Concentrations Resulting from Puff and Short-Period Releases of an Inert Radioactive Gas: A Volume of Atmospheric Diffusion Data." BNWL-1272, Pacific Northwest Laboratory, Richland, Washington, Feb. 1970.

Nickola, P. W., J. D. Ludwick and J. V. Ramsdell, Jr., "An Inert Gas Tracer System for Monitoring the Real-Time History of a Diffusing Plume or Puff." J. App. Meteorol. 9(4):621-626, Aug. 1970.

Nickola, P. W., "Measurements of the Movement, Concentration and Dimensions of Clouds Resulting from Instantaneous Point Sources." J. Appl. Meteorol. 10(5):967-973, Oct. 1971.

Nickola, P. W., J. V. Ramsdell, C. S. Glantz and R. E. Kerns, "Hanford Atmospheric Dispersion Data: 1960 Through June 1967." NUREG/CR-3456, PNL-4814, U.S. Nuclear Regulatory Commission, Washington, D.C., 1983.

Ramsdell, J. V., C. S. Glantz, and R. E. Kerns, "Hanford Atmospheric Dispersion Data: 1959-1974." Atmos. Environ., 19:83-86, 1985.

Rankin, M. O., "A Zinc Sulfide Particle Detector." HW-55917, Hanford Laboratories, General Electric Co., Richland, Washington, 1958.

Ratcliffe, C. A. and E. M. Sheen, "An Automatic Data Collection System for Meteorological Tower Instrumentation." J. Appl. Meteorol. 3(6):807-809, Dec. 1964.

Robinson, E., J. A. MacLeod and C. E. Lapple, "A Meteorological Tracer Technique Using Uranine Dye." J. of Meteorol. 16:63-67, Feb. 1959.

Sehmel, G. A., "Subisokinetic Sampling of Particles in an Air Stream." BNWL-217, Pacific Northwest Laboratory, Richland, Washington, Mar. 1966.

Simpson, C. L., "Some Measurements of Deposition of Matter and its Relation to Diffusion from a Continuous Point Source in a Stable Atmosphere." Hanford Atomic, Products Operation, HW-69292-REV-26PPE [Available from the National Technical Information Service, Springfield, Virginia], 1961.

Stein, F., N. Esman and M. Corn, "The Density of Uranine Aerosol Particles." Am. Indust. Hyg. Ass. J. 27(5):428-430, Sept.-Oct. 1966.

Stone, W. A., and J. M. Thorp, O. P. Gifford and D. J. Hoitink, "Climatology Summary for the Hanford Area." PNL-4622, Pacific Northwest Laboratory, Richland, Washington, 1983.

Wolf, M. A. and M. T. Dana, "Experimental Studies in Precipitation Scavenging." In: Pacific Northwest Laboratory Annual Report for 1968 to the USAEC Division of Biology and Medicine, Vol. II: Physical Sciences, Part I, Atmospheric Sciences, BNWL-1051, Part 1: 18-25, Pacific Northwest Laboratory, Richland, Washington, Nov. 1969.

FILE DESCRIPTION

Overview

The Hanford 67-Series diffusion data are archived in six subsets as shown below. The first subset contains summary information on all the diffusion tests based on Table 2 in Nickola (1977). The next four subsets contain the tracer concentration data from Nickola's Appendix A and comprise the bulk of the data in the archive. The tracer concentration data are archived in four subsets corresponding to natural divisions in the data. The sixth, and final subset, contains profiles of meteorological conditions during the diffusion tests based on data in Nickola's Appendix C.

CONTENTS OF M&T DATA ARCHIVE SET 3

SUBSET NUMBER	CONTENTS	SOURCE
1	Summary information on all tracer tests	Table 2 in Nickola (1977)
2	Surface and tower tracer concentration data for D and C series tests, D1 to D4, and C1 to C5	Appendix A in Nickola (1977)
3	Surface concentration data for U series, U56 to U86	Appendix A in Nickola (1977)
4	Surface and tower tracer concentration data for U series, U87 to U92	Appendix A in Nickola (1977)
5	Surface and tower tracer concentration data for V series, V1 to V8	Appendix A in Nickola (1977)
6	Profiles of Meteorological conditions during tracer tests	Appendix C in Nickola (1977)

The tracer concentration data in the second, third, fourth, and fifth subsets all have exactly the same tabular format. As a result, the data maps for all these subsets are identical with the exception of the record numbers where they occur.

The tracer concentration data appears sequentially by date in the archive. All the tracer tests for test D1 occur first, followed by all the tracer data for test D2, and so forth. The various tracer tests for each test period appear in a consistent order. The order in which tracer data is presented is zinc sulfide, fluorescein, rhodamine B, and krypton-85.

The series of tables given below describe the contents of M&T Data Archive Set 3. These tables are data variables listing, data subset summary, data subset variables listings, and data file characteristics.

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3

NAME	UNITS	RECORD	DEFINITION
AZMANG	\DEG	\00382	\Azimuth angle for data on this line
AZMANG	\DEG	\06646	\Azimuth angle for data on this line
AZMANG	\DEG	\23876	\Azimuth angle for data on this line
AZMANG	\DEG	\26754	\Azimuth angle for data on this line
COMMENTS	\NO UNITS	\00392	\Comments on run from Nickola (1977)
COMMENTS	\NO UNITS	\06656	\Comments on run from Nickola (1977)
COMMENTS	\NO UNITS	\23886	\Comments on run from Nickola (1977)
CONCQ	\S/CU.M	\00385	\E/Q, Normalized exposure
CONCQ	\S/CU.M	\06649	\E/Q, Normalized exposure
CONCQ	\S/CU.M	\23879	\E/Q, Normalized exposure
CONCQ	\S/CU.M	\26757	\E/Q, Normalized exposure
CONCQ4	\S/CU.M	\00389	\E/Q,Crosswind integrated value
CONCQ4	\S/CU.M	\06653	\E/Q,Crosswind integrated value
CONCQ4	\S/CU.M	\23883	\E/Q,Crosswind integrated value
CONCQ4	\S/CU.M	\26761	\E/Q,Crosswind integrated value
CONCUQ	\1/SQ.M	\00386	\EU/Q, Normalized exposure times wind speed
CONCUQ	\1/SQ.M	\06650	\EU/Q, Normalized exposure times wind speed
CONCUQ	\1/SQ.M	\23880	\EU/Q, Normalized exposure times wind speed
CONCUQ	\1/SQ.M	\26758	\EU/Q, Normalized exposure times wind speed
CONCUQ4	\1/SQ.M	\00390	\EU/Q,Crosswind integrated value
CONCUQ4	\1/SQ.M	\06654	\EU/Q,Crosswind integrated value
CONCUQ4	\1/SQ.M	\23884	\EU/Q,Crosswind integrated value
CONCUQ4	\1/SQ.M	\26762	\EU/Q,Crosswind integrated value
DAY	\NO UNITS	\00366	\Day of month
DAY	\NO UNITS	\06630	\Day of month
DAY	\NO UNITS	\23860	\Day of month
DAY	\NO UNITS	\26738	\Day of month
DELTEMPHI	\DEGF	\00232	\Temperature difference 15 to 61 m
DELTEMPLO	\DEGF	\00231	\Temperature difference 0.9 to 30 m
DIST	\M	\00375	\Measurement arc distance (typical)
DIST	\M	\00387	\Measurement distance

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 (cont.)

NAME	UNITS	RECORD	DEFINITION
DIST	\M	\06639	\Measurement arc distance(typical)
DIST	\M	\06651	\Measurement distance
DIST	\M	\23869	\Measurement arc distance (typical)
DIST	\M	\23881	\Measurement distance
DIST	\M	\26747	\Measurement arc distance (typical)
DIST	\M	\26759	\Measurement distance
DISTINNER	\M	\00222	\Sampling distance from source,m - nearest arc
DISTOUTER	\M	\00223	\Sampling distance from source,m - farthest arc
DURATIONF	\MIN	\00216	\Release duration for fluorescein
DURATIONK	\MIN	\00220	\Release duration for krypton-85
DURATIONR	\MIN	\00218	\Release duration for rhodamine B
DURATIONZ	\MIN	\00214	\Release duration for Zinc Sulfide
ELEV	\M	\00373	\Elevation of tracer release
ELEV	\M	\06637	\Elevation of tracer release
ELEV	\M	\23867	\Elevation of tracer release
ELEV	\M	\26745	\Elevation of tracer release
EXPOSURE	\G*S/CU.M	\00384	\Exposure multiplied by FACTOR as defined for table
EXPOSURE	\G*S/CU.M	\06648	\Exposure multiplied by FACTOR as defined for table
EXPOSURE	\G*S/CU.M	\23878	\Exposure multiplied by FACTOR as defined for table
EXPOSURE	\G*S/CU.M	\26756	\Exposure multiplied by FACTOR as defined for table
FACTOR	\NO UNITS	\00379	\EXPOSURE multiplied by this factor
FACTOR	\NO UNITS	\06643	\EXPOSURE multiplied by this factor
FACTOR	\NO UNITS	\23873	\EXPOSURE multiplied by this factor
FACTOR	\NO UNITS	\26751	\EXPOSURE multiplied by this factor
GRIDSOURC	\NO UNITS	\00213	\Grid source (U = unstable grid, S = stable grid)
HGTMEASUR	\M	\00383	\Measurement height for data
HGTMEASUR	\M	\06647	\Measurement height for data
HGTMEASUR	\M	\23877	\Measurement height for data
HGTMEASUR	\M	\26755	\Measurement height for data
HGTRELEAF	\M	\00217	\Release height for fluorescein
HGTRELEAK	\M	\00221	\Release height for krypton-85
HGTRELEAR	\M	\00219	\Release height for rhodamine B
HGTRELEAZ	\M	\00215	\Release height for zinc sulfide
HGTTEMPEE	\FEET	\35306	\ 9\TEMPERATU (air temperature) measurement heights
HGTTEMPEM	\M	\35304	\ 9\TEMPERATU (air temperature) measurement heights
HGTUDIRE	\FEET	\35321	\13\UDIR (wind direc.) measurement heights
HGTUDIRM	\M	\35319	\13\UDIR (wind direc.) measurement heights

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 (cont.)

NAME	UNITS	RECORD	DEFINITION
HGTUDSTDE	\FEET	\35329	\13\UDSTD (wind direc. std. deviation) measurement heights
HGTUDSTDM	\M	\35327	\13\UDSTD (wind direc. std. deviation) measurement heights
HGTUSPEED	\M	\00377	\Height for preceding wind speed
HGTUSPEED	\M	\06641	\Height for preceding wind speed
HGTUSPEED	\M	\23871	\Height for preceding wind speed
HGTUSPEED	\M	\26749	\Height for preceding wind speed
HGTUSPEED	\M	\35311	\11\USPEED (wind speed) measurement heights
HGTUSPEEE	\FEET	\35313	\11\USPEED (wind speed) measurement heights
LABELTEXT	\NO UNITS	\35302	\Text label for table
MONTH	\NO UNITS	\00365	\Month (text format)
MONTH	\NO UNITS	\06629	\Month (text format)
MONTH	\NO UNITS	\23859	\Month (text format)
MONTH	\NO UNITS	\26737	\Month (text format)
REMARK	\SET	\00381	\REMARK as defined for SET
REMARK	\SET	\06645	\REMARK as defined for SET
REMARK	\SET	\23875	\REMARK as defined for SET
REMARK	\SET	\26753	\REMARK as defined for SET
RUN	\NO UNITS	\00212	\Experiment run label
RUN	\NO UNITS	\00225	\Experiment run label
RUN	\NO UNITS	\00364	\Name of test run
RUN	\NO UNITS	\06628	\Name of test run
RUN	\NO UNITS	\23858	\Name of test run
RUN	\NO UNITS	\26736	\Name of test run
RUN	\NO UNITS	\35308	\Run
RUN	\NO UNITS	\35315	\Run
RUN	\NO UNITS	\35323	\Run
RUN	\NO UNITS	\35331	\Run
SIGMAT1.5	\DEG	\00229	\Wind direction standard deviation 1.5m, Beckman and Whitley V
SIGMAT62.	\DEG	\00230	\Wind direction standard deviation 62.m, Aerovane
TEMPERATU	\DEG F	\35309	\ 9\Air temperature profile
TEXT	\NO UNITS	\00362	\HEADER
TEXT	\NO UNITS	\06626	\HEADER
TEXT	\NO UNITS	\23854	\HEADER
TEXT	\NO UNITS	\26732	\HEADER
TIMESTART	\HHMM	\00368	\Tracer release -- start time
TIMESTART	\HHMM	\06632	\Tracer release -- start time
TIMESTART	\HHMM	\23862	\Tracer release -- start time
TIMESTART	\HHMM	\26740	\Tracer release -- start time
TIMESTOP	\HHMM	\00369	\Tracer release -- end time
TIMESTOP	\HHMM	\06633	\Tracer release -- end time
TIMESTOP	\HHMM	\23863	\Tracer release -- end time
TIMESTOP	\HHMM	\26741	\Tracer release -- end time

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 (cont.)

NAME	UNITS	RECORD	DEFINITION
TIMEZONE	\NO UNITS	\00370	\Time zone
TIMEZONE	\NO UNITS	\06634	\Time zone
TIMEZONE	\NO UNITS	\23864	\Time zone
TIMEZONE	\NO UNITS	\26742	\Time zone
TOWERNUM	\NO UNITS	\00224	\Total number of towers active (less for some tracers)
TRACERNAM	\NO UNITS	\00372	\Name of tracer used
TRACERNAM	\NO UNITS	\06636	\Name of tracer used
TRACERNAM	\NO UNITS	\23866	\Name of tracer used
TRACERNAM	\NO UNITS	\26744	\Name of tracer used
UDIR	\DEGREES	\35324	\ 7\Wind direction profile (Aerovanes)
UDIR	\DEGREES	\35325	\ 6\Wind direction profile (Beckman-Whitley Vanes)
UDSTD	\DEGREES	\35332	\ 7\Wind direction standard deviation profile (Aerovanes)
UDSTD	\DEGREES	\35333	\ 6\Wind direction standard deviation profile (Beckman-Whitley Vanes)
USPEED	\M/S	\00376	\Wind speed
USPEED	\M/S	\06640	\Wind speed
USPEED	\M/S	\23870	\Wind speed
USPEED	\M/S	\26748	\Wind speed
USPEED1.5	\M/S	\00227	\Mean wind speed measured at 1.5m
USPEED61.	\M/S	\00228	\Mean wind speed measured at 61.m
USPEEDA	\DEG F	\35316	\ 6\Wind speed profile (Primarily Beckman-Whitley Cups)
USPEEDBW	\DEG F	\35317	\ 5\Wind speed profile (Primarily Aerovanes)
YEAR	\NO UNITS	\00367	\Year
YEAR	\NO UNITS	\06631	\Year
YEAR	\NO UNITS	\23861	\Year
YEAR	\NO UNITS	\26739	\Year

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 - SUBSET 1

NAME	UNITS	RECORD	DEFINITION
DELTEMPHI	\DEGF	\00232	\Temperature difference 15 to 61 m
DELTEMPLO	\DEGF	\00231	\Temperature difference 0.9 to 30 m
DISTINNER	\M	\00222	\Sampling distance from source,m - nearest arc
DISTOUTER	\M	\00223	\Sampling distance from source,m - farthest arc
DURATIONF	\MIN	\00216	\Release duration for fluorescein
DURATIONK	\MIN	\00220	\Release duration for krypton-85
DURATIONR	\MIN	\00218	\Release duration for rhodamine B
DURATIONZ	\MIN	\00214	\Release duration for Zinc Sulfide
GRIDSOURC	\NO UNITS	\00213	\Grid source (U = unstable grid, S = stable grid)
HGTRELEAF	\M	\00217	\Release height for fluorescein
HGTRELEAK	\M	\00221	\Release height for krypton-85
HGTRELEAR	\M	\00219	\Release height for rhodamine B
HGTRELEAZ	\M	\00215	\Release height for zinc sulfide
RUN	\NO UNITS	\00212	\Experiment run label
RUN	\NO UNITS	\00225	\Experiment run label
SIGMAT1.5	\DEG	\00229	\Wind direction standard deviation 1.5m, Beckman and Whitley V
SIGMAT62.	\DEG	\00230	\Wind direction standard deviation 62.m, Aerovane
TOWERNUM	\NO UNITS	\00224	\Total number of towers active (less for some tracers)
USPEED1.5	\M/S	\00227	\Mean wind speed measured at 1.5m
USPEED61.	\M/S	\00228	\Mean wind speed measured at 61.m

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 - SUBSET 2

NAME	UNITS	RECORD	DEFINITION
AZMANG	\DEG	\00382	\Azimuth angle for data on this line
COMMENTS	\NO UNITS	\00392	\Comments on run from Nickola (1977)
CONCQ	\S/CU.M	\00385	\E/Q, Normalized exposure
CONCQ4	\S/CU.M	\00389	\E/Q,Crosswind integrated value
CONCUQ	\1/SQ.M	\00386	\EU/Q, Normalized exposure times wind speed
CONCUQ4	\1/SQ.M	\00390	\EU/Q,Crosswind integrated value
DAY	\NO UNITS	\00366	\Day of month
DIST	\M	\00375	\Measurement arc distance (typical)
DIST	\M	\00387	\Measurement distance
ELEV	\M	\00373	\Elevation of tracer release
EXPOSURE	\G*S/CU.M	\00384	\Exposure multiplied by FACTOR as defined for table
FACTOR	\NO UNITS	\00379	\EXPOSURE multiplied by this factor
HGTMEASUR	\M	\00383	\Measurement height for data
HGTUSPEED	\M	\00377	\Height for preceding wind speed
MONTH	\NO UNITS	\00365	\Month (text format)
REMARK	\SET	\00381	\REMARK as defined for SET
RUN	\NO UNITS	\00364	\Name of test run
TEXT	\NO UNITS	\00362	\HEADER
TIMESTART	\HHMM	\00368	\Tracer release -- start time
TIMESTOP	\HHMM	\00369	\Tracer release -- end time
TIMEZONE	\NO UNITS	\00370	\Time zone
TRACERNAM	\NO UNITS	\00372	\Name of tracer used
USPEED	\M/S	\00376	\Wind speed
YEAR	\NO UNITS	\00367	\Year

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 - SUBSET 3

NAME	UNITS	RECORD	DEFINITION
AZMANG	\DEG	\06646	\Azimuth angle for data on this line
COMMENTS	\NO UNITS	\06656	\Comments on run from Nickola (1977)
CONCQ	\S/CU.M	\06649	\E/Q, Normalized exposure
CONCQ4	\S/CU.M	\06653	\E/Q,Crosswind integrated value
CONCUQ	\1/SQ.M	\06650	\EU/Q, Normalized exposure times wind speed
CONCUQ4	\1/SQ.M	\06654	\EU/Q,Crosswind integrated value
DAY	\NO UNITS	\06630	\Day of month
DIST	\M	\06639	\Measurement arc distance (typical)
DIST	\M	\06651	\Measurement distance
ELEV	\M	\06637	\Elevation of tracer release
EXPOSURE	\G*S/CU.M	\06648	\Exposure multiplied by FACTOR as defined for table
FACTOR	\NO UNITS	\06643	\EXPOSURE multiplied by this factor
HGTMEASUR	\M	\06647	\Measurement height for data
HGTUSPEED	\M	\06641	\Height for preceding wind speed
MONTH	\NO UNITS	\06629	\Month (text format)
REMARK	\SET	\06645	\REMARK as defined for SET
RUN	\NO UNITS	\06628	\Name of test run
TEXT	\NO UNITS	\06626	\HEADER
TIMESTART	\HHMM	\06632	\Tracer release -- start time
TIMESTOP	\HHMM	\06633	\Tracer release -- end time
TIMEZONE	\NO UNITS	\06634	\Time zone
TRACERNAM	\NO UNITS	\06636	\Name of tracer used
USPEED	\M/S	\06640	\Wind speed
YEAR	\NO UNITS	\06631	\Year

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 - SUBSET 4

NAME	UNITS	RECORD	DEFINITION
AZMANG	\DEG	\23876	\Azimuth angle for data on this line
COMMENTS	\NO UNITS	\23886	\Comments on run from Nickola (1977)
CONCQ	\S/CU.M	\23879	\E/Q, Normalized exposure
CONCQ4	\S/CU.M	\23883	\E/Q,Crosswind integrated value
CONCUQ	\1/SQ.M	\23880	\EU/Q, Normalized exposure times wind speed
CONCUQ4	\1/SQ.M	\23884	\EU/Q,Crosswind integrated value
DAY	\NO UNITS	\23860	\Day of month
DIST	\M	\23869	\Measurement arc distance (typical)
DIST	\M	\23881	\Measurement distance
ELEV	\M	\23867	\Elevation of tracer release
EXPOSURE	\G*S/CU.M	\23878	\Exposure multiplied by FACTOR as defined for table
FACTOR	\NO UNITS	\23873	\EXPOSURE multiplied by this factor
HGTMEASUR	\M	\23877	\Measurement height for data
HGTUSPEED	\M	\23871	\Height for preceding wind speed
MONTH	\NO UNITS	\23859	\Month (text format)
REMARK	\SET	\23875	\REMARK as defined for SET
RUN	\NO UNITS	\23858	\Name of test run
TEXT	\NO UNITS	\23854	\HEADER
TIMESTART	\HHMM	\23862	\Tracer release -- start time
TIMESTOP	\HHMM	\23863	\Tracer release -- end time
TIMEZONE	\NO UNITS	\23864	\Time zone
TRACERNAM	\NO UNITS	\23866	\Name of tracer used
USPEED	\M/S	\23870	\Wind speed
YEAR	\NO UNITS	\23861	\Year

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 - SUBSET 5

NAME	UNITS	RECORD	DEFINITION
AZMANG	\DEG	\26754	\Azimuth angle for data on this line
CONCQ	\S/CU.M	\26757	\E/Q, Normalized exposure
CONCQ4	\S/CU.M	\26761	\E/Q,Crosswind integrated value
CONCUQ	\1/SQ.M	\26758	\EU/Q, Normalized exposure times wind speed
CONCUQ4	\1/SQ.M	\26762	\EU/Q,Crosswind integrated value
DAY	\NO UNITS	\26738	\Day of month
DIST	\M	\26747	\Measurement arc distance (typical)
DIST	\M	\26759	\Measurement distance
ELEV	\M	\26745	\Elevation of tracer release
EXPOSURE	\G*S/CU.M	\26756	\Exposure multiplied by FACTOR as defined for table
FACTOR	\NO UNITS	\26751	\EXPOSURE multiplied by this factor
HGTMEASUR	\M	\26755	\Measurement height for data
HGTUSPEED	\M	\26749	\Height for preceding wind speed
MONTH	\NO UNITS	\26737	\Month (text format)
REMARK	\SET	\26753	\REMARK as defined for SET
RUN	\NO UNITS	\26736	\Name of test run
TEXT	\NO UNITS	\26732	\HEADER
TIMESTART	\HHMM	\26740	\Tracer release -- start time
TIMESTOP	\HHMM	\26741	\Tracer release -- end time
TIMEZONE	\NO UNITS	\26742	\Time zone
TRACERNAM	\NO UNITS	\26744	\Name of tracer used
USPEED	\M/S	\26748	\Wind speed
YEAR	\NO UNITS	\26739	\Year

DATA VARIABLES LISTING FOR M&T DATA ARCHIVE SET 3 - SUBSET 6

NAME	UNITS	RECORD	DEFINITION
HGTTEMPEE	\FEET	\35306	\ 9\TEMPERATU (air temperature) measurement heights
HGTTEMPEM	\M	\35304	\ 9\TEMPERATU (air temperature) measurement heights
HGTUDIRE	\FEET	\35321	\13\UDIR (wind direc.) measurement heights
HGTUDIRM	\M	\35319	\13\UDIR (wind direc.) measurement heights
HGTUDSTDE	\FEET	\35329	\13\UDSTD (wind direc. std. deviation) measurement heights
HGTUDSTDM	\M	\35327	\13\UDSTD (wind direc. std. deviation) measurement heights
HGTUSPEED	\M	\35311	\11\USPEED (wind speed) measurement heights
HGTUSPEEE	\FEET	\35313	\11\USPEED (wind speed) measurement heights
LABELTEXT	\NO UNITS	\35302	\Text label for table
RUN	\NO UNITS	\35308	\Run
RUN	\NO UNITS	\35315	\Run
RUN	\NO UNITS	\35323	\Run
RUN	\NO UNITS	\35331	\Run
TEMPERATU	\DEG F	\35309	\ 9\Air temperature profile
UDIR	\DEGREES	\35324	\ 7\Wind direction profile (Aerovanes)
UDIR	\DEGREES	\35325	\ 6\Wind direction profile (Beckman-Whitley Vanes)
UDSTD	\DEGREES	\35332	\ 7\Wind direction standard deviation profile (Aerovanes)
UDSTD	\DEGREES	\35333	\ 6\Wind direction standard deviation profile (Beckman-Whitley Vanes)
USPEEDA	\DEG F	\35316	\ 6\Wind speed profile (Primarily Beckman-Whitley Cups)
USPEEDBW	\DEG F	\35317	\ 5\Wind speed profile (Primarily Aerovanes)

HEADER FILE OF DATA TAPE, MICROMETEOROLOGICAL AND TRACER DATA ARCHIVE SET NUMBER 3, REVISION 1, HANFORD-67 ATMOSPHERIC DISPERSION EXPERIMENTS

TAPE FILE	FILE CONTENTS	BLOCK SIZE BYTES	LOGICAL RECORD LENGTH	LINES PER BLOCK	FILE TOTAL LINES	FILE TOTAL CHAR	ODD CHECK-SUM	EVEN CHECK-SUM	
FILE#1	HEADER FILE,	2600	130	20	13				(Checksum is sum of print-
FILE#2	DOCUMENTATION REP.	2600	130	20	3565				able ASCII bytes on each
FILE#3	VARIABLES LIST	2600	130	20	61				line excluding trailing
FILE#4	EXPER.SUMMARY(SES)	2600	130	20	135				blanks on the right.)
FILE#5	HANFORD-67 DATA	2600	130	20	35588	2317562	28641	43028	

REVISION LOG FOR M&T DATA ARCHIVE SET 3

ARCHIVE NUMBER	REVISION NUMBER	DATE	NOTES
003	000	04-30-86	Draft Data Archive
003	001	09-02-86	Final Data Archive

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STANDARD EXPERIMENT SUMMARY

The following is a list of values for variables of common interest in studies of this type that may be used to determine the relative utility of the Subject data set or individual runs within the data set. This list does not represent all variables in the Hanford-67 Series data set. The full nature of the data set is outlined above and is defined precisely in the data map. The tables below are based on the summary table given by Nickola (1977).

SUMMARY OF HANFORD-67 SERIES TESTS

RUN #	TRACER RUN	GRID	ZN-SUL TIME min	ZN-SUL HT m	FLUORO TIME min	FLUORO HT m	RHOD-B TIME min	RHOD-B HT m	KRY-85 TIME min	KRY-85 HT m	MEAS. CLOSE DIST. m	MEAS. FAR DIST. m	ACTIVE NUMBER OF TOWERS
01	D1	S	30	002	30	002	0	0	0	0	200	3200	20
02	D2	S	30	002	30	002	0	0	0	0	200	3200	20
03	D3	S	30	002	30	002	0	0	0	0	200	3200	20
04	D4	S	16	002	16	002	0	0	0	0	200	3200	20
05	C1	S	0	0	0	0	0	0	15	001	200	800	6
06	C2	S	0	0	0	0	0	0	15	001	200	800	6
07	C3	S	0	0	0	0	0	0	14	001	200	800	6
08	C4	S	0	0	0	0	0	0	10	001	200	800	6
09	C5	S	20	2	0	0	0	0	20	001	200	800	10
10	U56	U	30	2	30	26	0	0	0	0	200	3200	0
11	U57	U	30	2	30	26	0	0	0	0	400	3200	0
12	U58	U	30	2	30	26	0	0	0	0	400	3200	0
13	U59	U	30	26	30	2	0	0	0	0	800	12800	0
14	U60	U	30	26	30	2	0	0	0	0	800	12800	0
15	U61	U	30	26	15	2	0	0	0	0	800	12800	0
16	U62	U	30	26	20	2	0	0	0	0	800	12800	0
17	U63	U	30	26	25	2	0	0	0	0	400	12800	0
18	U64	U	30	26	20	2	0	0	0	0	400	7000	0
19	U65	U	30	26	30	2	0	0	0	0	400	12800	0
20	U66	U	30	26	30	2	0	0	0	0	400	7000	0
21	U67	U	30	26	30	2	0	0	0	0	400	7000	0
22	U68	U	30	26	30	2	0	0	0	0	400	12800	0
23	U69	U	30	26	0	0	0	0	0	0	400	12800	0
24	U70	U	30	26	30	2	0	0	0	0	400	12800	0
25	U71	U	30	26	15	56	0	0	0	0	400	12800	0

SUMMARY OF HANFORD-67 SERIES TESTS (cont.)

RUN #	TRACER RUN	GRID	ZN-SUL TIME min	ZN-SUL HT m	FLUORO TIME min	FLUORO HT m	RHOD-B TIME min	RHOD-B HT m	KRY-85 TIME min	KRY-85 HT m	MEAS. CLOSE DIST. m	MEAS. FAR DIST. m	ACTIVE NUMBER OF TOWERS
26	U72	U	30	26	20	56	0	0	0	0	400	7000	0
27	U73	U	30	26	20	56	0	0	0	0	400	12800	0
28	U74	U	30	26	30	56	0	0	0	0	400	7000	0
29	U75	U	30	26	30	56	0	0	0	0	400	12800	0
30	U76	U	30	26	30	56	0	0	0	0	400	7000	0
31	U77	U	30	26	30	56	0	0	0	0	400	12800	0
32	U78	U	30	26	30	56	0	0	0	0	400	7000	0
33	U79	U	30	26	30	56	0	0	0	0	400	12800	0
34	U80	U	30	26	30	56	0	0	0	0	400	3200	0
35	U81	U	30	26	30	56	0	0	0	0	400	12800	0
36	U82	U	30	26	30	56	0	0	0	0	400	12800	0
37	U83	U	30	26	30	56	0	0	0	0	400	7000	0
38	U84	U	30	111	0	0	0	0	0	0	400	12800	0
39	U85	U	30	111	30	56	0	0	0	0	400	12800	0
40	U86	U	30	111	30	56	0	0	0	0	400	12800	0
41	U87	U	26	111	0	0	0	0	0	0	400	12800	1
42	U88	U	30	111	16	56	0	0	0	0	400	12800	1
43	U89	U	30	111	30	56	0	0	0	0	400	12800	1
44	U90	U	30	111	4	56	0	0	0	0	400	12800	1
45	U91	U	30	111	30	56	0	0	0	0	400	12800	1
46	U92	U	30	111	30	56	0	0	0	0	400	12800	1
47	V1	U	30	26	0	0	30	26	0	0	200	3200	20
48	V2	U	30	26	0	0	30	26	30	26	200	3200	20
49	V3	U	30	26	0	0	30	26	0	0	200	3200	20
50	V4	U	29	26	0	0	31	26	0	0	200	3200	17
51	V5	U	30	26	0	0	30	26	30	26	200	3200	20
52	V6	U	30	26	0	0	30	26	30	26	200	3200	20
53	V7	U	30	26	0	0	0	0	30	26	200	3200	20
54	V8	U	10	26	0	0	0	0	0	0	200	3200	20

SUMMARY OF HANFORD-67 SERIES TESTS (cont.)

RUN #	RUN	WIND SPEED AT 1.5m m/s	WIND SPEED AT 61m m/s	SIGMA-THETA AT 1.5. deg	SIGMA-THETA AT 61m deg	TEMPERATURE GRADIENT BETWEEN HEIGHTS OF .9-30m deg F	TEMPERATURE GRADIENT BETWEEN HEIGHTS OF 15-16m deg F
01	D1	1.1	3.9	22	10	1.7	0.7
02	D2	1.6	6.6	10	5	6.4	2.0
03	D3	2.4	4.7	33	17	1.9	0.6
04	D4	1.2	4.8	37	4	1.3	0.6
05	C1	1.2	5.8	7	3	6.9	6.9
06	C2	3.9	999.0	6	999	-1.6	-1.2
07	C3	7.6	999.0	10	999	-3.2	-2.4
08	C4	3.8	999.0	13	999	-4.6	-2.3
09	C5	2.6	7.5	7	3	1.0	999.0
10	U56	1.6	6.0	22	5	2.1	2.3
11	U57	1.3	3.4	9	4	5.9	0.7
12	U58	2.9	6.9	8	6	1.7	0.6
13	U59	1.8	3.9	15	8	1.3	0.1
14	U60	1.2	5.7	14	6	4.1	1.5
15	U61	5.0	10.1	6	3	0.4	0.0
16	U62	5.2	9.2	6	6	-0.4	-0.5
17	U63	2.9	7.5	6	2	1.2	0.6
18	U64	1.4	5.3	5	2	6.7	5.5
19	U65	2.7	6.7	15	7	0.5	0.1
20	U66	1.3	3.9	31	9	2.6	1.7
21	U67	2.1	5.3	11	5	0.2	0.4
22	U68	2.1	6.0	13	4	1.4	0.5
23	U69	2.6	5.8	9	5	0.6	0.1
24	U70	4.6	8.7	8	5	0.1	0.0
25	U71	1.5	4.3	15	11	1.3	0.3

SUMMARY OF HANFORD-67 SERIES TESTS (cont.)

RUN #	RUN	WIND SPEED AT 1.5m m/s	WIND SPEED AT 61m m/s	SIGMA-THETA AT 1.5. deg	SIGMA-THETA AT 61m deg	TEMPERATURE GRADIENT BETWEEN HEIGHTS OF .9-30m deg F	TEMPERATURE GRADIENT BETWEEN HEIGHTS OF 15-16m deg F
26	U72	1.9	6.2	20	5	2.1	1.1
27	U73	2.7	6.7	8	4	0.9	0.7
28	U74	1.7	6.5	10	3	2.3	1.3
29	U75	1.3	2.5	6	8	5.4	3.9
30	U76	3.2	7.2	9	5	0.8	0.8
31	U77	1.6	3.7	9	4	0.3	0.0
32	U78	3.8	7.4	6	2	-0.5	-0.3
33	U79	1.9	6.8	7	4	2.5	2.1
34	U80	0.9	2.9	16	7	6.7	3.4
35	U81	2.8	7.1	14	11	1.3	1.3
36	U82	1.1	4.5	22	5	6.3	3.1
37	U83	1.5	6.7	7	3	6.1	5.2
38	U84	0.9	5.1	11	5	2.0	1.2
39	U85	3.0	8.3	13	6	-0.4	1.3
40	U86	0.8	5.0	11	5	5.4	2.3
41	U87	1.0	3.6	30	17	5.4	1.7
42	U88	1.3	7.6	11	3	2.0	4.2
43	U89	0.9	3.1	26	14	5.9	1.0
44	U90	0.9	4.3	13	6	6.6	0.5
45	U91	0.9	3.8	12	10	2.8	1.2
46	U92	0.9	4.8	8	4	3.4	1.1
47	V1	3.5	6.1	14	8	-3.4	-1.6
48	V2	2.8	4.9	12	11	-1.0	-1.0
49	V3	2.5	4.3	10	8	-2.1	-1.4
50	V4	1.8	2.9	11	5	-0.2	-1.2
51	V5	1.2	7.4	14	3	4.9	3.3
52	V6	2.9	8.8	6	4	1.7	2.1
53	V7	3.2	4.6	20	19	-4.1	-2.0
54	V8	1.8	3.4	9	4	-0.9	-0.7

REFERENCES

Barad, M. L. and J. J. Fuquay (Eds.). The Green Glow Diffusion Program. Geophysical Research Papers No. 73, Vols. I and II, AFCRL-62-251 (I and II), Air Force Cambridge Research Laboratories, Bedford, Massachusetts, (also as HW-71400 (I and II), Hanford Laboratories, General Electric Co., Richland, Washington), (I) Jan. and (II) Apr. 1962.

Dana, M. T. Calibration of an Ultrasonic Nozzle for Aerosol Generation. Pacific Northwest Laboratory Annual Report for 1970 to the USAEC Division of Biology and Medicine, Vol. II: Physical Sciences, Part I, Atmospheric Sciences. BNWL-1551, Vol. II, Part 1:98-101, Pacific Northwest Laboratory, Richland, Washington, June 1971.

Droppo, J. G., and C. R. Watson. Introduction to Micrometeorological and Tracer Data Archive Procedures. EPA-600/3-85/053, Environmental Protection Agency, Research Triangle Park, North Carolina, June 1985.

Eggleton, A. E. J. and N. Thompson. Loss of Fluorescent Particles in Atmospheric Diffusion Experiments by Comparison with Radio-xenon Tracer. Nature, 192:935-936, Dec. 1961.

Fuquay, J. J., and C. L. Simpson and W. T. Hinds. Prediction of Environmental Exposures from Sources Near the Ground Based on Hanford Experimental Data. J. of Appl. Meteorol., 3(6):761-770, Dec. 1962.

Green, H. L. and W. R. Lane. Particulate Clouds: Dusts, Smokes and Mists. E. & F. N. Spon, Ltd., London, England, 1957.

Hales, J. M. and Staff. Pacific Northwest Laboratory Annual Report for 1976, to the ERDA Assistant Administrator for Environment and Safety, Part 3, Atmospheric Sciences. BNWL-2100 PT3, Pacific Northwest Laboratory, Richland, Washington, Aug. 1977.

Leighton, P. A., W. A. Perkins, S. W. Grinnell and F. X. Webster. The Fluorescent Particle Atmospheric Tracer. J. Appl. Meteorol., 4(3):334-348, June 1965.

Leighton, P. A. The Stanford Fluorescent-Particle Tracer Technique. [Defense Documentation Center, AD 91-94], Dept. of Chemistry, Stanford University, Palo Alto, California, June 1955.

Ludwick, J. D. and R. W. Perkins. Liquid Scintillation Techniques Applied to Counting Phosphorescence Emission. Anal. Chem., 33(9):1230-1235.

Ludwick, J. D. Dual Atmospheric Tracer Techniques for Diffusion Studies Using Phosphorescence - Fluorescence Analysis. HW-70892, Hanford Atomic Products Operation, General Electric Co., Richland, Washington, March 1961.

Ludwick, J. D. Atmosperhic Diffusion Studies with Fluorescein and Zinc Sulfide Particles as Dual Tracers. J. Geophys. Res., 71(6):1553-1558, Mar. 1966.

Ludwick, J. D., J. J. Lashock, R. E. Connally, and P. W. Nickola. Automatic Real Time Air Monitoring of 85Kr Utilizing the 4096 Memory of a Multiparameter Analyzer. Rev. Sci. Inst., 39(6):853-859, June 1968.

Nickola, P. W. and M. F. Scoggins. Atmospheric Tracer Technology. Hanford Radiological Sciences Research and Development Annual Report for 1963, HW-81746:1.43-1.51, Hanford Atomic Products Operation, General Electric Co., Richland, Washington, Jan. 1964.

Nickola, P. W. Field Testing of a Fluorescein-Zinc Sulfide Dual Atmospheric Tracer Technique. BNWL-103, Pacific Northwest Laboratory, Richland, Washington, Aug. 1965.

Nickola, P. W., J. V. Ramsdell, Jr., and J. D. Ludwick. Detailed Time-Histories of Concentrations Resulting from Puff and Short-Period Releases of an Inert Radioactive Gas: A Volume of Atmospheric Diffusion Data. BNWL-1272, Pacific Northwest Laboratory, Richland, Washington, Feb. 1970a2.

Nickola, P. W., J. D. Ludwick and J. V. Ramsdell, Jr. An Inert Gas Tracer System for Monitoring the Real-Time History of a Diffusing Plume or Puff. J. App. Meteorol., 9(4):621-626, Aug. 1970b.

Nickola, P. W. Measurements of the Movement, Concentration and Dimensions of Clouds Resulting from Instantaneous Point Sources. J. Appl. Meteorol., 10(5):967-973, Oct. 1971.

Nickola, P. W. The Hanford 67-Series: A Volume of Atmospheric Diffusion Measurements. PNL-2433, Pacific Northwest Laboratory, Richland, Washington, 1977. [This document is the published source of all the data contained in Micrometeorological and Tracer Data Archive Sets 003, 004, 005, and 006.]

Ratcliffe, C. A. and E. M. Sheen. An Automatic Data Collection System for Meteorological Tower Instrumentation. J. Appl. Meteorol., 3(6):807-809, Dec. 1964.

Rankin, M. O. A Zinc Sulfide Particle Detector. HW-55917, Hanford Laboratories, General Electric Co., Richland, Washington, 1958.

Robinson, E., J. A. MacLeod, and C. E. Lapple. A Meteorological Tracer Technique Using Uranine Dye. J. of Meteorol., 16:63-67, Feb. 1959.

Sehmel, G. A. Subisokinetic Sampling of Particles in an Air Stream. BNWL-217, Pacific Northwest Laboratory, Richland, Washington, Mar. 1966.

Stein, F., N. Esman and M. Corn. The Density of Uranine Aerosol Particles. Am. Indust. Hyg. Ass. J., 27(5):428-430, Sept.-Oct. 1966.

Wolf, M. A. and M. T. Dana. Experimental Studies in Precipitation Scavenging. Pacific Northwest Laboratory Annual Report for 1968 to the USAEC Division of Biology and Medicine, Vol. II: Physical Sciences, Part I, Atmospheric Sciences. BNWL-1051, Part 1:18-25, Pacific Northwest Laboratory, Richland, Washington, Nov. 1969.