US Department of the Interior
National Park Service
National Center for
Preservation Technology and Training
Publication No. 1995-06

Influence of Atmospheric Pollutants on Soiling of a Limestone Building Surface

Progress Report for the
National Park Service
U.S. Department of the Interior
for Cooperative Agreement CA 424-1-9005
with Carnegie Mellon University

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September 1995

Funding for this report was provided by the National Park Service's National Center for Preservation Technology and Training, Natchitoches, Louisiana. NCPTT promotes and enhances the preservation of prehistoric and historic resources in the United States for present and future generations through the advancement and dissemination of preservation technology and training.

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Chapter 1: Introduction

Air pollution has been responsible for increasing the rate of deterioration of many historically and culturally valuable monuments. This phenomena is not confined to the United States; churches, cathedrals, and monuments worldwide have sustained damage as a result of air pollutants. Unfortunately, common building and sculpting materials such as limestone, marble, and bronze are among the most susceptible to attack by anthropogenic atmospheric pollutants. This project is intended to provide information that will assist efforts by many individuals and groups to preserve monuments that are vulnerable to air pollution damage.

Goals

The principal goal is to formulate a model that will predict the deposition of atmospheric pollutants to complex structures such as the Cathedral of Learning. Secondary objectives that will aid in achieving this goal include the characterization of the physics of pollutant mass transfer to the surface for given meteorological conditions and surface geometry, and documentation of soiling patterns.

Work Conducted Since 1994 Progress Report

Extensive monitoring at the Cathedral has continued through July 6, 1995. This includes the use of surrogate vertical surfaces to collect pollutant flux data as well as a staged filterpack system used to measure pollutant airborne concentrations. In total, we have obtained 1.25 years of flux data and 1.75 years of airborne concentration data for all of the pollutants measured. For some of the air pollutants such as SO_4 particles and NO_3 particles, we have been collecting data since December 1992.

In this report, we discuss in detail work conducted since the last progress report was written 12 months ago. First, we discuss background material in Chapter 2 in order to put recent work in perspective. Then in Chapter 3, we discuss experimental methods used in this project. In Chapers 4 and 5, we present data and interpretations, respectively. Finally, we draw conclusions from the results and suggest future work in Chapter 6. Additional information is included in the Appendices. Appendix A contains a list of laboratory procedures used in cleaning equipment and preparing samples. Appendix B includes tables of airborne concentration and deposition flux data. Documentation of soiling patterns on one type of repeated architectural feature on the Cathedral is summarized in Appendix C. A history of soiling patterns using archival photographs is presented in Appendix D.

Several additional efforts are currently underway but are not reported here since work is still in progress. The extent of rain washing of carbon spots applied to the Cathedral walls is also being investigated. In addition, the number of motor vehicles in the immediate vicinity of the Cathedral is being estimated. Information regarding traffic density will be used as input for a box model that will estimate the contribution of motor vehicles to airborne carbon concentrations. Finally, a Geographic Information System (GIS) that will aid in the storage and retrieval of the large amount of data generated by our investigations is being developed.

Chapter 2: Background

Although the deterioration and soiling of buildings, statues, and monuments by air pollutants are well documented, there remains a considerable gap in the body of knowledge about the mechanisms by which these phenomena occur. One of the greatest difficulties is caused by the large number of variables that may play a significant role in the relevant processes. Some factors that are important in the study of stone decay and soiling include: local meteorology, surface characteristics, physical and chemical properties of the pollutant, large-scale geometry of the surface, and large-scale geometry of the surrounding landscape. An overview of air pollution damage to calcareous stone as well as a summary of the relevant literature and chemistry can be found in the ‘Background’ section and Appendix A of the previous year’s Progress Report for this project (Lutz et al., 1994). The remainder of this section focuses on the process of dry deposition, and more specifically, on pollutant transport to the surface of interest. The ensuing material draws on The NAPAP State of Science and Technology Report 20 (Sherwood et al., 1990) and Davidson and Wu (1990).

Dry deposition can be defined as the process by which a gas or particle is transported to and deposited on a surface in the absence of precipitation. One way to model dry deposition is by using a resistance analogy. In this model,

$V_d = (R_a + R_b + R_c)^{-1} + R_g^{-1}$ where (2.1)

V_d = deposition velocity
R_a = aerodynamic resistance
R_b = boundary layer resistance
R_b = surface resistance
R_g = gravitational resistance

The aerodynamic resistance quantifies the transport of a pollutant to the viscous sublayer from a point far from the surface, while the boundary layer resistance quantifies the transport of a pollutant across the viscous sublayer. The surface resistance is a measure of the affinity of a pollutant to a particular receptor. The gravitational resistance is the inverse of the sedimentation velocity of a particle. For gases and small particles, R_g can be ignored. The transport of a pollutant from the ambient atmosphere to a surface where there is perfect retention is only a function of the aerodynamic and boundary layer resistances.

When modeling dry deposition, it is convenient to consider a range of spatial scales. At one extreme, we can consider the landscape as a whole. In this instance, the deposition velocity is dependent on the many contributions of the different elements that comprise the surface. For example, the flux of a pollutant to a forest will depend on the structure and characteristics of all the different objects that are found in the forest such as trees, bushes, soil, hills, and lakes and rivers. At the other extreme, we might consider deposition to a particular object in the landscape such as a leaf, a particular section of wall on a building, or the microlayer on a water surface. In this case, deposition would be a function of the geometry and the surface characteristics of the receptor object. The resistance analogy may be used to model thy deposition at either end of this continuum of lengths.

The mathematical expressions used to estimate the flux of a pollutant to a particular landscape are closely related to the expressions used to quantify the flux of air momentum to a surface. Therefore, it is illustrative to consider the wind speed profile and the resultant momentum transfer in the atmospheric boundary layer. In the region above the viscous sublayer where the molecular viscosity of air is negligible compared to the turbulent eddy viscosity, the wind profile follows a logarithmic expression. If the atmosphere is neutrally stable, windspeed as a function of height can be expressed as

$$u(z) = \left(\frac{u_*}{k}\right)\ln\left(\frac{z-d}{z_o}\right) \text{ where} \qquad (2.2)$$

$u_\bullet$ = friction velocity $(T_o/\rho)^{0.5}$
T_o = surface shear stress
ρ = density of air
k = Von Karman constant = 0.4
z_o = roughness height
d = zero-plane displacement thickness

The zero-plane displacement thickness is included in the formulation because when considering tall, densely spaced objects such as trees or buildings, it is not convenient to use ground level ($z = 0$) as a reference height. The roughness height z_o refers to the height above the displacement thickness at which the wind speed would equal zero if the wind profile were extrapolated. Both z_o and d are mathematical fitting parameters.

The only resistance to the transport of momentum to the surface is provided by the region above the viscous sublayer where the wind speed is given by equation (2.2). Therefore, a deposition velocity for air momentum can be quantified solely by the aerodynamic resistance which can be expressed as

$$R_{am} = \left(\frac{u}{u_*^2}\right)F_m\left(\frac{z-d}{L}\right) \text{ where} \qquad (2.3)$$

$F_m\left(\frac{z-d}{L}\right)$ = correction for non-neutral atmospheric conditions
$F_m\left(\frac{z-d}{L}\right) = 1$ for neutral conditions
L = Monin-Obukhov length scale of turbulence and is a function of the meteorological conditions.

An equivalent expression may be developed for the aerodynamic resistance to the transport of pollutants. Differences in the eddy diffusivities of momentum and concentration may be incorporated into a function F((z-d)/L) such that

$$R_a = \left(\frac{u}{u_*^2}\right) F\left(\frac{z-d}{L}\right) \text{ where} \qquad (2.4)$$

$$F\left(\frac{z-d}{L}\right) = \varphi\, F_m\left(\frac{z-d}{L}\right) \text{ and } \varphi \text{ is a constant.}$$

Unlike the case of air momentum, the deposition velocity for a contaminant must include both a boundary layer resistance (R_b) and a surface resistance (R_c). In formulating an expression for the boundary layer resistance, it is convenient to define a roughness height for contaminant transport, z_{oc}. This variable refers to the height above the displacement thickness d at which the concentration of a contaminant would be equal to zero if the concentration profile were extrapolated. The boundary layer resistance can be expressed as

$$R_b = \left(\frac{1}{ku_*}\right) \ln\left(\frac{z_o}{z_{oc}}\right) \qquad (2.5)$$

Although this is a simple expression for R_b, z_{oc}. is generally difficult to measure directly. Therefore, semi-empirical expressions relating $\ln(z_o/z_{oc})$ to other more easily measurable parameters have been developed. For example, Sherwood et al. (1985) have suggested the use of an expression of the form

lnI~~2-~’) = cRe~Sc~ where (2.6)

Re.^{m}. = surface roughness Reynolds number = $u_* z_o/v$,
v = kinematic viscosity of air
Sc = Schmidt number = v/ D
D = Brownian or molecular diffusivity.
c = constant
m = empirically determined exponent usually in the range of 0.2 - 0.5
n = empirically determined exponent usually in the range of 0.5 - 0.8.

The values of c, m, and n, are dependent on the nature of the roughness elements of the landscape. In general, values of these parameters used for fibrous roughness elements such as vegetative canopies are different from those used for bluff bodies such as buildings.

Equations (2.4), (2.5), and (2.6) may be combined to give an estimate of the sum of the aerodynamic and boundary layer resistances to contaminant transport.

$$R_a + R_b = \left(\frac{1}{u_*}\right)\left[\left(\frac{c}{k}\right) Re_*^m Sc^n + \left(\frac{u}{u_*}\right) F\left(\frac{z-d}{L}\right)\right] \qquad (2.7)$$

It should be noted that whereas Ra may be similar for particles and gases, Rb is generally much smaller for gases (e.g., see Wu et al., 1992).

Although the resistance analogy may be used to model deposition on the scale of landscapes as well as individual receptors, the above formulations for R_a and R_b may only be appropriate for the former. In particular, the expressions presented for Rb have assumed that a logarithmic wind speed profile is applicable. Whereas this assumption is valid when considering an entire landscape with somewhat uniform height and spacing of roughness elements, the wind speed profile above an isolated obstacle may be significantly different. In addition, bluff bodies such as buildings experience zones of flow separation and street canyon effects. Therefore, the expressions presented for the aerodynamic and boundary layer resistances should not be applied to individual receptors before careful consideration of the implicit assumptions.

Chapter 3: Experimental Methods

The Cathedral of Learning is a forty-two story limestone building located in an urban setting on the Uninversity of Pittsburgh campus in Pittsburgh, Pennsylvania. The sampling conducted at the Cathedral can be divided into two categories, meteorological and chemical. Meteorological sampling is conducted on the 5th floor southwest patio, the 16th floor southwest patio and the roof. The chemical sampling has been restricted to the 5th floor southwest patio although pilot scale studies at other locations have been initiated.

Meteorological Measurements

Each of the three sampling locations, 5th floor, 16th floor, and roof, are equipped with a Campbell Scientific model 2lX datalogger unit. In addition, the 5th floor is equipped with a model AM4 16 multiplexer which is operated in conjunction with the datalogger. All meteorological data are electronically collected by the dataloggers once a minute. The data are then averaged over 30 minutes and the averages are downloaded to SM-192 storage modules. The storage modules are periodically retrieved and the data are transferred to a personal computer on the Carnegie Mellon campus. Table 3.1 gives a summary of the meteorological equipment used at each of the three sampling locations.

Table 3.1 Summary of meteorological equipment at the Cathedral of Learning

Location	Equipment Name	Model #	Number deployed
5th floor SW patio	relative humidity/ temperature sensor	Met One 083 C-1	1
	U-V-W anemometer	R.M. Young	1
	thermocouple	Omega	5
	moisture sensors	Omega	6
16th floor SW patio	relative humidity/ temperature sensor	Met One 083C-1	1
	thermocouple	Omega	5
	moisture sensor	Omega	6
Roof	wind speed sensor	Met One 0l4A	1
	wind direction sensor	Met One 024A	1
	solar radiation sensor	Met One 096-1	2
	tipping bucket rain gauge	Met One 370	1

Chemical Sampling

Two forms of chemical sampling have been in use at the Cathedral, namely airborne concentration measurements and measurements of pollutant fluxes to vertical surrogate surfaces. Both types of sampling have been conducted primarily at the 5th floor SW patio. A brief summary of the experimental apparatus is given below. An in-depth discussion of the procedures and handling techniques is given in the Sampling Design section of the previous year's Progress Report (Lutz et al. 1994). Some of the techniques for cleaning materials in the laboratory have changed since early 1994. Appendix A outlines the procedures for washing all the items that are now used in our experiments on a regular basis.

Airborne Concentration Measurements

A multi-staged filter pack system is used to measure airborne concentrations of nitric acid vapor (HNO_3) and sulfur dioxide (SO_2) gas, and nitrate (NO_3), sulfate (SO_4), and carbon (C) particles (Figure 3.1). The filterpack system is enclosed in a 5 gallon polyethylene bucket and deployed on a 1.5 m sampling tower. Two replicate filterpack systems are used for data assurance purposes. Each time the sampling equipment is changed, a field blank is deployed for a period of at least five minutes. The airborne sampling equipment is changed every 10 days on average. Filters are removed from the filterpacks and frozen until the time of extraction. The quartz fiber filters which are used to collect carbon particles are analyzed by Desert Research Institute (Chow et al., 1993). The remaining filters are analyzed at Carnegie Mellon by a Dionex 4500i Ion Chromatograph.

As of April of 1995, we have been testing a modified version of the air sampling stations. In the modified stations, filterpacks do not have to be placed in a bucket. The filterpacks are placed directly on the air sampling towers and are covered by an inverted polyethylene bucket which acts only as a rainshield. The modified system has the advantage that the air sampling equipment is not as bulky and therefore easier to transport to and from the Cathedral. This feature will be particularly useful during intensive sampling periods which require a large number of air sampling stations operating concurrently.

Measurements of Pollutant Fluxes to Vertical Surrogate Surfaces

Two types of surrogate surfaces are used at the Cathedral, greased Teflon sheets and potassium carbonate impregnated Whatman filters. The greased Teflon is assumed to be a perfect sink for particles, whereas the treated Whatman filters are assumed to be perfect collectors for sulfur dioxide gas. Two of each type of surrogate surface are mounted onto a Teflon coated aluminum sheet (Figure 3.2). Five of the aluminum sheets are deployed vertically at different locations on the 5th floor patio for periods of approximately one month (Figure 3.3). At the end of the sampling period, the sheets are removed and analyzed by ion chromatography. As with the airborne concentration measurements, a field blank is deployed for a few minutes each time the surrogate surfaces are changed.

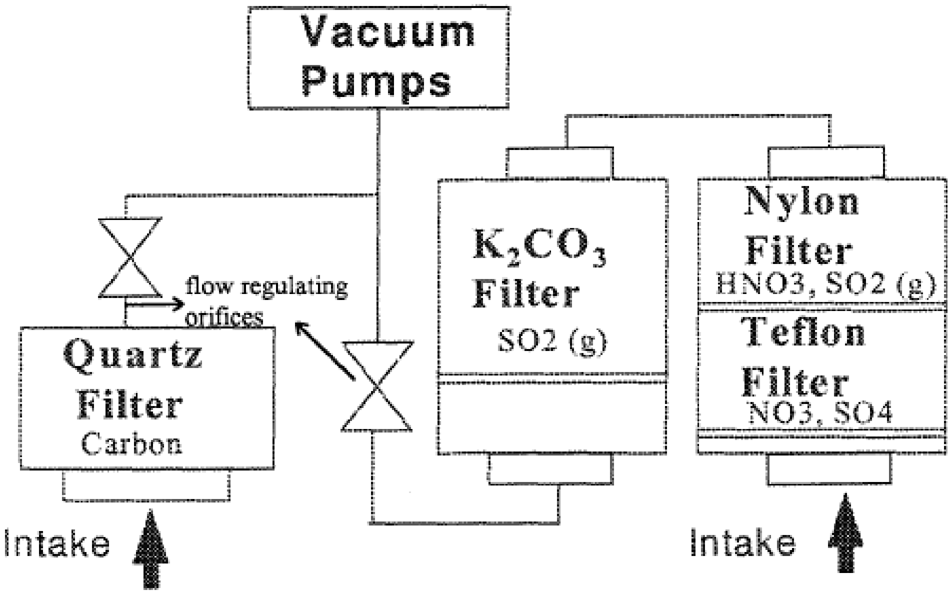


Figure 3.1. Schematic of the staged filterpack equipment used in airborne concentration experiments. In order to reduce the possibility of breakthrough, two Nylasorb nylon filters are placed back to back in one stage. This is also done for the K_2CO_3-impregnated Whatman filters.

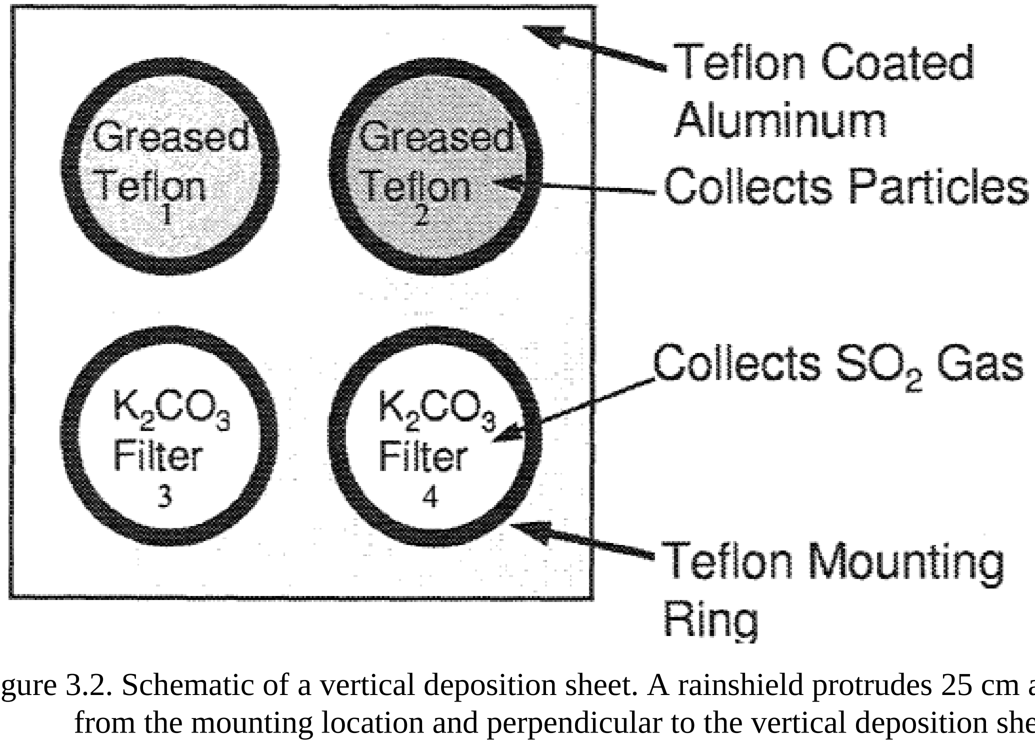


Figure 3.2. Schematic of a vertical deposition sheet. A rainshield protrudes 25 cm away from the mounting location and perpendicular to the vertical deposition sheet.

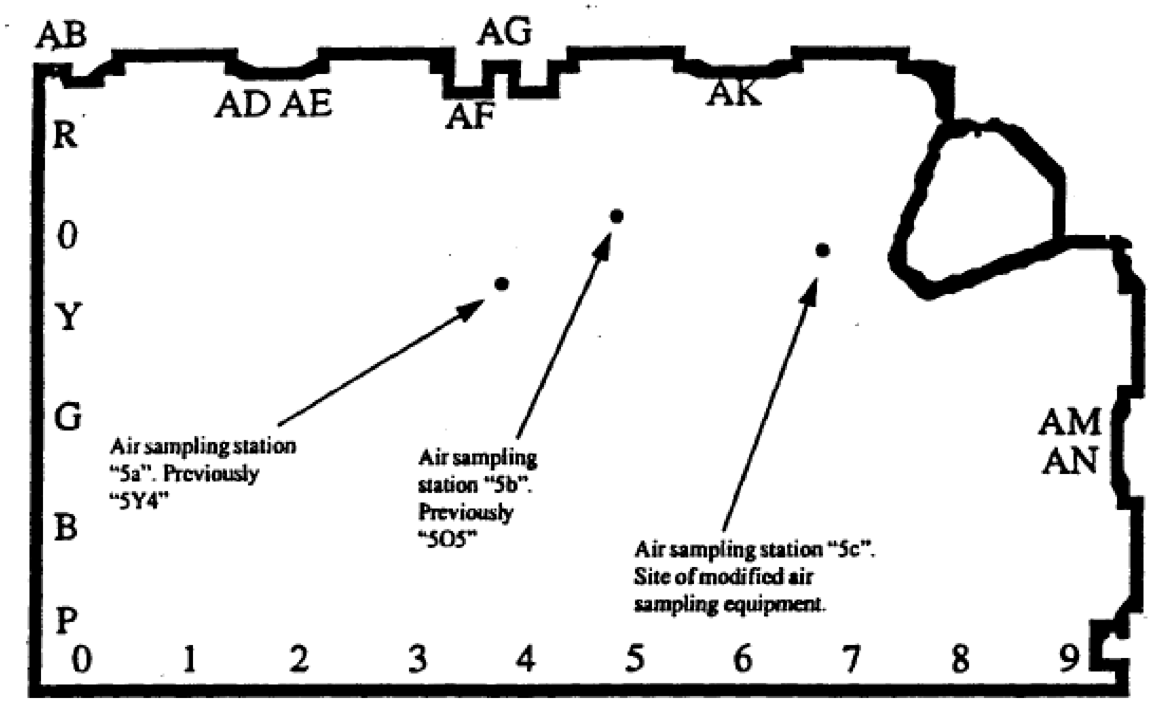


Figure 3.3. Locations of air sampling stations and vertical deposition sheets on the fifth floor patio of the Cathedral. Locations AB, AD, AE, AK, and AM were routinely used for the measurement of vertical deposition fluxes of NO_3 and SO_4 particles as well as SO_2 gas.

Chapter 4: Presentation of Chemical Data

Airborne concentration measurements for chemical species have been gradually phased in since December of 1992. Airborne concentrations of SO_4 and NO_3 particles have been measured since December 1, 1992. Carbon particle concentrations have been measured since March 27, 1993. Measurement of SO_2 and HNO_3 gas started on September 11, 1993. Continuous measurement of all of the above airborne species continued through July 6, 1995. Although some pilot scale tests had been conducted in October of 1993, we did not deploy surrogate vertical surfaces on a regular basis until April 18, 1994. Since then, measurements of the flux of SO_2 gas and SO_4 and NO_3 particles have been made continuously through July 6, 1995.

For each set of airborne concentration and vertical deposition flux samples, a field blank is deployed for a few minutes. The purpose of the field blank is to assure that measured values represent true quantities and not artifacts of the experimental method. The mass of a chemical species found on the field blanks is subtracted from the sample mass in an attempt to correct measured values for chemical species already present on the apparatus at the time of deployment. The field blank masses of SO_4 and NO_3 are shown in Tables 4.1 and 4.2 for the airborne concentration and vertical deposition flux measurements, respectively.

The final results for airborne concentrations appear in Table 4.3 . The evaporation of ammonium nitrate aerosol from the Teflon filter and the subsequent re-absorption by the Nylasorb filter may result in erroneous concentration measurements. Specifically, NO_3 particle concentrations may be underestimated whereas HNO_3 vapor concentrations may be overestimated. However, the total NO_3 concentration (NO_3 particles + HNO_3 vapor) is conserved. This value is reported under the column heading “Total NO_3 concentration” in Table 4.3 . More complete tables for the dates 12/1/92 to 6/30/94 which include results from replicate analyses, blank mass corrections, and the relevant formulas are available in Appendices B and C of the 1994 Progress Report. The same data for the period 6/30/94 to 7/6/95 are presented in Appendix B of this report.

The final results of flux measurements to vertical surrogate surfaces are given in Table 4.4 . NO_3 and SO_4 particle and SO_2 gas average airborne concentrations, deposition fluxes, and deposition velocities are summarized in Tables 4.5, 4.6, and 4.7 . The deposition velocity Vd is calculated according to

$$Vd = J/C \text{ where} \qquad (4.1)$$

J = average flux to the surrogate surface

C = average airborne concentration.

The standard deviation of the deposition velocity is calculated using Equation (4.2).

$$\sigma_v = \sqrt{\left(\frac{0.0116 \cdot \sigma_F}{C}\right)^2 + \left(\frac{0.0116 \cdot F \cdot \sigma_C}{C^2}\right)^2} \text{ where} \qquad (4.2)$$

σ_v= standard deviation of deposition velocity (cm/s)

σ_F= standard deviation of deposition flux (nglcm^2/day)

F = deposition flux ($ng/cm^2/day$)
σ_C = standard deviation of airborne concentration (ug/m^3)
C = time-weighted average airborne concentration (ug/m^3) over the deposition sampling period

Tables in Appendices B and C of the 1994 Progress Report document intermediate calculations of flux and airborne concentration in greater detail for the period 3/18/94 to 6/30/94. The same information for the period 6/30/94 to 7/6/95 is included in Appendix B of this report.

Table 4.1. SO_4 and NO_3 Mass on Airborne Concentration Field Blanks

sample	Zefluor Filters		Nylasorb Filters		Whatman Filters	
	NO3 mass (ug)^a	SO4 mass (ug)^b	NO3 mass (ug)^c	SO4 mass (ug)^d	NO3 mass (ug)^e	SO4 mass (ug)^f
07/07/94-5a blank	0^g	1.95	0.60	1.78	6.96	3.69
07/14/94-5b blank	0^g	0.76	1.03	2.35	1.46	22.60
07/21/94-5a blank	0.45	0.47	0.46	1.27	1.55	24.99
07/28/94-5b blank	0^g	0.40	0.65	0.84	0’	13.09
08/05/94-5a blank	0^g	1.55	0^h	0.88	0’	25.13
08/12/94-5b blank	0^g	2.01	0.48	1.22	6.30	21.73
08/18/94-5a blank	1.51	1.35	0^h	0.85	1.53	50.81
08/25/94-5b blank	1.75	0.84	1.26	1.61	0’	32.17
09/09/94-5a blank	0.65	0^g	1.19	1.84	23.85	0’
09/21/94-5b blank	0^g	0^g	1.72	1.75	30.27	3.60
10/10/94-5a blank	0.24	0^g	2.13	1.78	12.02	0’
10/19/94-5b blank	0.47	0^g	0^h	0.90	10.62	0’
10/28/94-5b blank	0^g	0^g	0^h	1.43	23.48	3.99
11/21/94-5a blank	0.74	0^g	0.33	1.10	45.58	0’
12/01/94-5a blank	0.32	0.58	0^h	0.91	29.34	4.58
12/19/94-5b blank	0.35	0.68	0^h	1.68	2.10	60.17
01/13/95-5a blank	0.94	0.61	0^h	1.11	7.61	26.20
01/20/95-5b blank	1.24	0.86	0^h	2.65	0’	0’
01/30/95-5a blank	0^g	0^g	0^h	1.29	1.94	0’
02/07/95-5b blank	0^g	0^g	0^h	1.09	0’	0’
02/14/95-5a blank	0^g	0.69	0^h	1.32	0’	0’
02/21/95-5b blank	1.45	0.63	0^h	0.89	2.06	3.46
02/28/95-5a blank	0.59	0^g	0^h	0.49	0’	5.58
03/07/95-5b blank	0.71	0.48	0^h	0.84	0	0’
03/14/95-5b blank	1.26	0^g	0.99	0.87	0.95	6.28
03/21/95-5a blank	0.80	0^g	0.43	0.84	1.84	5.98
03/28/95-5b blank	1.05	0.25	0.61	0.82	1.51	5.76
04/11/95-5b blank	0.76	0^g	0^h	0^h	0^l	0^l
04/11/95-5c blank	0.22	0.29	0^h	0^h	0^l	0^l
04/19/95-5a blank	0^l	0^l	0.38	0^h	0^l	0^l
04/19/95-5c blank	1.37	0.34	0.33	0^h	0^l	0^l
05/02/95-5a blank	1.32	0.81	0.42	1.33	0^l	0^l
05/02/95-5c blank	1.05	0.80	0.42	1.03	0^l	0^l
05/10/95-5b blank	0.55	1.83	0^h	0.62	0^l	0^l
05/10/95-5c blank	0.96	1.92	0^h	0.46	0^l	0^l
05/17/95-5a blank	2.15	1.76	0^h	0.45	0^l	0^l
05/17/95-5c blank	1.68	1.81	0^h	0.47	0^l	0^l
05/24/95-5b blank	0.58	1.88	0^h	0.49	0^l	0^l
05/24/95-5c blank	0.61	1.85	0^h	0.45	0^l	0^l
06/09/9S-5b blank	0.61	1.76	0^h	0.61	0^l	0^l
06/09/95-5c blank	0.32	1.69	0.26	0.88	0^l	0^l

Table 4.1. SO_4 and NO_3 Mass on Airborne Concentration Field Blanks

sample	Zefluor Filters		Nylasorb Filters		Whatman Filters	
	NO_3 mass (ug)[a]	SO_4 mass (ug)[b]	NO_3 mass (ug)[c]	SO_4 mass (ug)[d]	NO_3 mass (ug)[e]	SO_4 mass (ug)[f]
06/16/95-5b blank	0.62	0.41	0.27	0.36	0.91	0[I]
06/16/95-5c blank	0.62	0.51	0.48	0.41	1.40	0[I]
06/27/95-5b blank	0.61	0.36	0.72	0.80	1.31	0[I]
06/27/95-5c blank	0.39	0.27	0[h]	0[h]	1.62	0[I]

[a] Average NO_3 mass found on Zefluor blanks was 0.70 ± 0.55 ug.
[b] Average SO_4 mass found on Zefluor blanks was 0.80 ± 0.64 ug.
[c] Average NO_3 mass found on Nylasorb blanks was 0.61 ± 0.61 ug.
[d] Average SO_4 mass found on Nylasorb blanks was 0.98 ± 0.56 ug.
[e] Average NO_3 mass found on Whatman blanks was 5.2 ± 10.1 ug.
[f] Average SO_4 mass found on Whatman blanks was 7.8 ± 13.7 ug.
[g] IC detection limit of 1 ppb.
[h] IC detection limit of 2 ppb.
[I] IC detection burnt of 10 ppb.

Table 4.2. SO_4 and NO_3 mass on Vertical deposition flux field blanks

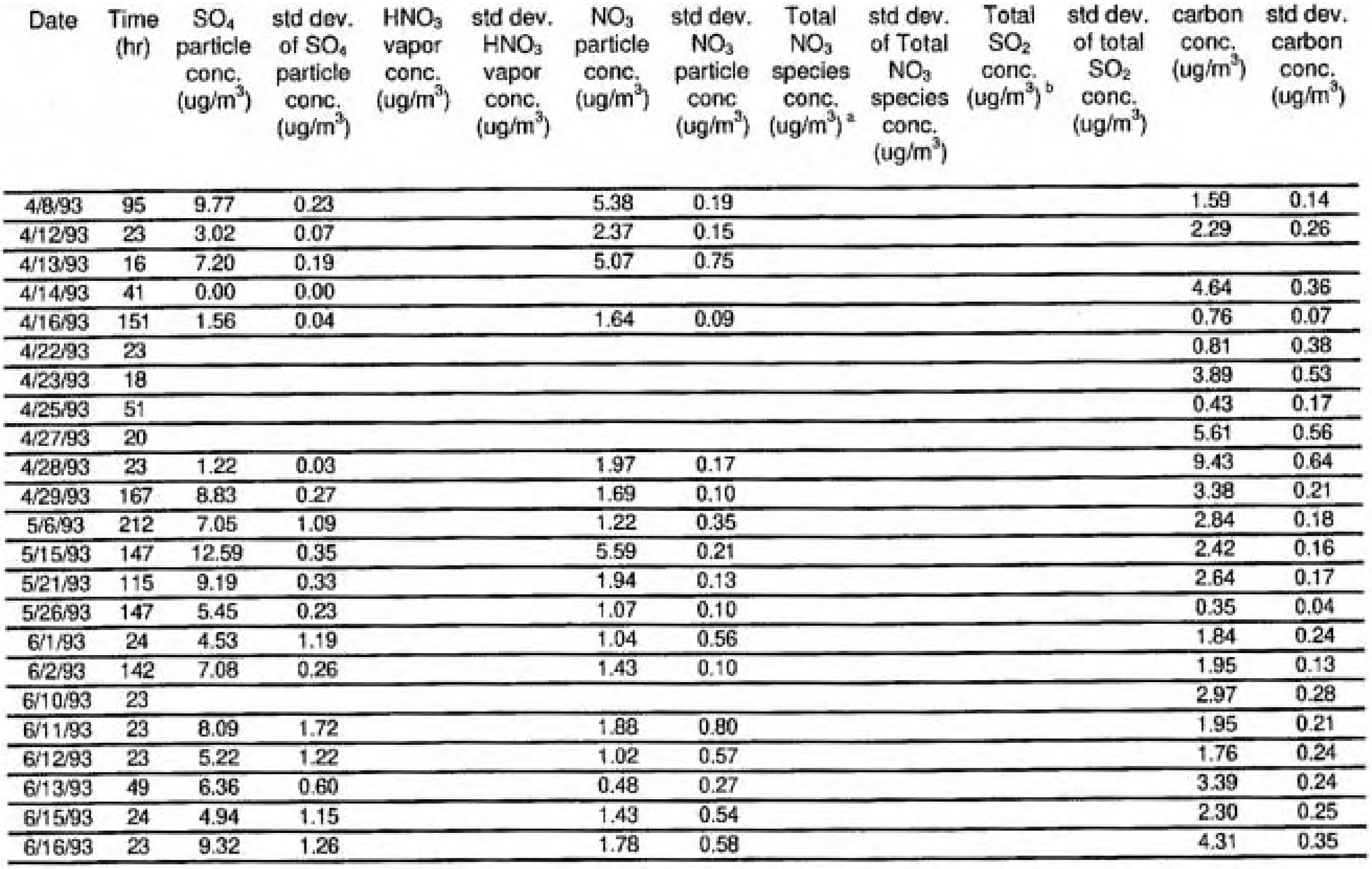
sample	Vertical Whatman Filters		Vertical Greased Teflon Sheets	
	NO3 mass (ug)[a]	SO4 mass (ug)[b]	NO3 mass (ug)[c]	SO4 mass (ug)[d]
06/30/94-ae-1,3-blank	0[f]	54.01	0.30	7.86
06/30/94-ae-2,4-blank	16.41	23.59	[e]	[e]
07/21/94-ag-1,3-blank	14.47	24.05	0.16	8.78
07/21/94-ag-2,4-blank	26.13	9.70	0.81	6.26
08/05/94-am-1,3-blank	17.98	33.98	1.15	10.73
08/05/94-am-2,4-blank	3.03	32.33	0.40	5.20
08/18/94-ak-1,3-blank	11.61	36.10	0.94	7.03
08/18/94-ak-2,4-blank	11.64	53.87	0.59	7.14
09/09/94-ae-1,3-blank	9.61	146.57	0.38	7.35
09/09/94-ae-2,4-blank	6.01	65.74	0.11	3.57
12/01/94-ag-1,3-blank	19.98	9.74	0.59	5.52
12/01/94-ag-2,4-blank	18.08	125.59	0.12	5.02
12/19/94-am-1,3-blank	10.38	0[f]	0.03	7.85
12/19/94-am-2,4-blank	13.06	6.92	0.53	7.46
01/30/95-ak-1,3-blank	13.47	0[f]	0.30	1.68
01/30/95-ak-2,4-blank	11.76	13.60	0.17	5.21
02/28/95-ae-1,3-blank	10.53	0[f]	[e]	[e]
02/28/95-ae-2,4-blank	7.4.8	0[f]	0.91	7.82
03/28/95-ad-1,3-blank	13.32	55.45	0.63	2.76
03/28/95-ad-2,4-blank	13.50	52.51	0.52	2.69
05/02/95-am-1,3-blank	8.84	18.71	1.49	1.00
05/02/95-am-2,4-blank	11.47	16.80	1.19	0.78
06/09/95-ad-1,3-blank	13.75	14.42	0.93	0.63
06/09/95-ad-2,4-blank	12.60	11.43	2.19	0.96

[a] Average NO_3 mass found on vertical Whatman filter blanks was 12.32 ± 5.33 ug.
[b] Average SO_4 mass found on vertical Whatman filter blanks was 40.25 ± 37.59 ug
[c] Average NO_3 mass found on vertical greased Teflon blanks was 0.62 ± 0.51 ug.
[d] Average SO_4 mass found on vertical greased Teflon blanks was 5.15 ± 2.85 ug.
[e] Sample volume was too small for analysis after mineral spirits evaporation.
[f] IC detection limit of 4 ppb.

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95

Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3)^a	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3)^b	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
12/1/92	169	3.71	0.23			3.68	0.37						
12/9/92	24	7.90	2.50			0.97	0.37						
12/10/92	95	3.28	0.18			1.95	0.09						
12/14/92	28	6.27	0.52			8.48	0.40						
12/15/92	188	7.66	0.31			3.74	0.23						
12/23/92	168	9.40	1.85			3.91	1.18						
12/30/92	215	6.72	0.72			1.89	0.29						
1/8/93	144	8.07	0.41			1.79	0.23						
1/14/93	192	7.52	1.05			1.51	0.35						
1/22/93	147	4.51	0.15			3.11	0.19						
1/28/93	120	4.74	1.07			2.65	0.39						
2/3/93	24	1.02	0.08			1.33	0.68						
2/5/93	26	1.86	1.33			1.74	1.07						
2/6/93	116	11.66	0.39			5.52	0.30						
2/11/93	167	6.54	0.15			2.17	0.10						
2/18/93	171	7.91	0.26			4.80	0.66						
2/25/93	187	11.03	3.52			5.18	2.39						
3/5/93	167	4.67	1.25			1.82	0.35						
3/12/93	167	5.04	0.34			1.35	0.12						
3/20/93	123	9.09	1.31			1.81	0.13						
3/27/93	71	12.81	0.30			2.69	0.19					1.49	0.15
3/31/93	30	10.54	6.87			1.94	0.86					5.90	0.47
4/1/93	144	0.28	0.03			1.58	0.14					1.83	0.13

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95

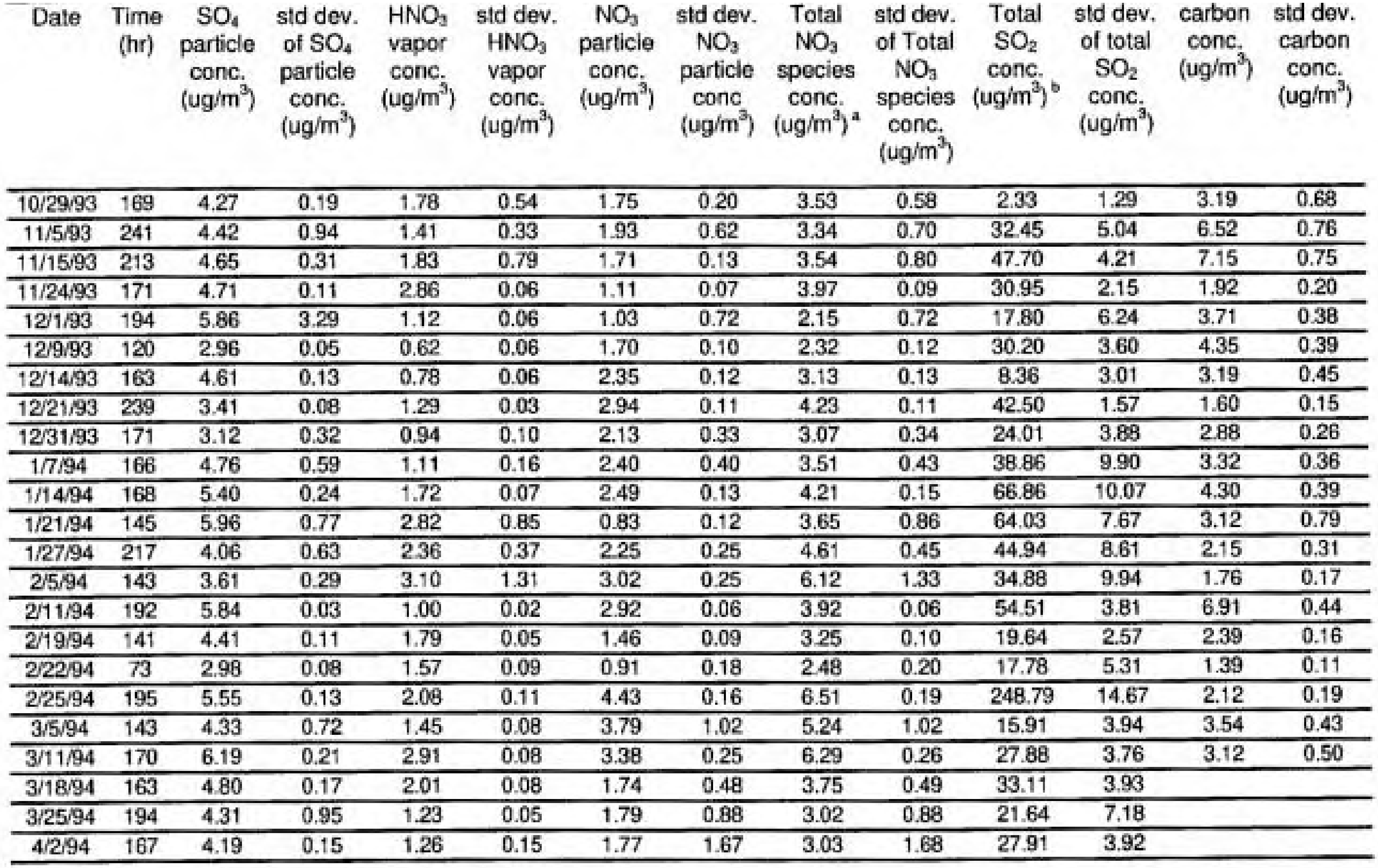


Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3) [a]	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3) [b]	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
4/8/93	95	9.77	0.23			5.38	0.19					1.59	0.14
4/12/93	23	3.02	0.07			2.37	0.15					2.29	0.26
4/13/93	16	7.20	0.19			5.07	0.75						
4/14/93	41	0.00	0.00									4.64	0.36
4/16/93	151	1.56	0.04			1.64	0.09					0.76	0.07
4/22/93	23											0.81	0.38
4/23/93	18											3.89	0.53
4/25/93	51											0.43	0.17
4/27/93	20											5.61	0.56
4/28/93	23	1.22	0.03			1.97	0.17					9.43	0.64
4/29/93	167	8.83	0.27			1.69	0.10					3.38	0.21
5/6/93	212	7.05	1.09			1.22	0.35					2.84	0.18
5/15/93	147	12.59	0.35			5.59	0.21					2.42	0.16
5/21/93	115	9.19	0.33			1.94	0.13					2.64	0.17
5/26/93	147	5.45	0.23			1.07	0.10					0.35	0.04
6/1/93	24	4.53	1.19			1.04	0.56					1.84	0.24
6/2/93	142	7.08	0.26			1.43	0.10					1.95	0.13
6/10/93	23											2.97	0.28
6/11/93	23	8.09	1.72			1.88	0.80					1.95	0.21
6/12/93	23	5.22	1.22			1.02	0.57					1.76	0.24
6/13/93	49	6.36	0.60			0.48	0.27					3.39	0.24
6/15/93	24	4.94	1.15			1.43	0.54					2.30	0.25
6/16/93	23	9.32	1.26			1.78	0.58					4.31	0.35

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95

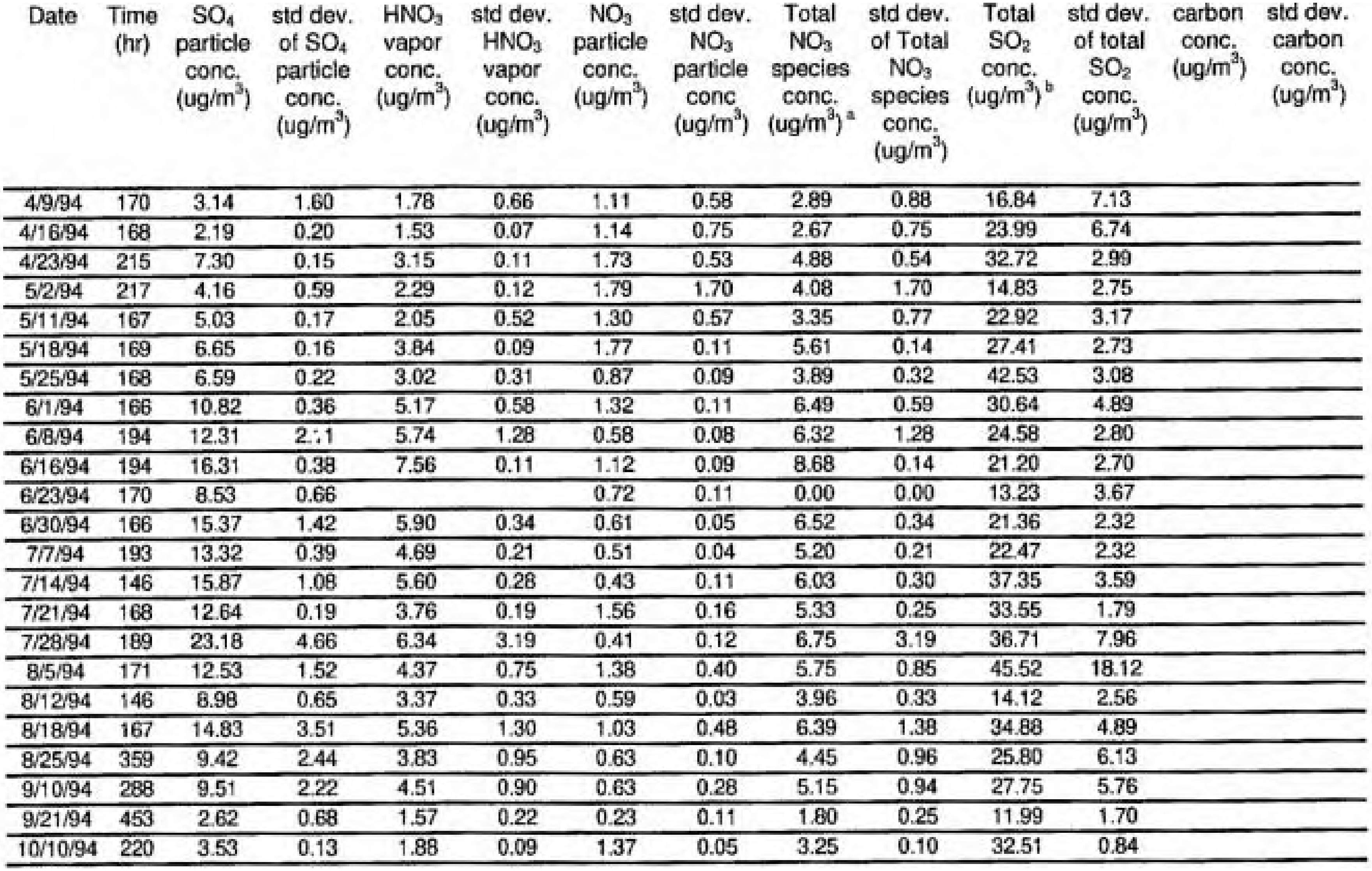
Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3)[a]	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3)[b]	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
6/17/93	23	28.00	1.59			1.95	0.57					13.59	0.64
6/18/93	96	14.95	0.46			1.08	0.14					1.99	0.14
6/22/93	24	4.23	1.16			1.37	0.54					2.82	0.87
6/23/93	47	7.89	0.63			0.73	0.28					3.75	0.26
6/25/93	143	9.44	0.30			1.37	0.10					2.05	0.13
7/8/93	171	16.40	0.42			1.00	0.08					2.27	0.15
7/15/93	73	2.04	0.39			0.48	0.18					1.33	0.18
7/18/93	71	14.82	0.53			1.27	0.19					3.45	0.23
7/21/93	191	4.79	3.12			0.43	0.19					3.00	1.18
7/25/93	95	6.76	0.33			0.55	0.14					4.50	0.25
7/29/93	92											2.01	0.20
8/2/93	99	7.59	0.47			1.61	0.20					2.89	0.27
8/6/93	143	14.51	0.39			0.76	0.09					4.05	0.26
8/12/93	188	7.98	0.24			0.49	0.07					3.49	0.22
8/20/93	242	3.93	0.15			0.17	0.05					4.07	0.23
8/30/93	219	8.88	0.24			0.49	0.06					2.85	0.53
9/8/93	191	8.54	0.25			1.13	0.09						
9/11/93	24	2.46	1.62	1.81	0.38	1.80	0.86	3.61	0.94	25.05	20.46	5.32	0.76
9/13/93	192	5.94	0.43	1.19	0.69	1.66	1.54	2.85	1.69	27.83	20.57	3.46	0.31
9/21/93	237	6.30	0.15	1.21	0.52	1.48	0.97	2.69	1.10	19.58	3.15	2.81	0.28
10/1/93	167	6.34	0.36	2.72	0.39	1.04	0.29	3.76	0.49	40.90	12.79	4.20	0.58
10/8/93	293	7.40	0.40	2.70	0.22	1.67	0.29	4.37	0.36	27.68	4.97	3.48	0.69
10/20/93	213	5.00	1.92	2.43	0.30	1.81	0.25	4.24	0.39	66.57	5.95	8.66	0.53

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95



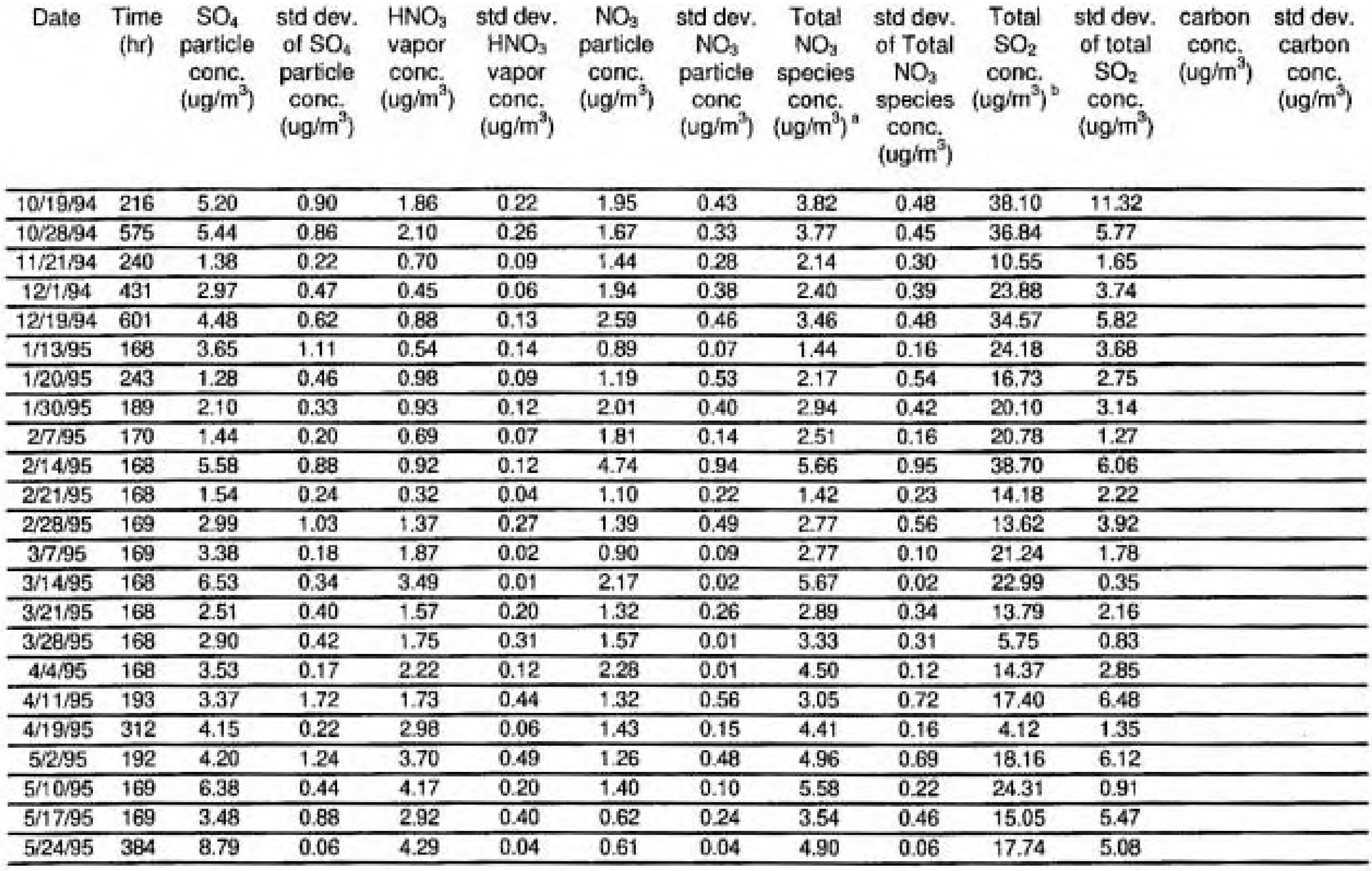
Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3)[a]	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3)[b]	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
10/29/93	169	4.27	0.19	1.78	0.54	1.75	0.20	3.53	0.58	2.33	1.29	3.19	0.68
11/5/93	241	4.42	0.94	1.41	0.33	1.93	0.62	3.34	0.70	32.45	5.04	6.52	0.76
11/15/93	213	4.65	0.31	1.83	0.79	1.71	0.13	3.54	0.80	47.70	4.21	7.15	0.75
11/24/93	171	4.71	0.11	2.86	0.06	1.11	0.07	3.97	0.09	30.95	2.15	1.92	0.20
12/1/93	194	5.86	3.29	1.12	0.06	1.03	0.72	2.15	0.72	17.80	6.24	3.71	0.38
12/9/93	120	2.96	0.05	0.62	0.06	1.70	0.10	2.32	0.12	30.20	3.60	4.35	0.39
12/14/93	163	4.61	0.13	0.78	0.06	2.35	0.12	3.13	0.13	8.36	3.01	3.19	0.45
12/21/93	239	3.41	0.08	1.29	0.03	2.94	0.11	4.23	0.11	42.50	1.57	1.60	0.15
12/31/93	171	3.12	0.32	0.94	0.10	2.13	0.33	3.07	0.34	24.01	3.88	2.88	0.26
1/7/94	166	4.76	0.59	1.11	0.16	2.40	0.40	3.51	0.43	38.86	9.90	3.32	0.36
1/14/94	168	5.40	0.24	1.72	0.07	2.49	0.13	4.21	0.15	66.86	10.07	4.30	0.39
1/21/94	145	5.96	0.77	2.82	0.85	0.83	0.12	3.65	0.86	64.03	7.67	3.12	0.79
1/27/94	217	4.06	0.63	2.36	0.37	2.25	0.25	4.61	0.45	44.94	8.61	2.15	0.31
2/5/94	143	3.61	0.29	3.10	1.31	3.02	0.25	6.12	1.33	34.88	9.94	1.76	0.17
2/11/94	192	5.84	0.03	1.00	0.02	2.92	0.06	3.92	0.06	54.51	3.81	6.91	0.44
2/19/94	141	4.41	0.11	1.79	0.05	1.46	0.09	3.25	0.10	19.64	2.57	2.39	0.16
2/22/94	73	2.98	0.08	1.57	0.09	0.91	0.18	2.48	0.20	17.78	5.31	1.39	0.11
2/25/94	195	5.55	0.13	2.08	0.11	4.43	0.16	6.51	0.19	248.79	14.67	2.12	0.19
3/5/94	143	4.33	0.72	1.45	0.08	3.79	1.02	5.24	1.02	15.91	3.94	3.54	0.43
3/11/94	170	6.19	0.21	2.91	0.08	3.38	0.25	6.29	0.26	27.88	3.76	3.12	0.50
3/18/94	163	4.80	0.17	2.01	0.08	1.74	0.48	3.75	0.49	33.11	3.93		
3/25/94	194	4.31	0.95	1.23	0.05	1.79	0.88	3.02	0.88	21.64	7.18		
4/2/94	167	4.19	0.15	1.26	0.15	1.77	1.67	3.03	1.68	27.91	3.92		

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95



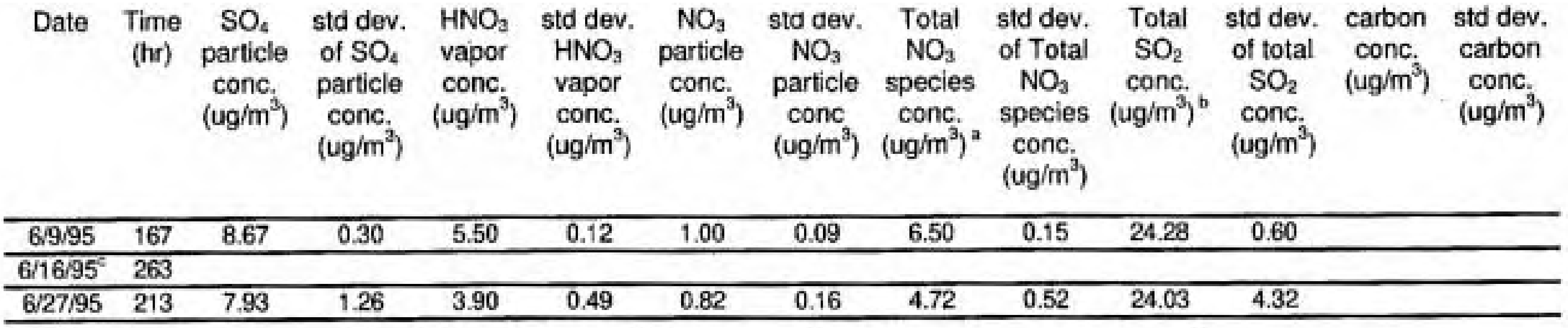
Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3) [a]	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3) [b]	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
4/9/94	170	3.14	1.60	1.78	0.66	1.11	0.58	2.89	0.88	16.84	7.13		
4/16/94	168	2.19	0.20	1.53	0.07	1.14	0.75	2.67	0.75	23.99	6.74		
4/23/94	215	7.30	0.15	3.15	0.11	1.73	0.53	4.88	0.54	32.72	2.99		
5/2/94	217	4.16	0.59	2.29	0.12	1.79	1.70	4.08	1.70	14.83	2.75		
5/11/94	167	5.03	0.17	2.05	0.52	1.30	0.57	3.35	0.77	22.92	3.17		
5/18/94	169	6.65	0.16	3.84	0.09	1.77	0.11	5.61	0.14	27.41	2.73		
5/25/94	168	6.59	0.22	3.02	0.31	0.87	0.09	3.89	0.32	42.53	3.08		
6/1/94	166	10.82	0.36	5.17	0.58	1.32	0.11	6.49	0.59	30.64	4.89		
6/8/94	194	12.31	2.11	5.74	1.28	0.58	0.08	6.32	1.28	24.58	2.80		
6/16/94	194	16.31	0.38	7.56	0.11	1.12	0.09	8.68	0.14	21.20	2.70		
6/23/94	170	8.53	0.66			0.72	0.11	0.00	0.00	13.23	3.67		
6/30/94	166	15.37	1.42	5.90	0.34	0.61	0.05	6.52	0.34	21.36	2.32		
7/7/94	193	13.32	0.39	4.69	0.21	0.51	0.04	5.20	0.21	22.47	2.32		
7/14/94	146	15.87	1.08	5.60	0.28	0.43	0.11	6.03	0.30	37.35	3.59		
7/21/94	168	12.64	0.19	3.76	0.19	1.56	0.16	5.33	0.25	33.55	1.79		
7/28/94	189	23.18	4.66	6.34	3.19	0.41	0.12	6.75	3.19	36.71	7.96		
8/5/94	171	12.53	1.52	4.37	0.75	1.38	0.40	5.75	0.85	45.52	18.12		
8/12/94	146	6.98	0.65	3.37	0.33	0.59	0.03	3.96	0.33	14.12	2.56		
8/18/94	167	14.83	3.51	5.36	1.30	1.03	0.48	6.39	1.38	34.88	4.89		
8/25/94	359	9.42	2.44	3.83	0.95	0.63	0.10	4.45	0.96	25.80	6.13		
9/10/94	288	9.51	2.22	4.51	0.90	0.63	0.28	5.15	0.94	27.75	5.76		
9/21/94	453	2.62	0.68	1.57	0.22	0.23	0.11	1.80	0.25	11.99	1.70		
10/10/94	220	3.53	0.13	1.88	0.09	1.37	0.05	3.25	0.10	32.51	0.84		

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95



Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3) [a]	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3) [b]	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
10/19/94	216	5.20	0.90	1.86	0.22	1.95	0.43	3.82	0.48	38.10	11.32		
10/28/94	575	5.44	0.86	2.10	0.26	1.67	0.33	3.77	0.45	36.84	5.77		
11/21/94	240	1.38	0.22	0.70	0.09	1.44	0.28	2.14	0.30	10.55	1.65		
12/1/94	431	2.97	0.47	0.45	0.06	1.94	0.38	2.40	0.39	23.88	3.74		
12/19/94	601	4.48	0.62	0.88	0.13	2.59	0.46	3.46	0.48	34.57	5.82		
1/13/95	168	3.65	1.11	0.54	0.14	0.89	0.07	1.44	0.16	24.18	3.68		
1/20/95	243	1.28	0.46	0.98	0.09	1.19	0.53	2.17	0.54	16.73	2.75		
1/30/95	189	2.10	0.33	0.93	0.12	2.01	0.40	2.94	0.42	20.10	3.14		
2/7/95	170	1.44	0.20	0.69	0.07	1.81	0.14	2.51	0.16	20.78	1.27		
2/14/95	168	5.58	0.88	0.92	0.12	4.74	0.94	5.66	0.95	38.70	6.06		
2/21/95	168	1.54	0.24	0.32	0.04	1.10	0.22	1.42	0.23	14.18	2.22		
2/28/95	169	2.99	1.03	1.37	0.27	1.39	0.49	2.77	0.56	13.62	3.92		
3/7/95	169	3.38	0.18	1.87	0.02	0.90	0.09	2.77	0.10	21.24	1.78		
3/14/95	168	6.53	0.34	3.49	0.01	2.17	0.02	5.67	0.02	22.99	0.35		
3/21/95	168	2.51	0.40	1.57	0.20	1.32	0.26	2.89	0.34	13.79	2.16		
3/28/95	168	2.90	0.42	1.75	0.31	1.57	0.01	3.33	0.31	5.75	0.83		
4/4/95	168	3.53	0.17	2.22	0.12	2.28	0.01	4.50	0.12	14.37	2.85		
4/11/95	193	3.37	1.72	1.73	0.44	1.32	0.56	3.05	0.72	17.40	6.48		
4/19/95	312	4.15	0.22	2.98	0.06	1.43	0.15	4.41	0.16	4.12	1.35		
5/2/95	192	4.20	1.24	3.70	0.49	1.26	0.48	4.96	0.69	18.16	6.12		
5/10/95	169	6.38	0.44	4.17	0.20	1.40	0.10	5.58	0.22	24.31	0.91		
5/17/95	169	3.48	0.88	2.92	0.40	0.62	0.24	3.54	0.46	15.05	5.47		
5/24/95	384	8.79	0.06	4.29	0.04	0.61	0.04	4.90	0.06	17.74	5.08		

Table 4.3. Airborne concentration species for the fifth floor from 12/1/92 to 6/27/95



Date	Time (hr)	SO_4 particle conc. (ug/m^3)	std dev. of SO_4 particle conc. (ug/m^3)	HNO_3 vapor conc. (ug/m^3)	std dev. HNO_3 vapor conc. (ug/m^3)	NO_3 particle conc. (ug/m^3)	std dev. NO_3 particle conc (ug/m^3)	Total NO_3 species conc. (ug/m^3) [a]	std dev. of Total NO_3 species conc. (ug/m^3)	Total SO_2 conc. (ug/m^3) [b]	std dev. of total SO_2 conc. (ug/m^3)	carbon conc. (ug/m^3)	std dev. carbon conc. (ug/m^3)
6/9/95	167	8.67	0.30	5.50	0.12	1.00	0.09	6.50	0.15	24.28	0.60		
6/16/95[c]	263												
6/27/95	213	7.93	1.26	3.90	0.49	0.82	0.16	4.72	0.52	24.03	4.32		

[a] Total NO_3 concentration = NO_3 particle concentration found on Zefluor filter + HNO_3 concentration on Nylasorb filter.

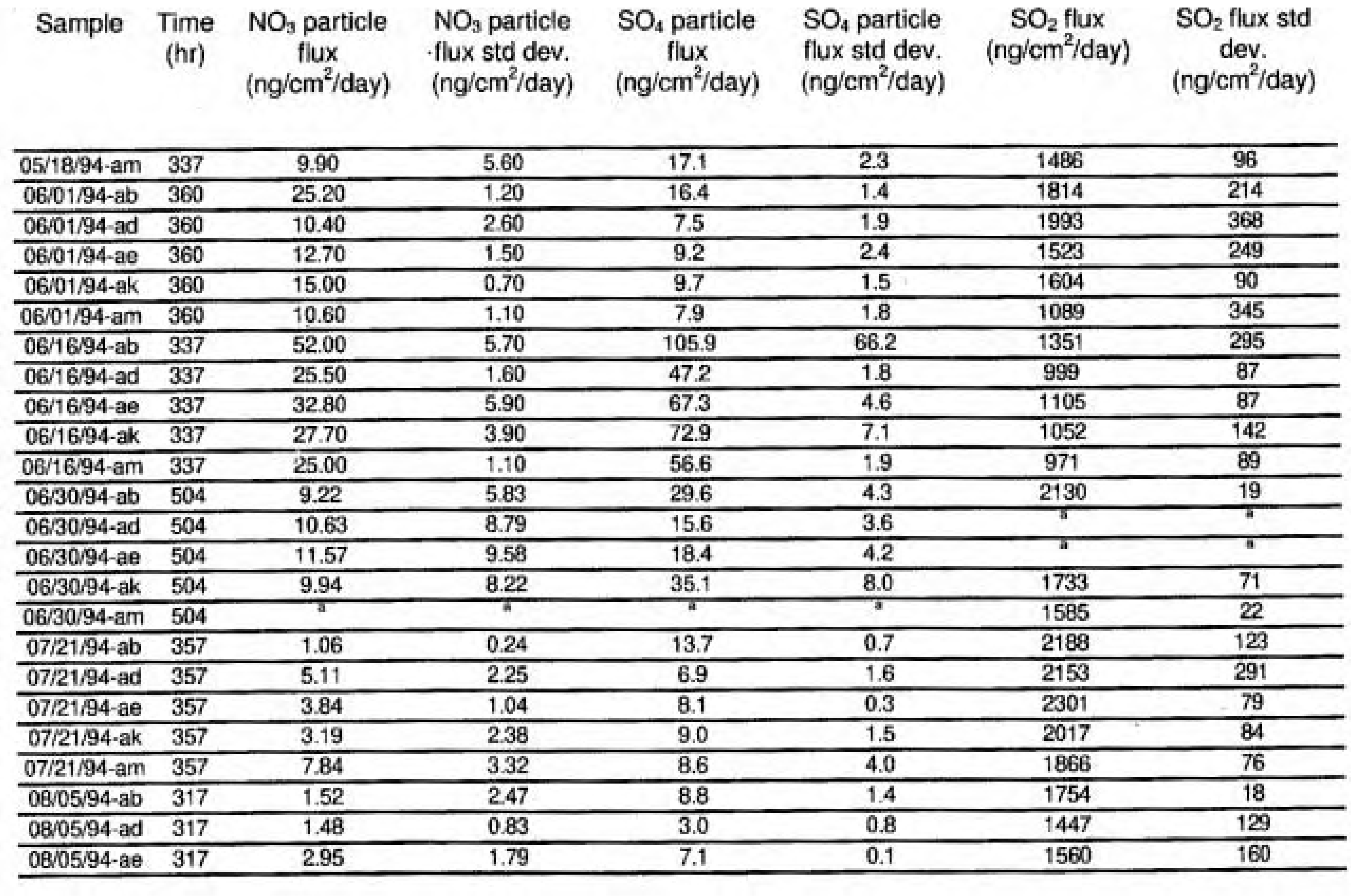
[b] total SO_2 concentraqtion = SO_4 concentration on Nylasorb filter + SO_4 concentration on Whatman filter

[c] Samples were lost due to a power outage at the Cathedral.

Table 4.4. Vertical Deposition Fluxes for the Period 3/18/94 to 6/9/95

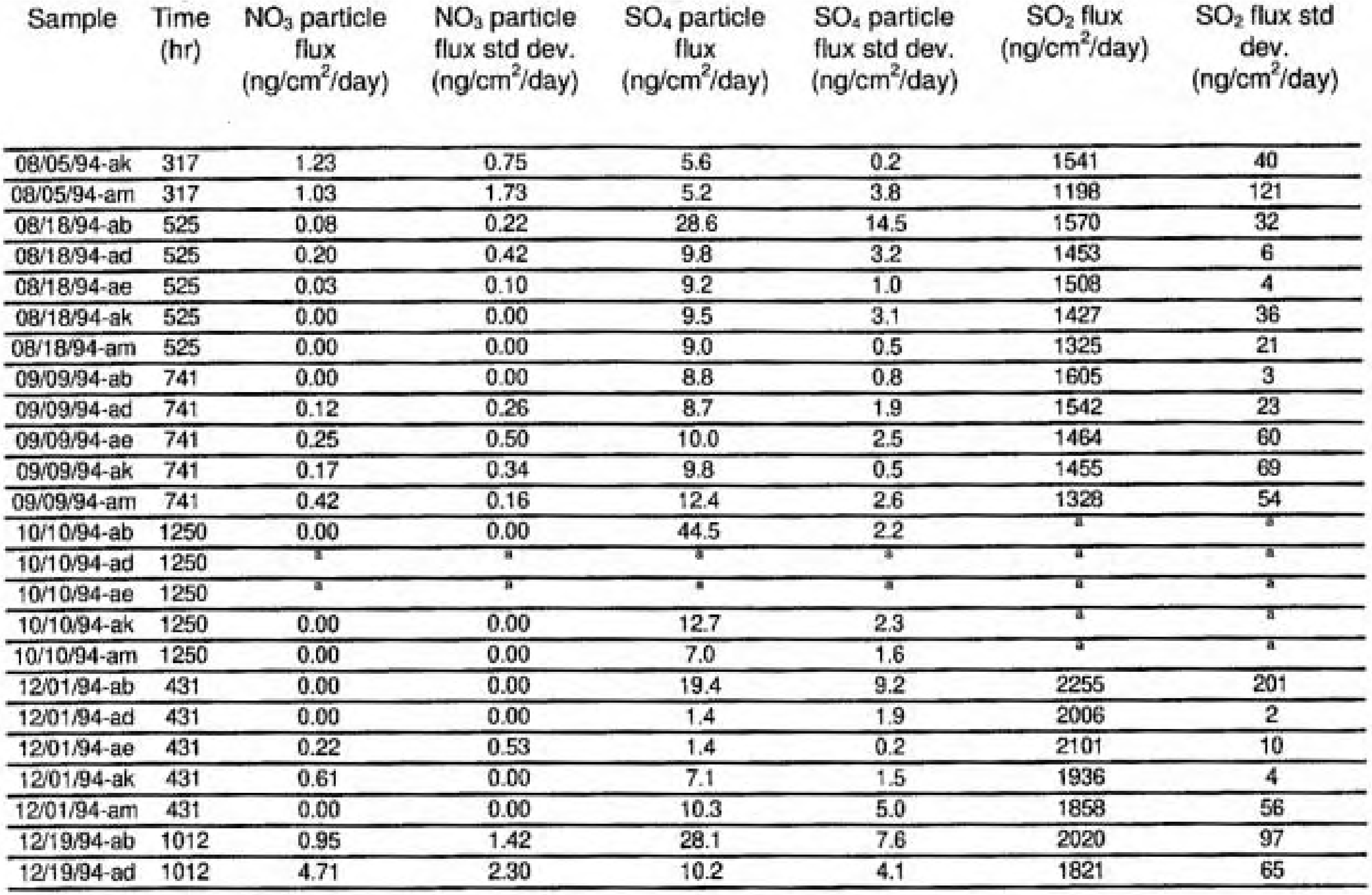
Sample	Time (hr)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	SO_4 particle flux (ng/cm^2/day)	SO_4 particle flux std dev. (ng/cm^2/day)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)
03/18/94-ab	358	16.30	9.30	28.9	1.7	964	80
03/18/94-ad	358	8.90	1.30	21.5	3.3	930	125
03/18/94-ae	358	16.30	3.30	23.4	5.2	2507	17
03/18/94-ak	358	5.60	1.10	11.8	1.8	883	108
03/18/94-am	358	24.10	18.80	12.0	2.9	800	52
04/02/94-ab	337	20.20	1.90	50.2	3.2	2479	192
04/02/94-ad	337	12.50	6.30	30.4	4.0	2327	62
04/02/94-ae	337	[a]	[a]	[a]	[a]	[a]	[a]
04/02/94-ak	337	14.40	4.00	43.0	3.6	2379	294
04/02/94-am	337	11.70	3.30	31.3	9.6	2597	208
04/16/94-ab	383	16.40	2.10	38.2	4.8	2125	50
04/16/94-ad	383	10.40	5.70	22.7	2.9	2296	20
04/16/94-ae	383	16.50	3.10	27.4	2.4	2217	171
04/16/94-ak	383	15.40	1.30	27.2	5.6	2042	53
04/16/94-am	383	11.00	5.30	22.2	2.1	1969	148
05/02/94-ab	384	17.00	1.60	17.1	3.7	1532	78
05/02/94-ad	384	10.70	2.20	9.8	1.7	1216	73
05/02/94-ae	384	11.80	4.00	11.0	1.7	1881	361
05/02/94-ak	384	9.70	1.60	7.0	1.9	1272	76
05/02/94-am	384	11.30	1.10	7.0	1.6	1211	67
05/18/94-ab	337	15.40	2.40	22.9	2.1	1703	93
05/18/94-ad	337	11.10	1.90	16.9	2.0	1721	12
05/18/94-ae	337	9.80	2.30	16.3	2.9	1722	99
05/18/94-ak	337	9.60	2.00	12.6	3.1	1669	106

Table 4.4. Vertical Deposition Fluxes for the Period 3/18/94 to 6/9/95



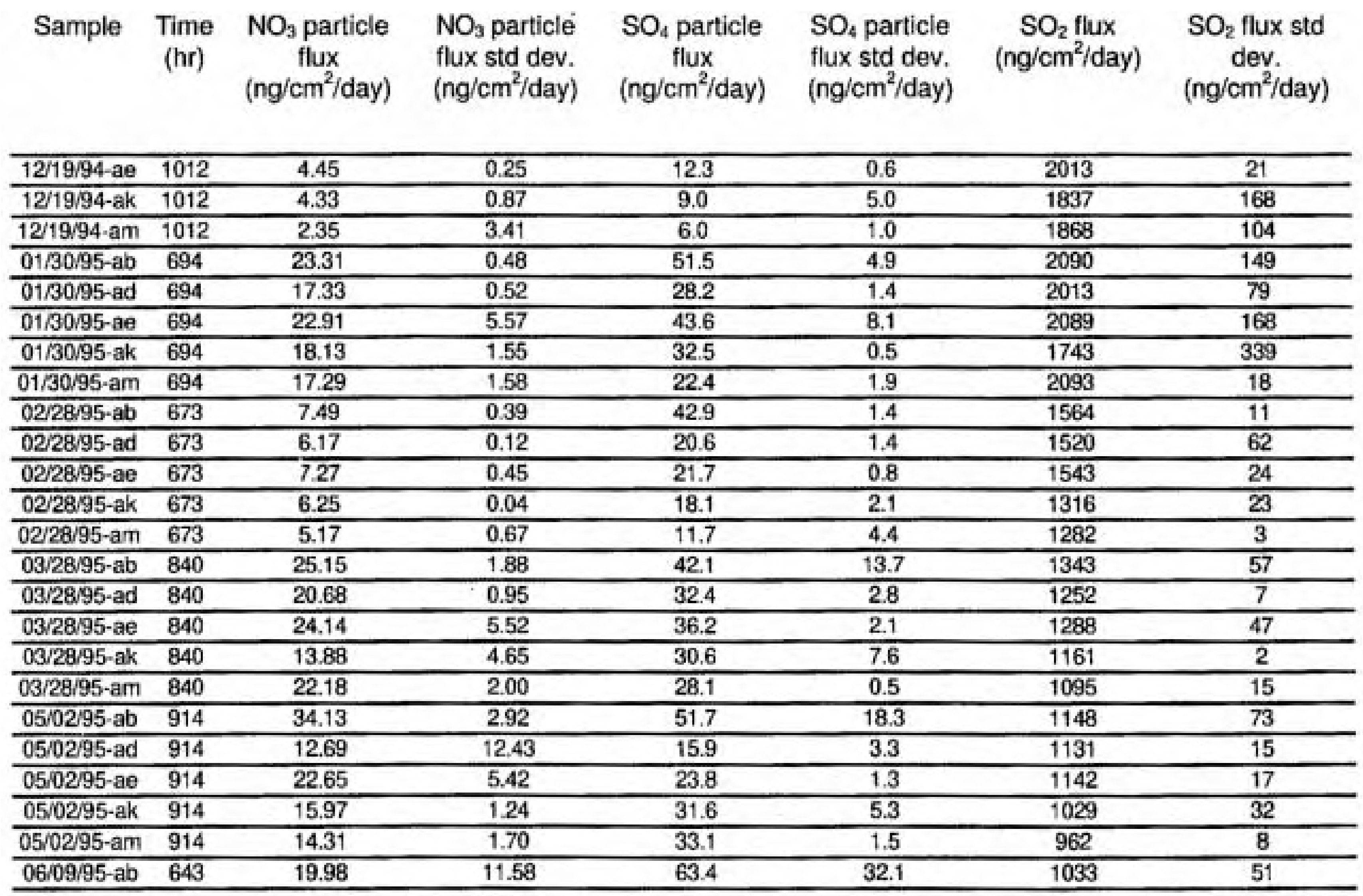
Sample	Time (hr)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	SO_4 particle flux (ng/cm^2/day)	SO_4 particle flux std dev. (ng/cm^2/day)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)
05/18/94-am	337	9.90	5.60	17.1	2.3	1486	96
06/01/94-ab	360	25.20	1.20	16.4	1.4	1814	214
06/01/94-ad	360	10.40	2.60	7.5	1.9	1993	368
06/01/94-ae	360	12.70	1.50	9.2	2.4	1523	249
06/01/94-ak	360	15.00	0.70	9.7	1.5	1604	90
06/01/94-am	360	10.60	1.10	7.9	1.8	1089	345
06/16/94-ab	337	52.00	5.70	105.9	66.2	1351	295
06/16/94-ad	337	25.50	1.60	47.2	1.8	999	87
06/16/94-ae	337	32.80	5.90	67.3	4.6	1105	87
06/16/94-ak	337	27.70	3.90	72.9	7.1	1052	142
06/16/94-am	337	25.00	1.10	56.6	1.9	971	89
06/30/94-ab	504	9.22	5.83	29.6	4.3	2130	19
06/30/94-ad	504	10.63	8.79	15.6	3.6	[a]	[a]
06/30/94-ae	504	11.57	9.58	18.4	4.2	[a]	[a]
06/30/94-ak	504	9.94	8.22	35.1	8.0	1733	71
06/30/94-am	504	[a]	[a]	[a]	[a]	1585	22
07/21/94-ab	357	1.06	0.24	13.7	0.7	2188	123
07/21/94-ad	357	5.11	2.25	6.9	1.6	2153	291
07/21/94-ae	357	3.84	1.04	8.1	0.3	2301	79
07/21/94-ak	357	3.19	2.38	9.0	1.5	2017	84
07/21/94-am	357	7.84	3.32	8.6	4.0	1866	76
08/05/94-ab	317	1.52	2.47	8.8	1.4	1754	18
08/05/94-ad	317	1.48	0.83	3.0	0.8	1447	129
08/05/94-ae	317	2.95	1.79	7.1	0.1	1560	160

Table 4.4. Vertical Deposition Fluxes for the Period 3/18/94 to 6/9/95



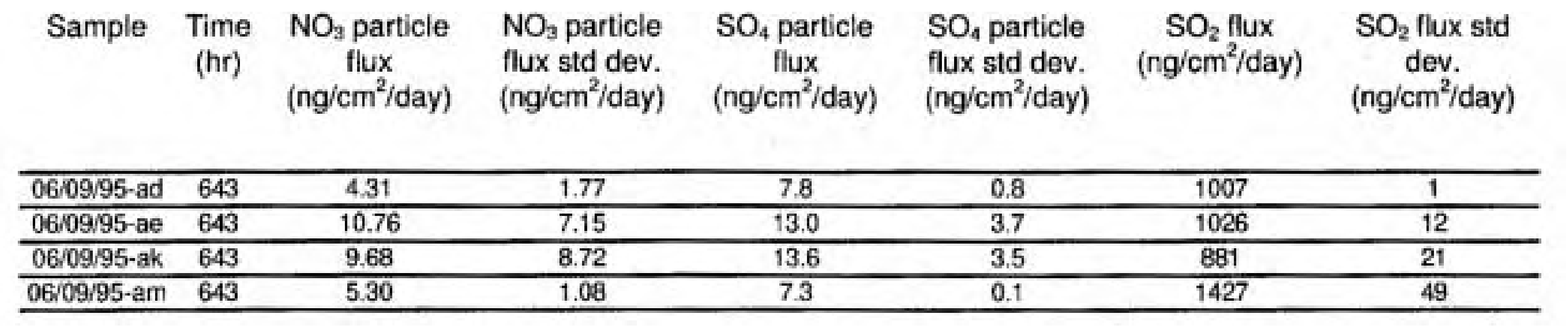
Sample	Time (hr)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	SO_4 particle flux (ng/cm^2/day)	SO_4 particle flux std dev. (ng/cm^2/day)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)
08/05/94-ak	317	1.23	0.75	5.6	0.2	1541	40
08/05/94-am	317	1.03	1.73	5.2	3.8	1198	121
08/18/94-ab	525	0.08	0.22	28.6	14.5	1570	32
08/18/94-ad	525	0.20	0.42	9.8	3.2	1453	6
08/18/94-ae	525	0.03	0.10	9.2	1.0	1508	4
08/18/94-ak	525	0.00	0.00	9.5	3.1	1427	36
08/18/94-am	525	0.00	0.00	9.0	0.5	1325	21
09/09/94-ab	741	0.00	0.00	8.8	0.8	1605	3
09/09/94-ad	741	0.12	0.26	8.7	1.9	1542	23
09/09/94-ae	741	0.25	0.50	10.0	2.5	1464	60
09/09/94-ak	741	0.17	0.34	9.8	0.5	1455	69
09/09/94-am	741	0.42	0.16	12.4	2.6	1328	54
10/10/94-ab	1250	0.00	0.00	44.5	2.2	^{a}	^{a}
10/10/94-ad	1250	^{a}	^{a}	^{a}	^{a}	^{a}	^{a}
10/10/94-ae	1250	^{a}	^{a}	^{a}	^{a}	^{a}	^{a}
10/10/94-ak	1250	0.00	0.00	12.7	2.3	^{a}	^{a}
10/10/94-am	1250	0.00	0.00	7.0	1.6	^{a}	^{a}
12/01/94-ab	431	0.00	0.00	19.4	9.2	2255	201
12/01/94-ad	431	0.00	0.00	1.4	1.9	2006	2
12/01/94-ae	431	0.22	0.53	1.4	0.2	2101	10
12/01/94-ak	431	0.61	0.00	7.1	1.5	1936	4
12/01/94-am	431	0.00	0.00	10.3	5.0	1858	56
12/19/94-ab	1012	0.95	1.42	28.1	7.6	2020	97
12/19/94-ad	1012	4.71	2.30	10.2	4.1	1821	65

Table 4.4. Vertical Deposition Fluxes for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	SO_4 particle flux (ng/cm^2/day)	SO_4 particle flux std dev. (ng/cm^2/day)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)
12/19/94-ae	1012	4.45	0.25	12.3	0.6	2013	21
12/19/94-ak	1012	4.33	0.87	9.0	5.0	1837	168
12/19/94-am	1012	2.35	3.41	6.0	1.0	1868	104
01/30/95-ab	694	23.31	0.48	51.5	4.9	2090	149
01/30/95-ad	694	17.33	0.52	28.2	1.4	2013	79
01/30/95-ae	694	22.91	5.57	43.6	8.1	2089	168
01/30/95-ak	694	18.13	1.55	32.5	0.5	1743	339
01/30/95-am	694	17.29	1.58	22.4	1.9	2093	18
02/28/95-ab	673	7.49	0.39	42.9	1.4	1564	11
02/28/95-ad	673	6.17	0.12	20.6	1.4	1520	62
02/28/95-ae	673	7.27	0.45	21.7	0.8	1543	24
02/28/95-ak	673	6.25	0.04	18.1	2.1	1316	23
02/28/95-am	673	5.17	0.67	11.7	4.4	1282	3
03/28/95-ab	840	25.15	1.88	42.1	13.7	1343	57
03/28/95-ad	840	20.68	0.95	32.4	2.8	1252	7
03/28/95-ae	840	24.14	5.52	36.2	2.1	1288	47
03/28/95-ak	840	13.88	4.65	30.6	7.6	1161	2
03/28/95-am	840	22.18	2.00	28.1	0.5	1095	15
05/02/95-ab	914	34.13	2.92	51.7	18.3	1148	73
05/02/95-ad	914	12.69	12.43	15.9	3.3	1131	15
05/02/95-ae	914	22.65	5.42	23.8	1.3	1142	17
05/02/95-ak	914	15.97	1.24	31.6	5.3	1029	32
05/02/95-am	914	14.31	1.70	33.1	1.5	962	8
06/09/95-ab	643	19.98	11.58	63.4	32.1	1033	51

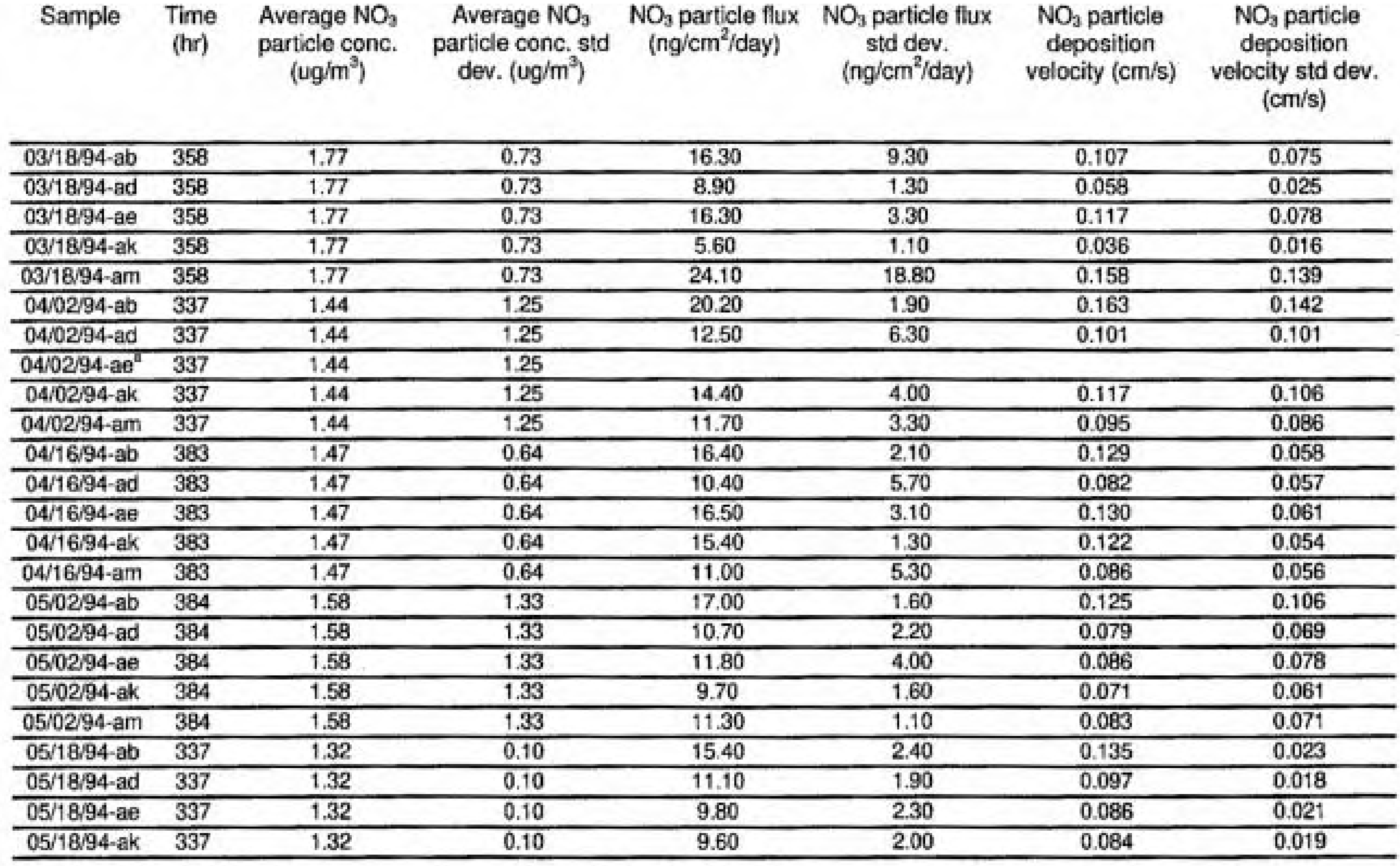
Table 4.4. Vertical Deposition Fluxes for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	SO_4 particle flux (ng/cm^2/day)	SO_4 particle flux std dev. (ng/cm^2/day)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)
06/09/95-ad	643	4.31	1.77	7.8	0.8	1007	1
06/09/95-ae	643	10.76	7.15	13.0	3.7	1026	12
06/09/95-ak	643	9.68	8.72	13.6	3.5	881	21
06/09/95-am	643	5.30	1.08	7.3	0.1	1427	49

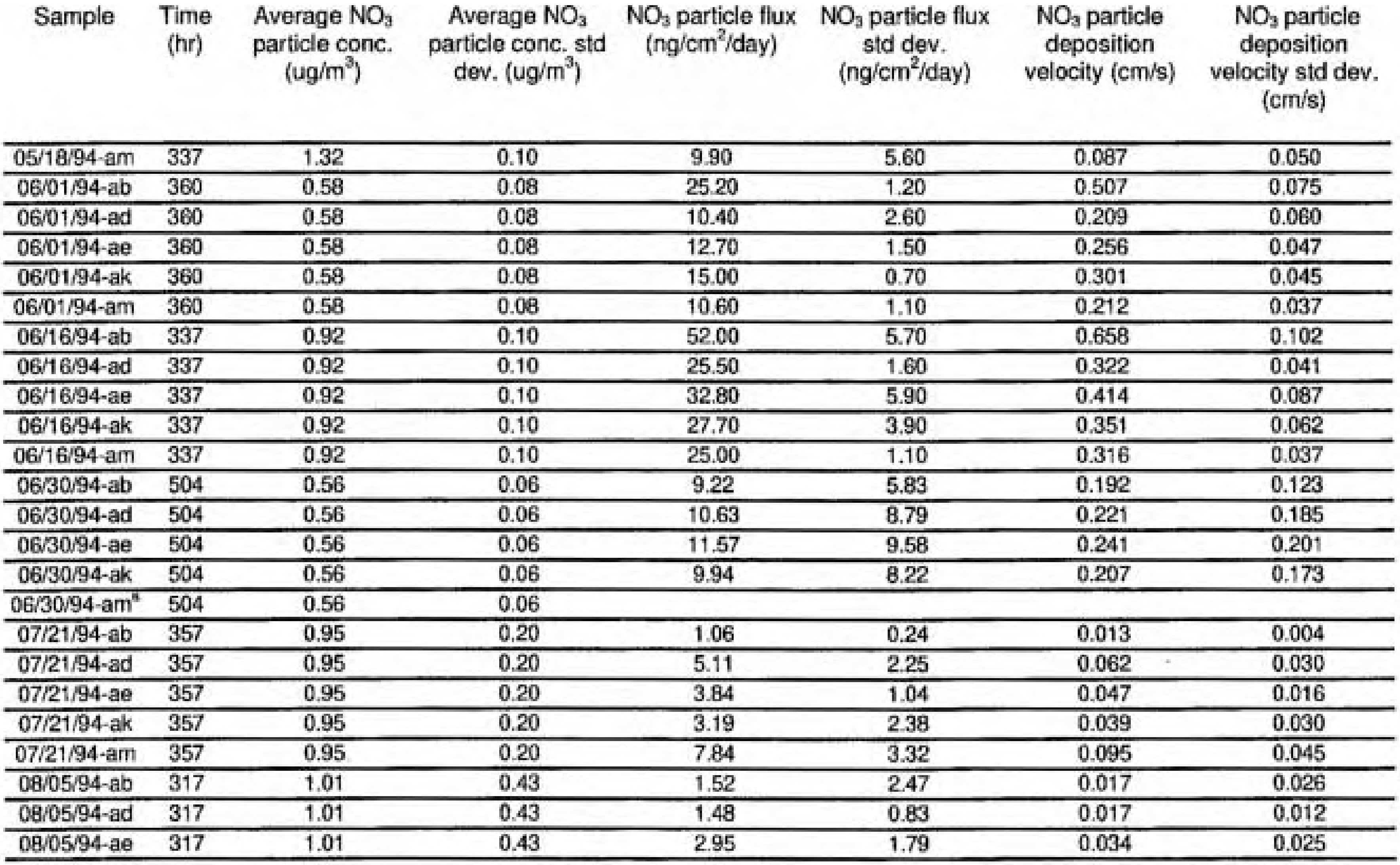
[a] The sample was lost during exposure period.

Table 4.5. NO_3 Particle Deposition Velocities for the Period 3/1 8/94 to 6/9/95



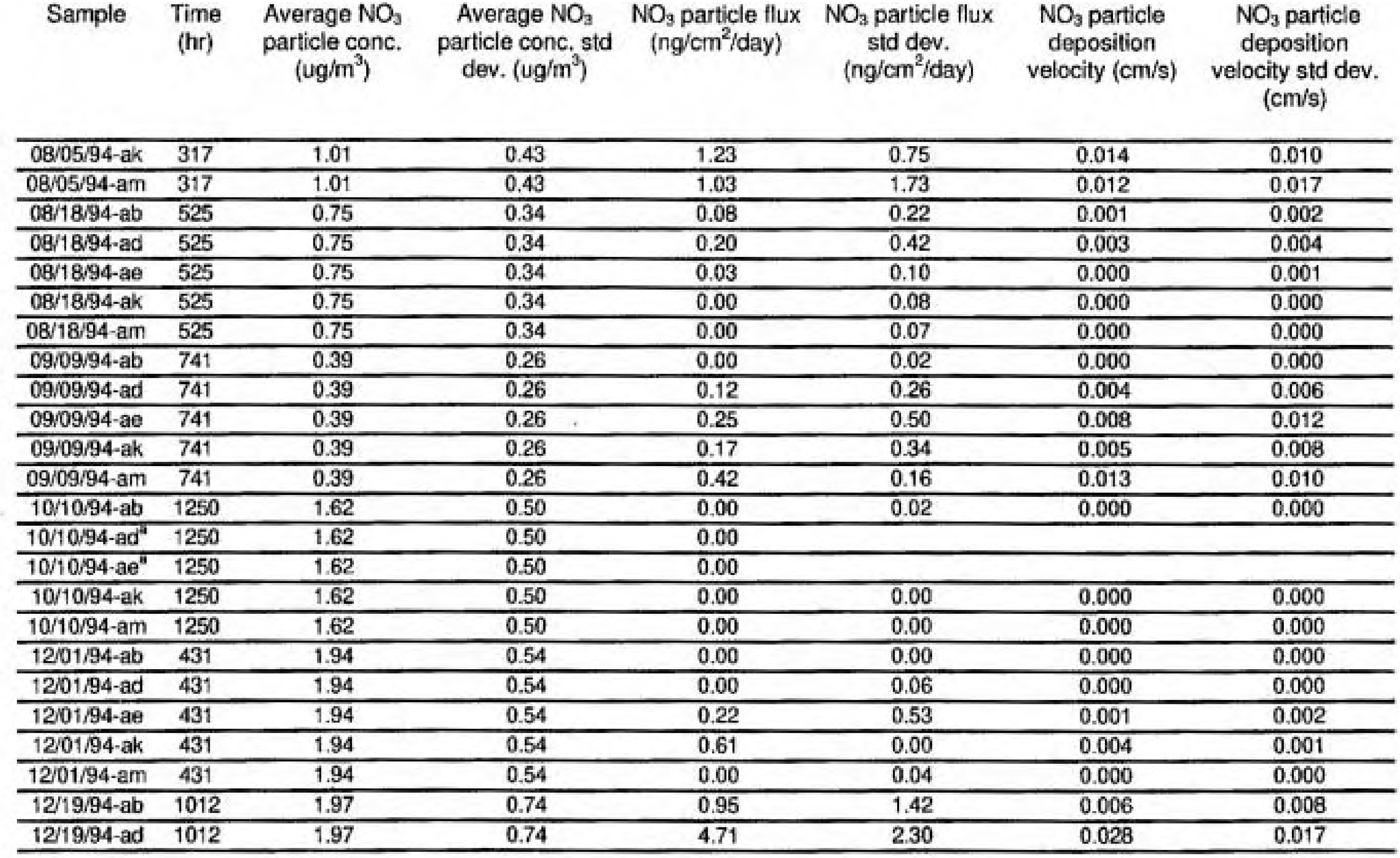
Sample	Time (hr)	Average NO_3 particle conc. (ug/m^3)	Average NO_3 particle conc. std dev. (ug/m^3)	NO_3 particle flux ($ng/cm^2/day$)	NO_3 particle flux std dev. ($ng/cm^2/day$)	NO_3 particle deposition velocity (cm/s)	NO_3 particle deposition velocity std dev. (cm/s)
03/18/94-ab	358	1.77	0.73	16.30	9.30	0.107	0.075
03/18/94-ad	358	1.77	0.73	8.90	1.30	0.058	0.025
03/18/94-ae	358	1.77	0.73	16.30	3.30	0.117	0.078
03/18/94-ak	358	1.77	0.73	5.60	1.10	0.036	0.016
03/18/94-am	358	1.77	0.73	24.10	18.80	0.158	0.139
04/02/94-ab	337	1.44	1.25	20.20	1.90	0.163	0.142
04/02/94-ad	337	1.44	1.25	12.50	6.30	0.101	0.101
04/02/94-ae[a]	337	1.44	1.25				
04/02/94-ak	337	1.44	1.25	14.40	4.00	0.117	0.106
04/02/94-am	337	1.44	1.25	11.70	3.30	0.095	0.086
04/16/94-ab	383	1.47	0.64	16.40	2.10	0.129	0.058
04/16/94-ad	383	1.47	0.64	10.40	5.70	0.082	0.057
04/16/94-ae	383	1.47	0.64	16.50	3.10	0.130	0.061
04/16/94-ak	383	1.47	0.64	15.40	1.30	0.122	0.054
04/16/94-am	383	1.47	0.64	11.00	5.30	0.086	0.056
05/02/94-ab	384	1.58	1.33	17.00	1.60	0.125	0.106
05/02/94-ad	384	1.58	1.33	10.70	2.20	0.079	0.069
05/02/94-ae	384	1.58	1.33	11.80	4.00	0.086	0.078
05/02/94-ak	384	1.58	1.33	9.70	1.60	0.071	0.061
05/02/94-am	384	1.58	1.33	11.30	1.10	0.083	0.071
05/18/94-ab	337	1.32	0.10	15.40	2.40	0.135	0.023
05/18/94-ad	337	1.32	0.10	11.10	1.90	0.097	0.018
05/18/94-ae	337	1.32	0.10	9.80	2.30	0.086	0.021
05/18/94-ak	337	1.32	0.10	9.60	2.00	0.084	0.019

Table 4.5. NO_3 Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



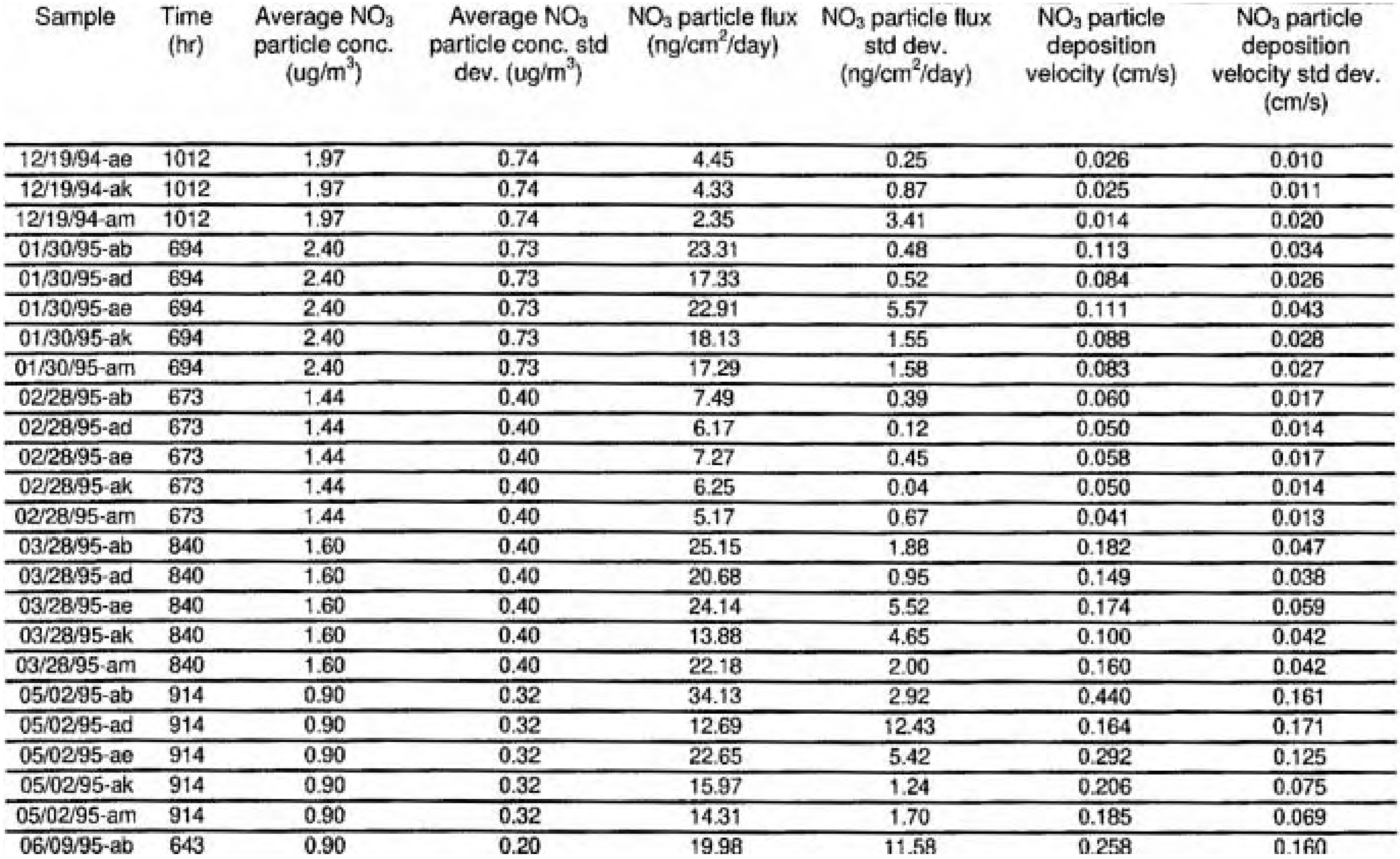
Sample	Time (hr)	Average NO_3 particle conc. (ug/m^3)	Average NO_3 particle conc. std dev. (ug/m^3)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	NO_3 particle deposition velocity (cm/s)	NO_3 particle deposition velocity std dev. (cm/s)
05/18/94-am	337	1.32	0.10	9.90	5.60	0.087	0.050
06/01/94-ab	360	0.58	0.08	25.20	1.20	0.507	0.075
06/01/94-ad	360	0.58	0.08	10.40	2.60	0.209	0.060
06/01/94-ae	360	0.58	0.08	12.70	1.50	0.256	0.047
06/01/94-ak	360	0.58	0.08	15.00	0.70	0.301	0.045
06/01/94-am	360	0.58	0.08	10.60	1.10	0.212	0.037
06/16/94-ab	337	0.92	0.10	52.00	5.70	0.658	0.102
06/16/94-ad	337	0.92	0.10	25.50	1.60	0.322	0.041
06/16/94-ae	337	0.92	0.10	32.80	5.90	0.414	0.087
06/16/94-ak	337	0.92	0.10	27.70	3.90	0.351	0.062
06/16/94-am	337	0.92	0.10	25.00	1.10	0.316	0.037
06/30/94-ab	504	0.56	0.06	9.22	5.83	0.192	0.123
06/30/94-ad	504	0.56	0.06	10.63	8.79	0.221	0.185
06/30/94-ae	504	0.56	0.06	11.57	9.58	0.241	0.201
06/30/94-ak	504	0.56	0.06	9.94	8.22	0.207	0.173
06/30/94-am[a]	504	0.56	0.06				
07/21/94-ab	357	0.95	0.20	1.06	0.24	0.013	0.004
07/21/94-ad	357	0.95	0.20	5.11	2.25	0.062	0.030
07/21/94-ae	357	0.95	0.20	3.84	1.04	0.047	0.016
07/21/94-ak	357	0.95	0.20	3.19	2.38	0.039	0.030
07/21/94-am	357	0.95	0.20	7.84	3.32	0.095	0.045
08/05/94-ab	317	1.01	0.43	1.52	2.47	0.017	0.026
08/05/94-ad	317	1.01	0.43	1.48	0.83	0.017	0.012
08/05/94-ae	317	1.01	0.43	2.95	1.79	0.034	0.025

Table 4.5. NO_3 Particle Deposition Velocities for the Period 3/1 8/94 to 6/9/95



Sample	Time (hr)	Average NO_3 particle conc. (ug/m^3)	Average NO_3 particle conc. std dev. (ug/m^3)	NO_3 particle flux ($ng/cm^2/day$)	NO_3 particle flux std dev. ($ng/cm^2/day$)	NO_3 particle deposition velocity (cm/s)	NO_3 particle deposition velocity std dev. (cm/s)
08/05/94-ak	317	1.01	0.43	1.23	0.75	0.014	0.010
08/05/94-am	317	1.01	0.43	1.03	1.73	0.012	0.017
08/18/94-ab	525	0.75	0.34	0.08	0.22	0.001	0.002
08/18/94-ad	525	0.75	0.34	0.20	0.42	0.003	0.004
08/18/94-ae	525	0.75	0.34	0.03	0.10	0.000	0.001
08/18/94-ak	525	0.75	0.34	0.00	0.08	0.000	0.000
08/18/94-am	525	0.75	0.34	0.00	0.07	0.000	0.000
09/09/94-ab	741	0.39	0.26	0.00	0.02	0.000	0.000
09/09/94-ad	741	0.39	0.26	0.12	0.26	0.004	0.006
09/09/94-ae	741	0.39	0.26	0.25	0.50	0.008	0.012
09/09/94-ak	741	0.39	0.26	0.17	0.34	0.005	0.008
09/09/94-am	741	0.39	0.26	0.42	0.16	0.013	0.010
10/10/94-ab	1250	1.62	0.50	0.00	0.02	0.000	0.000
10/10/94-ad[a]	1250	1.62	0.50	0.00			
10/10/94-ae[a]	1250	1.62	0.50	0.00			
10/10/94-ak	1250	1.62	0.50	0.00	0.00	0.000	0.000
10/10/94-am	1250	1.62	0.50	0.00	0.00	0.000	0.000
12/01/94-ab	431	1.94	0.54	0.00	0.00	0.000	0.000
12/01/94-ad	431	1.94	0.54	0.00	0.06	0.000	0.000
12/01/94-ae	431	1.94	0.54	0.22	0.53	0.001	0.002
12/01/94-ak	431	1.94	0.54	0.61	0.00	0.004	0.001
12/01/94-am	431	1.94	0.54	0.00	0.04	0.000	0.000
12/19/94-ab	1012	1.97	0.74	0.95	1.42	0.006	0.008
12/19/94-ad	1012	1.97	0.74	4.71	2.30	0.028	0.017

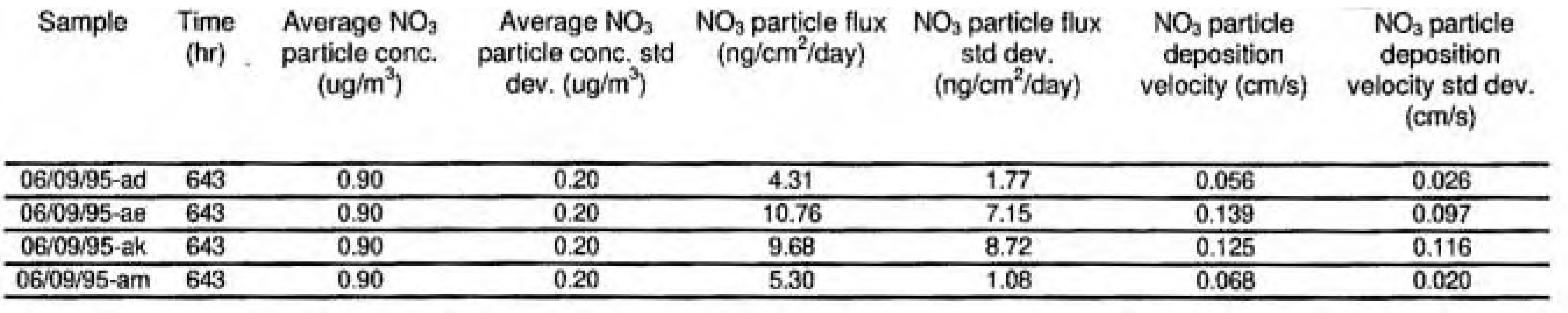
Table 4.5. NO_3 Particle Deposition Velocities for the Period 3/1 8/94 to 6/9/95



Sample	Time (hr)	Average NO_3 particle conc. (ug/m^3)	Average NO_3 particle conc. std dev. (ug/m^3)	NO_3 particle flux ($ng/cm^2/day$)	NO_3 particle flux std dev. ($ng/cm^2/day$)	NO_3 particle deposition velocity (cm/s)	NO_3 particle deposition velocity std dev. (cm/s)
12/19/94-ae	1012	1.97	0.74	4.45	0.25	0.026	0.010
12/19/94-ak	1012	1.97	0.74	4.33	0.87	0.025	0.011
12/19/94-am	1012	1.97	0.74	2.35	3.41	0.014	0.020
01/30/95-ab	694	2.40	0.73	23.31	0.48	0.113	0.034
01/30/95-ad	694	2.40	0.73	17.33	0.52	0.084	0.026
01/30/95-ae	694	2.40	0.73	22.91	5.57	0.111	0.043
01/30/95-ak	694	2.40	0.73	18.13	1.55	0.088	0.028
01/30/95-am	694	2.40	0.73	17.29	1.58	0.083	0.027
02/28/95-ab	673	1.44	0.40	7.49	0.39	0.060	0.017
02/28/95-ad	673	1.44	0.40	6.17	0.12	0.050	0.014
02/28/95-ae	673	1.44	0.40	7.27	0.45	0.058	0.017
02/28/95-ak	673	1.44	0.40	6.25	0.04	0.050	0.014
02/28/95-am	673	1.44	0.40	5.17	0.67	0.041	0.013
03/28/95-ab	840	1.60	0.40	25.15	1.88	0.182	0.047
03/28/95-ad	840	1.60	0.40	20.68	0.95	0.149	0.038
03/28/95-ae	840	1.60	0.40	24.14	5.52	0.174	0.059
03/28/95-ak	840	1.60	0.40	13.88	4.65	0.100	0.042
03/28/95-am	840	1.60	0.40	22.18	2.00	0.160	0.042
05/02/95-ab	914	0.90	0.32	34.13	2.92	0.440	0.161
05/02/95-ad	914	0.90	0.32	12.69	12.43	0.164	0.171
05/02/95-ae	914	0.90	0.32	22.65	5.42	0.292	0.125
05/02/95-ak	914	0.90	0.32	15.97	1.24	0.206	0.075
05/02/95-am	914	0.90	0.32	14.31	1.70	0.185	0.069
06/09/95-ab	643	0.90	0.20	19.98	11.58	0.258	0.160

]

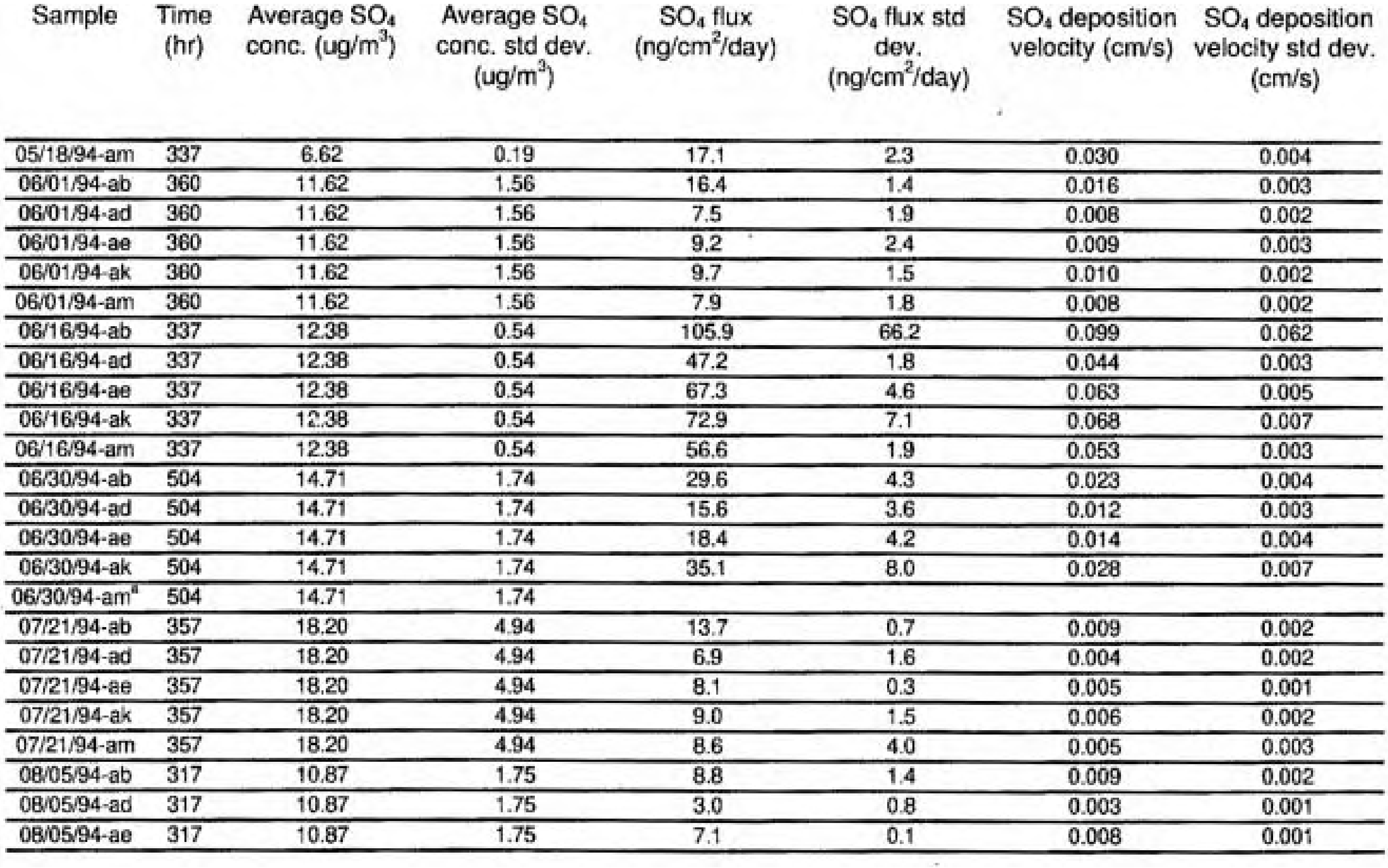
Table 4.5. NO_3 Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average NO_3 particle conc. (ug/m^3)	Average NO_3 particle conc. std dev. (ug/m^3)	NO_3 particle flux (ng/cm^2/day)	NO_3 particle flux std dev. (ng/cm^2/day)	NO_3 particle deposition velocity (cm/s)	NO_3 particle deposition velocity std dev. (cm/s)
06/09/95-ad	643	0.90	0.20	4.31	1.77	0.056	0.026
06/09/95-ae	643	0.90	0.20	10.76	7.15	0.139	0.097
06/09/95-ak	643	0.90	0.20	9.68	8.72	0.125	0.116
06/09/95-am	643	0.90	0.20	5.30	1.08	0.068	0.020

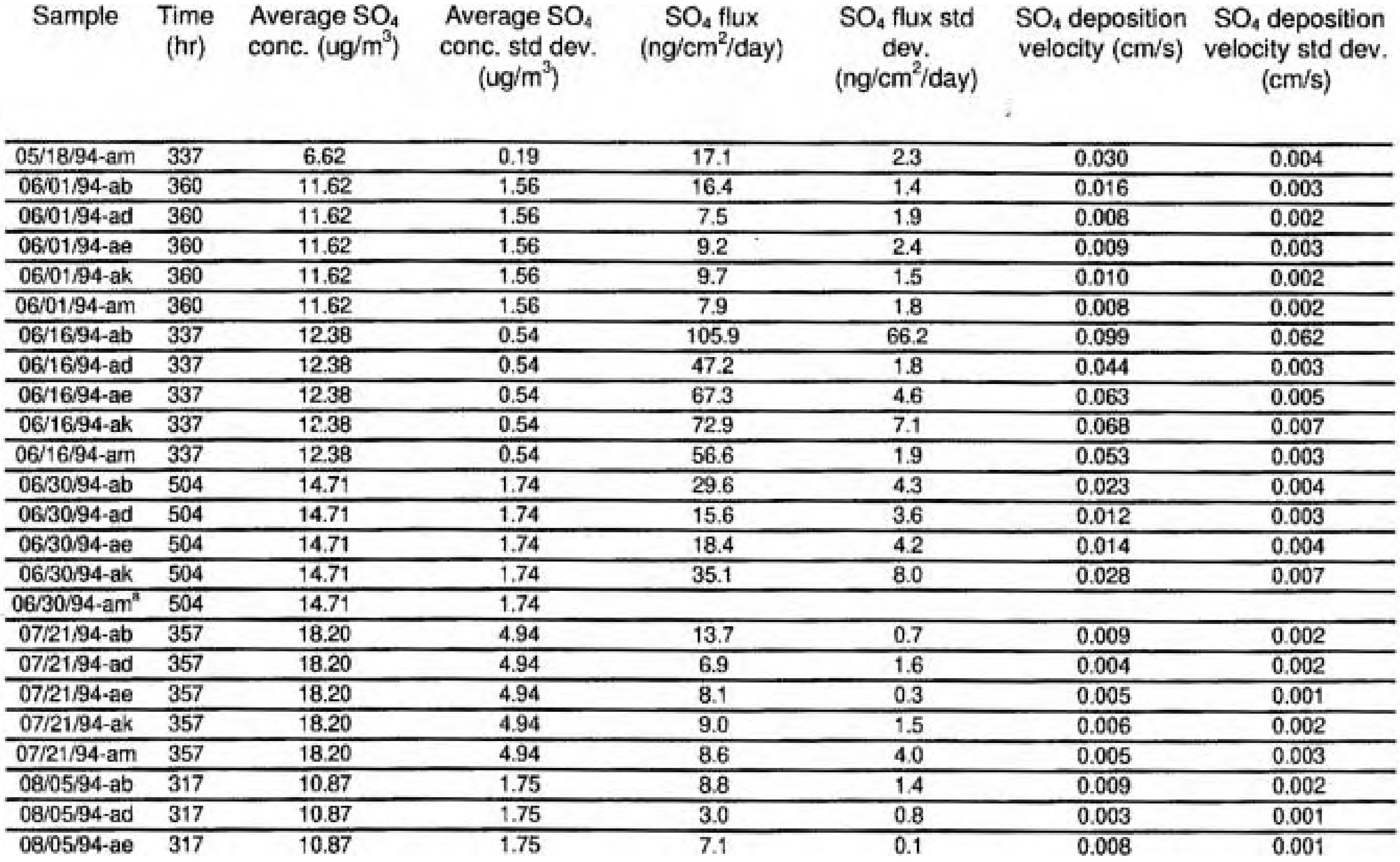
[a] The sample was lost during the exposure period.

Table 4.6. SO_4 Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



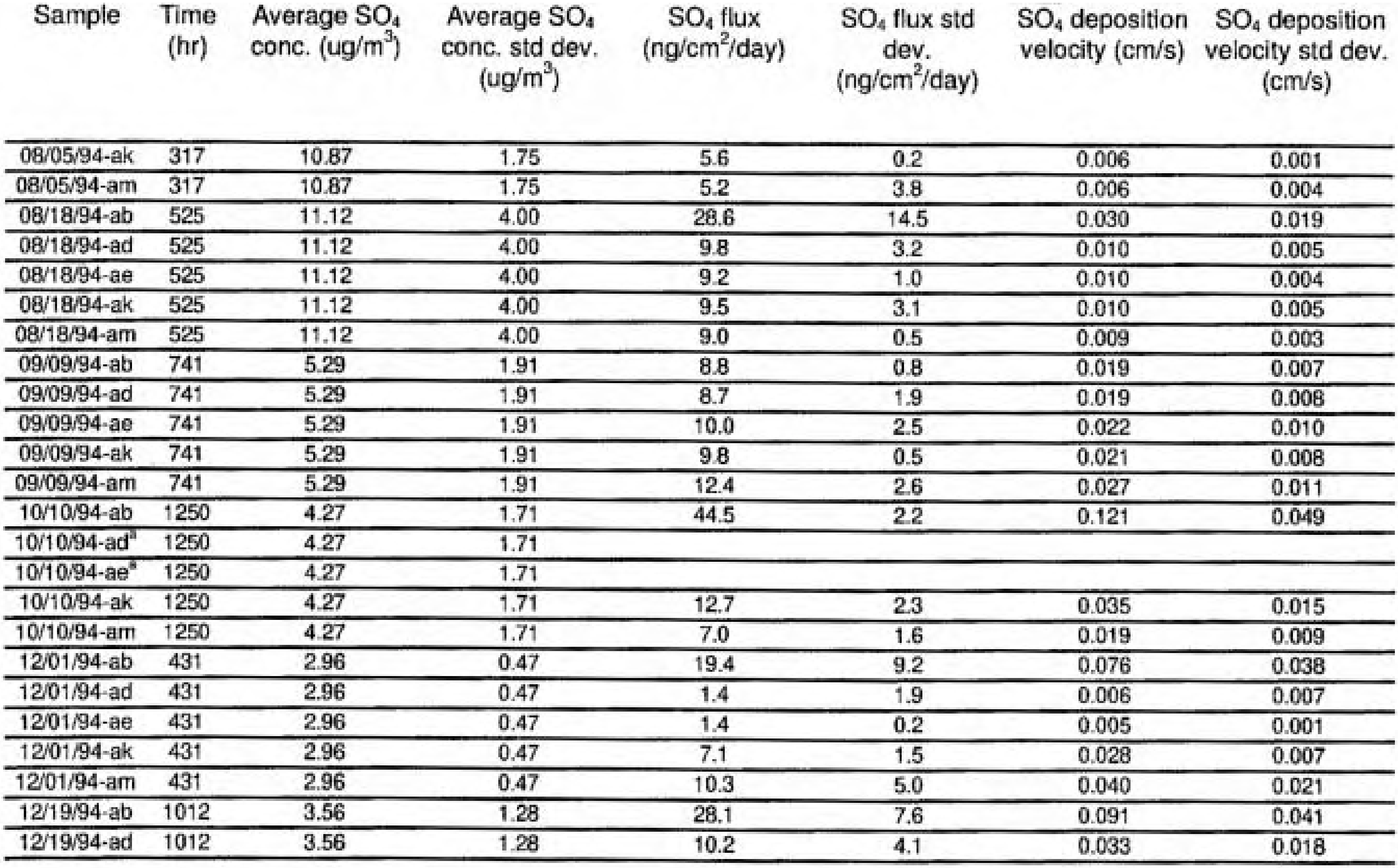
Sample	Time (hr)	Average SO_4 conc. (ug/m^3)	Average SO_4 conc. std dev. (ug/m^3)	SO_4 flux ($ng/cm^2/day$)	SO_4 flux std dev. ($ng/cm^2/day$)	SO_4 deposition velocity (cm/s)	SO_4 deposition velocity std dev. (cm/s)
05/18/94-am	337	6.62	0.19	17.1	2.3	0.030	0.004
06/01/94-ab	360	11.62	1.56	16.4	1.4	0.016	0.003
06/01/94-ad	360	11.62	1.56	7.5	1.9	0.008	0.002
06/01/94-ae	360	11.62	1.56	9.2	2.4	0.009	0.003
06/01/94-ak	360	11.62	1.56	9.7	1.5	0.010	0.002
06/01/94-am	360	11.62	1.56	7.9	1.8	0.008	0.002
06/16/94-ab	337	12.38	0.54	105.9	66.2	0.099	0.062
06/16/94-ad	337	12.38	0.54	47.2	1.8	0.044	0.003
06/16/94-ae	337	12.38	0.54	67.3	4.6	0.063	0.005
06/16/94-ak	337	12.38	0.54	72.9	7.1	0.068	0.007
06/16/94-am	337	12.38	0.54	56.6	1.9	0.053	0.003
06/30/94-ab	504	14.71	1.74	29.6	4.3	0.023	0.004
06/30/94-ad	504	14.71	1.74	15.6	3.6	0.012	0.003
06/30/94-ae	504	14.71	1.74	18.4	4.2	0.014	0.004
06/30/94-ak	504	14.71	1.74	35.1	8.0	0.028	0.007
06/30/94-am[a]	504	14.71	1.74				
07/21/94-ab	357	18.20	4.94	13.7	0.7	0.009	0.002
07/21/94-ad	357	18.20	4.94	6.9	1.6	0.004	0.002
07/21/94-ae	357	18.20	4.94	8.1	0.3	0.005	0.001
07/21/94-ak	357	18.20	4.94	9.0	1.5	0.006	0.002
07/21/94-am	357	18.20	4.94	8.6	4.0	0.005	0.003
08/05/94-ab	317	10.87	1.75	8.8	1.4	0.009	0.002
08/05/94-ad	317	10.87	1.75	3.0	0.8	0.003	0.001
08/05/94-ae	317	10.87	1.75	7.1	0.1	0.008	0.001

Table 4.6. SO$_4$ Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



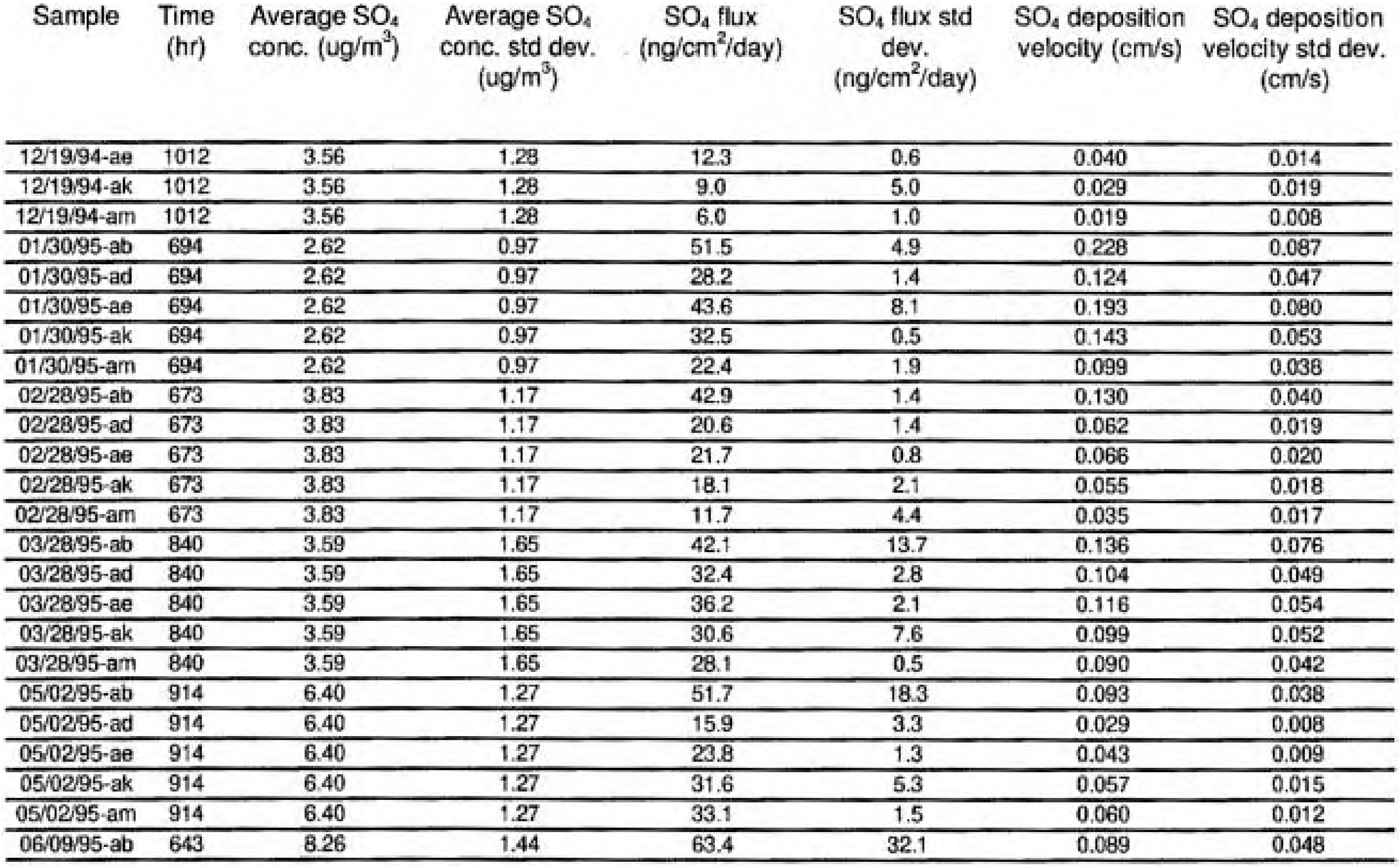
Sample	Time (hr)	Average SO$_4$ conc. (ug/m^3)	Average SO$_4$ conc. std dev. (ug/m^3)	SO$_4$ flux (ng/cm^2/day)	SO$_4$ flux std dev. (ng/cm^2/day)	SO$_4$ deposition velocity (cm/s)	SO$_4$ deposition velocity std dev. (cm/s)
05/18/94-am	337	6.62	0.19	17.1	2.3	0.030	0.004
06/01/94-ab	360	11.62	1.56	16.4	1.4	0.016	0.003
06/01/94-ad	360	11.62	1.56	7.5	1.9	0.008	0.002
06/01/94-ae	360	11.62	1.56	9.2	2.4	0.009	0.003
06/01/94-ak	360	11.62	1.56	9.7	1.5	0.010	0.002
06/01/94-am	360	11.62	1.56	7.9	1.8	0.008	0.002
06/16/94-ab	337	12.38	0.54	105.9	66.2	0.099	0.062
06/16/94-ad	337	12.38	0.54	47.2	1.8	0.044	0.003
06/16/94-ae	337	12.38	0.54	67.3	4.6	0.063	0.005
06/16/94-ak	337	12.38	0.54	72.9	7.1	0.068	0.007
06/16/94-am	337	12.38	0.54	56.6	1.9	0.053	0.003
06/30/94-ab	504	14.71	1.74	29.6	4.3	0.023	0.004
06/30/94-ad	504	14.71	1.74	15.6	3.6	0.012	0.003
06/30/94-ae	504	14.71	1.74	18.4	4.2	0.014	0.004
06/30/94-ak	504	14.71	1.74	35.1	8.0	0.028	0.007
06/30/94-am[a]	504	14.71	1.74				
07/21/94-ab	357	18.20	4.94	13.7	0.7	0.009	0.002
07/21/94-ad	357	18.20	4.94	6.9	1.6	0.004	0.002
07/21/94-ae	357	18.20	4.94	8.1	0.3	0.005	0.001
07/21/94-ak	357	18.20	4.94	9.0	1.5	0.006	0.002
07/21/94-am	357	18.20	4.94	8.6	4.0	0.005	0.003
08/05/94-ab	317	10.87	1.75	8.8	1.4	0.009	0.002
08/05/94-ad	317	10.87	1.75	3.0	0.8	0.003	0.001
08/05/94-ae	317	10.87	1.75	7.1	0.1	0.008	0.001

Table 4.6. SO_4 Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



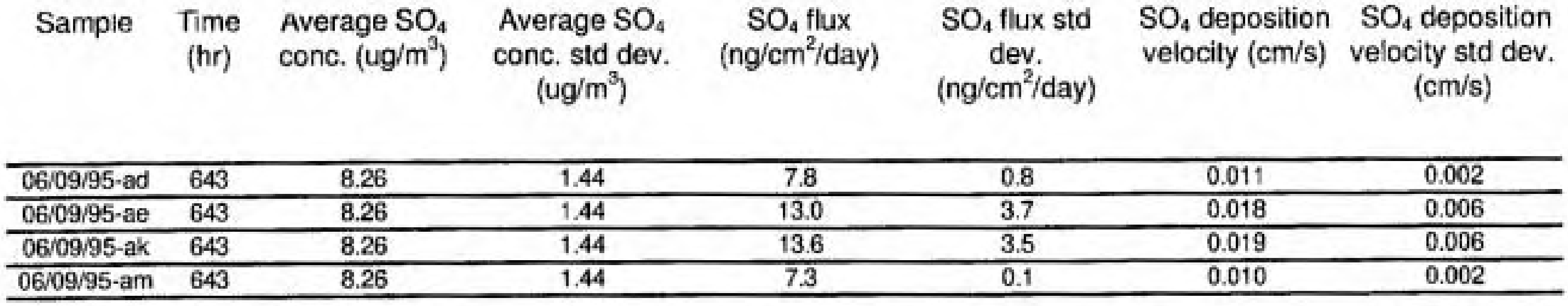
Sample	Time (hr)	Average SO_4 conc. (ug/m^3)	Average SO_4 conc. std dev. (ug/m^3)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	SO_4 deposition velocity (cm/s)	SO_4 deposition velocity std dev. (cm/s)
08/05/94-ak	317	10.87	1.75	5.6	0.2	0.006	0.001
08/05/94-am	317	10.87	1.75	5.2	3.8	0.006	0.004
08/18/94-ab	525	11.12	4.00	28.6	14.5	0.030	0.019
08/18/94-ad	525	11.12	4.00	9.8	3.2	0.010	0.005
08/18/94-ae	525	11.12	4.00	9.2	1.0	0.010	0.004
08/18/94-ak	525	11.12	4.00	9.5	3.1	0.010	0.005
08/18/94-am	525	11.12	4.00	9.0	0.5	0.009	0.003
09/09/94-ab	741	5.29	1.91	8.8	0.8	0.019	0.007
09/09/94-ad	741	5.29	1.91	8.7	1.9	0.019	0.008
09/09/94-ae	741	5.29	1.91	10.0	2.5	0.022	0.010
09/09/94-ak	741	5.29	1.91	9.8	0.5	0.021	0.008
09/09/94-am	741	5.29	1.91	12.4	2.6	0.027	0.011
10/10/94-ab	1250	4.27	1.71	44.5	2.2	0.121	0.049
10/10/94-ad[a]	1250	4.27	1.71				
10/10/94-ae[a]	1250	4.27	1.71				
10/10/94-ak	1250	4.27	1.71	12.7	2.3	0.035	0.015
10/10/94-am	1250	4.27	1.71	7.0	1.6	0.019	0.009
12/01/94-ab	431	2.96	0.47	19.4	9.2	0.076	0.038
12/01/94-ad	431	2.96	0.47	1.4	1.9	0.006	0.007
12/01/94-ae	431	2.96	0.47	1.4	0.2	0.005	0.001
12/01/94-ak	431	2.96	0.47	7.1	1.5	0.028	0.007
12/01/94-am	431	2.96	0.47	10.3	5.0	0.040	0.021
12/19/94-ab	1012	3.56	1.28	28.1	7.6	0.091	0.041
12/19/94-ad	1012	3.56	1.28	10.2	4.1	0.033	0.018

Table 4.6. SO_4 Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average SO_4 conc. (ug/m^3)	Average SO_4 conc. std dev. (ug/m^3)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	SO_4 deposition velocity (cm/s)	SO_4 deposition velocity std dev. (cm/s)
12/19/94-ae	1012	3.56	1.28	12.3	0.6	0.040	0.014
12/19/94-ak	1012	3.56	1.28	9.0	5.0	0.029	0.019
12/19/94-am	1012	3.56	1.28	6.0	1.0	0.019	0.008
01/30/95-ab	694	2.62	0.97	51.5	4.9	0.228	0.087
01/30/95-ad	694	2.62	0.97	28.2	1.4	0.124	0.047
01/30/95-ae	694	2.62	0.97	43.6	8.1	0.193	0.080
01/30/95-ak	694	2.62	0.97	32.5	0.5	0.143	0.053
01/30/95-am	694	2.62	0.97	22.4	1.9	0.099	0.038
02/28/95-ab	673	3.83	1.17	42.9	1.4	0.130	0.040
02/28/95-ad	673	3.83	1.17	20.6	1.4	0.062	0.019
02/28/95-ae	673	3.83	1.17	21.7	0.8	0.066	0.020
02/28/95-ak	673	3.83	1.17	18.1	2.1	0.055	0.018
02/28/95-am	673	3.83	1.17	11.7	4.4	0.035	0.017
03/28/95-ab	840	3.59	1.65	42.1	13.7	0.136	0.076
03/28/95-ad	840	3.59	1.65	32.4	2.8	0.104	0.049
03/28/95-ae	840	3.59	1.65	36.2	2.1	0.116	0.054
03/28/95-ak	840	3.59	1.65	30.6	7.6	0.099	0.052
03/28/95-am	840	3.59	1.65	28.1	0.5	0.090	0.042
05/02/95-ab	914	6.40	1.27	51.7	18.3	0.093	0.038
05/02/95-ad	914	6.40	1.27	15.9	3.3	0.029	0.008
05/02/95-ae	914	6.40	1.27	23.8	1.3	0.043	0.009
05/02/95-ak	914	6.40	1.27	31.6	5.3	0.057	0.015
05/02/95-am	914	6.40	1.27	33.1	1.5	0.060	0.012
06/09/95-ab	643	8.26	1.44	63.4	32.1	0.089	0.048

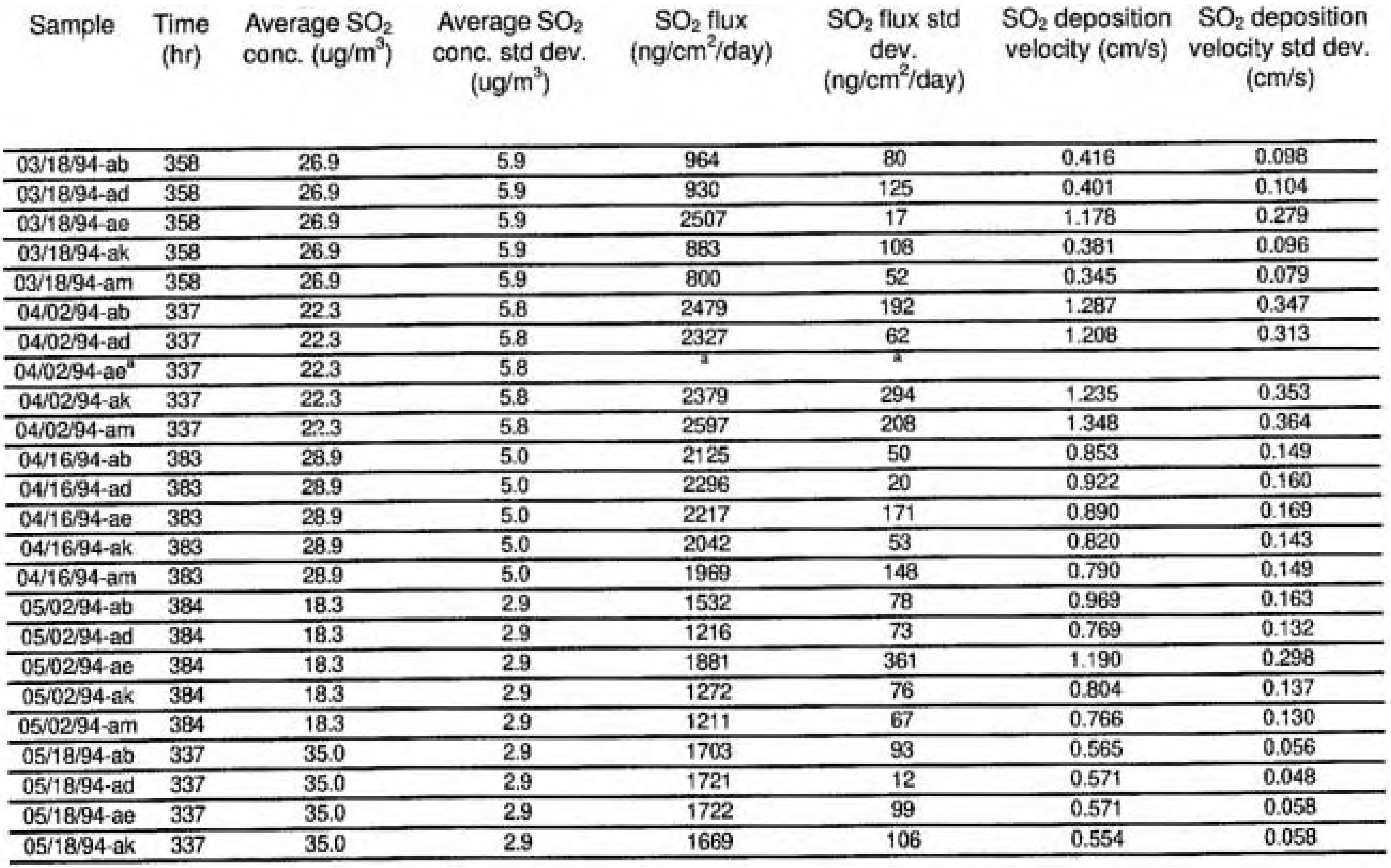
Table 4.6. SO_4 Particle Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average SO_4 conc. (ug/m^3)	Average SO_4 conc. std dev. (ug/m^3)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	SO_4 deposition velocity (cm/s)	SO_4 deposition velocity std dev. (cm/s)
06/09/95-ad	643	8.26	1.44	7.8	0.8	0.011	0.002
06/09/95-ae	643	8.26	1.44	13.0	3.7	0.018	0.006
06/09/95-ak	643	8.26	1.44	13.6	3.5	0.019	0.006
06/09/95-am	643	8.26	1.44	7.3	0.1	0.010	0.002

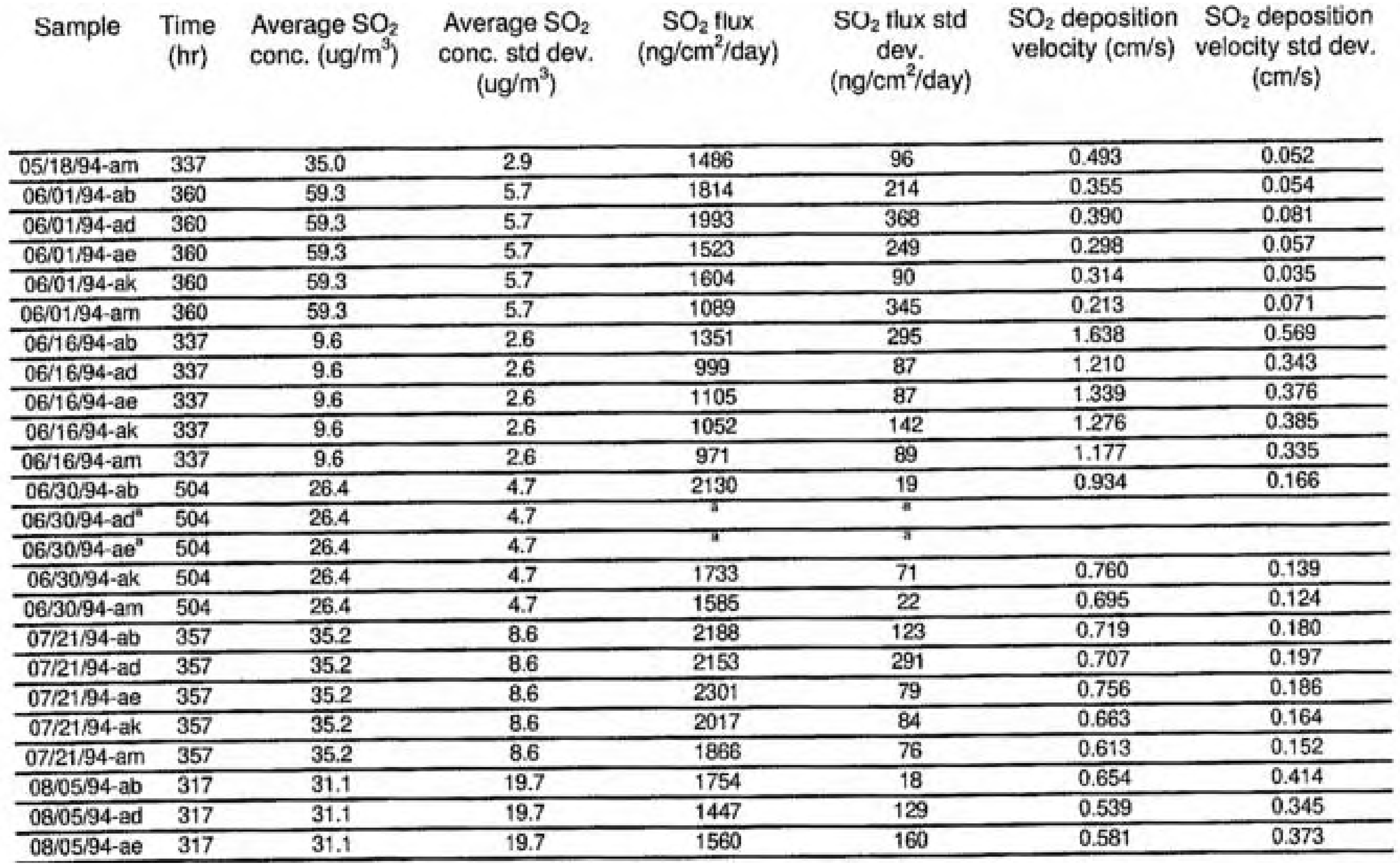
[a] The sample was lost dunng the exposure penoa.

Table 4.7. SO_2 Deposition Velocities for the Period 3/18/94 to 6/9/95



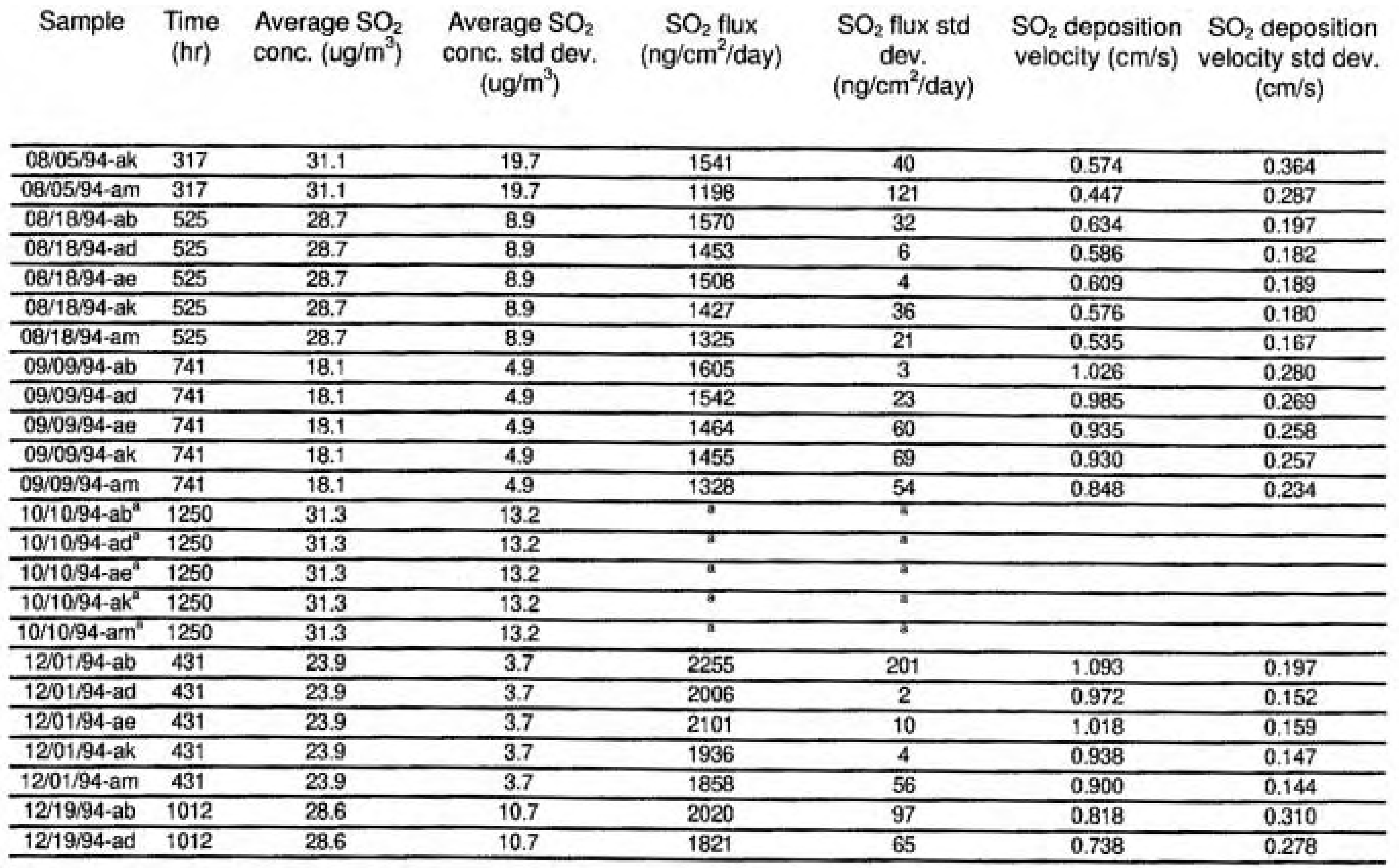
Sample	Time (hr)	Average SO_2 conc. (ug/m^3)	Average SO_2 conc. std dev. (ug/m^3)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)	SO_2 deposition velocity (cm/s)	SO_2 deposition velocity std dev. (cm/s)
03/18/94-ab	358	26.9	5.9	964	80	0.416	0.098
03/18/94-ad	358	26.9	5.9	930	125	0.401	0.104
03/18/94-ae	358	26.9	5.9	2507	17	1.178	0.279
03/18/94-ak	358	26.9	5.9	883	108	0.381	0.096
03/18/94-am	358	26.9	5.9	800	52	0.345	0.079
04/02/94-ab	337	22.3	5.8	2479	192	1.287	0.347
04/02/94-ad	337	22.3	5.8	2327	62	1.208	0.313
04/02/94-ae[a]	337	22.3	5.8	[a]	[a]		
04/02/94-ak	337	22.3	5.8	2379	294	1.235	0.353
04/02/94-am	337	22.3	5.8	2597	208	1.348	0.364
04/16/94-ab	383	28.9	5.0	2125	50	0.853	0.149
04/16/94-ad	383	28.9	5.0	2296	20	0.922	0.160
04/16/94-ae	383	28.9	5.0	2217	171	0.890	0.169
04/16/94-ak	383	28.9	5.0	2042	53	0.820	0.143
04/16/94-am	383	28.9	5.0	1969	148	0.790	0.149
05/02/94-ab	384	18.3	2.9	1532	78	0.969	0.163
05/02/94-ad	384	18.3	2.9	1216	73	0.769	0.132
05/02/94-ae	384	18.3	2.9	1881	361	1.190	0.298
05/02/94-ak	384	18.3	2.9	1272	76	0.804	0.137
05/02/94-am	384	18.3	2.9	1211	67	0.766	0.130
05/18/94-ab	337	35.0	2.9	1703	93	0.565	0.056
05/18/94-ad	337	35.0	2.9	1721	12	0.571	0.048
05/18/94-ae	337	35.0	2.9	1722	99	0.571	0.058
05/18/94-ak	337	35.0	2.9	1669	106	0.554	0.058

Table 4.7. SO_2 Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average SO_2 conc. (ug/m^3)	Average SO_2 conc. std dev. (ug/m^3)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)	SO_2 deposition velocity (cm/s)	SO_2 deposition velocity std dev. (cm/s)
05/18/94-am	337	35.0	2.9	1486	96	0.493	0.052
06/01/94-ab	360	59.3	5.7	1814	214	0.355	0.054
06/01/94-ad	360	59.3	5.7	1993	368	0.390	0.081
06/01/94-ae	360	59.3	5.7	1523	249	0.298	0.057
06/01/94-ak	360	59.3	5.7	1604	90	0.314	0.035
06/01/94-am	360	59.3	5.7	1089	345	0.213	0.071
06/16/94-ab	337	9.6	2.6	1351	295	1.638	0.569
06/16/94-ad	337	9.6	2.6	999	87	1.210	0.343
06/16/94-ae	337	9.6	2.6	1105	87	1.339	0.376
06/16/94-ak	337	9.6	2.6	1052	142	1.276	0.385
06/16/94-am	337	9.6	2.6	971	89	1.177	0.335
06/30/94-ab	504	26.4	4.7	2130	19	0.934	0.166
06/30/94-ad[a]	504	26.4	4.7	[a]	[a]		
06/30/94-ae[a]	504	26.4	4.7	[a]	[a]		
06/30/94-ak	504	26.4	4.7	1733	71	0.760	0.139
06/30/94-am	504	26.4	4.7	1585	22	0.695	0.124
07/21/94-ab	357	35.2	8.6	2188	123	0.719	0.180
07/21/94-ad	357	35.2	8.6	2153	291	0.707	0.197
07/21/94-ae	357	35.2	8.6	2301	79	0.756	0.186
07/21/94-ak	357	35.2	8.6	2017	84	0.663	0.164
07/21/94-am	357	35.2	8.6	1866	76	0.613	0.152
08/05/94-ab	317	31.1	19.7	1754	18	0.654	0.414
08/05/94-ad	317	31.1	19.7	1447	129	0.539	0.345
08/05/94-ae	317	31.1	19.7	1560	160	0.581	0.373

Table 4.7. SO_2 Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average SO_2 conc. (ug/m^3)	Average SO_2 conc. std dev. (ug/m^3)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)	SO_2 deposition velocity (cm/s)	SO_2 deposition velocity std dev. (cm/s)
08/05/94-ak	317	31.1	19.7	1541	40	0.574	0.364
08/05/94-am	317	31.1	19.7	1198	121	0.447	0.287
08/18/94-ab	525	28.7	8.9	1570	32	0.634	0.197
08/18/94-ad	525	28.7	8.9	1453	6	0.586	0.182
08/18/94-ae	525	28.7	8.9	1508	4	0.609	0.189
08/18/94-ak	525	28.7	8.9	1427	36	0.576	0.180
08/18/94-am	525	28.7	8.9	1325	21	0.535	0.167
09/09/94-ab	741	18.1	4.9	1605	3	1.026	0.280
09/09/94-ad	741	18.1	4.9	1542	23	0.985	0.269
09/09/94-ae	741	18.1	4.9	1464	60	0.935	0.258
09/09/94-ak	741	18.1	4.9	1455	69	0.930	0.257
09/09/94-am	741	18.1	4.9	1328	54	0.848	0.234
10/10/94-ab[a]	1250	31.3	13.2	[a]	[a]		
10/10/94-ad[a]	1250	31.3	13.2	[a]	[a]		
10/10/94-ae[a]	1250	31.3	13.2	[a]	[a]		
10/10/94-ak[a]	1250	31.3	13.2	[a]	[a]		
10/10/94-am[a]	1250	31.3	13.2	[a]	[a]		
12/01/94-ab	431	23.9	3.7	2255	201	1.093	0.197
12/01/94-ad	431	23.9	3.7	2006	2	0.972	0.152
12/01/94-ae	431	23.9	3.7	2101	10	1.018	0.159
12/01/94-ak	431	23.9	3.7	1936	4	0.938	0.147
12/01/94-am	431	23.9	3.7	1858	56	0.900	0.144
12/19/94-ab	1012	28.6	10.7	2020	97	0.818	0.310
12/19/94-ad	1012	28.6	10.7	1821	65	0.738	0.278

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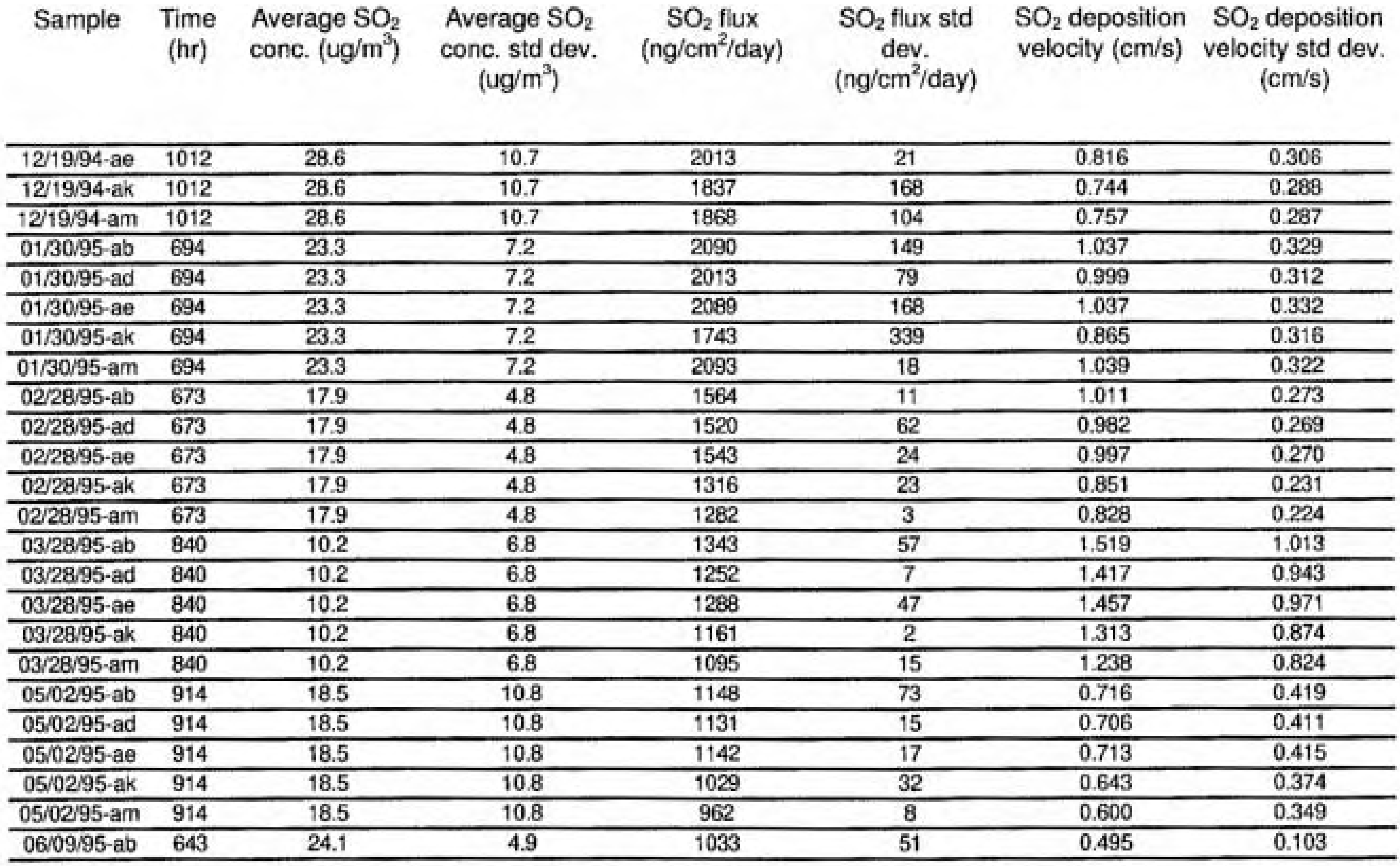
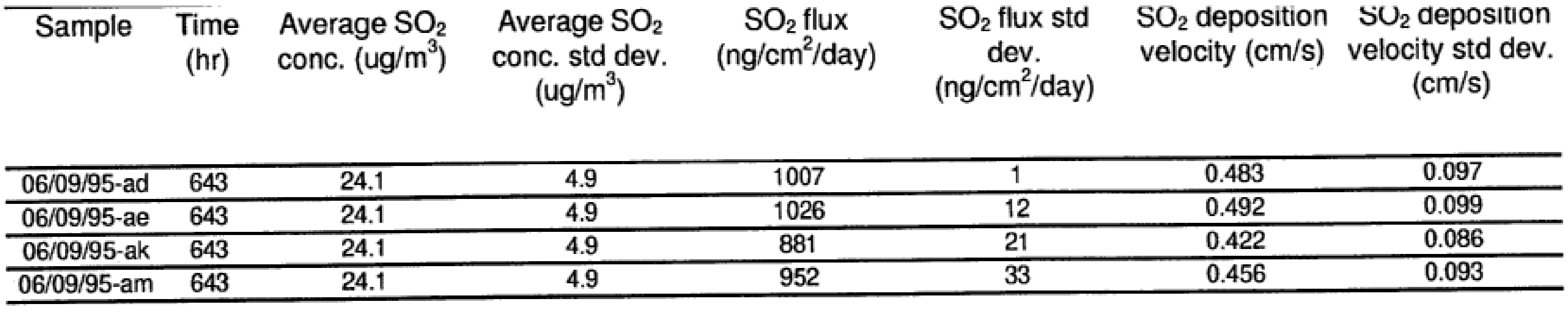
Table 4.7. SO_2 Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average SO_2 conc. (ug/m^3)	Average SO_2 conc. std dev. (ug/m^3)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)	SO_2 deposition velocity (cm/s)	SO_2 deposition velocity std dev. (cm/s)
12/19/94-ae	1012	28.6	10.7	2013	21	0.816	0.306
12/19/94-ak	1012	28.6	10.7	1837	168	0.744	0.288
12/19/94-am	1012	28.6	10.7	1868	104	0.757	0.287
01/30/95-ab	694	23.3	7.2	2090	149	1.037	0.329
01/30/95-ad	694	23.3	7.2	2013	79	0.999	0.312
01/30/95-ae	694	23.3	7.2	2089	168	1.037	0.332
01/30/95-ak	694	23.3	7.2	1743	339	0.865	0.316
01/30/95-am	694	23.3	7.2	2093	18	1.039	0.322
02/28/95-ab	673	17.9	4.8	1564	11	1.011	0.273
02/28/95-ad	673	17.9	4.8	1520	62	0.982	0.269
02/28/95-ae	673	17.9	4.8	1543	24	0.997	0.270
02/28/95-ak	673	17.9	4.8	1316	23	0.851	0.231
02/28/95-am	673	17.9	4.8	1282	3	0.828	0.224
03/28/95-ab	840	10.2	6.8	1343	57	1.519	1.013
03/28/95-ad	840	10.2	6.8	1252	7	1.417	0.943
03/28/95-ae	840	10.2	6.8	1288	47	1.457	0.971
03/28/95-ak	840	10.2	6.8	1161	2	1.313	0.874
03/28/95-am	840	10.2	6.8	1095	15	1.238	0.824
05/02/95-ab	914	18.5	10.8	1148	73	0.716	0.419
05/02/95-ad	914	18.5	10.8	1131	15	0.706	0.411
05/02/95-ae	914	18.5	10.8	1142	17	0.713	0.415
05/02/95-ak	914	18.5	10.8	1029	32	0.643	0.374
05/02/95-am	914	18.5	10.8	962	8	0.600	0.349
06/09/95-ab	643	24.1	4.9	1033	51	0.495	0.103

Table 4.7. SO_2 Deposition Velocities for the Period 3/18/94 to 6/9/95



Sample	Time (hr)	Average SO_2 conc. (ug/m^3)	Average SO_2 conc. std dev. (ug/m^3)	SO_2 flux (ng/cm^2/day)	SO_2 flux std dev. (ng/cm^2/day)	SO_2 deposition velocity (cm/s)	SO_2 deposition velocity std dev. (cm/s)
06/09/95-ad	643	24.1	4.9	1007	1	0.483	0.097
06/09/95-ae	643	24.1	4.9	1026	12	0.492	0.099
06/09/95-ak	643	24.1	4.9	881	21	0.422	0.086
06/09/95-am	643	24.1	4.9	952	33	0.456	0.093

[a] The sample was lost during the exposure period.

Chapter 5: Data Interpretation

In this section, the chemical and meteorological data are plotted to identify temporal trends. The chemical data can be separated into two sections, namely, airborne concentrations and fluxes to vertical deposition sheets. The following is a list of the figures in this section. The final column lists the time period over which the data are available.

Airborne Concentrations

On the whole, airborne concentrations of SO_4 particles (Figure 5.1) are variable over the course of the entire year. However, SO_4 particle concentrations exhibit a considerable peak in the summer of 1994 and a less conspicuous peak in the summer of 1993. During the fall of 1993 and winter of 1993-1994, concentrations are around 5 ug/m^3. Midway through spring they rise to approximately 15 ug/m^3, reaching a summertime maximum of 22 ug/m^3. In the fall of 1994 the concentrations drop sharply and remain low through the winter of 1995.

Airborne concentrations of HNO_3 vapor (Figure 5.2) seem to exhibit temporal variations that are very similar to SO_4 particle concentrations. During the cold months, concentrations are generally between 1 and 3 uglm^3. The peak in the summer of 1994 correlates well with the SO_4 particle concentration peak. Figure 5.3 shows the concentrations of SO_4 particles and HNO_3 vapor plotted together. In general, the peaks and troughs tend to follow each other closely throughout the year. This relationship between SO_4 particles and HNO_3 vapor may be an indication of a common source. However, it may also signify effects of meteorology; for example, high temperatures may favor both SO_2 to SO_4 conversion and also artifact formation of HNO_3 (see below). These hypotheses cannot be verified without further analysis.

NO_3 particle concentrations (Figure 5.4) are lowest during the summer in sharp contrast to SO_4 particle and HNO_3 vapor concentrations. A plot of the NO_3 particle fraction of total NO_3 (HNO_3 + NO_3 particle) reveals that most of the NO_3 species in the summer of 1994 is in the form of HNO_3 vapor (Figure 5.5). However, care should be taken in interpreting these data. Over sampling periods longer than a few hours, ammonium nitrate (NH_4NO_3) aerosol may evaporate from the Zefluor Teflon filter and redeposit onto the Nylasorb filter. Therefore, measured NO_3 particle concentrations may be underestimating actual concentrations. Because the evaporated NH_4NO_3 aerosol redeposits onto the Nylasorb filter, measured HNO_3 vapor concentrations may be overestimates.

Airborne concentrations of SO_2 gas appear in Figure 5.6. A pronounced temporal pattern seems to be absent from these concentrations. With the exception of the 2/25/94 sample, all concentrations are lower than 100 ug/m^3. A scatter plot of SO_2 vs. SO_4 particle concentrations (Figure 5.7) shows that there is no significant correlation between these two pollutants ($R^2 = 0.04$ not including the one outlier on 2/25/94 with high SO_2 concentration shown on the figure).

Carbon concentration samples between 9/11/93 and 6/27/95 are pending analysis by Desert Research Institute. The available airborne concentrations are plotted in Figure 5.8. Some of the samples before the fall of 1993 were collected over a time period shorter than a week (see Table 4.3 for exposure times). With the limited data, it is possible to plot SO_2 and carbon particle concentrations on the same graph (Figure 5.9). The two pollutants show some correlation ($R^2 = 0.2$ not including the outlier on 2/25/94).

Fluxes to Vertical Deposition Sheets

Average airborne concentrations, deposition fluxes, and deposition velocities for NO_3 particles are shown in Figure 5.10. Discretion must be exercised when considering NO_3 particle deposition fluxes and deposition velocities. As mentioned above, NO_3 airborne concentrations may be underestimated because of NH_4NO_3 evaporation from the Teflon filter. In principal, NH_4NO_3 deposited on the greased Teflon surrogate surface may also evaporate. However, the extent of evaporation of NH_4NO_3 is likely to be much greater for the Zefluor Teflon filter since the air flowing through the filter enhances mass transport. Another factor is the possible sorption of HNO_3 by the greased Teflon surrogate surface, resulting in an overestimate of NO_3 particle deposition flux. The net effect of the biased measurements of NO_3 particle airborne concentrations and deposition fluxes is that deposition velocities may be overestimated.

Although average NO_3 particle airborne concentrations show an increase in the winter months, deposition fluxes seem to decline in the fall after an initial increase in late spring and early summer. From mid-summer 1994 to December 1994, deposition fluxes and deposition velocities are not significantly different from zero. In addition, location “ab” tends to have the highest deposition fluxes of all locations for most of the data points. The same pattern can be seen for the SO_4 particles (Figure 5.11) and to a lesser extent, the SO_2

deposition fluxes (Figure 5.12). This phenomenon could be a result of a greater degree of turbulent delivery at location “ab”. SO_4 and NO_3 particles may be more influenced by location because they are more dependent on turbulent delivery through the viscous sublayer and regions just above the sublayer than are gases such as SO_2.

All three species show peaks in deposition velocities for the 6/16/94, 1/30/95, and 5/2/95 samples. The fact that all of these species show peaks on the same dates is to be expected, since factors such as wind speed, wind direction, and turbulence intensity which may affect the deposition velocity of one pollutant will have a similar influence on the other pollutants. SO_4 particles and SO_2 gas both have high deposition velocities for the 4/2/95 samples.

Overall, SO_2 gas has the highest deposition velocity, averaging 0.8 cm/s, and a maximum of 1.6 cm/s for the “ab” location. SO_4 particle deposition velocities are lower with a maximum of 0.23 cm/s for the “ab” location. NO_3 particle deposition velocities are variable with a maximum of 0.7 cm/s for the “ab” location and a minimum that is not significantly different from zero.

Meteorological Measurements

The wind speed and direction are supplied by sensors on the roof of the Cathedral. All measurements reported reflect thirty minute averages. Examples of the data are shown in this section. A wind rose for the period 6/22/94-12/2/94 appears in Figure 5.13. In Figures 5.14 and 5.15 the same data are separated into dry and wet period wind roses. On all three graphs, the wind is from the South-East for the largest fraction of time. Nonetheless, the dry period wind rose, wet period wind rose, and overall wind rose are similar, suggesting the absence of drastic changes in wind direction during rainy days. Wind roses also are shown for the specific deposition sampling periods 1/30/95-2/28/95 and 2/28/95-3/28/95 in Figures 5.16 and 5.17, respectively. Separate dry and wet wind roses are not shown because during these sampling times, any precipitation is likely to be in the form of snow. The wind roses in Figures 5.16 and 5.17 are similar to each other as well as to those for the period 6/22/94-12/2/94, indicating that a change of season may only cause a minimal change in wind direction.

A wind speed frequency graph for 6/22/94-12/2/94 is shown in Figure 5.18. The data are separated into wet and dry periods. During the dry periods, the wind speed is between 0.5 and 1.0 m/s for the greatest portion of time. On the other hand, the range 1.0-1.5 m/s has the highest frequency during rain events. Wind speed frequencies are also plotted for the deposition sampling periods 1/30/95-2/28/95 and 2/28/95-3/28/95 in Figures 5.19 and 5.20, respectively. Unlike the wind roses for these two periods, the wind speed frequency curves are not similar. The wind speed is less than 1 m/s 35% of the time during the deposition period starting on 1/30/95 compared to 52% of the time for the period starting 2/28/95.

Figure 5.1. SO_4 Particle Airborne Concentrations for the period 12/1/9210 7/6/95

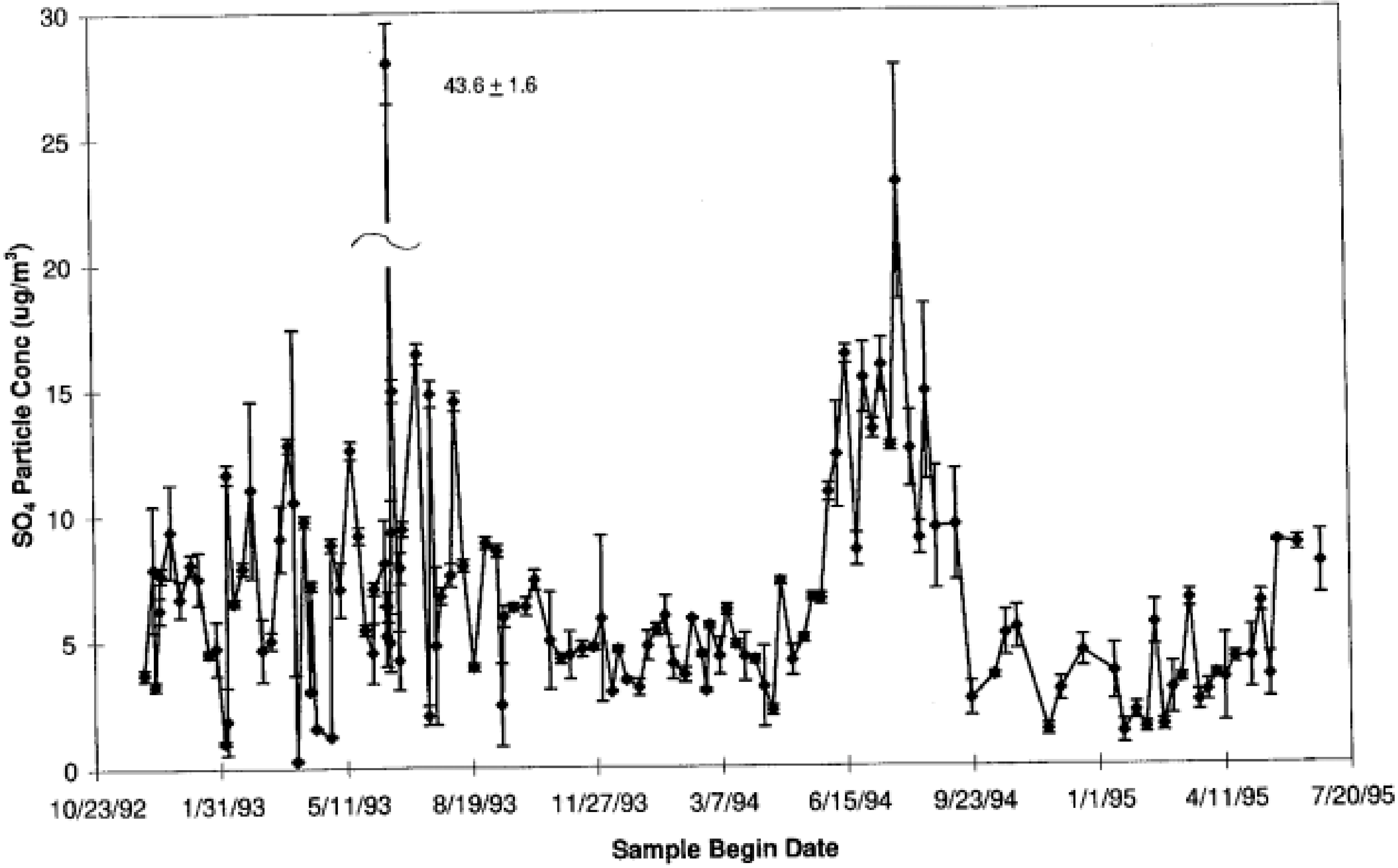


Figure 5.2. HNO_3 Vapor Airborne Concentrations From Nylasorb Filters for the Period 9/11/93 to 7/6/95

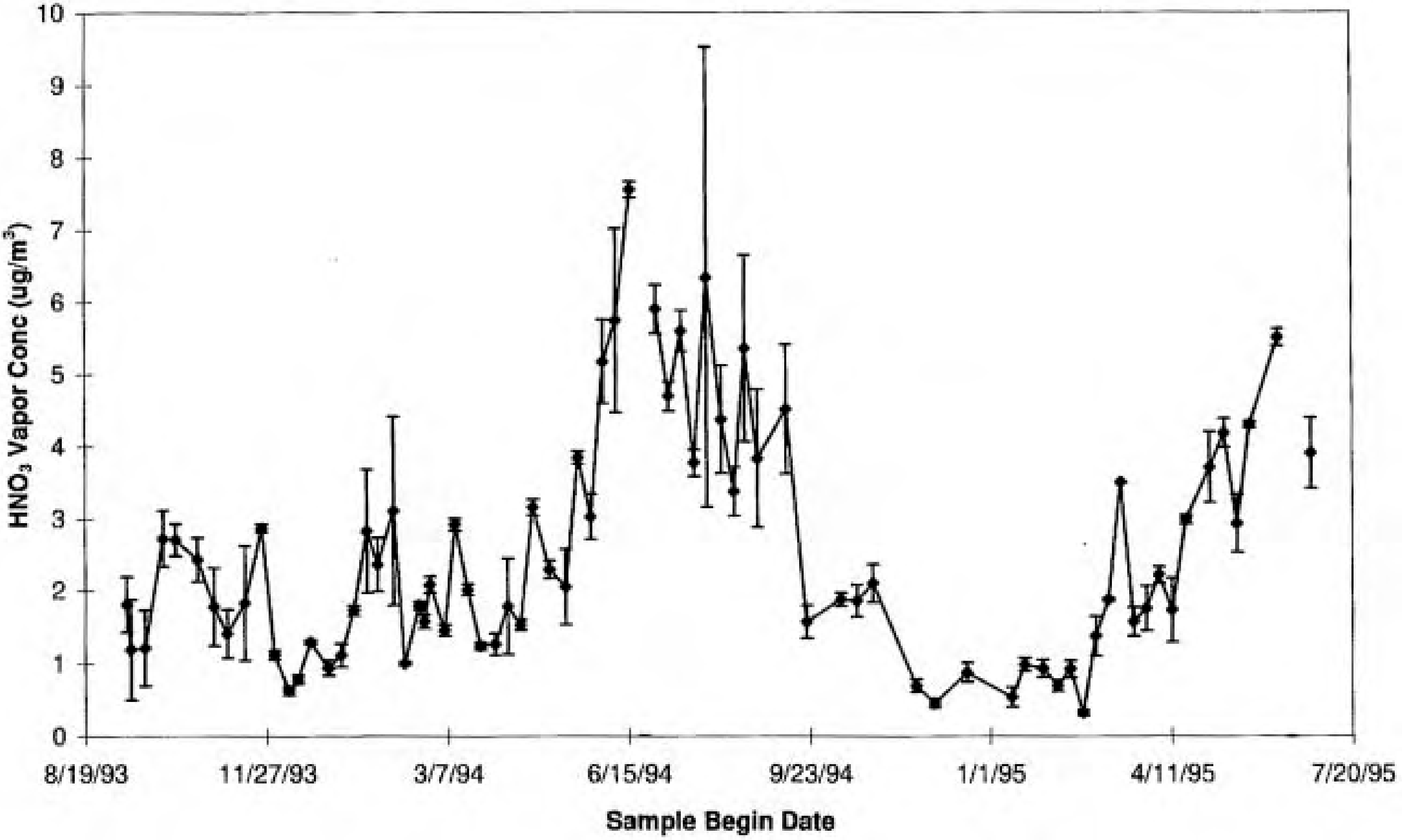


Figure 5.3. Airborne Concentrations of SO_4 Particle and HNO_3 Vapor for the Period 9/11/93 to 7/6/95

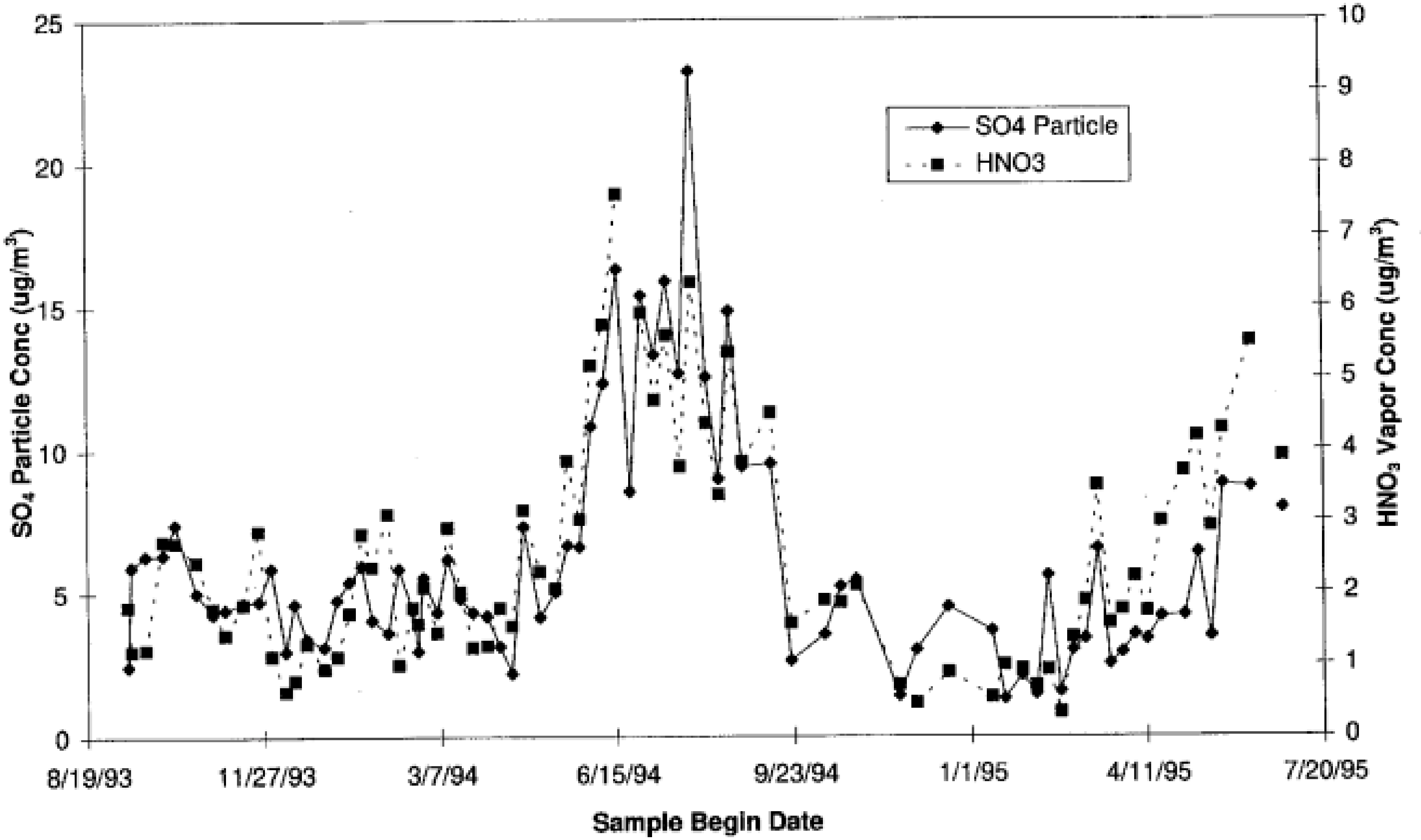


Figure 5.4. NO_3 Particle Airborne Concentrations for the Period 12/1/92 to 7/6/95

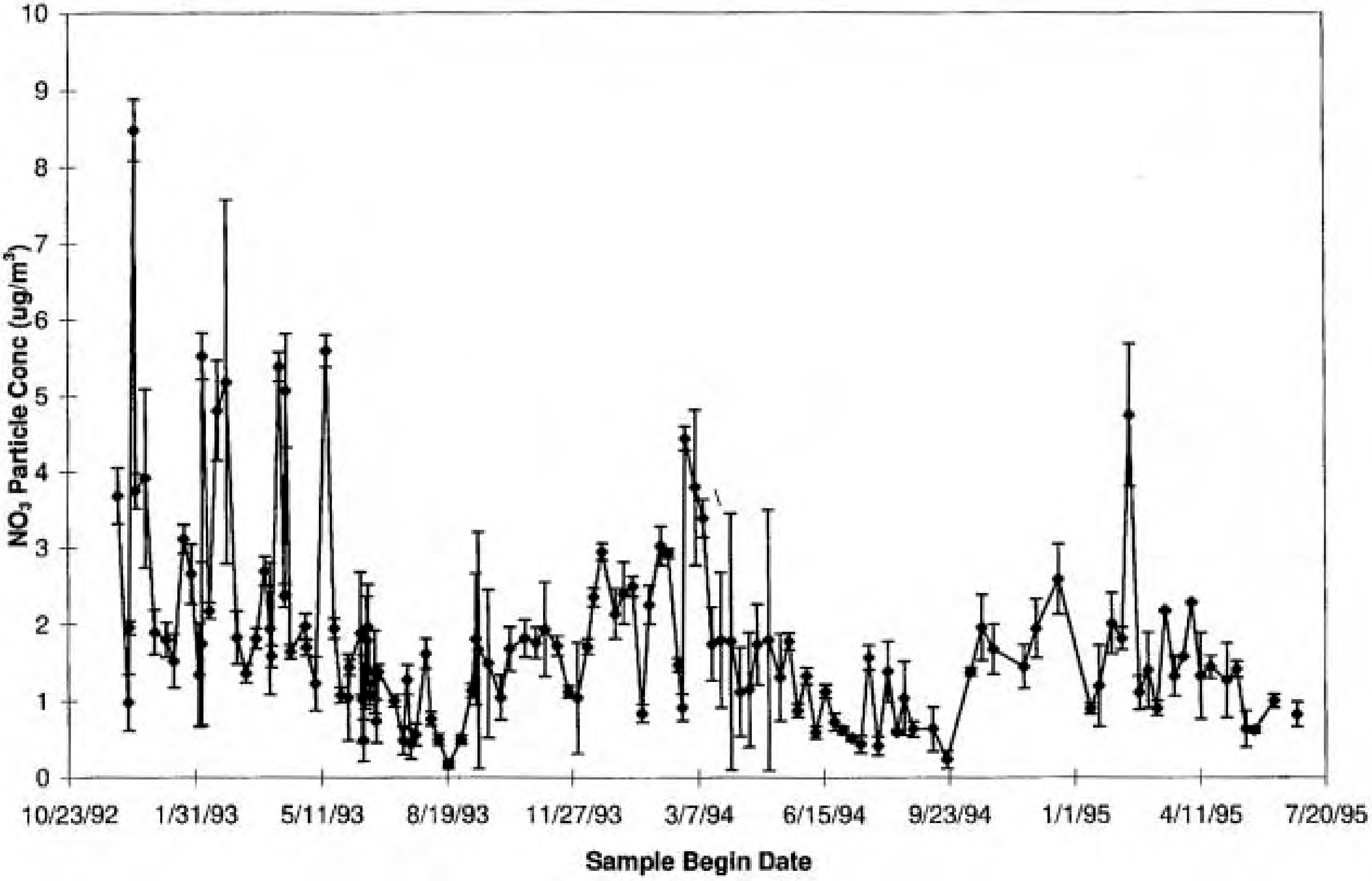


Figure 5.5. NO_3 Particle Fraction of Total NO_3 Species for the Period 9/11/93 to 7/6/95

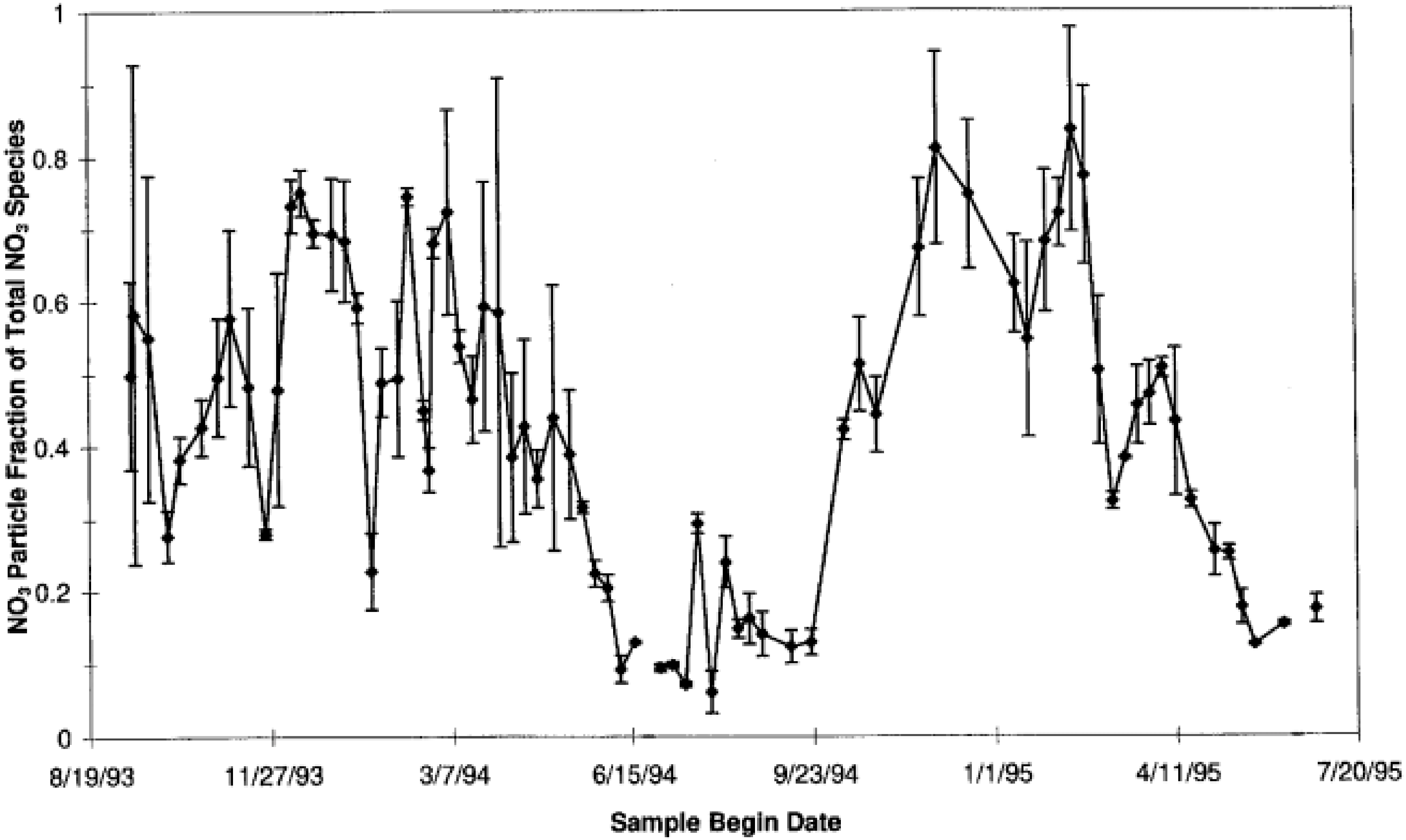


Figure 5.6. SO_2 Gas Airborne Concentrations for the Period 9/11/93 to 7/6/95

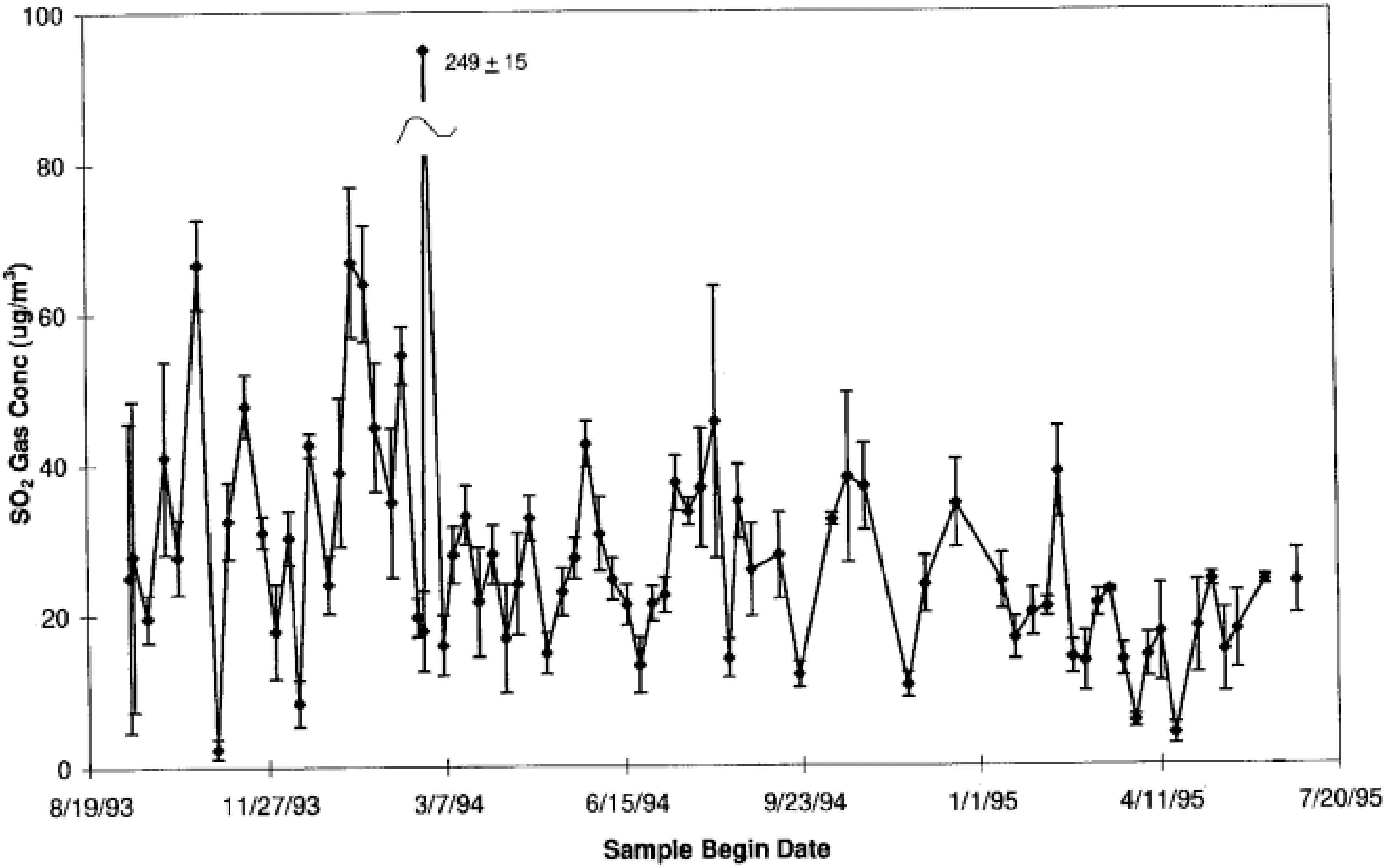


Figure 5.7. SO2 Gas Concentrations vs. SO4 Particle Concentrations for the Period 9/11/93 to 7/6/95

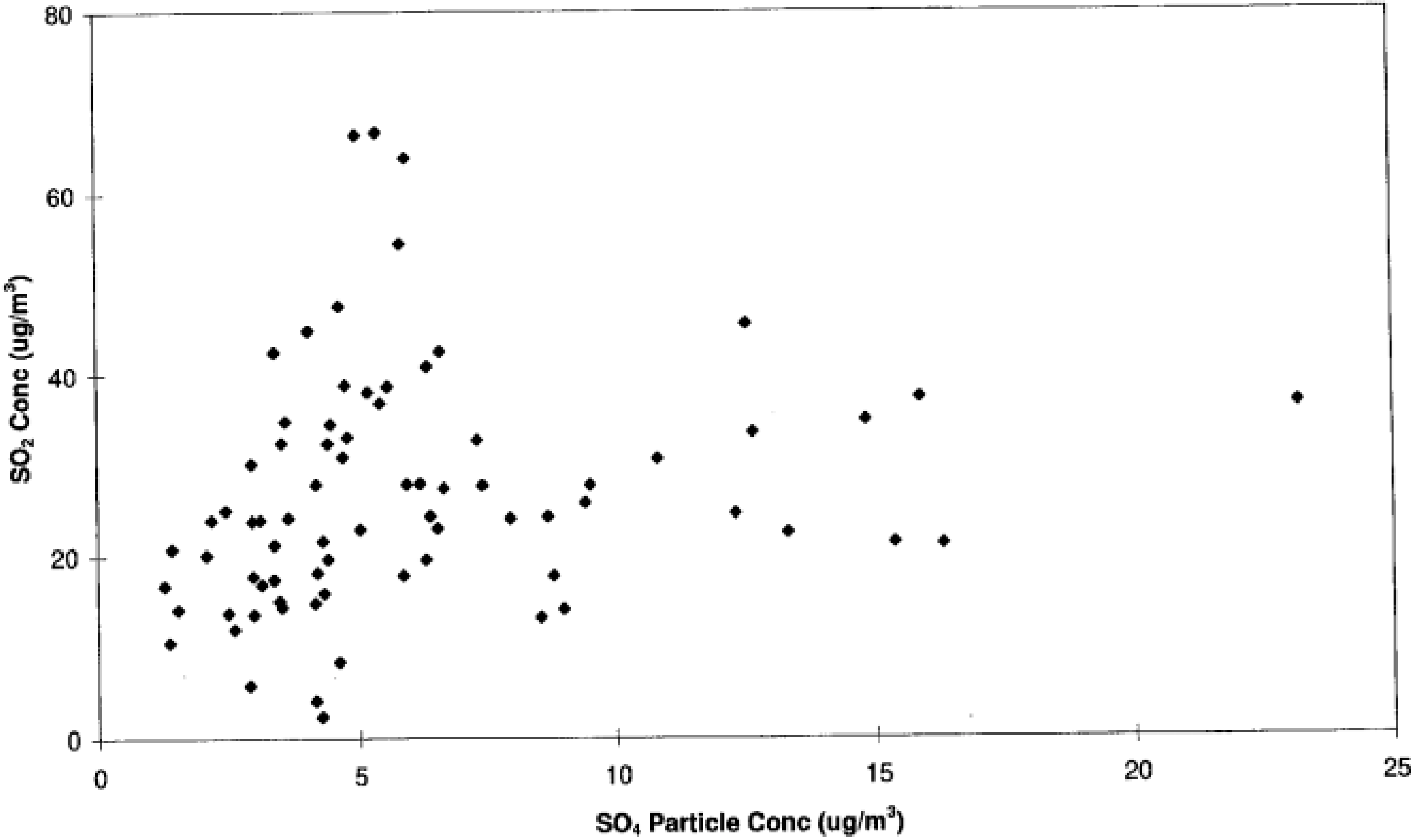


Figure 5.8. Carbon Airborne Concentrations for the Period 3/27/93 to 3/18/94

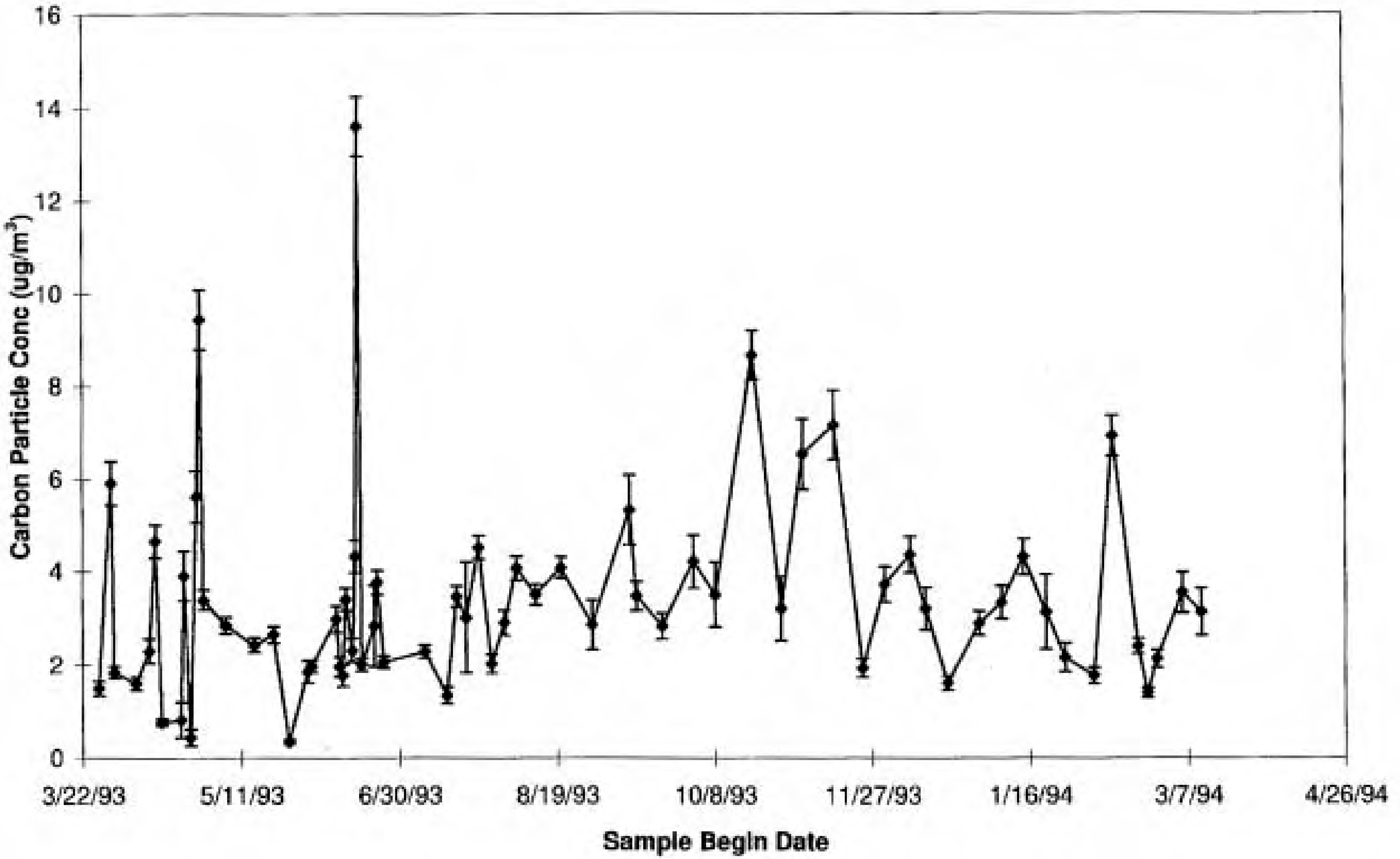


Figure 5.9 SO_2 Gas and Carbon Particle Concentration for the Period 9/11//93 to 3/18/94

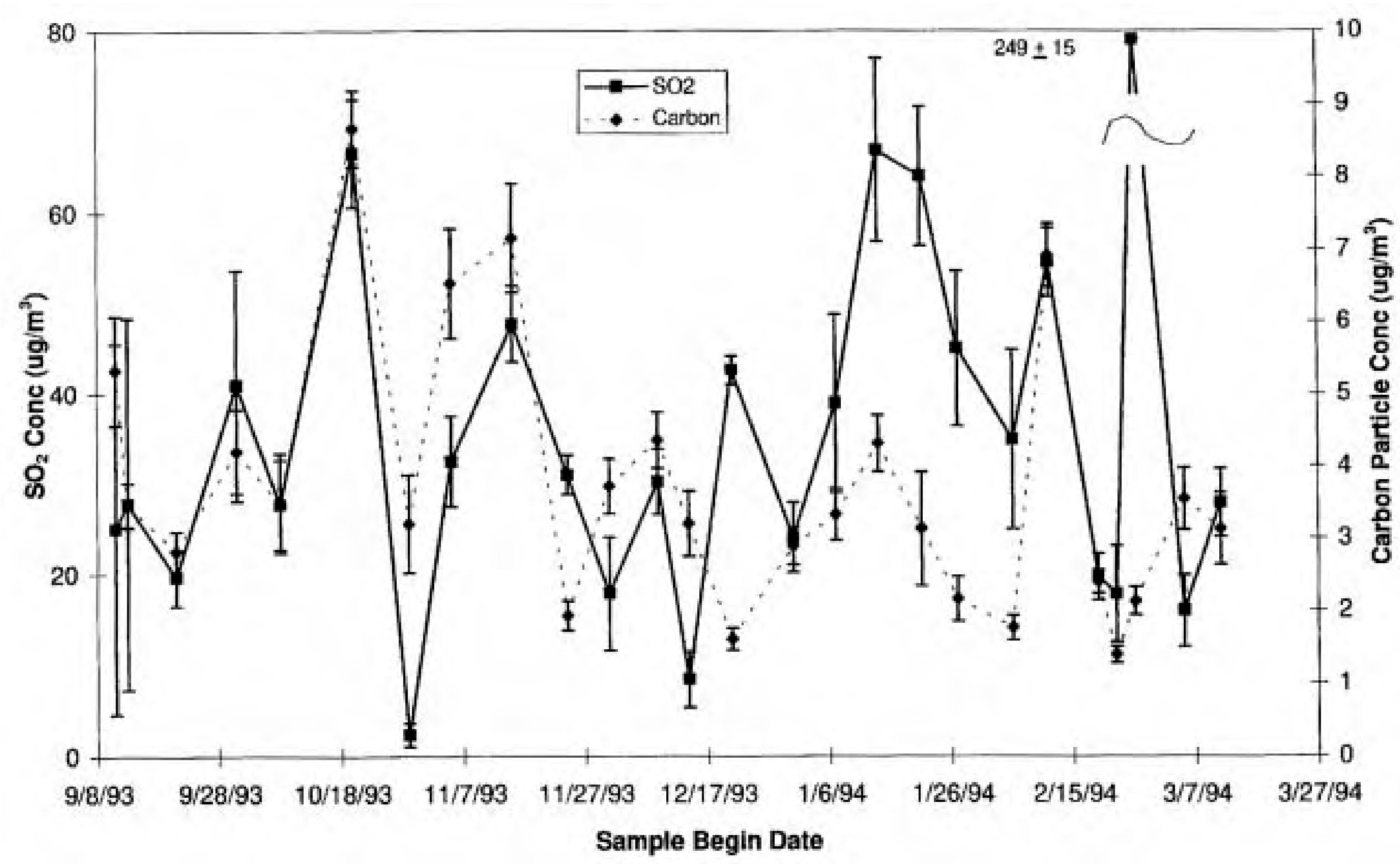


Figure 5.10. NO_3 Particle Airborne Concentrations, Deposition Fluxes and Deposition Velocities for the Period 3/18/94 to 7/6/95

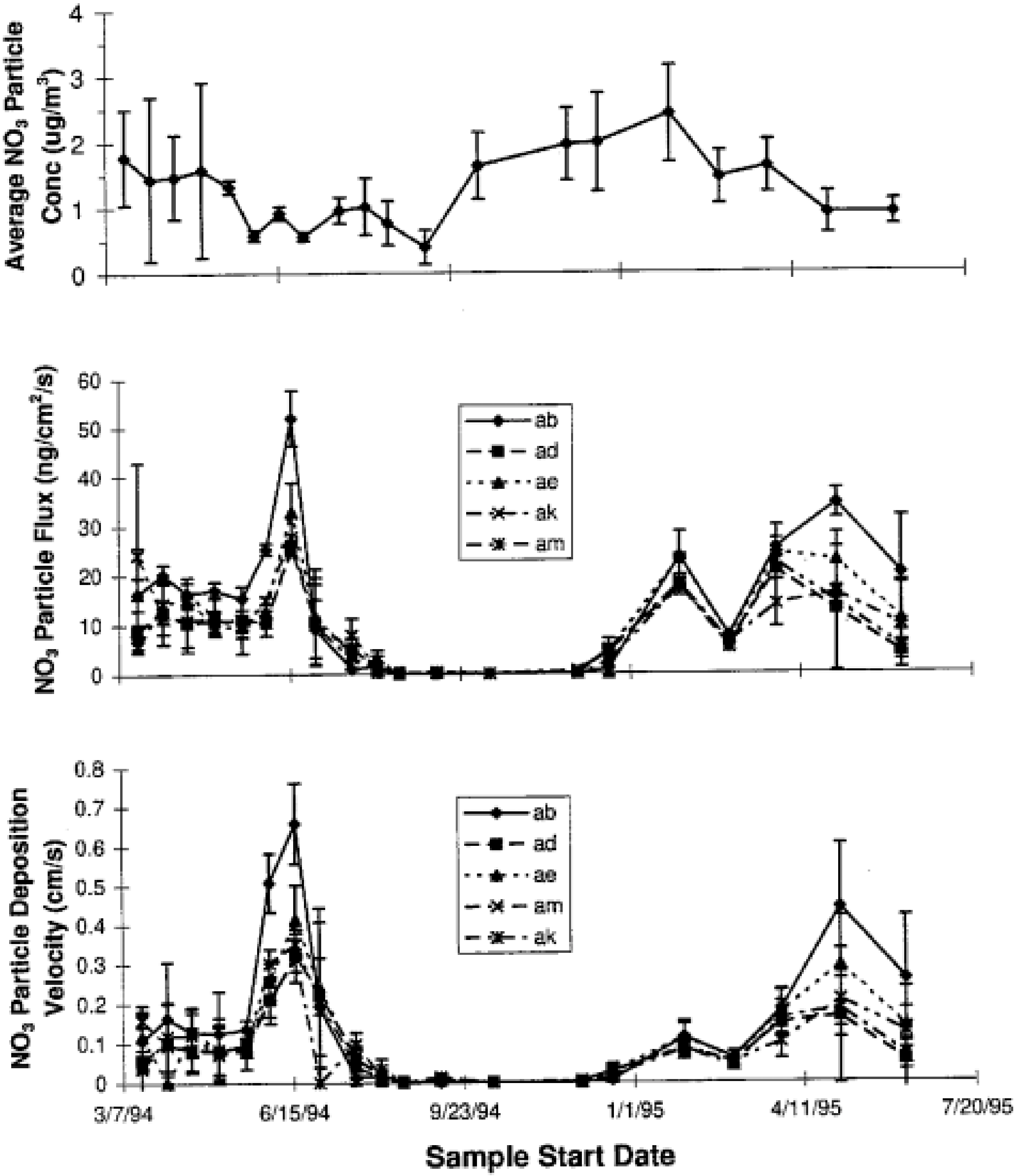


Figure 5.11. SO_4 Particle Airborne Concentrations, Deposition Fluxes, and Deposition Velocities for the Period 3/18/94 to 7/6/95

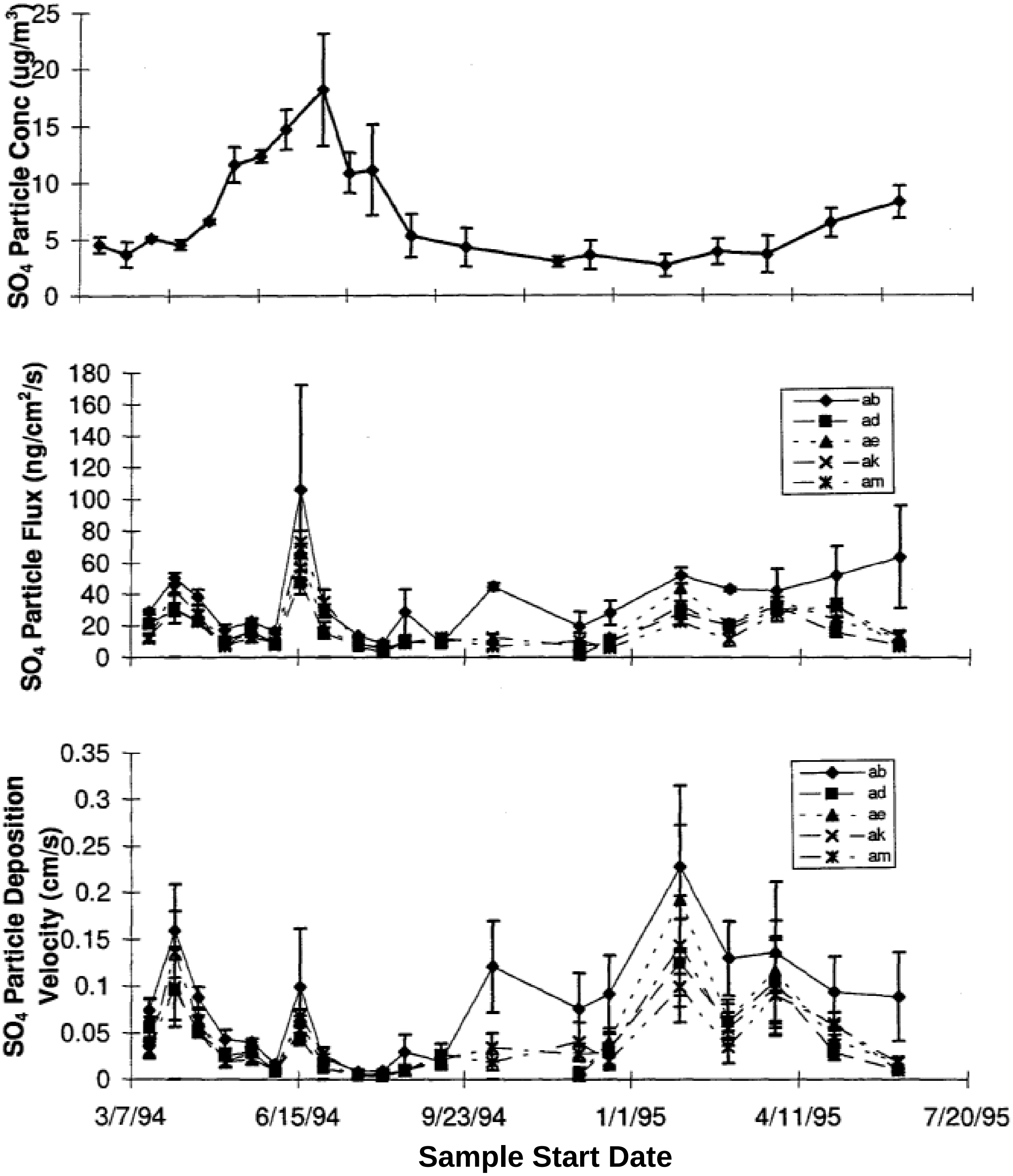
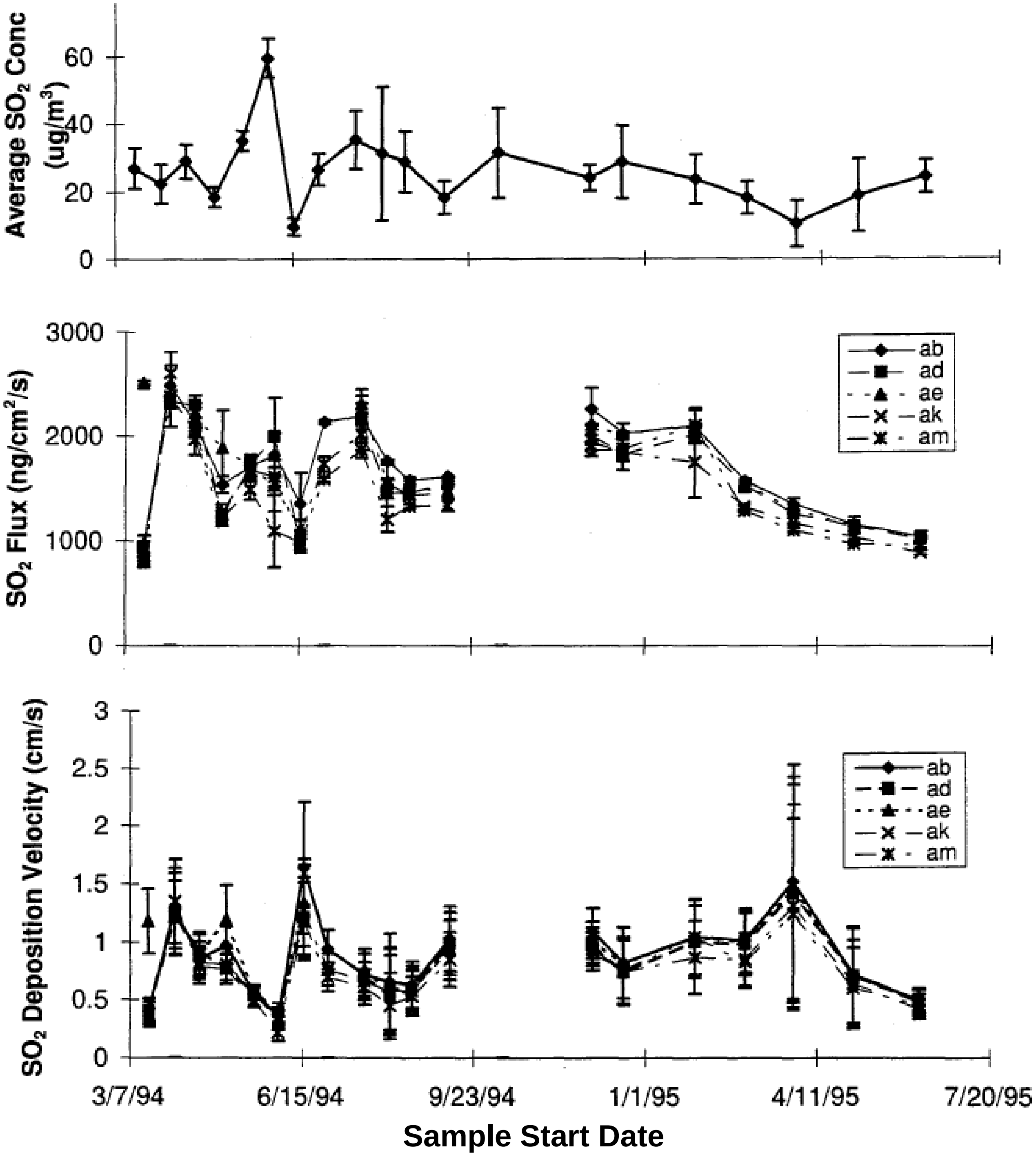


Figure 5.12. SO_2 Airborne Concentrations, Deposition Fluxes, and Deposition Velocities for the Period 3/18/94 to 7/6/95



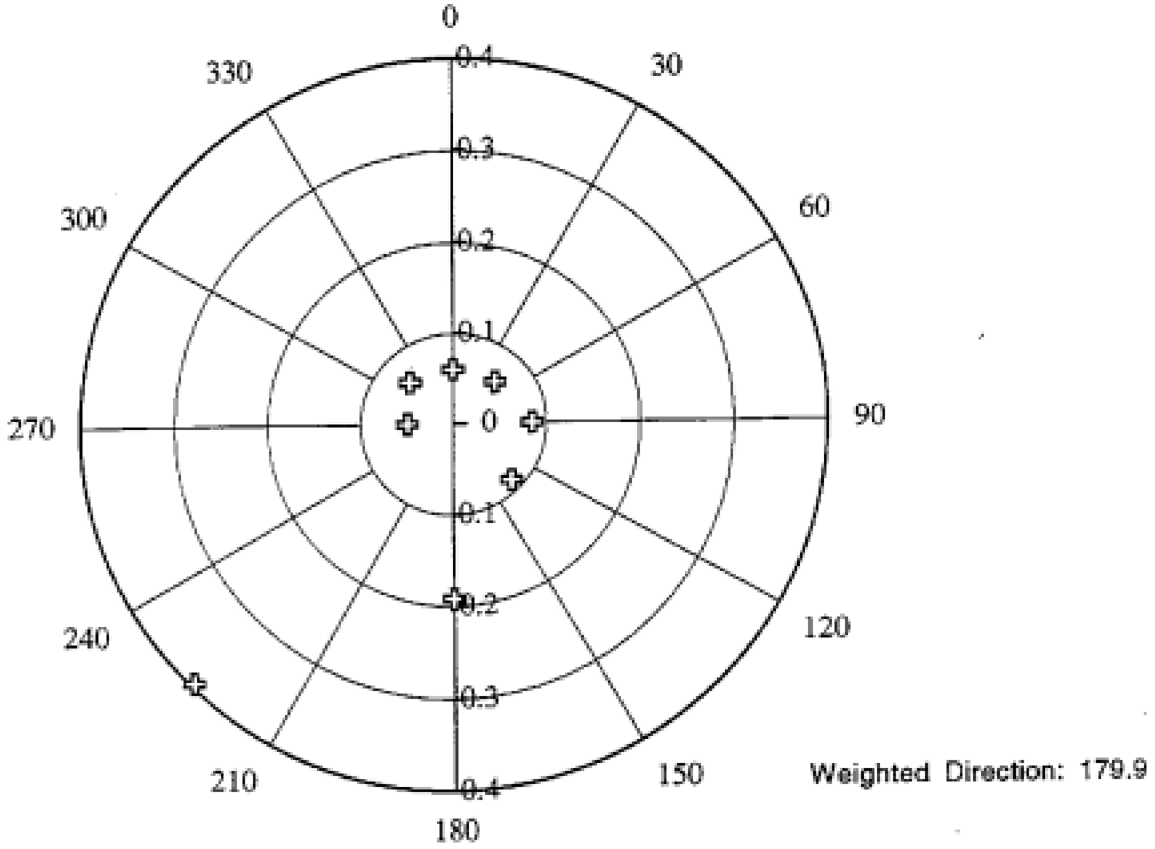


Figure 5.13. Wind Rose for the Period 6/22/94-12/2/94. The numbers on the circumference correspond to the wind direction in degrees. 0 corresponds to the North. The crosses are placed in the midpoint of a 45 degree interval. The radial scale represents the fraction of time the wind is coming from the direction indicated.

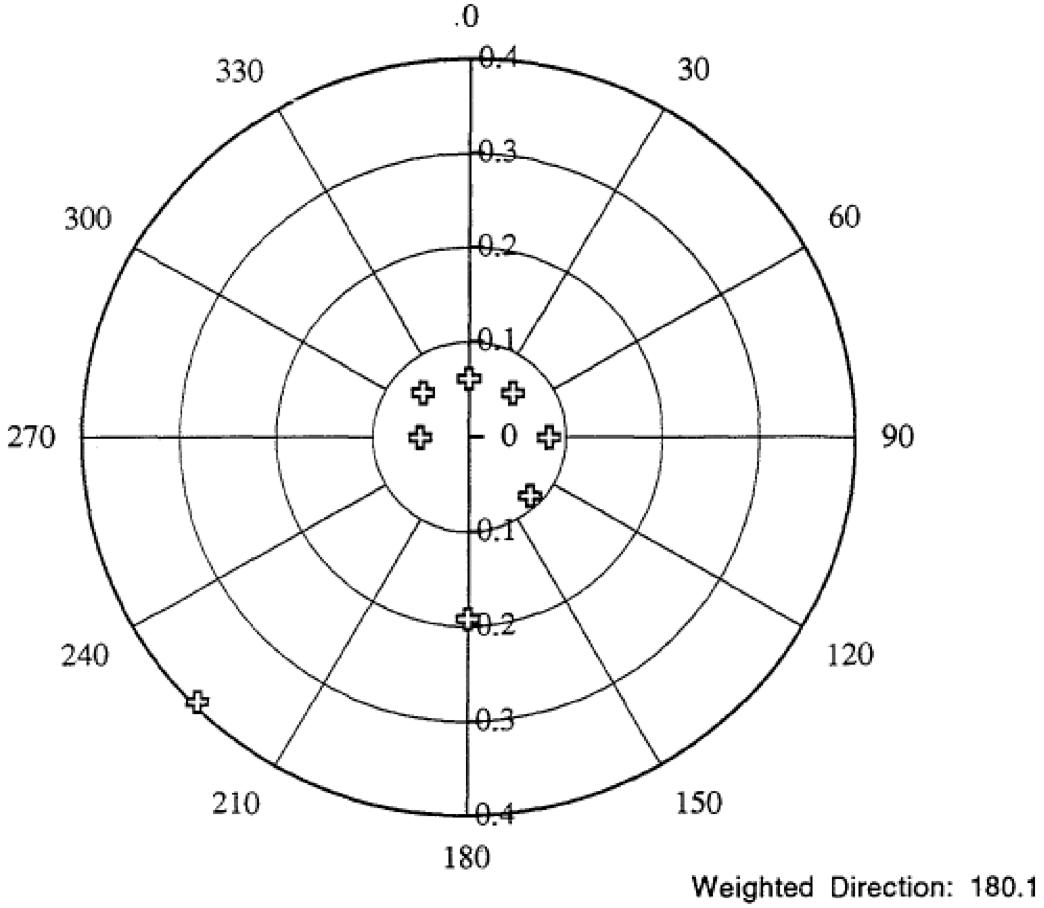


Figure 5.14. Dry Fraction Wind Rose for the Period 6/22/94-12/2/94. The numbers on the circumference correspond to the wind direction in degrees. 0 corresponds to the North. The crosses are placed in the midpoint of a 45 degree interval. The radial scale represents the fraction of time the wind is coming from the direction indicated.

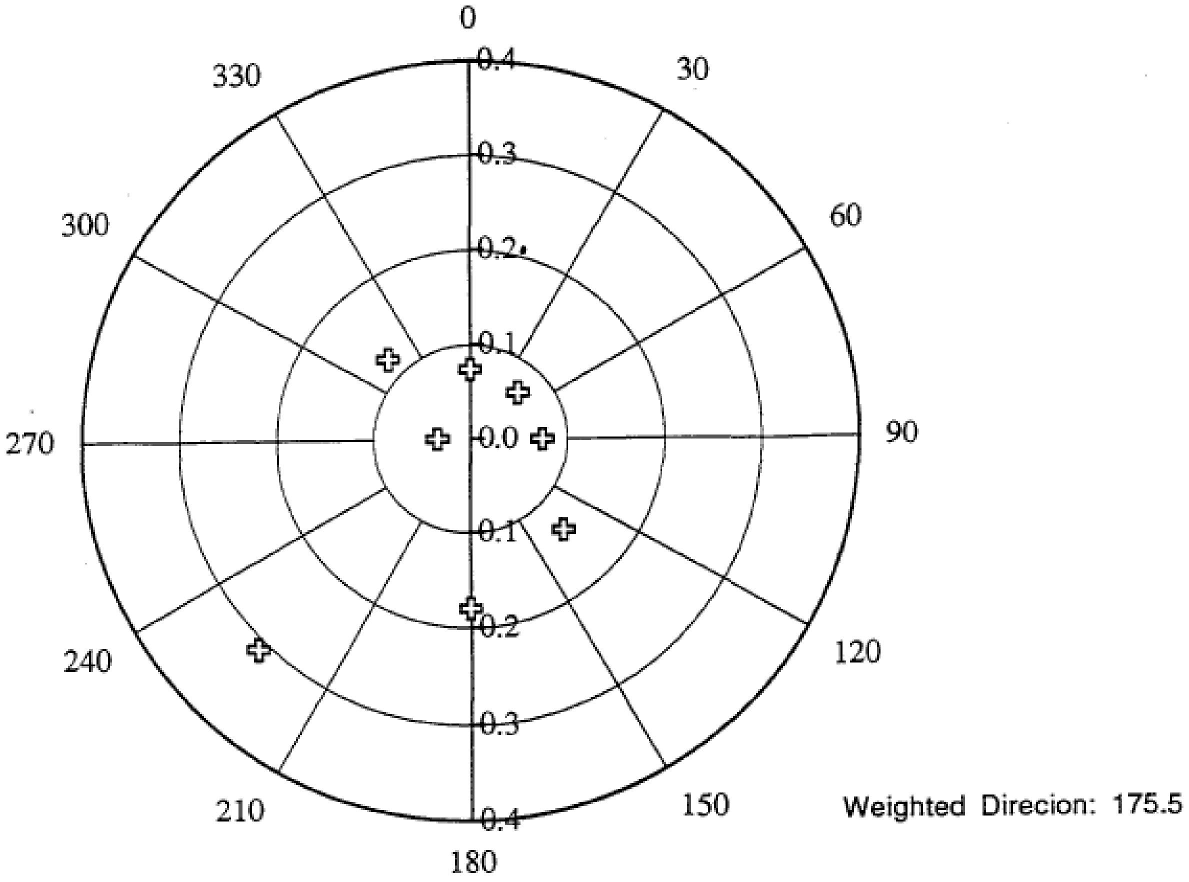


Figure 5.15. Wet Fraction Wind Rose for the Period 6/22/94-12/2/94. The numbers on the circumference correspond to the wind direction in degrees. 0 corresponds to the North. The crosses are placed in the midpoint of a 45 degree interval. The radial scale represents the fraction of time the wind is coming from the direction indicated.

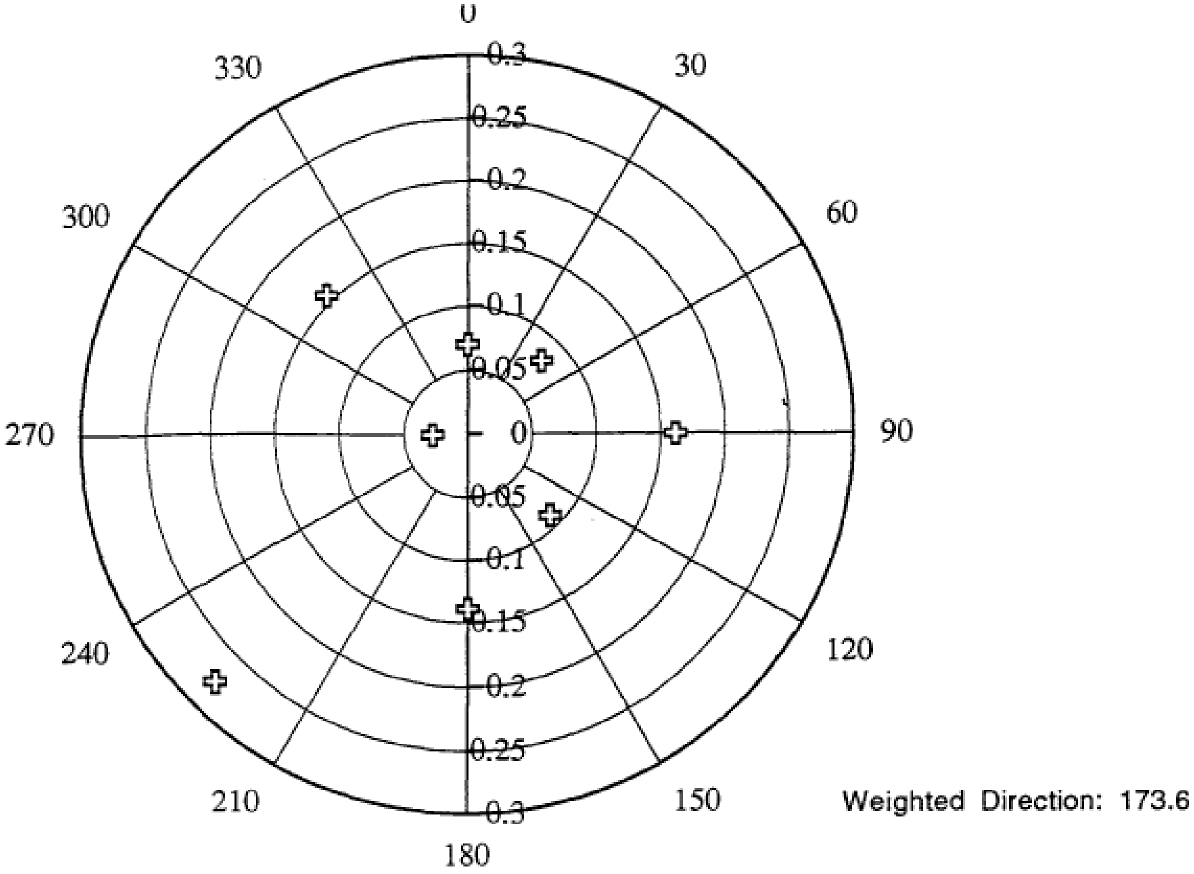


Figure 5.16. Wind Rose for Deposition Sampling Period 1/30/95-2/28/95. The numbers on the circumference correspond to the wind direction in degrees. 0 corresponds to the North. The crosses are placed in the midpoint of a 45 degree interval. The radial scale represents the fraction of time the wind is coming from the direction indicated.

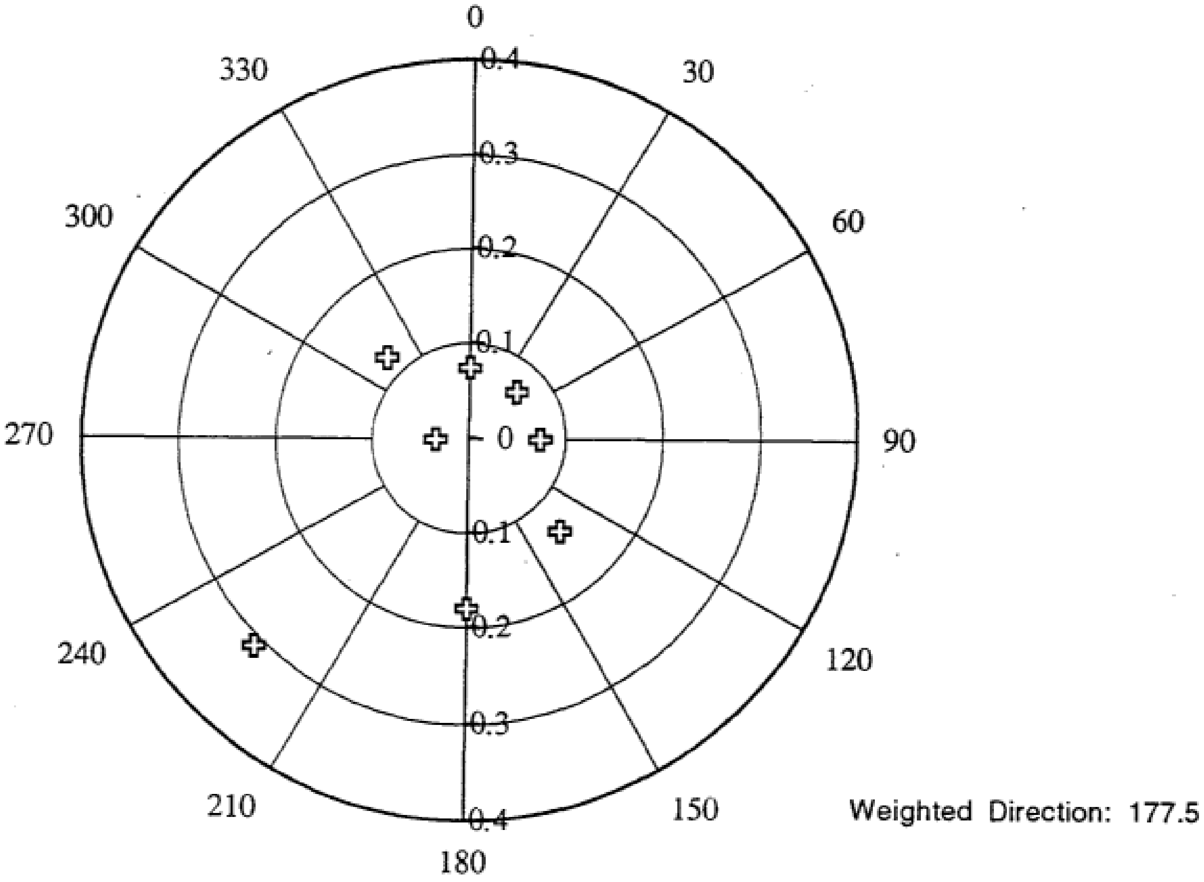


Figure 5.17. Wind Rose for Deposition Sampling Period 2/28/95-3/28/95. The numbers on the circumference correspond to the wind direction in degrees. 0 corresponds to the North. The crosses are placed in the midpoint of a 45 degree interval. The radial scale represents the fraction of time the wind is coming from the direction indicated.

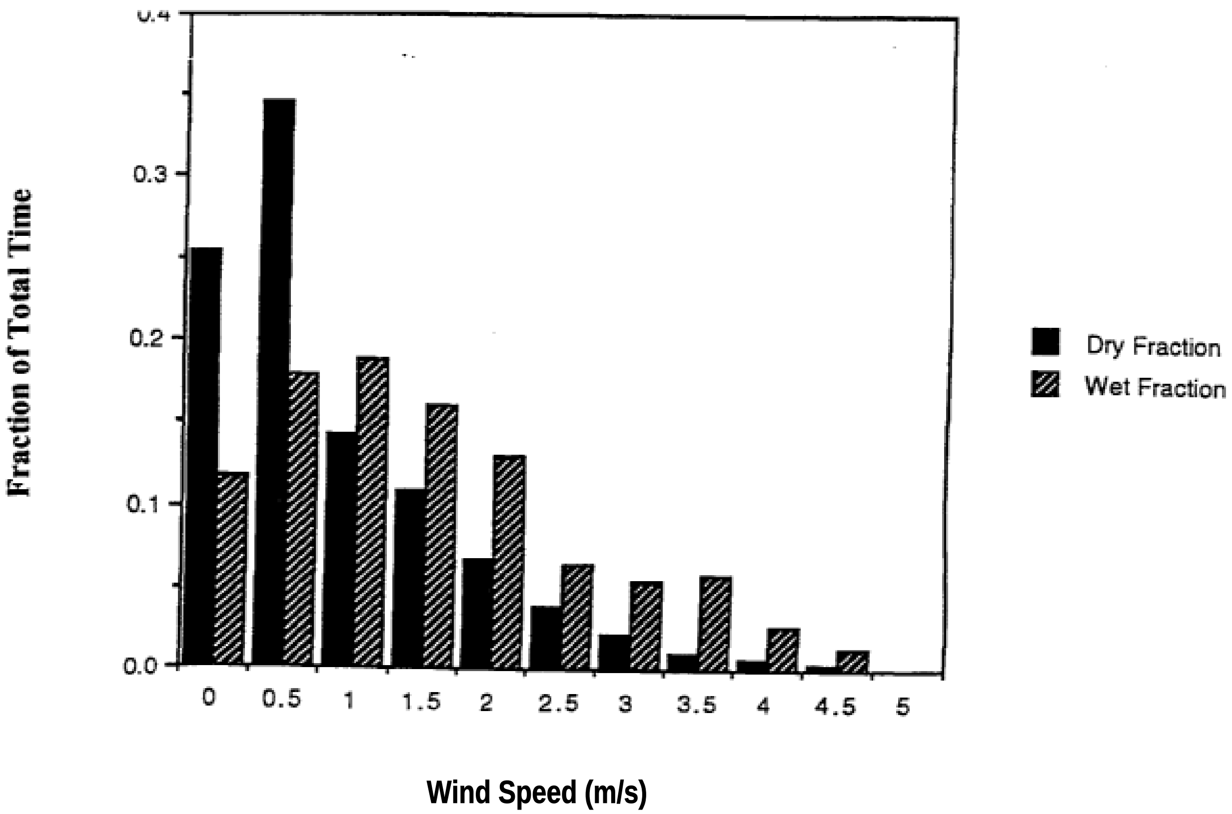


Figure 5.18. Wet and Dry Fraction Wind Speed Frequencies for the Period 6/22/94-12/2/94. The numbers on the x-axis correspond to the lower end of a 0.5 m/s interval.

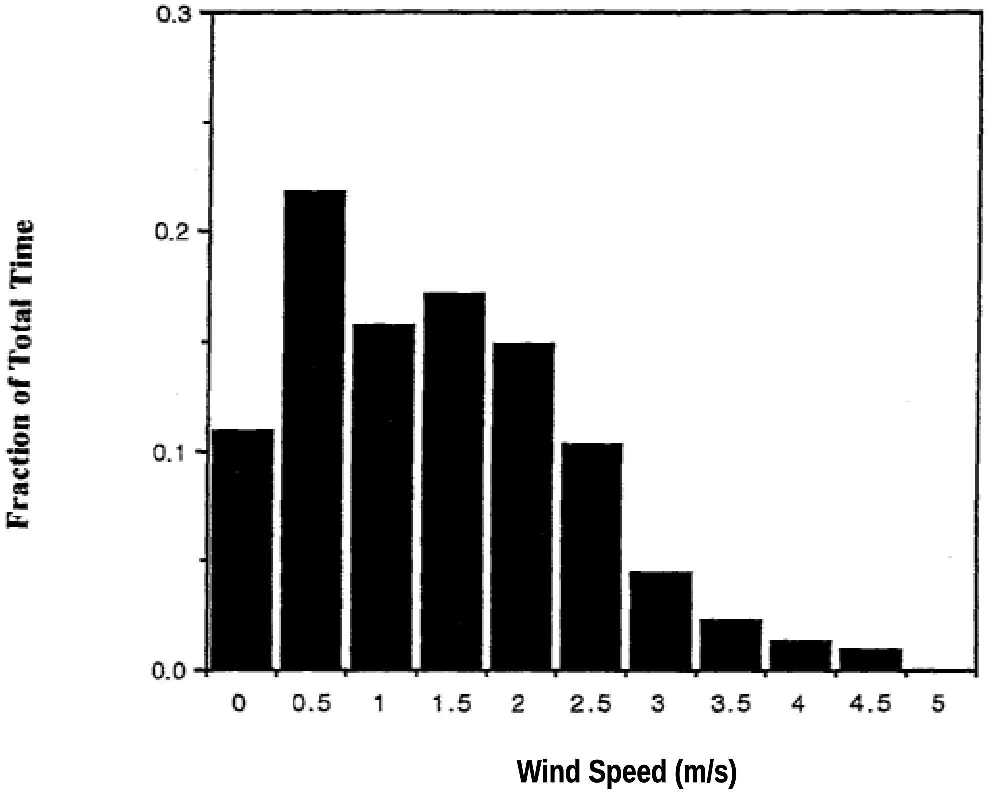


Figure 5.19. Wind Speed Frequencies for Deposition Sampling Period 1/30/95-2/28/95. The numbers on the x-axis correspond to the lower end of a 0.5 m/s interval.

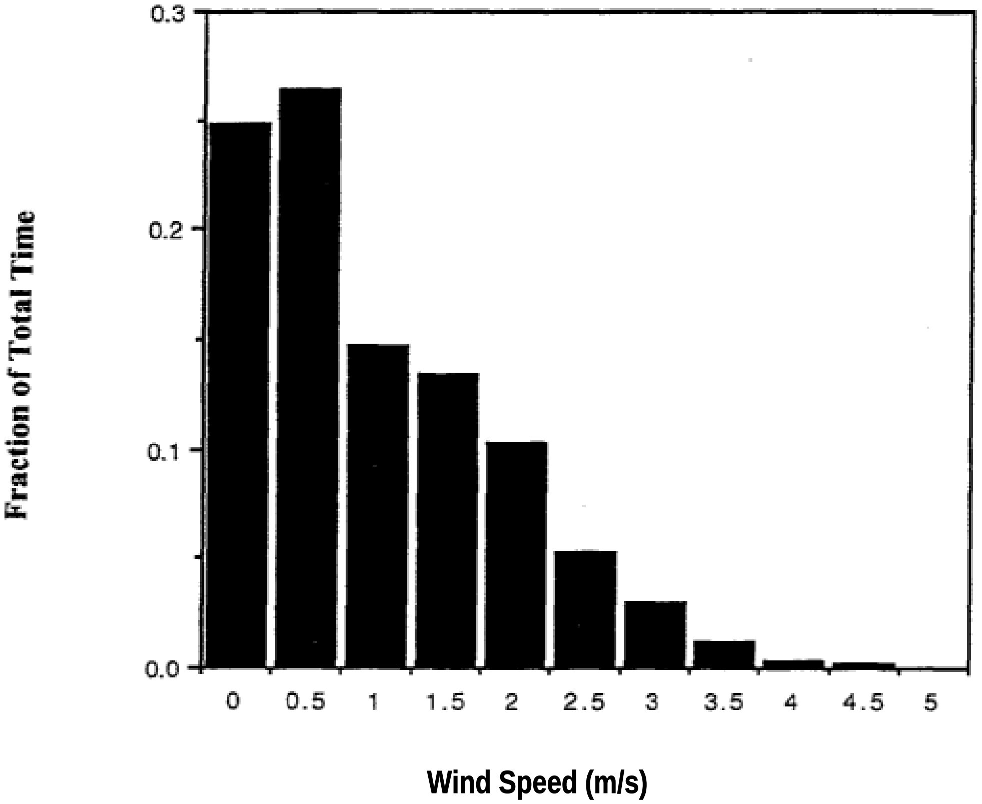


Figure 5.20. Wind Speed Frequencies for Deposition Sampling Period 2/28/95-3/28/95. The numbers on the x-axis correspond to the lower end of a 0.5 m/s interval.

Chapter 6: Conclusions and Future Work

The work conducted at the Cathedral thus far plays a part in a larger research plan to study processes responsible for air pollutant damage to limestone structures. The culmination of this work will eventually be a model that can estimate dry deposition as a function of geometry of the structure, surface characteristics, and meteorology. The compilation of chemical data has been necessary for future work. In addition, the characterization of meteorology is essential for the formulation of any dry deposition model. Future work planned builds upon the data already collected. This future work includes the measurement of vertical profiles of airborne concentrations and deposition fluxes. In addition, greater emphasis is placed on the smaller scale physical aspects of the dry deposition process.

Airborne Concentrations

Most of the species collected at the Cathedral exhibit temporal trends in addition to a considerable amount of variability between successive samples. SO_2 is an exception, showing no notable changes in concentration over the course of the seasons. Except for an outlier sample on 2/25/95, SO_2 concentrations are generally lower than 70 ug/m^3. With the available carbon concentrations, it is possible to show that between 9/11/93 and 3/18/94 SO_2 and carbon are somewhat correlated ($R^2 = 0.2$ not including an outlier SO_2 sample on 2/25/94). On the other hand, SO_2 gas and SO_4 particle concentrations show no significant correlation. SO_4 particle concentrations peak in the summers of 1993 and 1994 reaching a maximum of 22 ug/m^3 in the summer of 1994. HNO_3 concentrations follow SO_4 particle concentrations closely (R^2 0.7) with a maximum of 7 ug/m^3 in the summer of 1994. Concentrations of HNO_3 during the cold months are between 1 and 3 ug/m^3. NO_3 particle concentrations are lowest in the summer, in sharp contrast to SO_4 particle and HNO_3 concentrations.

Vertical Deposition Fluxes and Deposition Velocities

NO_3 particle deposition fluxes are somewhat variable over the course of the year, reaching a maximum of 53 ng/cm^2/day on 6/16/94. A few samples show deposition fluxes that are not significantly different from zero. SO_4 particle fluxes are also variable although all measured fluxes are greater than zero. SO_2 gas fluxes and deposition velocities are much greater than those for SO_4 and NO_3 particles. The maximum SO_2 deposition velocity is 1.6 cm/s compared to 0.23 cm/s and 0.7 cm/s for SO_4 and NO_3 particles, respectively. For the 6/16/94, 1/30/95, and 5/2/95 samples, all three species show a peak in deposition velocities. Additionally, SO_4 particles and SO_2 gas both have a peak in deposition velocities for the 4/2/95 samples.

For all three species, location “ab” has the greatest deposition fluxes and deposition velocities for most of the samples. This may be a result of enhanced turbulent delivery at this location. For the remainder of the sampling locations, deposition velocities are not significantly variable from one location to another. Locations “ab”, “ad”, “ae”, and “ak” are on sections of the Cathedral walls that are soiled. Location “am”, on the other hand, is on a section that is not visibly soiled. Therefore, one possible conclusion is that the rate of deposition is not significantly different for soiled and unsoiled areas of the Cathedral walls.

Meteorological Measurements

The wind direction is primarily from the SE for the period 6/22/94-12/2/94 and during two month-long deposition sampling periods in early 1995. In general the wind roses show no significant differences between the period starting in 6/22/94 and the deposition sampling periods. Although there are some differences in wind direction between wet and dry periods for the 1994 data, they appear to be minor. This suggests that the direction of the wind is not very dependent on factors such as the time of year or precipitation. Plots of wind speed frequencies indicate that there are, however, some differences between wet and dry periods, as well as between the two deposition sampling periods. In all cases, the half-hour average wind speed never exceeds 5 m/s.

Future Work

Future experiments are intended to enlarge the database created so far as well as increase the breadth of information about the mechanisms of dry deposition at the Cathedral. In order to increase our understanding from a macroscale point of view, future experiments include characterization of vertical profiles of concentrations and deposition fluxes, estimation of the nearby stationary source and mobile source contributions to pollutant concentrations measured at the Cathedral, and comparison of washoff rates as a function of location on the Cathedral surface. For a better understanding of the physical mechanisms of the deposition process, we plan several experiments that will aid us in estimating the individual contributions of the aerodynamic and boundary layer resistances for both particles and gases. Several additional undergraduate projects are still underway.

Starting in the fall of 1995, we will attempt to quantify the extent of vertical variations in airborne concentrations and deposition fluxes at the Cathedral. To this end, airborne concentration measurements will be conducted on the fifth floor patio, sixteenth floor patio, and roof. Concurrently, surrogate vertical surfaces will be deployed on the fifth floor and sixteenth floor patios. We will use the surrogate surfaces to measure the deposition flux of SO_2 at two different elevations. We will initiate these experiments with the intent of gaining insight into the preferential soiling of the lower areas of the Cathedral. Depending on our findings, it may also be possible to infer if the observed concentrations are due mainly to mobile or stationary sources.

The Bellefield Boiler is a small coal-fired steam plant located within a few hundred meters of the Cathedral. The two sides of the Cathedral that are facing in the direction of the boiler show the greatest amount of soiling. It is not clear if the boiler is the cause of the observed soiling or if the pollutants that affect the Cathedral originate from mobile sources or more distant stationary sources. We are attempting to determine whether or not emissions from the boiler have a significant impact on the Cathedral. In another undergraduate project, we are assessing the traffic density in the immediate vicinity of the Cathedral. This information, combined with knowledge of motor vehicle emissions, can be used as input for a box model that will give a rough approximation of the mobile source contribution to carbon concentrations observed at the Cathedral.

We are initiating experiments that will help identify the physical mechanisms of particle and gas deposition to the Cathedral walls. For this purpose, an aerosol generator may be used as a source of monodisperse fluorescent particles. Surrogate surfaces mounted on the walls will be used to collect the particles. Meteorological parameters such as wind speed profile and turbulence intensity are to be measured concurrently. Similar experiments can be performed for gas phase pollutants. In this case, we intend to measure the sublimation of naphthalene using a naphthalene source as well as the flux of SO_2 using a potassium carbonate impregnated Whatman filter. The airborne concentration of SO_2 gas will be measured concurrently. The background airborne concentration of naphthalene is assumed negligible. In principal, the sublimation of naphthalene and the deposition of SO_2 are analogous processes. Since these species are both gases, discrepancies between the deposition velocity for the two species are entirely due to differences in Brownian diffusivities that give rise to differences in the boundary layer resistances. We are determining the effectiveness of the aerosol generator and naphthalene experiments by performing pilot-scale studies.

In addition to the above listed experiments, several undergraduate projects are continuing. One of these projects is the comparative study of washoff rates. In this project, black carbon spots are applied to the Cathedral walls at various locations. The spots are checked against a Kodak gray scale every two weeks. The data collected allow us to estimate the comparative rate of washoff at different locations on the Cathedral.

Progress continues to be made in the development of a GIS (Geographic Information System). A computer model of the Cathedral is used to assign attributes to specific locations. For example, we are going to integrate the percent soiled data from the “crosses” (see Appendix C) into the GIS. In general, the GIS system is expected to be a tool to facilitate the storage and retrieval of data that have spatial attributes.

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Appendix A: Washing Procedures

This appendix contains a list of washing procedures for equipment used in the project. Some of the cleaning procedures have changed since the previous year's progress report (Lutz et al., 1994). There are 10 items listed in this appendix that are washed and used on a regular basis. These are:

Item name	**Use or purpose**
30 ml and 125 ml* polyethylene and polypropylene *bottles	**Storage of sample extracts**
Polyethylene Tupperware *boxes* 14 cm by 14 cm	**Greased Teflon sheets are placed in these boxes during extraction**
Filterpacks	**Airborne sampling filterpacks**
Vertical deposition plates	**Teflon coated aluminum sheets (12 in. by 12 in.) on which the surrogate vertical surfaces are mounted**
Teflon *rings*	**Used to mount surrogate vertical surfaces on deposition sheets**
Schotts bottles: glass bottles with colored caps	**Used to store solvents and DI water as well as grease solution for greased Teflon surfaces**
Greased Teflon vertical deposition sheets	**Circular Teflon discs that are coated with grease on one side to make the greased Teflon surrogate surfaces**
Vertical deposition sheet cover trays	**Used to cover vertical deposition sheets when they are being transported to and from the Cathedral**
Teflon *tweezers*	**Used for all sample handling purposes that require physical contact**
Whatman filters	**Potassium carbonate impregnated Whatman filters used for air sampling and deposition flux measurements of SO_2**

Any references to water, methanol, or mineral spirits implies DI water, Fisher Scientific Optima grade methanol, or Aldrich mineral spirits, respectively. Any reference to drying implies drying in a laminar flow hood.

Bottles 30 and 125 ml

1. Briefly rinse inside of cap and bottle under the DI water tap.

2. Fill with water (about half full for 30 ml bottles and a third full for 125 ml bottles) and shake for about 30 seconds. All rinsing for bottles is best accomplished by simultaneously shaking as many bottles as you can hold. In addition, with every water rinse, you should run a little water into the inside of the cap and the mouth of the bottle.

3. Fill with a small amount of methanol (finger width) and shake for about 30 seconds.

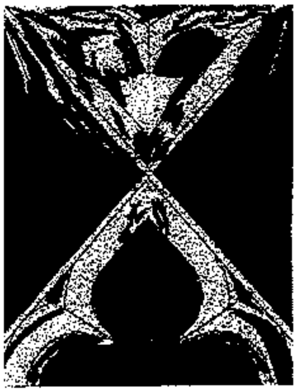
4. Rinse with water twice.

5. Completely fill with water and place cap on tightly.

6. Place in the ultrasound bath for 30 minutes. Make sure that you either place all the bottles in a clean bag full of water, or that the water in the sonicator is clean.

7. Empty out the contents of the bottle, and rinse once more with water.

8. Place bottles and caps on their sides on a clean surface in the hood.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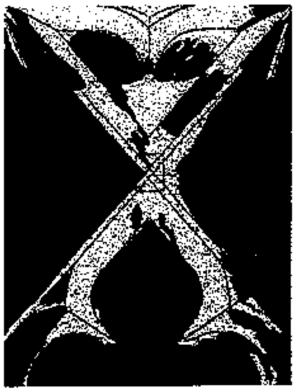
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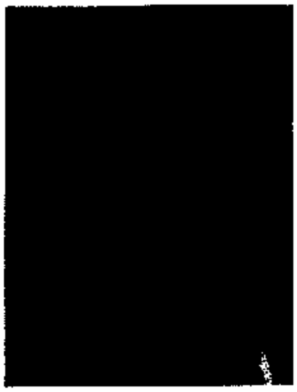
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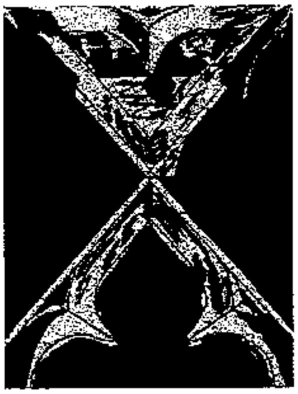
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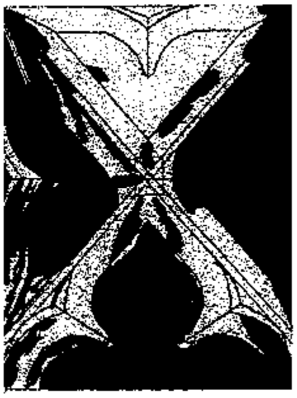
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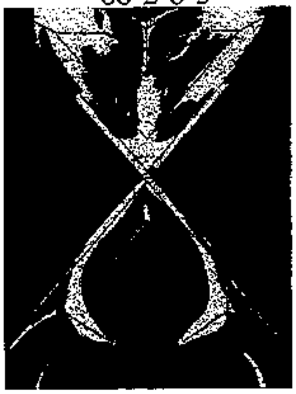
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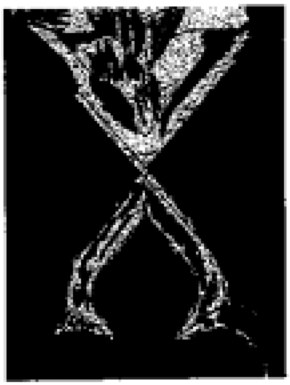
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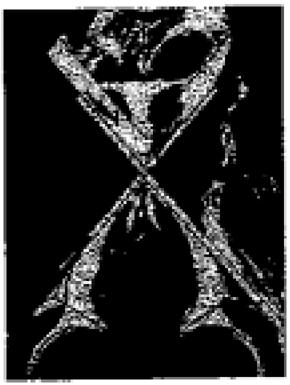
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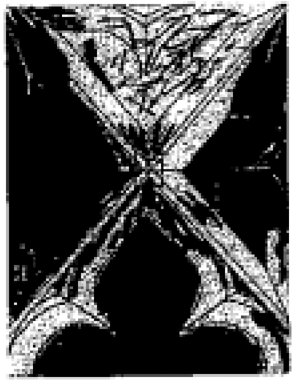
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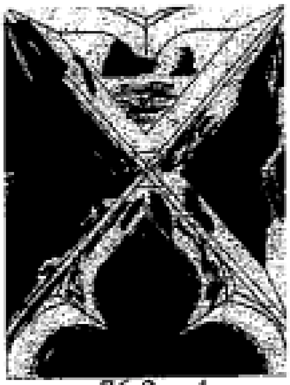
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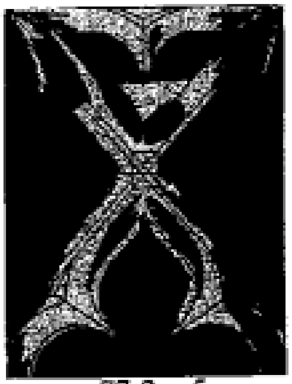
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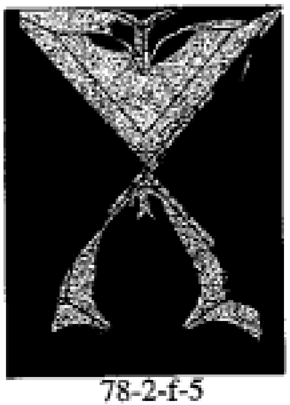
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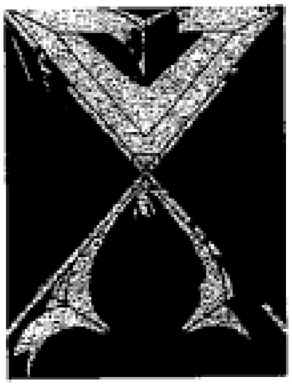
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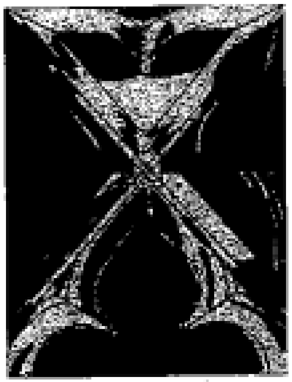
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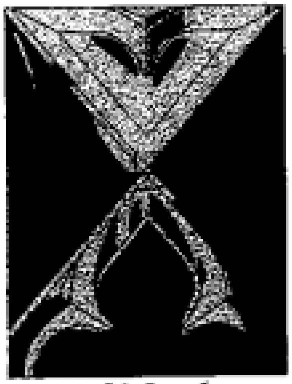
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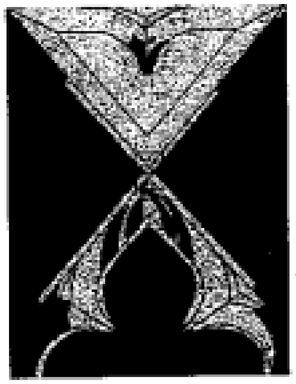
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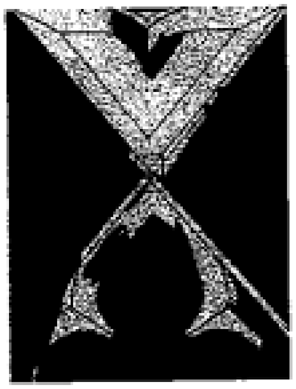
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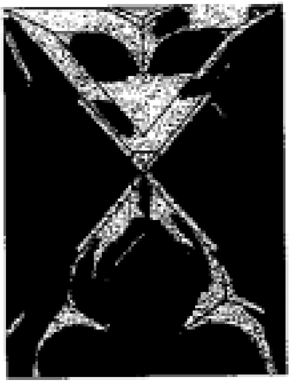
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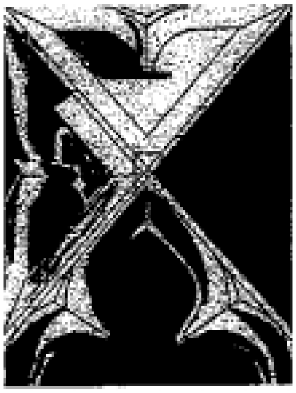

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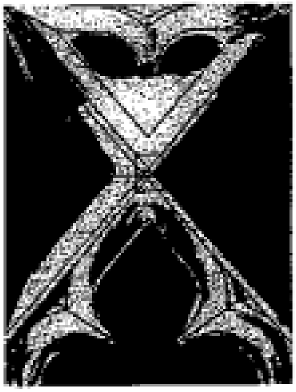

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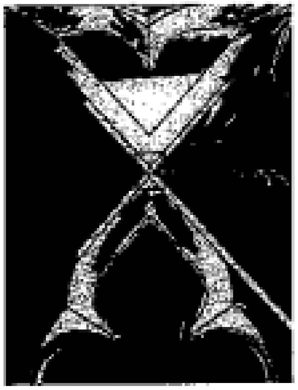

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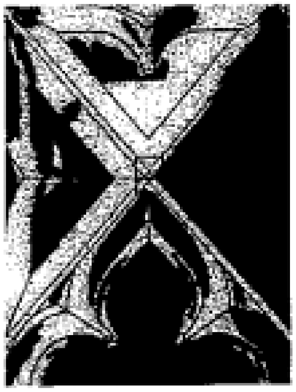

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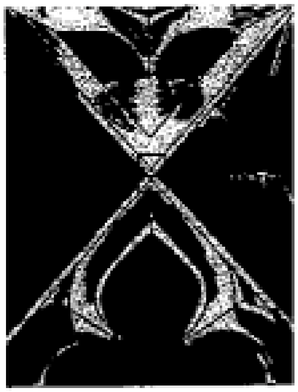

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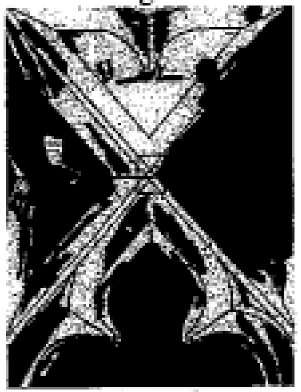

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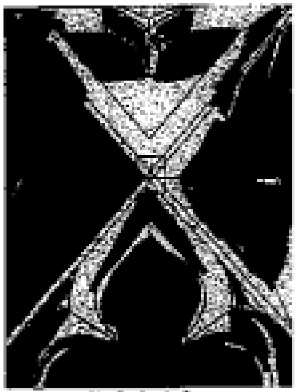

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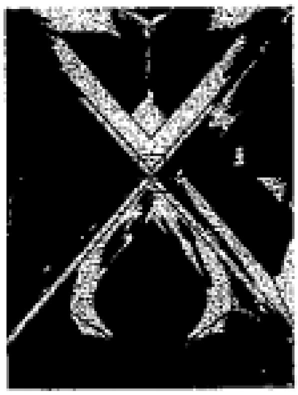

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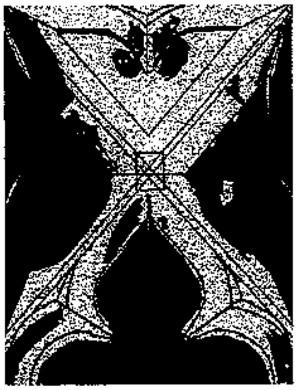
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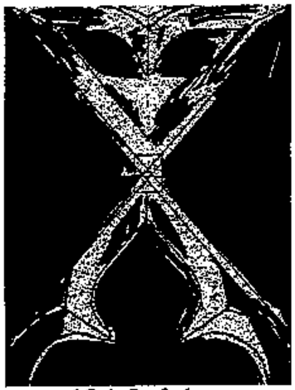
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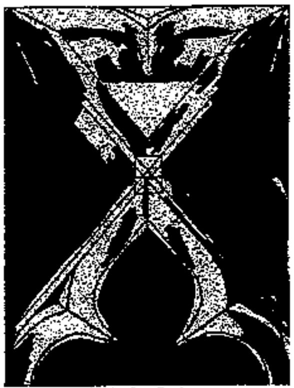
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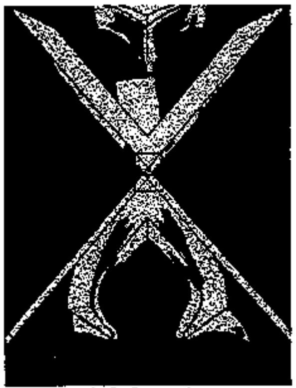
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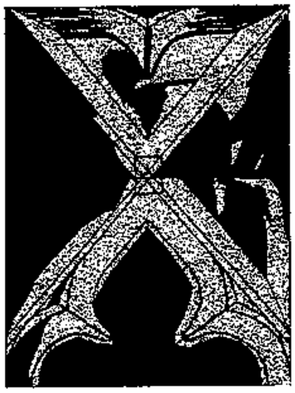
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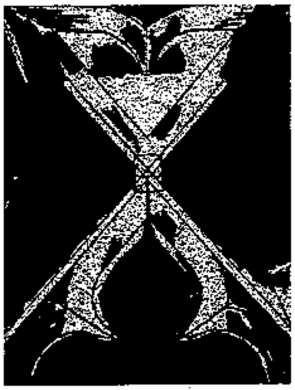
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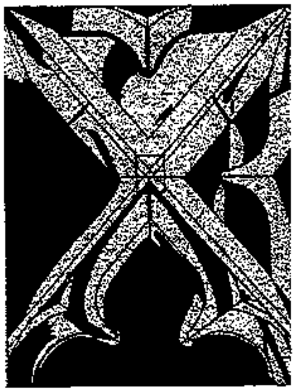
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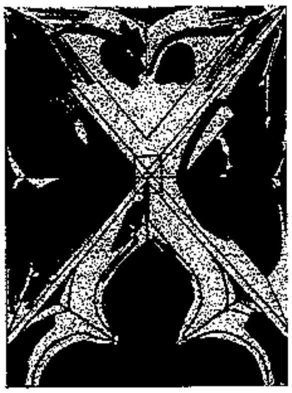
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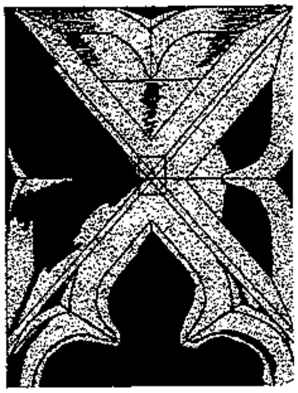
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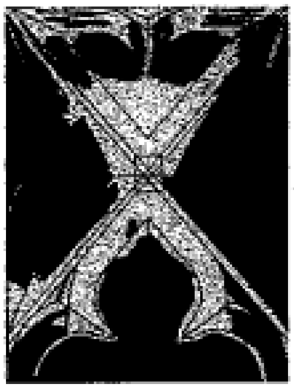

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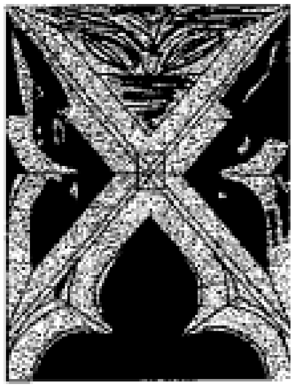

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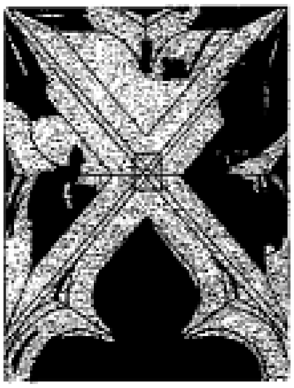

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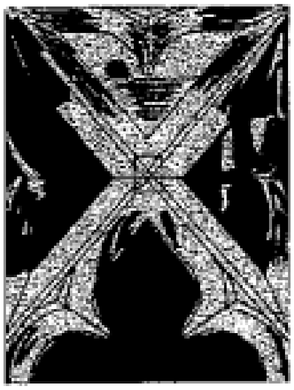

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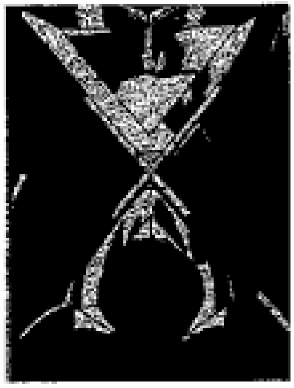

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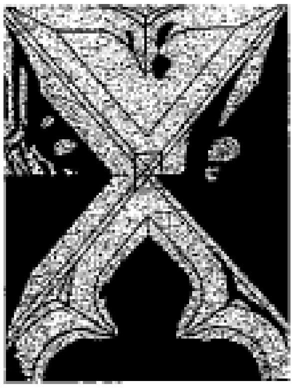

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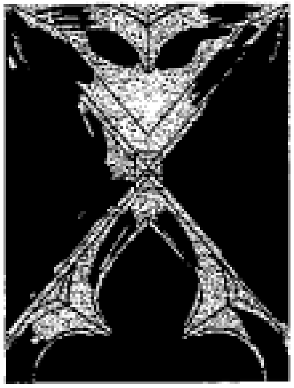

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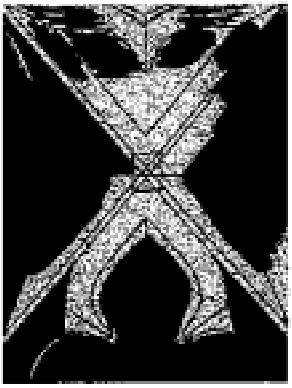

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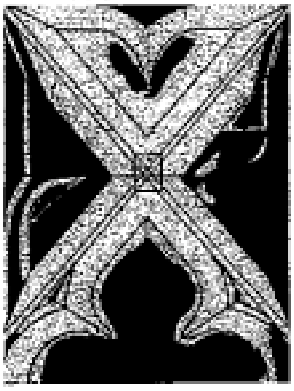

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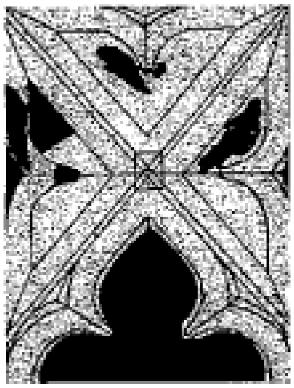

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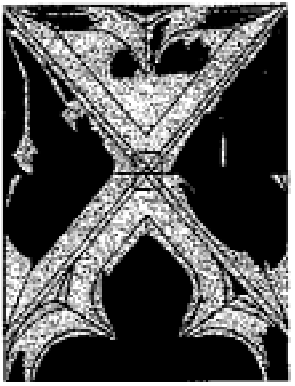

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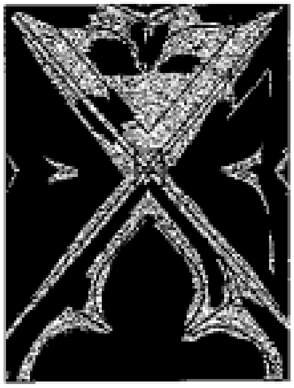

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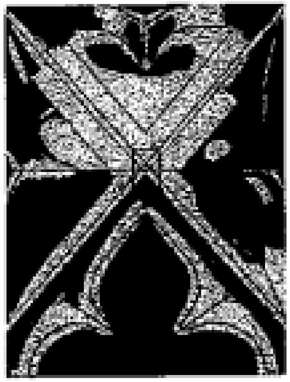
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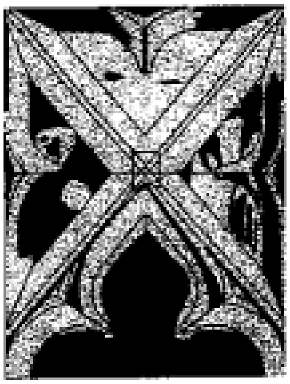
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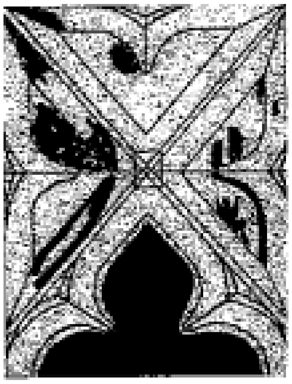
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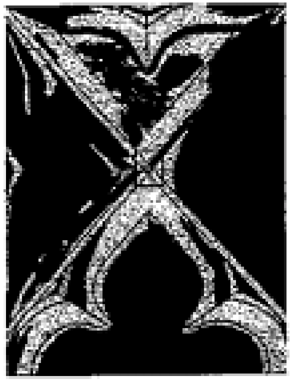
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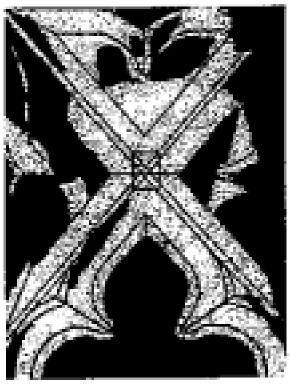
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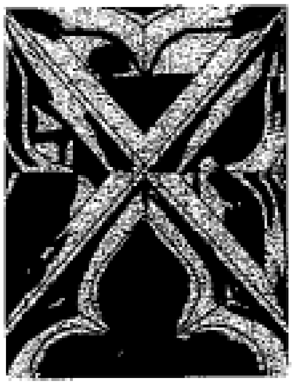
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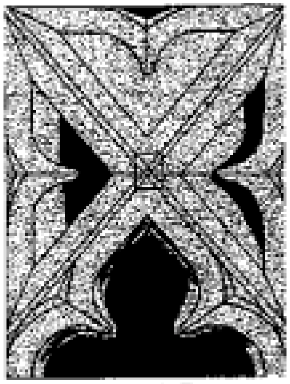
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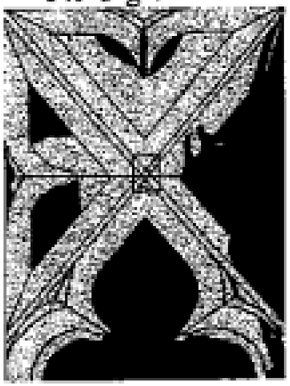
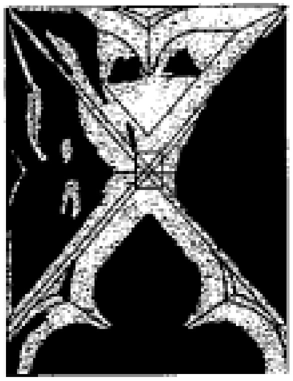

152-3-e-8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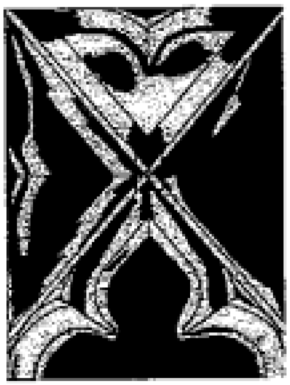
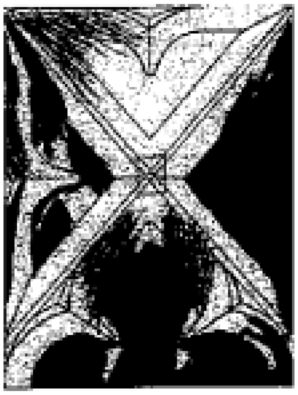

154-3-g-8


155-3-h-8


156-3-i-8


157-3-f-9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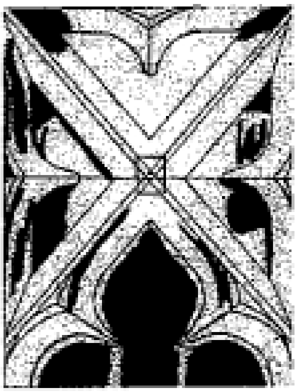
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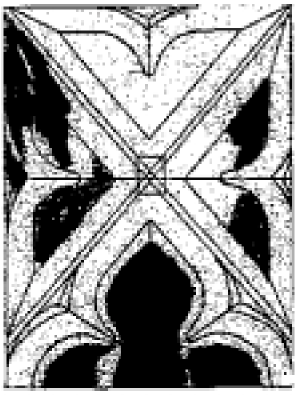
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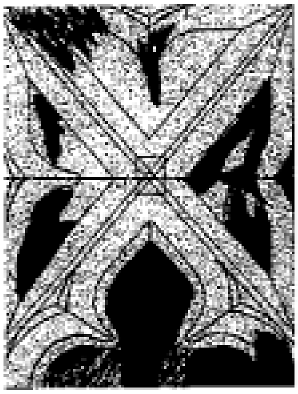
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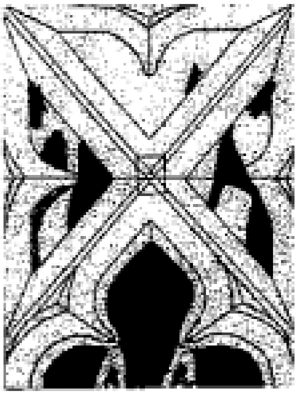
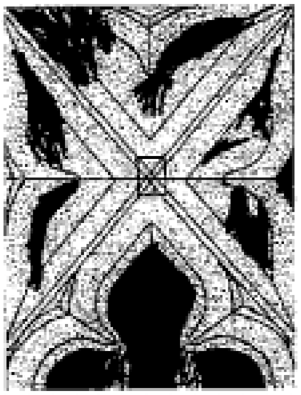

162-3-e-11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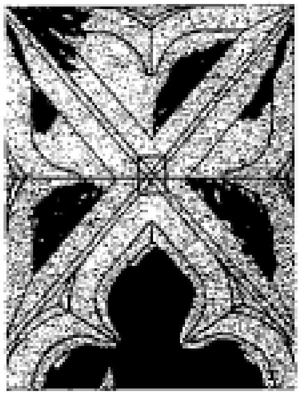
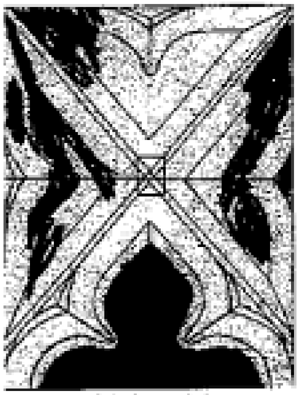
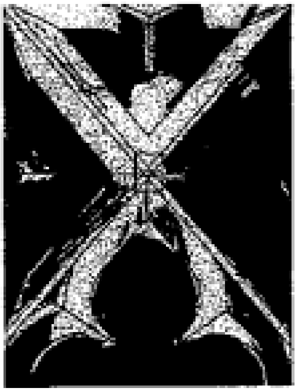
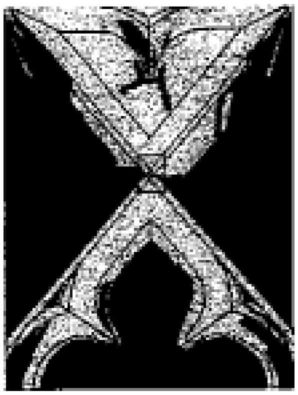
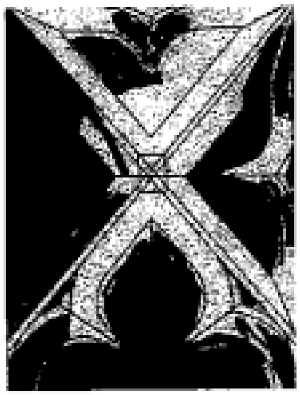
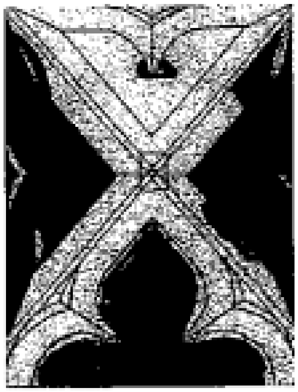

164-3-e-13

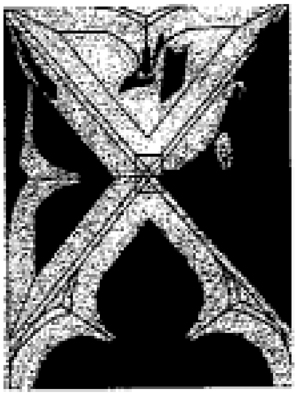

165-3-e-14

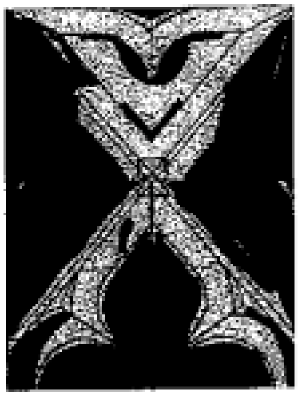

166-4-g-1

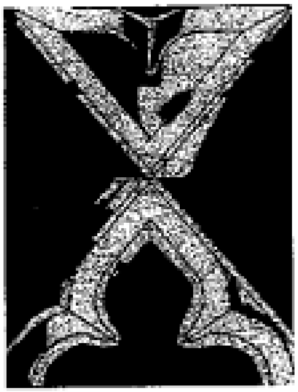

167-4-h-1

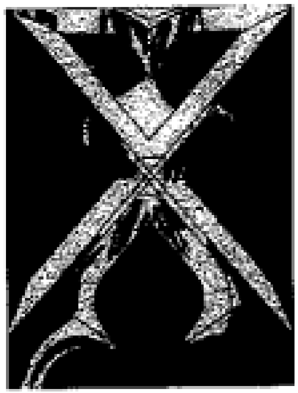

168-4-i-1

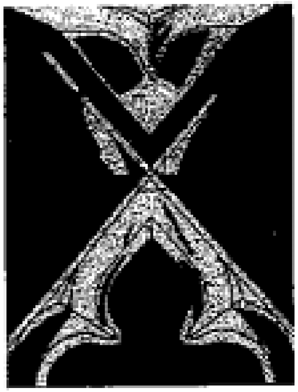

169-4-a-2

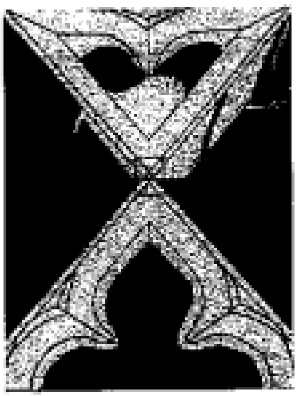

170-4-b-2

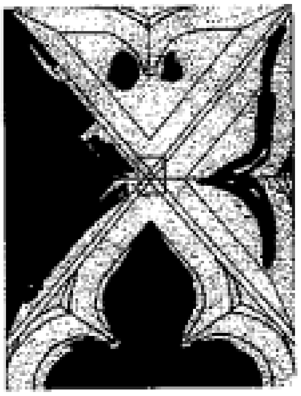

171-4-c-2


172-4-d-2

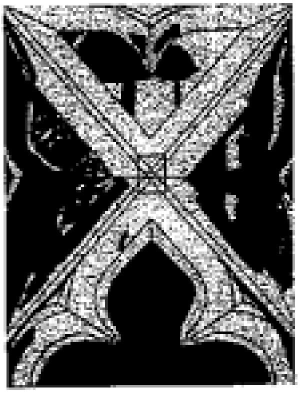

173-4-I-2


174-4-m-2

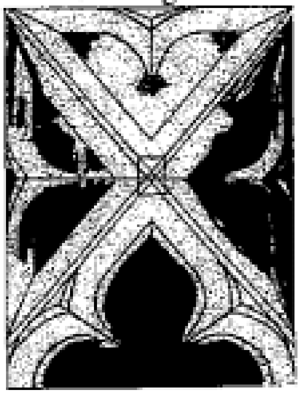

175-4-n-2

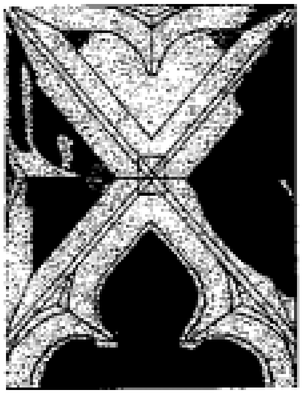

176-4-o-2


177-4-g-3

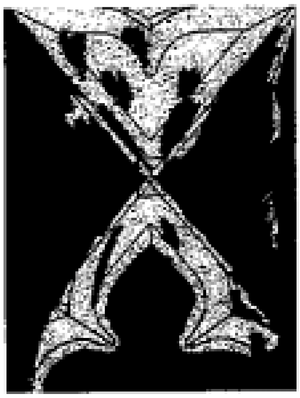

178-4-h-3

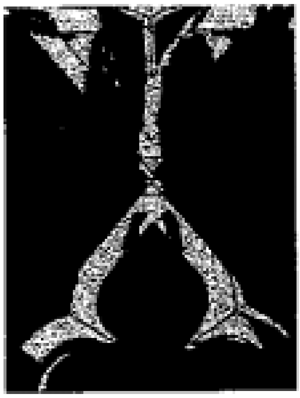

179-4-i-3

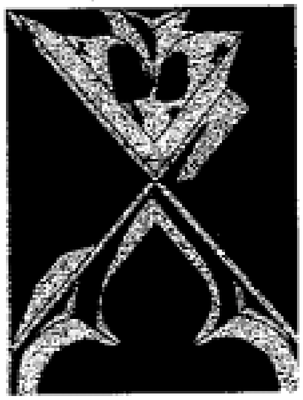

180-4-a-4


181-4-b-4


182-4-c-4

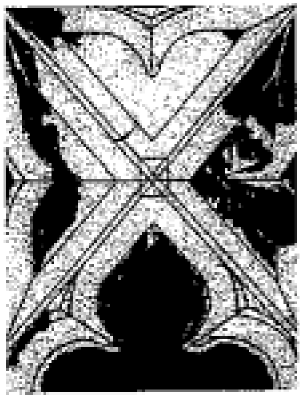

183-4-d-4

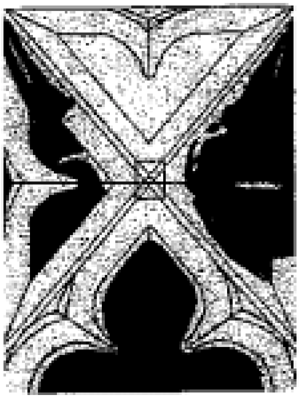

184-4-l-4

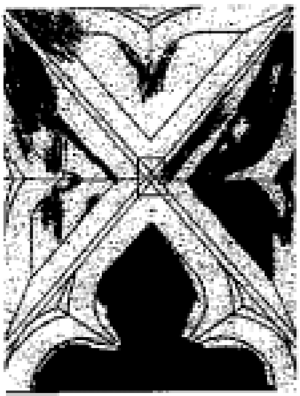

185-4-m-4

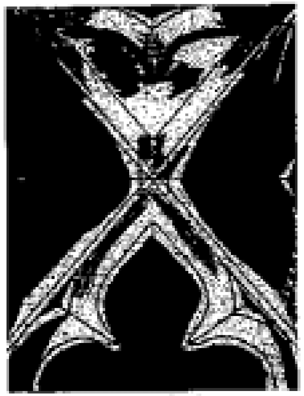

186-4-n-4

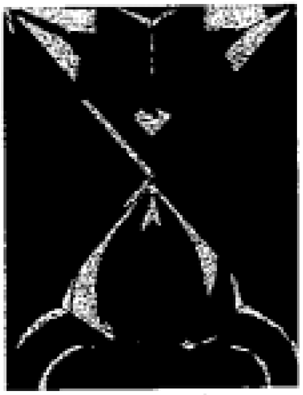

187-4-o-4

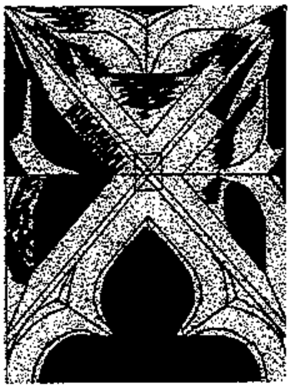

188-4-a-5


189-4-b-5


190-4-c-5

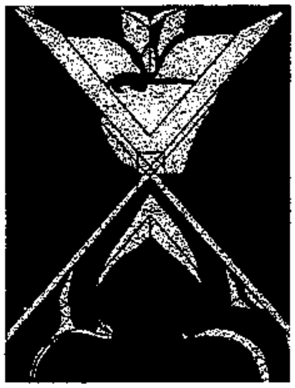

191-4-d-5


192-4-n-5

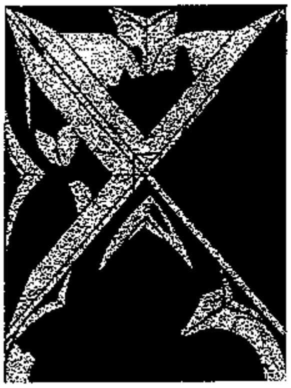


193-4-m-5

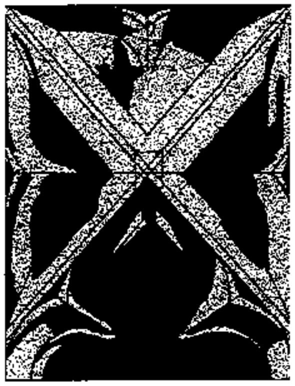
194-4-n-5



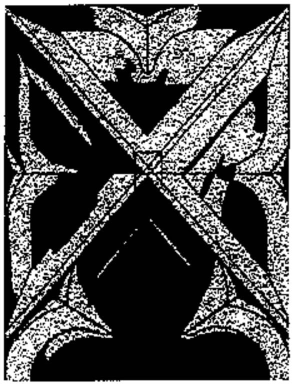
195-4-o-5



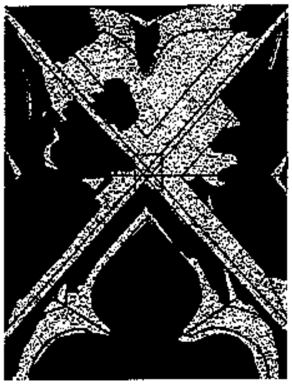
196-4-g-6



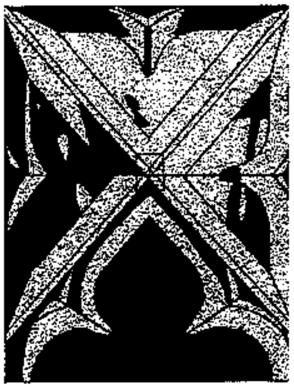
197-4-h-6



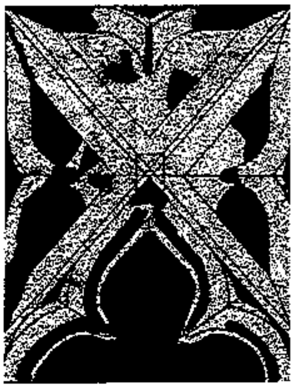
198-4-i-6



199-4-g-7



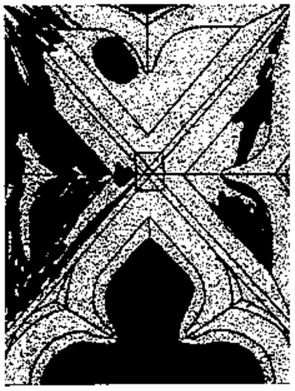
200-4-h-7



201-4-i-7

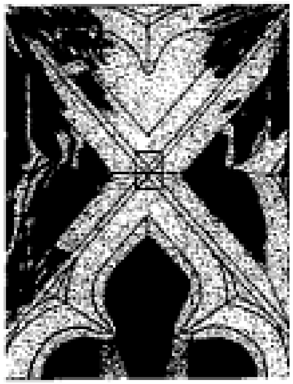
202-4-g-8

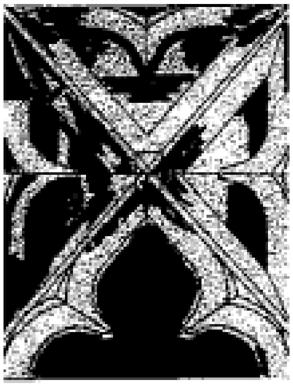
203-4-h-8

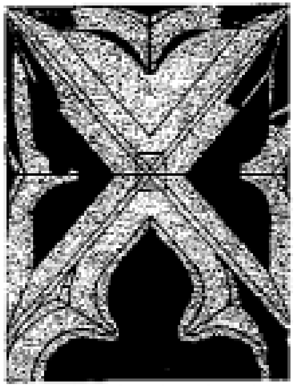


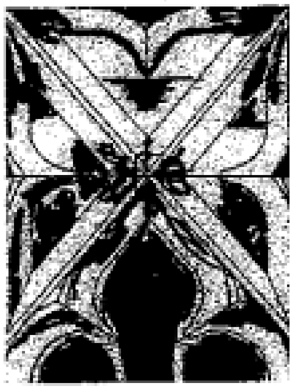
204-4-i-8

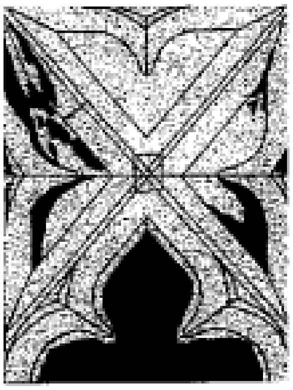

205-4-g-9

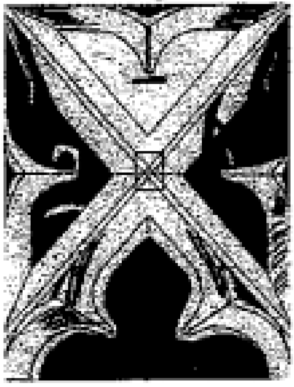

206-4-h-9

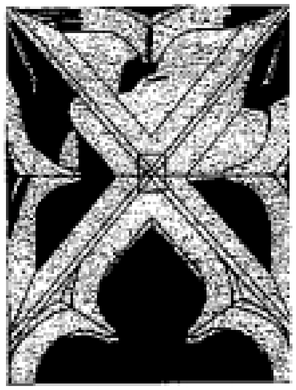

207-4-i-9

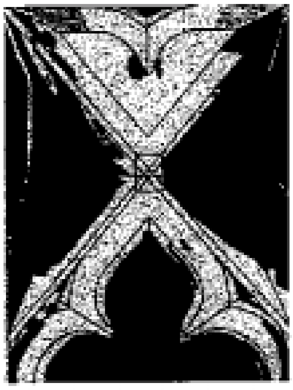

208-4-g-10

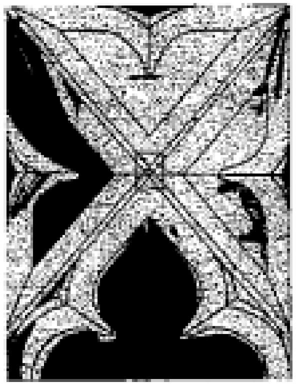

209-4-h-10

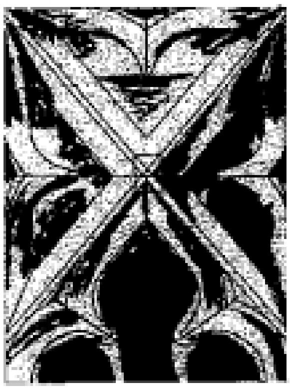

210-4-i-10

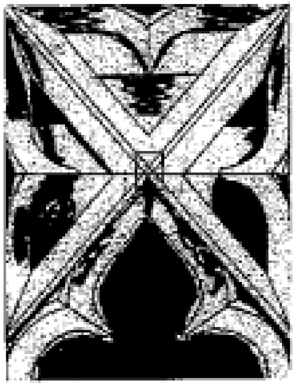

211-4-j-11

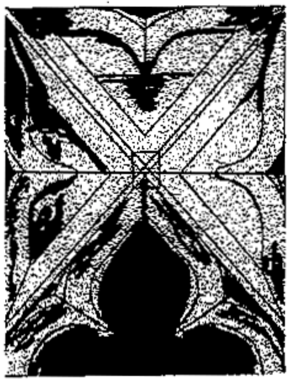

212-4-f-11


213-4-j-11

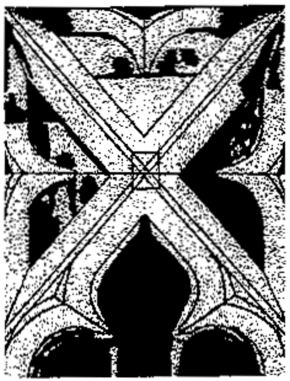

214-4-k-11


215-4-g-12

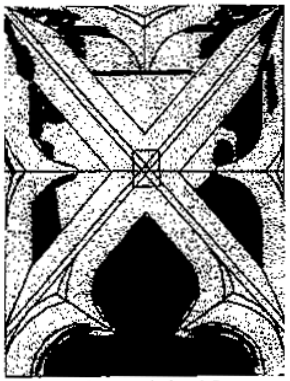

216-4-h-12



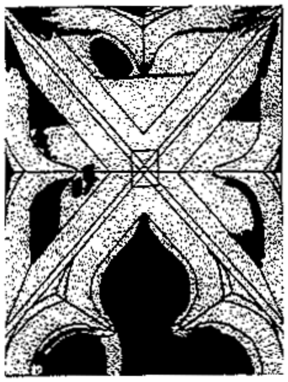
217-4-i-12



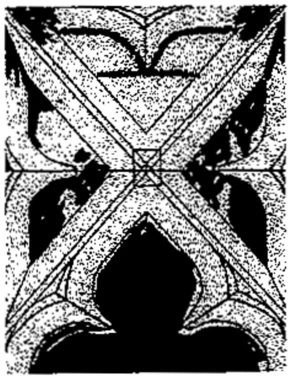
218-4-g-13



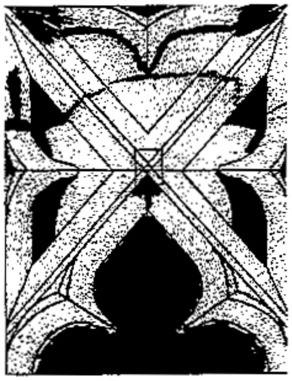
219-4-h-13



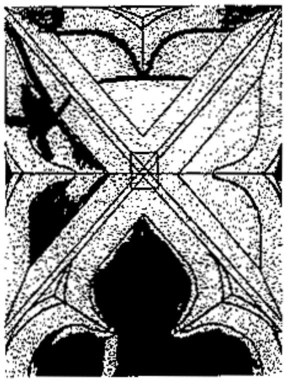
220-4-i-13



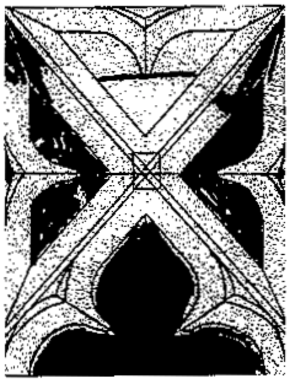
221-4-g-14



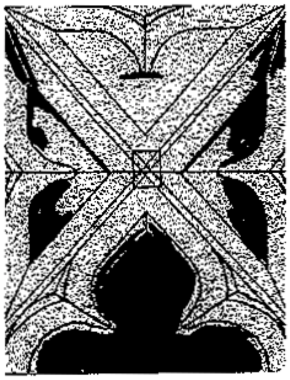
222-4-h-14



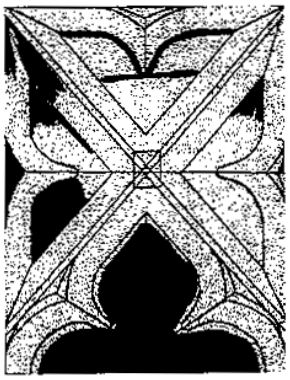
223-4-i-14



224-4-g-15



225-4-h-15



226-4-i-15

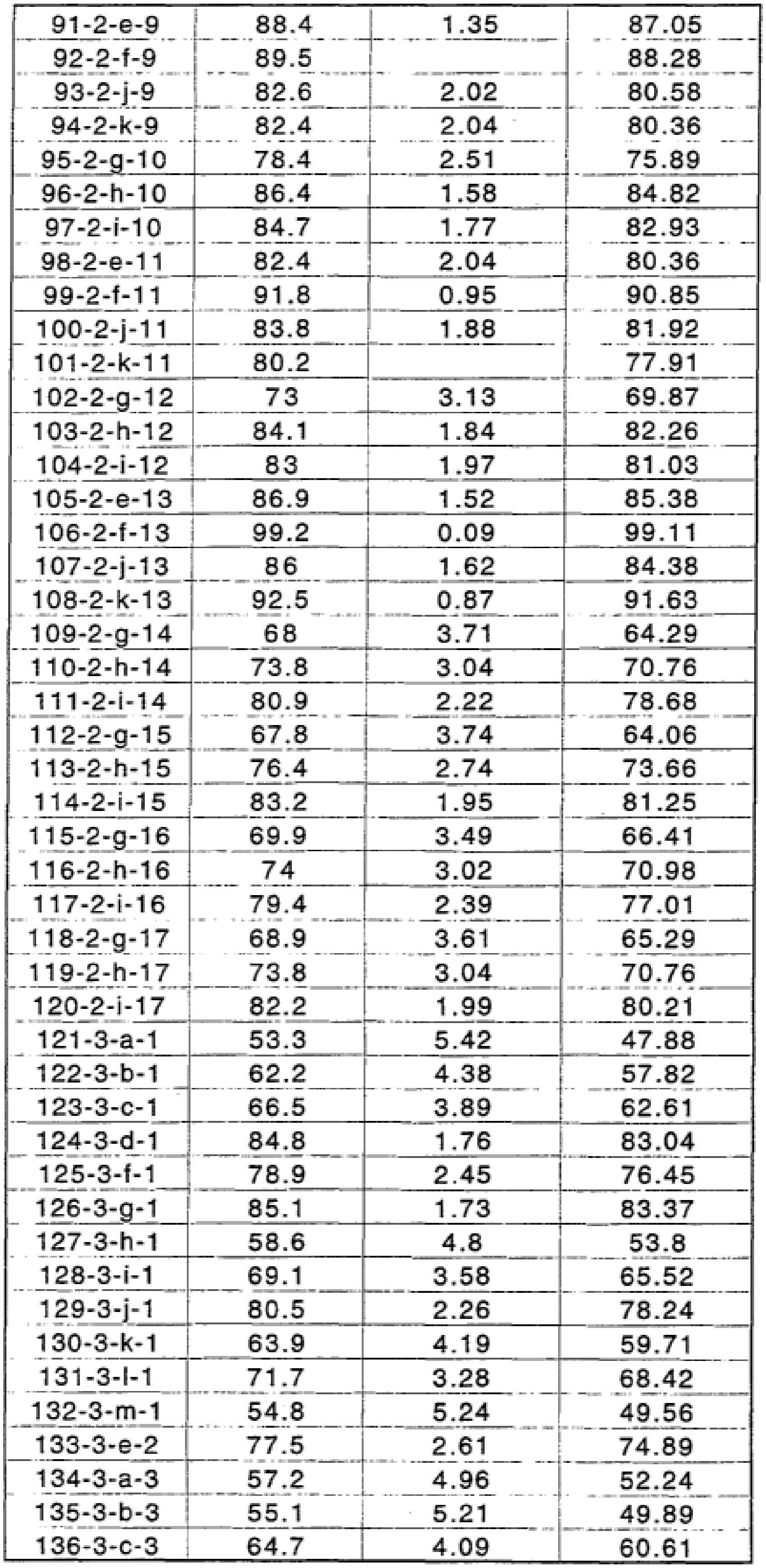
Table C-1

Cross #	Percent	Corr. Factor	True Percent
1-1-a-1	69.4	3.55	65.85
2-1-b-1	82.3	2.05	80.25
3-1-c-1	68.5	3.65	64.85
4-1-d-1	89.8	1.12	88.68
5-1-e-1	87.6	1.44	86.16
6-1-f-1	84.5	1.79	82.71
8-1-h-1	82.9	1.98	80.92
9-1-j-1	83.4	1.93	81.47
10-1-k-1	84.9	1.75	83.15
11-1-l-1	80.9	2.22	78.68
12-1-m-1	64.6	4.11	60.49
13-1-i-2	87.6	1.44	86.16
14-1-j-3	100	0	100
15-1-k-3	76.2	2.76	73.44
16-1-l-3	70.8	3.39	67.41
17-1-m-3	67.6	3.76	63.84
18-1-e-4	78.6	2.48	76.12
19-1-f-4	88.7	1.31	87.39
20-1-g-4	64.7	4.09	60.61
21-1-h-4	85.3	1.71	83.59
22-1-i-4	79.4	2.39	77.01
23-1-i-5	88.6	1.32	87.28
24-1-e-6	79.2	2.41	76.79
25-1-f-6	87.6	1.44	86.16
26-1-g-6	83.9	1.87	82.03
27-1-h-6	86	1.62	84.38
28-1-e-7	76.7	2.7	74
29-1-f-7	87.9	1.4	86.5
30-1-g-7	90.5	1.1	89.4
31-1-h-7	87.9	1.4	89.4
32-1-e-8	70.5	3.42	67.08
33-1-f-8	83.1	1.96	81.14
34-1-g-8	82.1	2.08	80.02
35-1-h-8	80.3	2.29	78.01
36-1-i-8	82.2	2.06	80.14
37-1-e-9	62.8	4.32	58.48
38-1-f-9	74.7	2.93	71.77
39-1-g-9	88.9	1.29	87.61
40-1-h-9	78.4	2.51	75.89
41-1-i-10	86.7	1.54	85.16
42-1-i-11	81.2	2.18	79.02
43-1-i-12	86.4	1.58	84.82
44-1-i-13	81	2.2	78.8

Table C-1

45-1-i-14	77.8	2.58	75.22
46-1-i-15	83.7	1.89	81.81
47-2-a-1	79.9	2.33	77.57
48-2-b-1	83.7	1.89	81.81
49-2-c-1	93.6	0.742	92.86
50-2-d-1	91.4	0.99	90.41
51-2-g-1	89.5	1.22	88.28
52-2-h-1	85.1	1.73	83.37
53-2-i-1	94.3	0.66	93.64
54-2-l-1	85.4	1.69	83.71
55-2-m-1	92.3	0.89	91.41
56-2-n-1	87.9	1.4	86.5
57-2-o-1	76.3	2.75	73.55
58-2-g-2	79.7	2.35	77.35
59-2-h-2	85.3	1.71	83.59
60-2-i-2	88.5	1.33	87.17
61-2-a-3	78.4	2.51	75.89
62-2-b-3	76.3	2.75	73.55
63-2-c-3	99.7	0.03	99.67
64-2-d-3	86.3	1.59	84.71
65-2-l-3	84.4	1.81	82.59
66-2-m-3	90.9	1.06	89.84
67-2-n-3	82.8	1.99	80.81
68-2-o-3	80.2	2.29	77.91
69-2-a-4	66.9	3.84	63.06
70-2-b-4	67.5	3.77	63.73
71-2-c-4	89	1.28	87.72
72-2-d-4	98.2	0.21	97.99
73-2-l-4	86.9	1.52	85.38
74-2-m-4	83.8	1.88	81.92
75-2-n-4	68.5	3.65	64.85
76-2-o-4	65.1	4.05	61.05
77-2-e-5	84.7	1.77	82.93
78-2-f-5	79	2.44	76.56
79-2-j-5	79.4	2.39	77.01
80-2-k-5	80.2		77.91
81-2-g-6	78.9	2.45	76.45
82-2-h-6	74.9	2.91	71.99
83-2-i-6	78.8	2.46	76.34
84-2-e-7	82.8		80.81
85-2-f-7	89.9	1.17	88.73
86-2-j-7	88.7	1.31	87.39
87-2-k-7	88.7	1.31	87.39
88-2-g-8	80.2		77.91
89-2-h-8	89.5	1.22	88.28
90-2-i-8	84.9	1.75	83.15

Table C-1



91-2-e-9	88.4	1.35	87.05
92-2-f-9	89.5		88.28
93-2-j-9	82.6	2.02	80.58
94-2-k-9	82.4	2.04	80.36
95-2-g-10	78.4	2.51	75.89
96-2-h-10	86.4	1.58	84.82
97-2-i-10	84.7	1.77	82.93
98-2-e-11	82.4	2.04	80.36
99-2-f-11	91.8	0.95	90.85
100-2-j-11	83.8	1.88	81.92
101-2-k-11	80.2		77.91
102-2-g-12	73	3.13	69.87
103-2-h-12	84.1	1.84	82.26
104-2-i-12	83	1.97	81.03
105-2-e-13	86.9	1.52	85.38
106-2-f-13	99.2	0.09	99.11
107-2-j-13	86	1.62	84.38
108-2-k-13	92.5	0.87	91.63
109-2-g-14	68	3.71	64.29
110-2-h-14	73.8	3.04	70.76
111-2-i-14	80.9	2.22	78.68
112-2-g-15	67.8	3.74	64.06
113-2-h-15	76.4	2.74	73.66
114-2-i-15	83.2	1.95	81.25
115-2-g-16	69.9	3.49	66.41
116-2-h-16	74	3.02	70.98
117-2-i-16	79.4	2.39	77.01
118-2-g-17	68.9	3.61	65.29
119-2-h-17	73.8	3.04	70.76
120-2-i-17	82.2	1.99	80.21
121-3-a-1	53.3	5.42	47.88
122-3-b-1	62.2	4.38	57.82
123-3-c-1	66.5	3.89	62.61
124-3-d-1	84.8	1.76	83.04
125-3-f-1	78.9	2.45	76.45
126-3-g-1	85.1	1.73	83.37
127-3-h-1	58.6	4.8	53.8
128-3-i-1	69.1	3.58	65.52
129-3-j-1	80.5	2.26	78.24
130-3-k-1	63.9	4.19	59.71
131-3-l-1	71.7	3.28	68.42
132-3-m-1	54.8	5.24	49.56
133-3-e-2	77.5	2.61	74.89
134-3-a-3	57.2	4.96	52.24
135-3-b-3	55.1	5.21	49.89
136-3-c-3	64.7	4.09	60.61

137-3-d-3	88.1	1.38	86.72
138-3-e-4	57	4.99	52.01
139-3-f-4	78.4	2.51	75.89
140-3-g-4	73.1	3.12	69.98
141-3-h-4	55.9	5.12	50.78
142-3-i-4	38.4	7.15	31.25
143-3-e-5	69.7	3.51	66.19
146-3-h-6	50.4	5.75	44.65
147-3-i-6	39.5	7.02	32.48
148-3-f-7	76.2	2.76	73.44
149-3-g-7	60.3	4.61	55.69
150-3-h-7	64.5	4.12	60.38
151-3-i-7	37.7	7.23	30.47
152-3-e-8	51.5	5.63	45.87
153-3-f-8	68.7	3.63	65.07
154-3-g-8	70.4	3.43	66.97
155-3-h-8	48.8	5.94	42.86
156-3-i-8	50.9	5.69	45.21
157-3-f-9	68.8	3.62	65.18
158-3-g-9	57.9	4.88	53.02
159-3-h-9	40.7	6.88	33.82
160-3-i-9	37.9	7.2	30.7
161-3-e-10	43.4	6.57	36.83
162-3-e-11	33	7.77	25.23
163-3-e-12	42.2	6.7	35.5
164-3-e-13	42.7	6.65	36.05
165-3-e-14	44.4	6.45	37.95
166-4-g-1	75.5	2.84	72.66
167-4-h-1	68.6	3.64	64.96
168-4-i-1	66.1	3.93	62.17
169-4-a-2	57.7	4.91	52.79
170-4-b-2	58.7	4.79	53.91
171-4-c-2	72.3	3.21	69.09
172-4-d-2	73.2	3.11	70.09
173-4-l-2	77.9	2.56	75.34
174-4-m-4	79.4	2.39	77.01
175-4-n-2	65.9	3.96	61.94
176-4-o-2	51.5	5.63	45.87
177-4-g-3	74.3	2.98	71.32
178-4-h-3	59.9	4.65	55.25
179-4-i-3	73.7	3.05	70.65
180-4-a-4	49.9	5.81	44.09
181-4-b-4	53.1	5.44	47.66
182-4-c-4	67.1	3.82	63.28
183-4-d-4	74.1	3	71.1
184-4-l-4	88.9	1.29	87.61

Table C-1

185-4-m-4	79.7	2.35	77.35
186-4-n-4	71.4	3.32	68.08
187-4-o-4	82.8	1.99	80.81
188-4-a-5	46.6	6.19	40.41
189-4-b-5	50.9	5.69	45.21
190-4-c-5	47.7	6.07	41.63
191-4-d-5	76.4	2.74	73.66
192-4-1-5	93.3	0.78	92.52
193-4-m-5	SS.3	5.19	50.11
194-4-n-5	59.7	4.67	55.03
195-4-o-5	82.3	2.05	80.25
196-4-g-6	75.2	2.88	72.32
197-4-h-6	64.4	4.13	60.27
198-4-i-6	59.3	4.72	54.58
200-4-h-7	58.1	4.86	53.24
202-4-g-8	60.9	4.54	56.36
203-4-h-8	62.1	4.39	57.71
204-4-i-8	48.9	5.93	42.97
205-4-g-9	68.1	3.7	64.4
206-4-h-9	54.3	5.3	49
207-4-i-9	57.6	4.92	52.68’
208-4-g-10	52.9	5.46	47.44
209-4-h-10	51.3	5.65	45.65
210-4-i-10	37.4	7.26	30.14
211-4-e-11	52	5.57	46.43
212-4-f-11	49.8	5.82	43.98
213-4-j-11	67.4	3.78	63.62
214-4-k-11	46.3	6.23	40.07
215-4-g-12	57.7	4.91	52.79
216-4-h-12	49.6	5.85	43.75
217-4-1-12	46.8	6.17	40.63
218-4-g-13	43.9	6.51	37.39
219-4-h-13	42.4	6.68	35.72
220-4-1-13	38.4	7.15	31.25
221-4-g-14	42.8	6.64	36.16
222-4-h-14	41.9	6.74	35.16
224-4-g-15	44.9		38.51
225-4-h-15	41.6		34.83
226-4-i-15	36.8		29.47

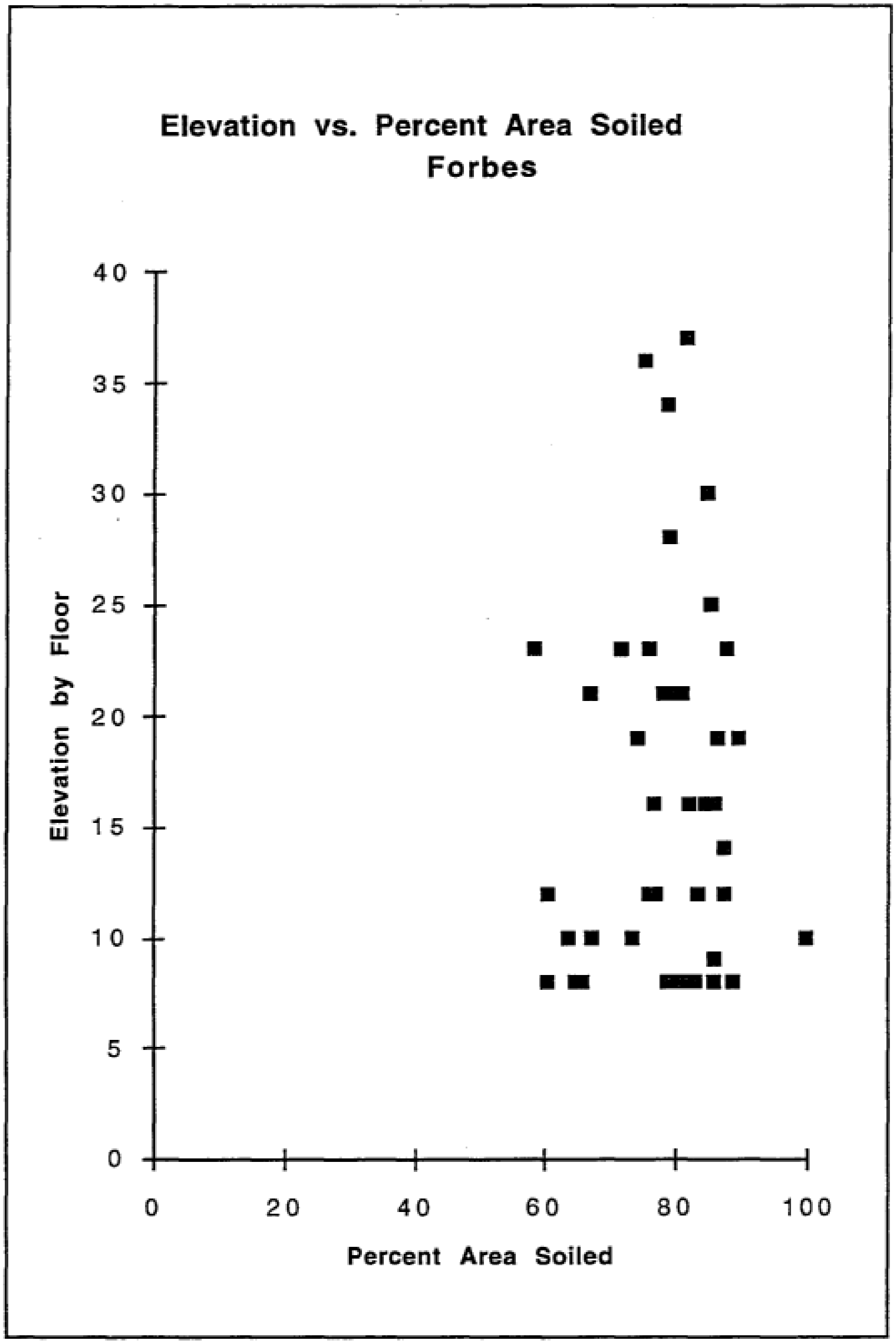
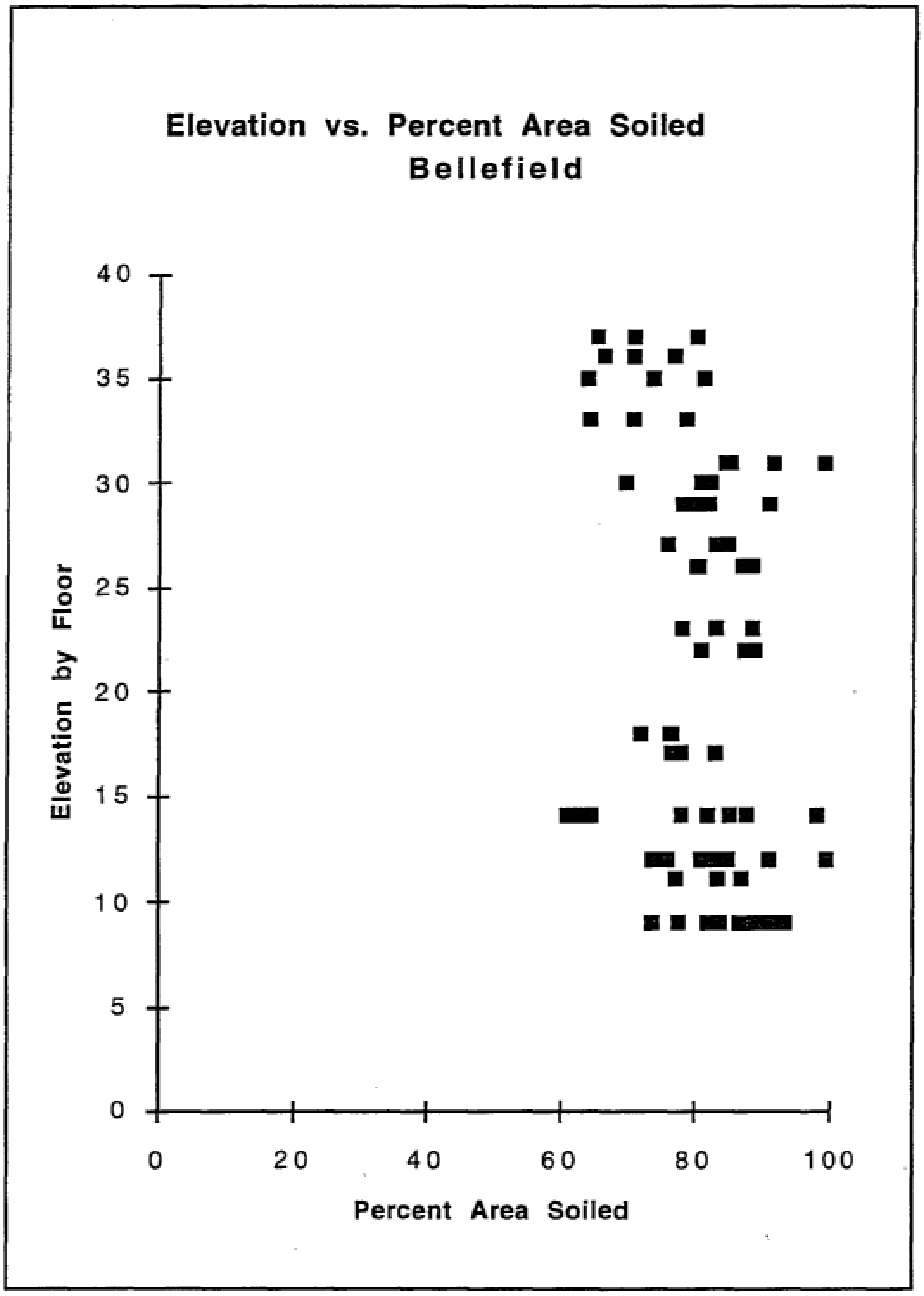
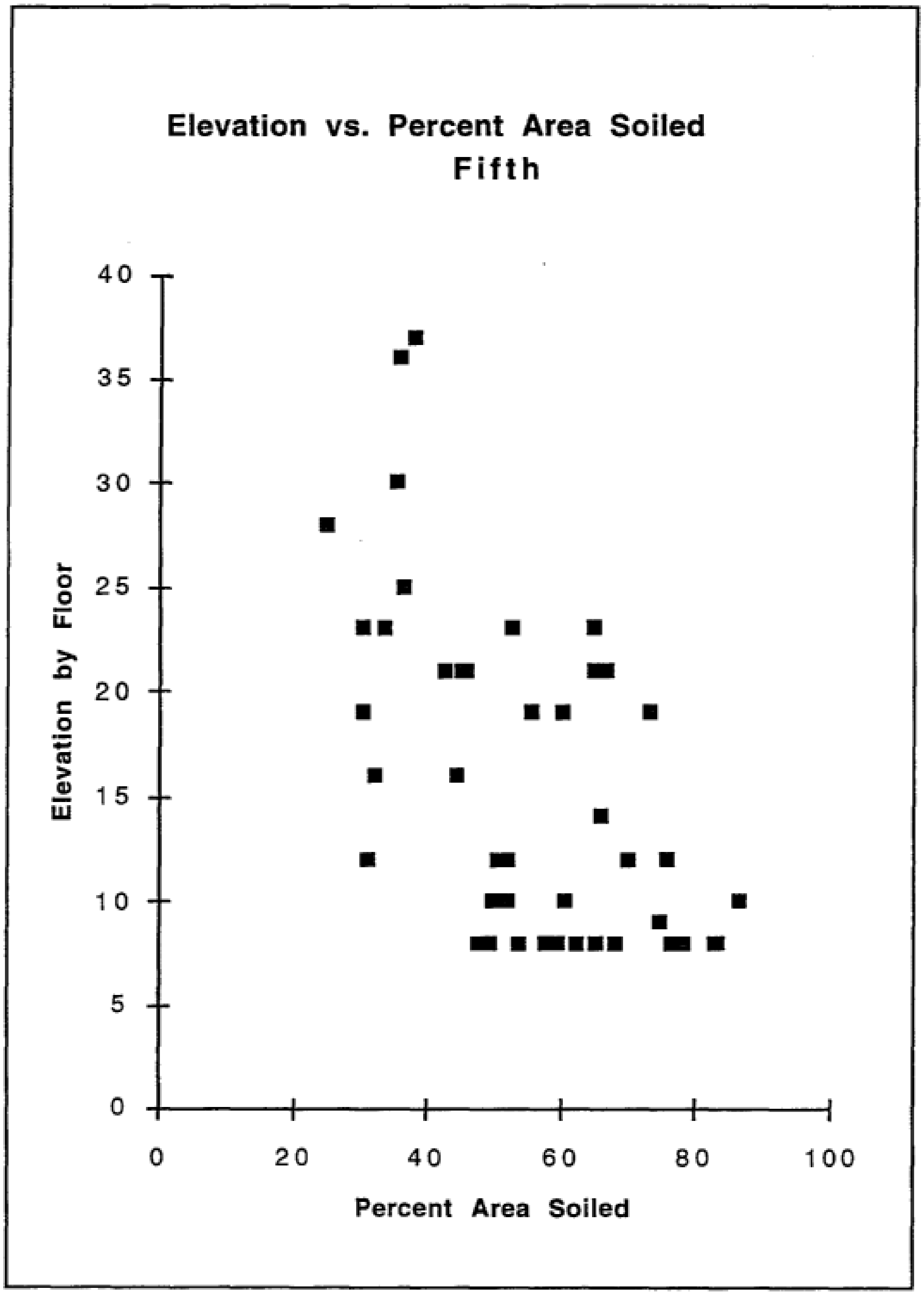
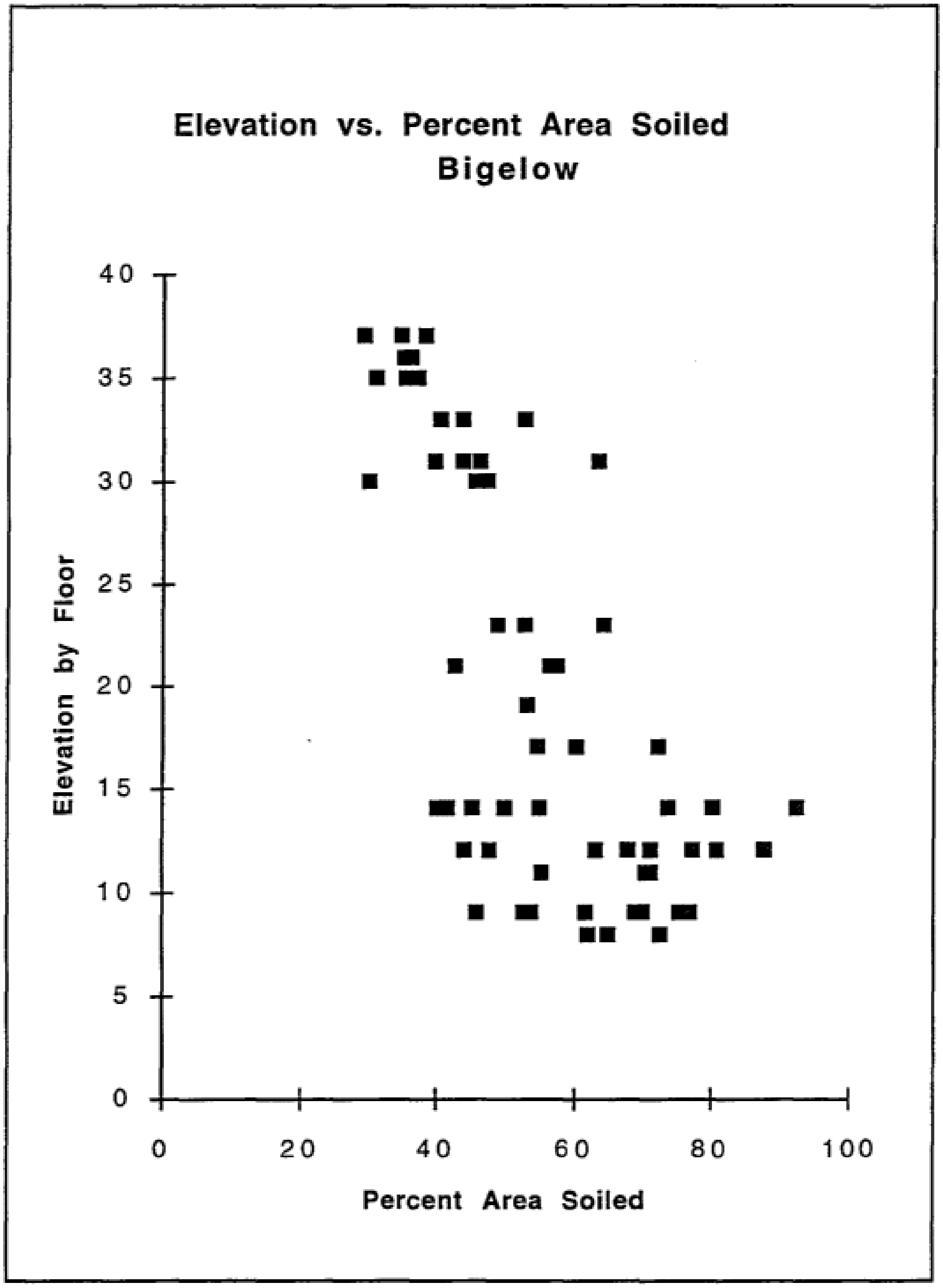

Elevation vs. Percent Area Soiled
Forbes
Elevation by Floor
Percent Area Soiled
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100

Figure C-3


Elevation vs. Percent Area Soiled
Bellefield


Elevation vs. Percent Area Soiled
Fifth
Elevation by Floor
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
Percent Area Soiled


Elevation vs. Percent Area Soiled
Bigelow
Elevation by Floor
Percent Area Soiled
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100

Appendix D

Changes in Soiling Patterns Over Time at the Cathedral of Learning Based on Archival Photographs

Justin O. Parkhurst

Introduction:

Currently there is severe soiling on the Cathedral of Learning which discolors it a dark gray or black. However, the soiling is not uniform on the sides of the Cathedral. Indeed, two of the sides are relatively clean (the Fifth Avenue side and the Bigelow Boulevard side), while the other two sides (the Forbes Avenue and Bellefield Avenue sides) have a significant amount of soiling. Overall, the soiling has been hypothesized to be the result of two competing processes. The first is the deposition of carbon particles on the stone, especially on sections of stone which have reacted with SO_2 to form gypsum. The second of the competing processes is washoff of the particles by rain (NAPAP, 1990). In this model, soiling will increase whenever particle deposition occurs at a greater rate than washoff, and soiling will decrease whenever the opposite is true.

The building itself has some unique advantages for being the subject of a study of this kind. One advantage is that different soiling amounts are visible. The non-uniformity of soiling leads to a number of possible theories as to what could cause such an effect. Another advantage is that the Cathedral is the tallest structure in the area. This in turn means that any prevailing wind and weather patterns will not be altered much due to surrounding structures. However, the design of the building, with its multiple faces and its intricate stonework, leads to problems because these features alter the microscale wind patterns in complex ways.

The remainder of this report will be organized as follows: First the objectives of the research will be described, followed by the methods used for data collection. The results will then be presented, much of which is comparative photographs. Additional observations made at the building will also be listed, and finally conclusions will be drawn with further study suggested.

Objective:

The purpose of this study was to find information on how the soiling on the Cathedral of Learning was changing over time. Before this study, it was not known whether the soiling was a recent or past phenomenon, or if the soiling was increasing or decreasing. The history of the soiling is needed to help isolate its possible causes. This, in turn, can help the effort to learn more about similar soiling of other limestone buildings and monuments.

Methods:

The objective was achieved through the collection and use of archival photographs. In this way, soiling on specific areas of the building could be identified. Comparable photos - ones which showed similar faces of the building - were used to observe how the soiling patterns changed over time. A large number of modern photographs of the building were also taken during the course of this study.

The archival photographs came from a variety of sources, and copies of some of the photographs were made in the form of slides. The advantage of slides was they could be projected as large as needed and, through the use of two projectors, could be directly compared side by side. Many of the modern photos taken during this study were made into slides for this type of comparison. Some photographs, however, were not of sufficiently high quality to enable reproduction as slides. In these cases, photocopies (for our files) or written descriptions of important aspects were used as data, usually to further support evidence shown by the slides.

The specific sources of the archival photographs were as follows (see Appendix 1 for contact information):

- The Carnegie Public Library of Pittsburgh - many early photographs, including ones from the 1930's.
- The University of Pittsburgh Archives - a variety of photos, with some older ones as well.
- J. B. Jeffers Studios, a private company - some good pictures ranging from the 1970's to today.
- The Historical Society of Western Pennsylvania - a limited selection of dated pictures with some older photos.
- Herb Ferguson, of the University of Pittsburgh Photo Services - a large personal collection of photographs from the 1980's.

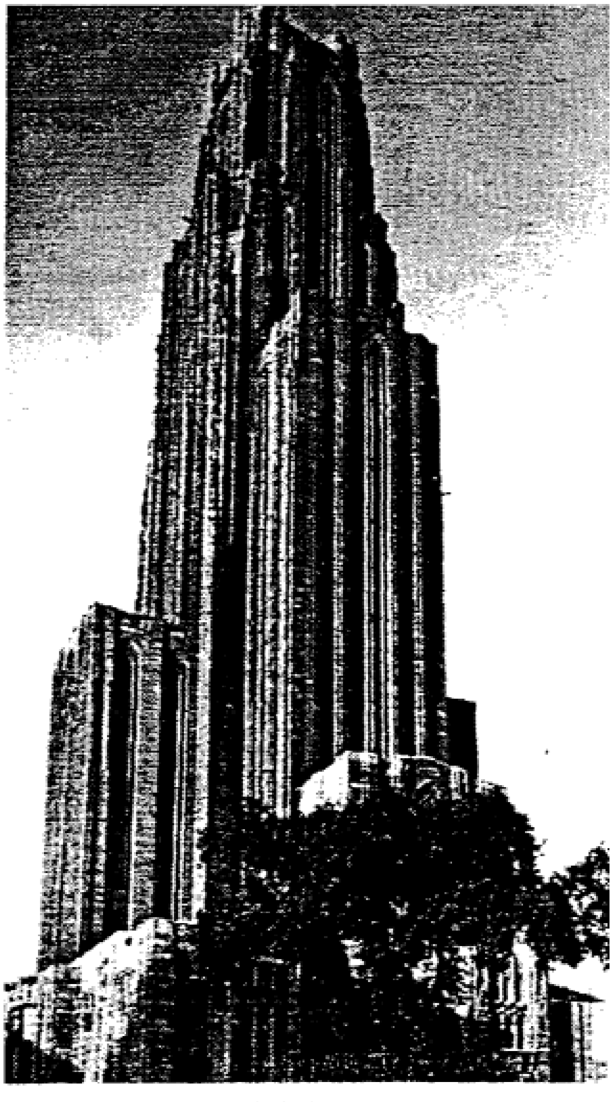
The Carnegie Public Library has a variety of resources for data and photographs. The most useful was the archival photo collection in their Pennsylvania room, which contained many of the archival photos used in this report. In addition, the library's collection of information related to local subjects contains newspaper clippings, magazine articles, pamphlets and other assorted printed media which are usually quite old, and is arranged by individual topics. One part of this collection is for the Cathedral of Learning, which contains articles about the building and pamphlets from University of Pittsburgh ceremonies, some of which contain pictures of the building. Other library resources include books on the Cathedral, and an assortment of newspapers on file. The books on the Cathedral were examined, but no in-depth attempt was made to find other books or newspaper articles which might contain photographs of the Cathedral. Individuals at the locations other than the library listed above were contacted in advance and informed of the goals of this research effort. They took the responsibility of finding relevant pictures from their collections.

Results:

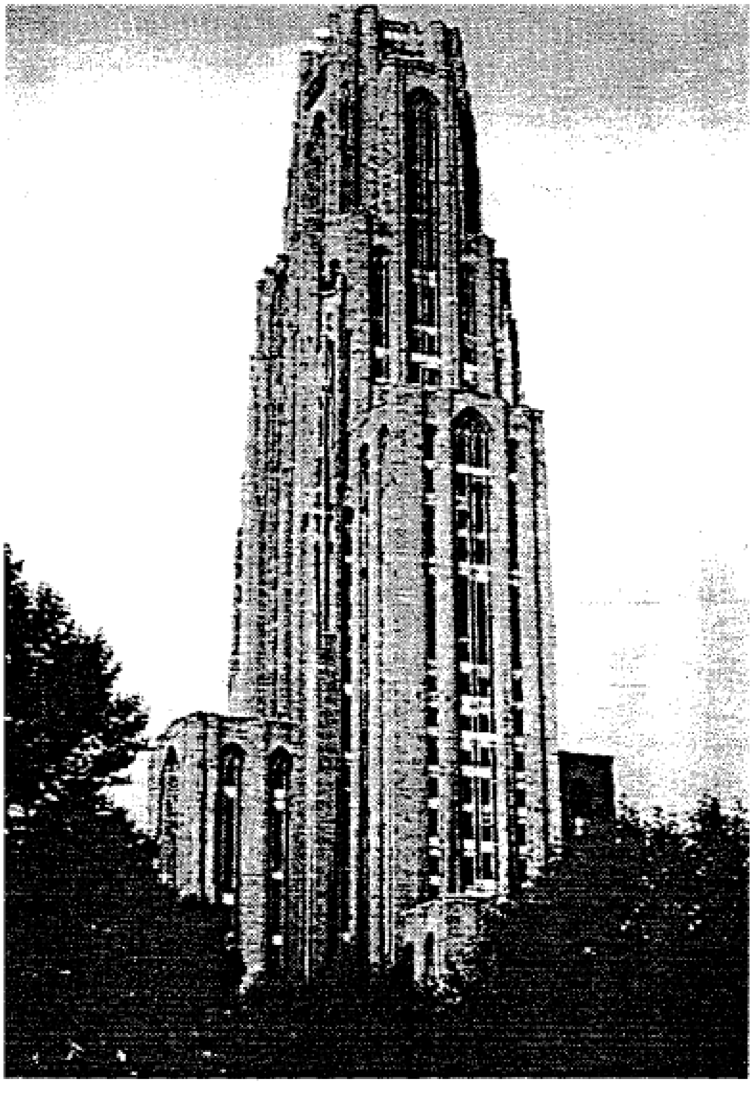
The results that follow are presented in the form of photographs, reprinted with a computer. In the last two sets of pictures, some computer manipulation has been done to highlight specific sections of interest. This was accomplished by changing the brightness and contrast of oval shaped sections (which appear clearer than the rest of the picture). The goal of this manipulation was to draw attention to the points of interest, and to clarify how the patterns actually appeared on the photo. Any manipulation was intended to get the scanned image to best represent the original slide.

The first pair of photos shows the Bigelow Boulevard side of the building. The first photo is from 1936 and shows the building soiled heavily from approximately the 5th floor to the roof, except for the very top floor. An interesting feature of the building was that the top floor was added in the mid 1930’s, about 4- 5 years after the rest of the building was completed. Because of this fact, the top piece has been a reference point to distinguish soiled sections from clean ones; without it, the entire building would be uniform and hard to identify as soiled or clean in old photos. In addition, the top piece has also proven helpful in dating when much of the soiling took place.

(Sources: 1 - U. of Pittsburgh Archives, 2 - Justin O. Parkhurst)

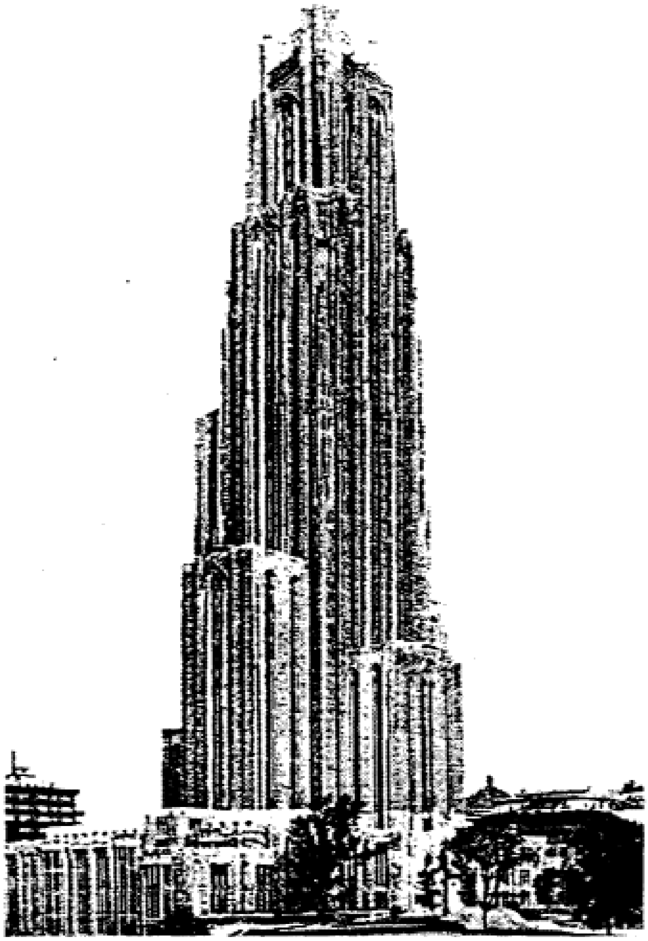


1936

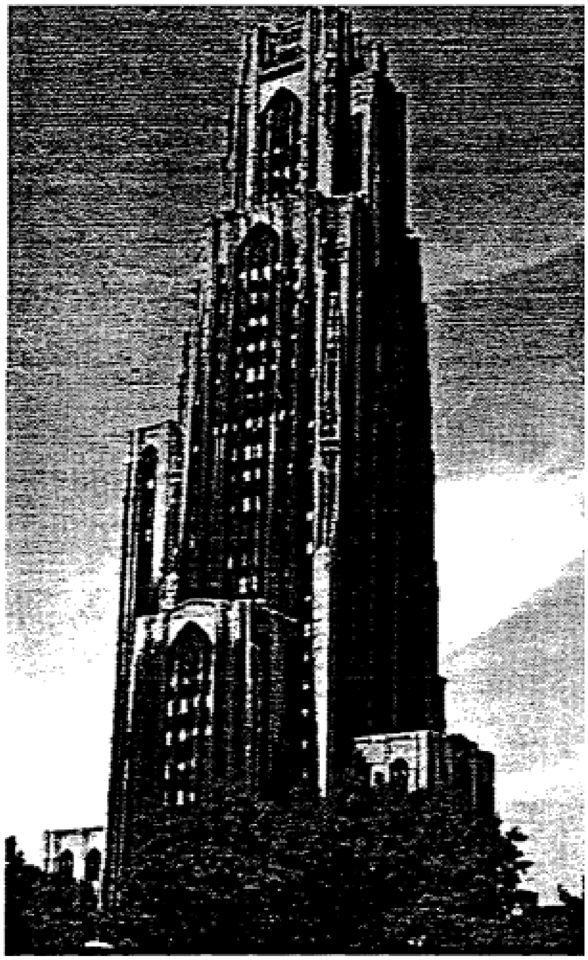


1995

The next two pictures similarly show the Forbes and Bellefield sides as they were in the late 1930s, and as they are today. Again, all but the top piece is soiled in the 1930's, and today, much more of the building is clean. However, these are the two most heavily soiled sides today. (Sources: 1 - Carnegie Library, 2 - Justin O. Parkhurst)



1937

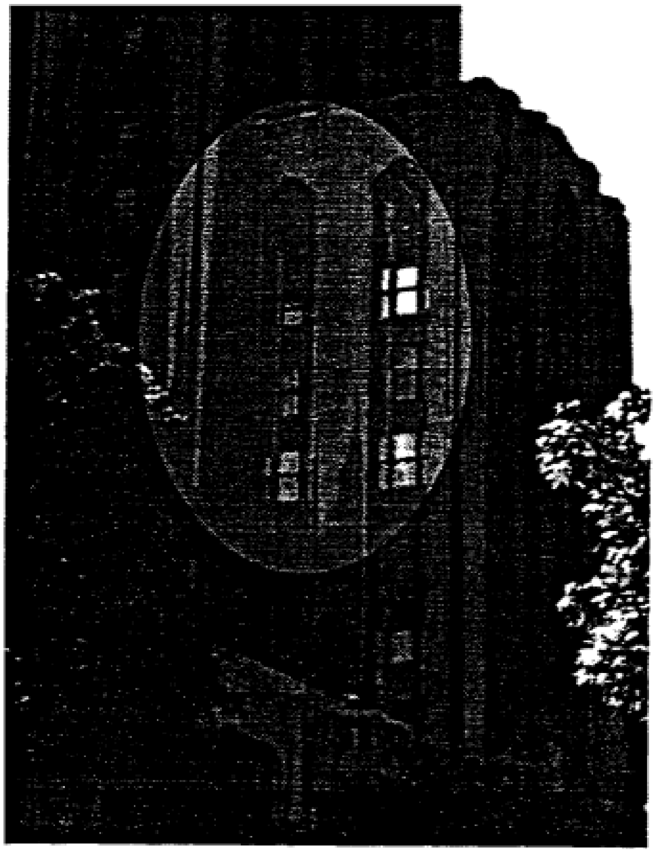


1995

In addition to the large scale observations shown in the first two sets of pictures, smaller scale changes of individual sections of the building were observable in some cases. The first such case shown here appears on the Forbes Avenue side of the building. The two photos clearly show that the soiled area has moved down approximately one story over this time. In the highlighted area of the 1950 photo, the boundary between clean and soiled areas, visible as a white notch, occurs at about two windows down from the top of the section, while the same boundary is three windows down in the 1995 picture. Another point of difference is that there is a single streak of white (absence of soiling) on the left side of the highlighted area in the 1950 photo, and there are two such streaks of white in 1995.

(Sources: 1 - Carnegie Library, 2- Justin 0. Parkhurst)

1950



1995

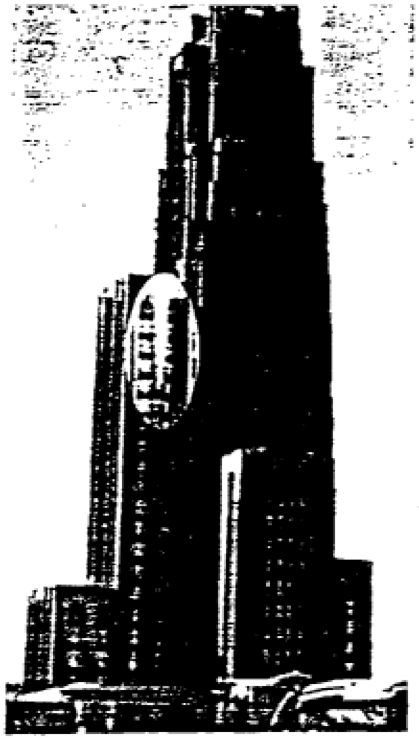
The final set of photos shows another section of the Forbes Avenue side of the building. The first in the series was dated c. 1930’s. This dating is somewhat vague, so aspects of the building were examined to help narrow the possible date. Since the top floor is completed on the building, the picture is from the late 1930’s at the earliest. It may even be from the early 1940’s as the top floor seems to be soiled (unlike photos dated 1936 and 1937). Other evidence placing it late in the 1930’s or early 1940’s is that some washoff has clearly started, another feature not found in photos from 1936 and 1937.

The highlighted area on this photo shows a white notch reaching about three window levels down from the top of the section (it may appear to be four windows, but there is actually decorative stonework at the top which resembles a window slot in some of the older photos).

The second picture is dated 1949. Here the white notch of interest has reached the fourth window down. The third picture is from 1951, and the notch is observed at the fourth window down. The fourth photo is from 1989 and shows the notch now clearly defined with a V shaped pattern at its bottom, reaching a little below the fourth window down. Although not completely clear here, analysis of the slide has shown two small areas of white just below the bottom of the V section (two dots of cleaner area). By 1995, this V has encompassed those two clean dots, which no longer are visible; the notch now reaches half way down the fifth window from the top, as shown by the fifth picture.

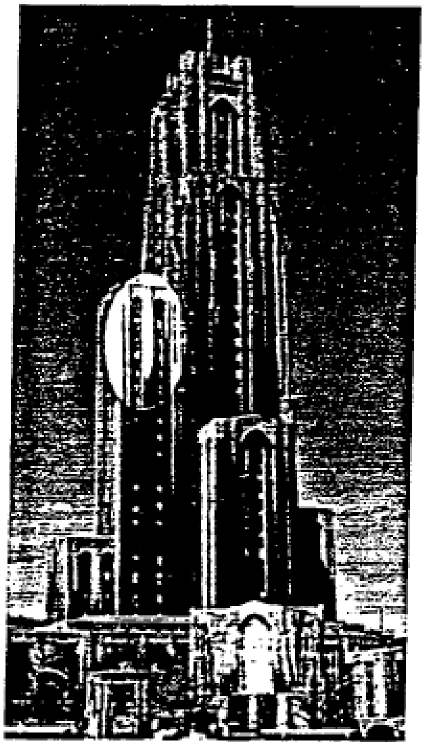
(Sources: 1 - Carnegie Library, 2 - Historical Society of Western Pennsylvania, 3 - Carnegie Library, 4 - Herb Ferguson, 5 - Justin 0. Parkhurst)

c. 1930’s

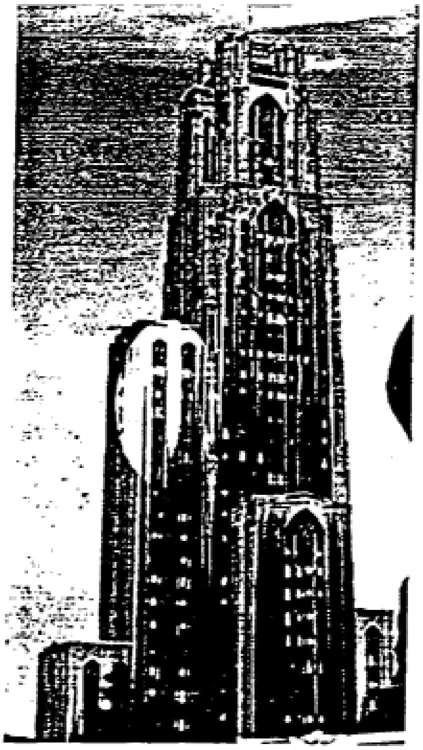


1949

1951



1989



1995

Additional Observations:

In addition to the photograph analysis, other observations were made of the current soiling patterns. One such observation is that there are darker areas in places where the stone has been cut into - the decorative stonework. Often the dirtiest areas are in the tops of archways and in other areas that are protected from rain.

A second, quite notable, observation was made on one of the walls where members of the Carnegie Mellon team are studying other aspects of the building's soiling. Cellulose filters and Teflon disks have been placed on a soiled area of one of the walls of the building to measure gas and particle deposition. To protect these surfaces from the rain, a small plastic rain shield was placed above them, protruding about 30cm perpendicular to the building face. This rain shield was placed there approximately one year ago, and today there are noticeable clean areas around the edge of, and below, the rain shield. This is presumably due to the effect of rainwater washing off the building surface.

Conclusions:

While there are only limited data, it is clear that much of the soiling occurred in the first 4-5 years of the building's life. It is harder to identify when the washoff process started, as even today some soiling may still be occurring. However, it is clear that cleaning has occurred, and continues to occur, at least on the Forbes Avenue side. This cleaning has occurred at different rates for different sides of the building. For example, the Bigelow Boulevard side appears to have had a similar amount of soiling as the Forbes or Bellefield sides in the late 1930's, yet today it is much cleaner.

It is thus likely that the soiling occurred in the early years because the particle deposition occurred at a much greater rate than particle washoff. Sometime later, perhaps in the 1940's the washoff started to occur at a greater rate due to decreased deposition, and the net effect was a gradual cleaning of the building. Not surprisingly, Pittsburgh started its smoke control measures in the late 1940's (Davidson, 1979).

A final conclusion can be drawn from the additional observations made of the building. It seems clear that rain is a major factor in removing soiling from some locations, as shown by the clean area found around a rain guard. The fact that significant soiling is found in rain protected areas also supports this hypothesis.

Further Study:

While this study has found some evidence pertaining to the period of the heaviest soiling of the Cathedral, more can be done to better understand the liming and factors influencing soiling and rain washoff. Experiments of other types are underway at Carnegie Mellon to address these issues. However projects similar to this one may also be valuable. For example, several other limestone structures exist in the immediate vicinity of the Cathedral of Learning and many of these building have similar dark soiling. Further research could be done to attempt to find archival photographs of these buildings, and attempt to study the patterns on them as well. Projects such as this may provide more evidence to answer questions about the soiling of the Cathedral, and about the soiling of similar limestone structures.

Appendix

Contact information for the sources used is as follows:

The Carnegie Library of Pittsburgh
Pennsylvania department: (412) 622 - 3154

The Historical Society of Western Pennsylvania
4338 Bigelow Boulevard
Pittsburgh, PA 15213
(412) 681 - 5533
Contact: Corey Seeman

J. B. Jeffers LTD.
5854 Solway St.
Pittsburgh, PA 15217
(412) 421 - 7916
Contact: Sue

University of Pittsburgh Archives
363 Hillman Library
Pittsburgh, PA 15260
(412) 648-7998
Contact: Rebecca Abromitis

Herb Ferguson
University of Pittsburgh Photo Services
University Center for Instructional Resources
Al14 SLIS Building
Pittsburgh, PA 15260
(412) 648 - 7224

Notes

Robert C. Alberta, Pitt The Story of the University of Pittsburgh 1787 - 1987. Pittsburgh, University of Pittsburgh Press, 1986.

Cliff Davidson, “Air Pollution In Pittsburgh: A Historical Perspective,” from APCA Journal, Vol. 29, No. 10, October 1979.

National Acid Precipitation Assessment Program, State of Science Report, 1990.

Boxes

1. Briefly rinse inside of box and cover with DI water from the tap.

2. Fill box about one quarter full of water, cover, and shake for about 15 seconds and discard water. It is easiest to do two or four boxes at a time, depending on how many you can hold per hand. This should be repeated 3 times.

3. Add enough methanol to cover bottom of box. shake for about 30 seconds and discard methanol.

4. Carefully smell the box to see if there is still grease in it. If there is a scent of grease, add a small amount of mineral spirits (a little goes A very long way) and shake. After discarding grease, immediately rinse with methanol once.

5. Rinse with DI water between *3-5* times depending on whether or nor the mineral spirits have been completely rinsed off.

6. Place on clean surface in hood so that the boxes and lids are on their sides and supporting each other (teepee style).

Filterpacks

1. Disassemble filterpacks. Place all Teflon filter holders (these are the circular disks with a screening pattern) into a clean 6 by 8 bag. Place the Teflon washers from the metal filterpacks (these are the very thin rings that are under the filter holder: be careful, they're delicate) in the same bag. Place all other Teflon parts in a 12 by 15 clean bag. Place metal filter holders in a 6 by 8 clean bag. Place all other metal parts in a 12 by 15 clean bag. You should have four bags.

Each of the bags from step 1 should undergo the following procedure:

2. Rinse the contents of the bag with DI water twice. This is done by leaving some air in the bag to allow for good mixing.

3. Add methanol to the bag. For the bags containing the filter holder, add enough methanol to barely cover all contents when the bag is closed. For the other bags, add enough methanol to be able to shake the bag around and get the methanol on all the surfaces. Try not to use more than is necessary; methanol is expensive!

4. Shake bag vigorously, being careful to avoid splashing. This should be done for about one minute for each bag.

5. To the bags with the filter holders, add about as much water as you did methanol. Don't dump out the methanol. The heat of mixing from the water and methanol provides a good way to dissolve contaminants. To the other bags, add enough water to cover all contents when bag is closed. Shake well for about 30 seconds and let sit for ten minutes or so with rubber bands closing the bags.

6. Dump out methanol-water solution, and perform two water rinses.

7. Fill the bags with enough water so that the contents are barely covered when bag is closed with a rubber band. Place bag in the ultrasound, and adjust the water level as necessary. Be sure that there is at least a little water in the ultrasound initially, since the bags are quite heavy, and the lack of buoyancy could break the basket.

8. Ultrasound for 30 minutes. Dump out the water in the bag, and perform another water rinse. Place all parts on a clean surface in a laminar flow hood.

Vertical Deposition Plates

1. Place one plate in a 12 by 18 bag (“dirty bag”). This will be a snug fit.

2. Add enough water to fill bag about a third of the way. Roll up the open side of the bag and shake the bag horizontally, working the water over the surface of the plate with your hand. This should be done three times.

3. Add a small amount of methanol and holding the open end of the bag so that the sheet is horizontal, shake and work over the surface with your hand.

4. Place in a “clean” bag and rinse with water three times.

5. Place plates vertically in the hood.

6. Discard “dirty” bag and rename the “clean” bag “dirty” noting that the bag is only to be used for washing vertical deposition plates. This will be the “dirty” bag for next time.

Rings

1. Put 4 or 5 rings in a 12 by 18 clean bag. This bag will be the “dirty” bag for the remainder of the rings that you wash. If there are visible smears on the rings, gently rub them off with methanol and a gloved hand. Rinse the rings before placing them in the bag.

2. Rinse three times with water (about 15 seconds), making sure that the water gets in between the rings. It is best to leave a little air in the bag when shaking so that the water splashes around.

3. Add a little methanol to the “dirty” bag and shake for about 30 seconds, again making sure that the methanol gets in between the rings.

4. Dump out the methanol and place the rings in another 12 by 18 clean bag. This will be the “clean” bag for the remainder of the washing session.

5. Rinse with water three times.

6. Making sure the surface is clean, place the rings on top of each other so that each ring covers about three quarters of the ring below it.

7. When washing session is over, discard “dirty” bag, and re-label the “clean” bag as the “dirty” bag. This will serve as the “dirty” bag for the next washing session. Note on the bag that it is to be used only for washing rings.

Schotts Bottles: Glass bottles with colored caps

1. Thoroughly rinse outside of bottle and cap with DI water from the tap.

2. Fill bottle about one quarter full of water, cap, and shake for about 15 seconds and discard water. This should be repeated 3 times.

(Omit steps 3 and 4 if you are sure that the bottle has only been used to store clean DI water.)

3. Add about a finger width of methanol to bottle. Shake for about one minute and discard methanol.

4. Carefully smell the bottle to see if there is grease in it. If there is a scent of grease, repeat steps 1 to 3.

5. Rinse with DI water 5 times. Every time you rinse, be sure to rinse the mouth of the bottle and the inside of the cap. Periodically, rinse the outside of the bottle as well, making sure that the cap is in place when you do this.

6. Place on clean surface in hood so that the bottles and covers are on their sides.

Remember: The Schotts bottles must be super clean because we use them for stock solutions and holding DI water which we use for IC work.

Greased Teflon Vertical Deposition Sheets

1. Note that there should be three different sets of boxes labeled I, II, and III.

2. Each set of boxes should contain mineral spirits (about one quarter full).

3. When the dirty Teflon sheets are ready to be cleaned, place them in the boxes marked III one at a time. Put as many in a box as will remain completely covered with mineral spirits.

4. The next day, or at least six hours later, remove each Teflon sheet individually and place in the box marked II. After at least another six hours, remove and place in box marked I. In this manner, the sheets first get a preliminary washing, then a more ‘clean’ washing, then a ‘very clean washing’.

5. When the sheets are ready to be removed from box I, use a new clean box and place 8-. 10 sheets in it at a time. Add water, shake thoroughly, and discard water. Repeat this procedure. After the second rinse, the sheets will still have mineral spirits on them, but this is not a problem. Remove the sheets from the ‘water rinse’ box and place on a clean surface in the hood to dry.

6. When all the sheets in the boxes marked I have been rinsed with water, discard the contents of the box marked III. Re-label the boxes marked II as III. Re-label the boxes marked I as II. In this way, we can save mineral spirits. If another set of sheets needs to be washed, you must obtain clean boxes, label them I, and fill about one quarter full of mineral spirits. Then, follow the procedure starting at step 2.

Vertical Deposition Sheet Cover Trays

1. Put enough water in tray to fill about halfway. Gently agitate the tray and discard the water. Repeat twice. If the trays appear visibly dirty, rub soiled areas with a little methanol and a clean gloved hand.

2. Add a small amount of methanol to tray and agitate. Discard.

3. Rinse twice with water.

4. Lean trays on the walls or any available clean vertical surface with the indent side facing away from wall.

Tweezers

1. Put one tweezer in a 6 by 8 clean bag.

2. Rinse three times with water (about 15 seconds). It is best to leave a little air in the bag when shaking so that the water splashes around.

3. Add a little methanol to the bag and shake for about 30 seconds.

4. Rinse with water three times.

5. Fill bag with about one fourth of water, close the bag with a rubber band avoiding too much air, and put the bag into the ultrasound. (clearly, you want to wash more than one tweezer at a time, but you must use different “clean” bags for each one so that the Teflon on the tweezers doesn’t get scratched). Ultrasound for thirty minutes.

6. Rinse twice more with DI water.

7. Dry on a clean surface in the hood.

Whatman Filter Preparation

1. Preheat oven to between 80 and 100 C.

2. Add 76 ml DI water to 24 ml of glycerin.

3. Fill a clean (rinsed with DI water a few times and dried) blood vial about one third of the way with potassium carbonate. Dissolve contents of vial in solution in box. Make sure all crystals have disappeared before continuing.

4. With a clean pair of tweezers, place either twenty five large Whatmans or 60 small Whatmans in the box one at a time.

5. Use clean aluminum foil to cover the trays in the oven. Leave sufficient gaps between the aluminum foil sheets to allow for convection of heat throughout oven. You might want to do this before making the potassium carbonate solution since the filters get soggy and become fragile the longer they sit in solution.

6. With the clean tweezers, remove the filters one by one from the solution and place in the oven. Generally, it is best to put in as many as can fit.

7. Check the filters periodically (every 30 or 40 seconds) to monitor progress. After about a minute or so, pick the filters up and place them back down. This helps in evaporating some of the fluid on the under side of the filter. If possible, flip the filters over instead.

8. Filters are ready to come out of the oven when they no longer stick to the foil, or when they start developing a yellow color. A hint of yellow on the filter is acceptable, but avoid over-browning. Immediately place dry filters in a clean bag, making sure that you keep bag closed when not loading and unloading filters. The impregnated Whatman filters are very hydrophilic, so we want to minimize contact with air.

9. When the entire batch of filters is complete, place the bags without sealing them in the Whatman dessicator for two hours. Thereafter, seal the bags and return to the dessicator.

note: the optimal operating temperature for the oven is between 80 and 100 C. For the oven in the soils lab, this corresponds to a setting of between 4 and 5. Invariably, when making whatmans, the temperature tends to fall below 80 C. Try to avoid this by not opening the oven door for extended periods.

Safety note: Do not put setting on oven at higher than 4 or 5. Also be careful when handling filters in the deep end of the oven. The sides and trays get very HOT.

As of May 1995, an oven is no longer used. Instead, an electric hot plate is covered with clean foil and placed in a laminar flow hood. This decreases the chance of contamination.

Appendix B: Sample Results

This appendix contains tables of data and explanations of the processes of calculating airborne concentrations and deposition fluxes for experimental samples from 6/30/94 to 7/6/95. Airborne concentrations of carbon are still pending analysis by Desert Research Institute and are not listed here. Tables B. 1 to B.5 give results for airborne concentration samples analyzed by ion chromatography. These five tables incorporate a similar way of calculating the airborne concentration. Each table has 11 columns. The first column is the sample name. The sample name is divided into two fields. The first field is 8 characters long and represents the sample start date. The second field is two characters long and describes the location of the sample. For example the sample label "06/30/94-5a" indicates that the sample start date was June 30, 1994, and that the sample was obtained on the fifth floor at location "a". Figure 3.3 shows the positions of the air sampling equipment with the appropriate location labels. Three location labels are used on the fifth floor "a", "b", and "c". The labels have changed from the ones used in the 1994 progress report. The labels "5Y4" and "5O5" in the previous year's report have been changed to "a" and "b", respectively, in this report. Location "c" refers to an additional sampling site on the fifth floor patio where a modified air sampling station has been operated.

The second column is the length of the experiment in hours. The third column is the flowrate (L/min) of the samples obtained by a dry test meter. The measurement from a dry test meter and the reading from an in-line rotameter are recorded at the beginning and end of each sample period. If the flowrate is not measured by dry test meter, then it is approximated from rotameter readings. This is accomplished by using a linear regression of rotameter readings vs. dry test meter measurements for all samples between 6/30/94 and 7/6/95 for which dry test meter readings were obtained. The flowrate reported in the Tables B. 1 through B.5 reflects the average of the flowrates at the beginning and at the end of the sampling period.

The fourth column is the mass of the contaminant in the sample. This is calculated by multiplying the concentration obtained from the average of two IC replicate analyses by the dilution factor of the sample, and the sample volume (30 ml). The standard deviation of the contaminant mass in the fifth column reflects the standard deviation of the replicate IC analyses. Replicate IC analyses have been performed for all samples except for those in the footnotes of the Tables. For the samples that are not IC replicates, the contaminant mass is multiplied by the average % standard deviation from all the IC replicate samples of the same type.

The sixth column is the net contaminant mass, which is the sample mass in column four minus the blank mass from a footnote at the end of the Table. The field blank values are given in Chapter 4. The formula for calculating the standard deviation of the net contaminant mass is Equation B- 1.

(B-l)

$\sigma_s = \sqrt{\sigma_s^2 + \sigma_B^2}$ where

σ_n =standard deviation of net mass

σ_s= standard deviation of sample mass

σ_B = standard deviation of blank mass

The contaminant concentration is calculated using Equation B-2.

$$C = \frac{N}{(T \times F \times 60)/1000} \quad \text{where} \qquad \text{(B-2)}$$

C = contaminant concentration (ug/m^3)
N = net contaminant mass (ug)
T length of experiment (hr)
F = flowrate (L/min)

The standard deviation of the contaminant concentration is calculated using Equation B-2, with C replaced by the standard deviation of the contaminant concentration σ_c and N replaced by the standard deviation of the net mass σ_n The average contaminant concentration is the average of two or three adjacent replicate samples. For example, if for a given experiment date samples 5a, 5b, and 5c are reported, the average contaminant concentration is the average of the three samples. On the other hand, if there are no replicate samples, the average contaminant concentration is merely the contaminant concentration of the single sample. In this latter case, the standard deviation of the contaminant concentration is calculated by making use of the average % standard deviation from all the replicate samples. An empty value of the average contaminant concentration and standard deviation indicates that the sample is a replicate and the average and standard deviation based on the replicate samples are in the row (containing non-empty values) above. In a limited number of cases, the standard deviation of the IC replicates exceeds the standard deviation of the adjacent replicate samples. The latter standard deviation is reported for these cases (as for all cases), and thus may be an underestimate of the true uncertainty.

The deposition fluxes to vertical greased Teflon and impregnated Whatman surrogate surfaces are reported in Tables B.6 through B.8. The measurement of any low concentrations of NO_3 that may have been present on the Whatman filters was not possible since the IC had been set up for analyzing high concentrations of SO_4. Therefore, a table is not included for NO_3 deposition to Whatman filters. The first column of each Table contains the sample name which is comprised of three fields, the sample start date, the location code, and the location of the sample on the vertical deposition sheet. The location code indicates the placement of the Teflon-coated aluminum sheets on the Cathedral walls; they are mapped out in Figure 3.3. The sample may be placed on the deposition sheet in one of four places, the upper left corner, upper right corner, lower left corner, and lower right corner (see Figure 3.2). These positions on the sheet are labeled 1, 2, 3, and 4, respectively. For example, a sample label of “09/09/94-am- 1” indicates that the sample start date is September 9, 1994, the location on the Cathedral walls is “am”, and the location on the vertical deposition sheet is the upper left hand corner. In general, the greased Teflon deposition surfaces were placed in the upper left (1) and upper right (2) corners, whereas the impregnated Whatman filters were placed in the lower left (3) and lower right (4) corners. The second column shows the length of the experiment in hours. The third column is the mass of contaminant in the sample which is calculated by multiplying the concentration obtained from the IC by the dilution factor of the sample, and by the volume of the sample. The sample volume is 120 ml for the Whatman filters, and between 6 and 12 ml for the greased Teflon samples, depending on the extent of evaporation. The standard deviation of contaminant mass, net contaminant mass, and standard deviation of net contaminant mass are calculated in the same manner as the airborne concentration measurements. The contaminant flux is calculated using Equation B-3.

$$J = \frac{N \times 1000}{(A \times T / 24)} \quad \text{where} \qquad \text{(B-3)}$$

J = contaminant flux (ng/cm^2/day)
N = net contaminant mass (ug)
A = exposure area (cm^2)
T = length of experiment (hr)

The exposure area is 87 cm^2. The standard deviation of the contaminant flux is calculated using Equation B-3, with J replaced by the standard deviation of the contaminant flux σ_j and N replaced by the standard deviation of the net mass σ_n. The average contaminant flux is the average of two adjacent replicate samples (e.g. “09/09/94-am-I” and “09/09/94-am-2”). If there are no replicate samples , the average contaminant flux is merely the contaminant flux J of the single sample. In this case, the contaminant flux standard deviation is based on the average % standard deviation from all replicate samples of the same type. An empty value of average contaminant flux and standard deviation indicates that the sample is an adjacent replicate, and the average contaminant flux and standard deviation based on the two adjacent samples are in the row above.

For some of the NO_3 particle deposition samples, the net contaminant mass is negative indicating that the subtracted field blank mass was greater than the contaminant mass found on the sample. These samples are reported as having deposition fluxes of zero and are noted in a footnote in the Table. In addition, all of the samples have been tested to see if they could be considered significantly greater than the blank. If the net contaminant mass is greater than 1.64 times its standard deviation, then the net mass is considered significant above the blank. Otherwise, the net mass is not considered significant at the $\gamma = 0.95$ confidence level, and the sample is marked with a footnote.

Table B.1. NO$_3$ Airborne Concentrations on Zefluor Filters

Sample	Time (h)	Flow rate L/min	NO$_3$ mass (ug)	NO$_3$ mass std dev. (ug)^a	Net NO$_3$ mass (ug)^b	Net NO$_3$ mass std dev. (ug)	NO$_3$ conc (ug/m^3)	NO$_3$ conc dev. (ug/m^3)	ave NO$_3$ conc (ug/m^3)	ave NO$_3$ conc std dev. (ug/m^3)^f
06/30/94-5a	166	0.75	5.03	0.04	4.33	0.56	0.58	0.07	0.61	0.05
06/30/94-5b	166	0.80	5.82	0.29	5.12	0.63	0.65	0.08		
07/07/94-5a	193	0.82	5.75	0.13	5.04	0.57	0.53	0.06	0.51	0.04
07/07/94-5b	193	1.24	7.61	0.21	6.90	0.59	0.48	0.04	.	
07/14/94-5a	146	0.90	3.48	0.08	2.77	0.56	0.35	0.07	0.43	0.11
07/14/94-5b	146	1.04	5.33	0.43	4.62	0.70	0.51	0.08		
07/21/94-5a	168	0.85	15.12	0.29	14.42	0.63	1.68	0.07	1.56	0.16
07/21/94-5b	168	1.14	17.38	0.01	16.68	0.55	1.45	0.05		
07/28/94-5a	189	1.04	4.56	0.28c	3.85	0.62	0.33	0.05	0.41	0.12
07/28/94-5b	189	0.97	6.14	0.38c	5.43	0.67	0.49	0.06		
08/05/94-5a	171	0.87	15.55	0.35	14.84	0.65	1.66	0.07	1.38	0.40
08/05/94-5b	171	1.06	12.57	0.73	11.87	0.92	1.10	0.08		
08/12/94-5a	146	0.87	5.04	0.40	4.33	0.68	0.57	0.09	0.59	0.03
08/12/94-5b	146	0.97	5.83	0.01	5.13	0.55	0.60	0.07		
08/18/94-5a	167	1.08	15.55	0.93	14.85	1.08	1.37	0.10	1.03	0.48
08/18/94-5b	167	1.12	8.44	0.42	7.74	0.70	0.69	0.06		
08/25/94-5a	359	0.87	13.80	0.18	13.10	0.58	0.70	0.03	0.63	0.10
08/25/94-5b	359	0.97	12.27	0.72	11.56	0.91	0.55	0.04		
09/09/94-5a	288	0.87	13.27	0.15	12.57	0.57	0.83	0.04	0.63	0.28
09/09/94-5b	288	0.94	7.73	0.07	7.02	0.56	0.43	0.03		
09/21/94-5a	453	0.85	4.25	0.20	3.55	0.59	0.15	0.03	0.23	0.11
09/21/94-5b	453	0.91	8.41	0.43	7.71	0.70	0.31	0.03		
10/10/94-5a	220	0.83	15.32	0.09	14.61	0.56	1.33	0.05	1.37	0.05
10/10/94-5b	220	0.94	18.17	0.61	17.47	0.82	1.41	0.07		
10/19/94-5a	216	0.68	20.54	0.51	19.84	0.76	2.26	0.09	1.95	0.43
10/19/94-5b	216	0.85	18.82	0.05	18.12	0.56	1.65	0.05		

Table B.1. NO$_3$ Airborne Concentrations on Zefluor Filters

Sample	Time (h)	Flow rate L/mi	NO$_3$ mass (ug)	NO$_3$ mass std dev. (ug)a	Net NO$_3$ mass (ug)b	Net NO$_3$ mass std dev. (ug)	NO$_3$ conc (ug/m^3)	NO$_3$ conc std dev. (ug/m^3)	ave NO$_3$ conc (ug/m^3)	ave NO$_3$ conc std dev. (ug/m^3)^f
10/28/94-5a	575	0.85	49.65	1.30	48.95	1.42	1.67	0.05	1 .67	0.33
11/21/94-Sb	240	1.00	21.42	0.04	20.71	0.56	1.44	0.04	1.44	0.28
12/01/94-5a	431	0.85	43.49	1.26	42.78	1.38	1.94	0.06	1.94	0.38
12/19/94-5a	601	0.85	90.18	1.62	89.48	1.71	2.91	0.06	2.59	0.46
12/19/94-5b	601	0.91	75.26	1.74	74.55	1.82	2.26	0.06		
01/13/95-5a	168	0.91	8.49	0.09	7.79	0.56	0.84	0.06	0.89	0.07
01/13/95~5b^d	168	0.86	8.88	5.14	8.17	5.17	0.95	0.60		
01/20/95-5a	243	0.89	11.30	0.72	10.59	0.91	0.81	0.07	1.19	0.53
01/20/95-5b	243	0.74	17.51	1.06	16.81	1.20	1.56	0.11		
01/30/95-5b	189	0.95	22.39	0.16	21.69	0.58	2.01	0.05	2.01	0.40
02/07/95-5a	170	0.84	15.25	0.86	14.54	1.03	1.71	0.12	1.81	0.14
02/07/95-5b	170	0.88	17.82	0.21	17.11	0.59	1.91	0.07		
02/14/95-5b	168	0.89	43.19	0.05	42.48	0.56	4.74	0.06	4.74	0.94
02/21/95-5a	168	0.91	10.84	2.37	10.14	2.43	1.10	0.26	1.10	0.22
02/28/95-5a	169	0.91	10.33	0.04	9.63	0.56	1.04	0.06	1.39	0.49
02/28/95-5b	169	0.90	16.59	0.02	15.89	0.56	1.74	0.06		
03/07/95-5a	169	1.23	11.00	0.93	10.30	1.09	0.83	0.09	0.90	0.09
03/07/95-5b	169	0.79	8.44	0.34	7.74	0.65	0.96	0.08		
03/14/95-5a	168	0.83	18.97	0.00	18.27	0.55	2.19	0.07	2.17	0.02
03/14/95-5b	168	0.81	18.27	1.26	17.56	1.38	2.16	0.17		
03/21/95-5a	168	1.01	14.14	0.03	13.43	0.56	1.32	0.05	1.32	0.26
03/28/95-5a	168	0.72	12.14	0.04	11.43	0.56	1.57	0.08	1.57	0.01
03/28/95-5b	168	1.07	17.63	0.97	16.93	1.12	1.56	0.10		
04/04/95-5a	168	1.34	31.55	0.51	30.85	0.75	2.29	0.06	2.28	0.01
04/04/95-5b	168	0.87	20.57	1.09	19.87	1.22	2.27	0.14		
04/11/95-5a	193	1.34	23.06	0.79	22.36	0.96	1.44	0.06	1.32	0.56

Table B.1. NO_3 Airborne Concentrations on Zefluor Filters

Sample	Time (h)	Flow rate L/min	NO_3 mass (ug)	NO_3 mass std dev. (ug)[a]	Net NO_3 mass (ug)[b]	Net NO_3 mass std dev. (ug)	NO_3 conc (ug/m3)	NO_3 conc dev. (ug/m^3)	ave NO_3 conc (ug/m^3)	ave NO_3 conc std dev. (ug/m^3)[f]
04/11/95-5b	193	0.88	7.91	0.20	7.20	0.59	0.71	0.06		
04/11/95-5c	193	1.01	21.93	1.02	21.23	1.16	1.82	0.10		
04/19/95-5a	312	0.86	25.38	0.01	24.67	0.55	1.54	0.03	1.43	0.15
04/19/95-5c	312	1.00	25.56	0.93	24.85	1.08	1.33	0.06		
05/02/95-5a	192	0.89	10.12	0.32	9.41	0.64	0.92	0.06	1.26	0.48
05/02/95-5c	192	1.00	19.17	0.70	18.47	0.89	1.60			
05/10/95-5a	169	0.89	12.24	0.58	11.53	0.80	1.28		1.40	0.10
05/10/95-5b	169	0.97	14.84	0.68	14.13	0.88	1.44	0.09		
05/10/95-5c	169	0.94	14.73	0.19	14.03	0.59	1.48	0.06		
05/17/95-5a	169	0.82	3.62	0.26	2.91	0.61	0.35	0.07	0.62	0.24
05/17/95-5b	169	0.83	7.11	0.69	6.40	0.88	0.76	0.10		
05/17/95-5c	169	1.01	8.47	0.63	7.77	0.84	0.76	0.08		
05/24/95-5a	384	1.12	15.87	1.38	15.17	1.48	0.59	0.06	0.61	0.04
05/24/95-5c	384	0.81	12.71	0.90	12.00	1.06	0.64	0.06		
06/09/95-5a	167	0.82	9.46	0.21	8.76	0.59	1.06	0.07	1.00	0.09
06/09/95-5c	167	0.87	8.90	0.08	8.19	0.56	0.94	0.06		
06/16/95-[e]	263									
06/27/95-5c	213	0.91	10.22	0.57	9.52	0.79	0.82	0.07	0.82	0.16

[a] The % standard deviation from IC replication is 6.2%.

[b] The subtracted blank mass was 0.70 ± 0.55 ug/m’.

[c] An IC replicate was not performed for this sample.

[d] The net contaminant mass was less than 1.64 times the net contaminant mass standard deviation.

[e] Sample was lost due to a power outage at the Cathedral.

[f] The average % standard deviation from adjacent replicates was 19.8%.

Table B.2. SO$_4$ Airborne Concentrations on Zefluor Filters

Sample	Time (h)	Flow rate L/min	SO$_4$ mass (ug)	SO$_4$ mass std dev. (ug)[a]	Net SO$_4$ mass (ug)[b]	Net So$_4$ mass std dev. (ug)	SO$_4$ conc (ug/m^3)	SO$_4$ conc std dev. (ug/m^3)	ave SO$_4$ conc (ug/m^3)	ave SO$_4$ conc std dev. (ug/m^3)[d]
06/30/94-5a	166	0.75	108.29	0.81	107.49	1.03	14.34	0.14	15.34	1.42
06/30/94-5b	166	0.80	130.18	7.74	129.38	7.76	16.35	0.98		
07/07/94-5a	193	0.82	128.88	2.24	128.08	2.33	13.57	0.25	13.30	0.39
07/07/94-5b	193	1.24	188.21	18.12	187.41	18.14	13.02	1.26		
07/14/94-5a	146	0.90	119.81	2.44	119.01	2.53	15.08	0.32	15.85	1.08
07/14/94-5b	146	1.04	151.06	9.57	150.26	9.59	16.61	1.06		
07/21/94-5a	168	0.85	110.35	0.06	109.55	0.64	12.75	0.07	12.62	0.19
07/21/94-5b	168	1.14	144.86	6.62	144.07	6.55	12.49	0.57		
07/28/94-5a	189	1.04	312.19	11.47[c]	311.40	11.49	26.46	0.98	23.16	4.66
07/28/94-5b	189	0.97	219.17	8.05[c]	218.37	8.08	19.86	0.73		
08/05/94-5a	171	0.87	122.30	3.12	121.50	3.18	13.59	0.36	12.51	1.52
08/05/94-5b	171	1.06	124.69	4.05	123.89	4.10	11.44	0.38		
08/12/94-5a	146	0.87	72.62	2.38	71.82	2.47	9.41	0.32	8.95	0.65
08/12/94-5b	146	0.97	72.89	1.67	72.10	1.79	8.49	0.21		
08/18/94-5a	167	1.08	188.06	0.81	187.27	1.03	17.29	0.10	14.81	3.51
08/18/94-5b	167	1.12	138.53	10.59	137.73	10.60	12.32	0.95		
08/25/94-5a	359	0.87	209.74	0.51	208.94	0.82	11.13	0.04	9.41	2.43
08/25/94-5b	359	0.97	161.28	4.48	160.48	4.53	7.68	0.22		
09/09/94-5a	288	0.87	167.73	0.94	166.94	1.13	11.07	0.08	9.50	2.22
09/09/94-5b	288	0.94	129.93	2.91	129.14	2.98	7.93	0.18		
09/21/94-5a	453	0.85	50.16	1.16	49.36	1.32	2.13	0.06	2.61	0.68
09/21/94-5b	453	0.91	77.54	2.13	76.74	2.22	3.10	0.09		
10/10/94-5a	220	0.83	38.20	0.67	37.41	0.93	3.42	0.08	3.51	0.14
10/10/94-5b	220	0.94	45.56	0.49	44.77	0.80	3.61	0.06		
10/19/94-5a	216	0.68	51.93	3.14	51.13	3.20	5.82	0.36	5.18	0.90
10/19/94-5b	216	0.85	50.73	2.79	49.94	2.86	4.55	0.26		

Table B.2. SO_4 Airborne Concentrations on Zefluor Filters

Sample	Time (h)	Flow rate L/min	SO_4 mass (ug)	SO_4 mass std dev. (ug) [a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 conc (ug/m^3)	SO_4 conc std dev. (ug/m^3)	ave SO_4 conc (ug/m^3)	ave SO_4 conc std dev. (ug/m^3)[d]
10/28/94-5a	575	0.85	160.24	12.79	159.45	12.80	5.43	0.44	5.43	0.86
11/21/94-5b	240	1.00	20.39	0.73	19.60	0.97	1.36	0.07	1.36	0.22
12/01/94-5a	431	0.85	66.04	1.51	65.24	1.64	2.96	0.07	2.96	0.47
12/19/94-5a	601	0.85	151.83	3.18	151.04	3.24	4.91	0.11	4.47	0.62
12/19/94-5b	601	0.91	133.70	7.84	132.91	7.87	4.03	0.24		
01/13/95-5a	168	0.91	41.52	0.75	40.72	0.99	4.41	0.11	3.63	1.11
01/13/95-5b	168	0.86	25.31	0.16	24.52	0.66	2.84	0.08		
01/20/95-5a	243	0.89	13.10	0.52	12.30	0.82	0.95	0.06	1.27	0.45
01/20/95-5b	243	0.74	17.88	0.78	17.09	1.00	1.59	0.09		
01/30/95-5b	189	0.95	23.27	0.12	22.48	0.65	2.08	0.06	2.08	0.33
02/07/95-5a	170	0.84	11.62	0.14	10.82	0.65	1.27	0.08	1.41	0.20
02/07/95-5b	170	0.88	14.73	0.39	13.94	0.75	1.56	0.08		
02/14/95-5b	168	0.89	50.62	1.12	49.82	1.29	5.55	0.14	5.55	0.88
02/21/95-5a	168	0.91	14.79	0.47	13.99	0.79	1.52	0.09	1.52	0.24
02/28/95-5a	169	0.91	21.46	0.38	20.67	0.74	2.24	0.08	2.97	1.03
02/28/95-5b	169	0.90	34.52	0.34	33.72	0.72	3.70	0.08		
03/07/95-5a	169	1.23	41.04	3.05	40.24	3.12	3.24	0.25	3.36	0.17
03/07/95-5b	169	0.79	28.80	1.22	28.00	1.38	3.48	0.17		
03/14/95-5a	168	0.83	57.17	0.20	56.37	0.67	6.74	0.08	6.50	0.34
03/14/95-5b	168	0.81	51 .70	1.83	50.90	1.94	6.26	0.24		
03/21/95-5a	168	1.01	26.18	0.16	25.38	0.66	2.49	0.06	2.49	0.40
03/28/95-5a	168	0.72	23.80	0.39	23.01	0.75	3.17	0.10	2.88	0.41
03/28/95-5b	168	1.07	28.83	0.77	28.03	1.00	2.59	0.09		
04/04/95-5a	168	1.34	46.72	1.63	45.93	1.75	3.41	0.13	3.53	0.17
04/04/95-5b	168	0.87	32.70	1.20	31.90	1.35	3.65	0.15		
04/11/95-5a	193	1.34	66.16	4.41	65.37	4.46	4.21	0.29	3.37	1.72

Table B.2. SO_4 Airborne Concentrations on Zefluor Filters

Sample	Time (h)	Flow rate L/min	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net So_4 mass std dev. (ug)	SO_4 conc (ug/m^3)	SO_4 conc std dev. (ug/m^3)	ave SO_4 conc (ug/m^3)	ave SO_4 conc std dev. (ug/m^3)[d]
04/11/95-5b	193	0.88	15.07	0.81	14.28	1.03	1.40	0.10		
04/11/95-5c	193	1.01	53.64	3.76	52.85	3.82	4.52	0.33		
04/19/95-5a	312	0.86	69.94	0.55	69.15	0.84	4.31	0.05	4.15	0.22
04/19/95-5c	312	1.00	75.49	3.08	74.69	3.14	4.00	0.17		
05/02/95-5a	192	0.89	34.80	0.25	34.01	0.68	3.33	0.07	4.20	1.24
05/02/95-5c	192	1.00	59.32	1.71	58.52	1.82	5.08	0.16		
05/10/95-5a	169	0.89	53.65	1.55	52.85	1.68	5.89	0.19	6.38	0.44
05/10/95-5b	169	0.97	65.15	1.46	64.36	1.59	6.56	0.16		
05/10/95-5c	169	0.94	64.21	1.31	63.41	1.46	6.70	0.15		
05/17/95-5a	169	0.82	21.29	1.47	20.49	1.61	2.48	0.19	3.48	0.88
05/17/95-5b	169	0.83	35.49	1.62	34.69	1.74	4.12	0.21		
05/17/95-5c	169	1.01	39.88	0.52	39.09	0.82	3.84	0.08		
05/24/95-5a	384	1.12	228.51	7.22	227.71	7.25	8.83	0.28	8.79	0.06
05/24/95-5c	384	0.81	164.65	1.16	163.85	1.32	8.75	0.07		
06/09/95-5a	167	0.82	74.25	2.39	73.45	2.47	8.88	0.30	8.67	0.30
06/09/95-5c	167	0.87	74.91	3.23	74.11	3.29	8.46	0.38		
06/16/95-[e]	263									
06/27/95-5c	213	0.91	93.03	3.10	92.23	3.16	7.93	0.27	7.93	1.26

[a] The % standard deviation from IC replication is 3.7%.

[b] The subtracted blank mass was 0.80 ± 0.64 ug/m^3.

[c] An IC replicate was not performed for this Sample.

[d] The average % standard deviation from adjacent replicates was 15.9%.

[e] Sample was lost due to a power outage at the Cathedral.

Table B.3. HNO_3 Airborne Concentrations on Nylasorb Filters

Sample	Time (h)	Flow rate L/min	NO_3 mass (ug)	NO_3 mass std dev. (ug) [a]	Net NO_3 mass (ug) [b]	Net NO_3 mass std dev. (ug)	HNO_3 conc (ug/m^3)	HNO_3 conc std dev. (ug/m^3)	ave HNO_3 conc (ug/m^3)	ave HNO_3 conc std dev. (ug/m^3)[d]
06/30/94-5a	166	0.75	42.83	1.51	42.22	1.63	5.63	0.22	5.87	0.34
06/30/94-5b	166	0.80	48.98	1.22	48.38	1.37	6.11	0.17		
07/07/94-5a	193	0.82	43.25	1.43	42.65	1.56	4.52	0.17	4.67	0.21
07/07/94-5b	193	1.24	69.97	1.53	69.37	1.64	4.82	0.11		
07/14/94-5a	146	0.90	46.13	1.32	45.52	1.45	5.77	0.18	5.57	0.28
07/14/94-5b	146	1.04	49.21	1.43	48.60	1.56	5.37	0.17		
07/21/94-5a	168	0.85	31.58	0.05	30.98	0.62	3.61	0.07	3.74	0.19
07/21/94-5b	168	1.14	45.35	1.37	44.74	1.50	3.88	0.13		
07/28/94-5a	189	1.04	101.53	1.35	100.92	1.49	8.57	0.13	6.32	3.19
07/28/94-5b	189	0.97	45.27	1.68[c]	44.67	1.79	4.06	0.16		
08/05/94-5a	171	0.87	44.21	1.64[c]	43.61	1.75	4.88	0.20	4.35	0.75
08/05/94-5b	171	1.06	42.02	1.56[c]	41.41	1.67	3.82	0.15		
08/12/94-5a	146	0.87	27.90	0.79	27.29	1.00	3.58	0.13	3.34	0.33
08/12/94-5b	146	0.97	26.97	0.79	26.36	1.00	3.11	0.12		
08/18/94-5a	167	1.08	68.36	2.24	67.75	2.32	6.26	0.21	5.34	1.30
08/18/94-5b	167	1.12	50.03	0.79	49.43	1.00	4.42	0.09		
08/25/94-5a	359	0.87	84.91	2.24	84.30	2.32	4.49	0.12	3.82	0.95
08/25/94-5b	359	0.97	66.22	3.42	65.61	3.47	3.14	0.17		.
09/09/94-5a	288	0.87	78.03	1.18	77.42	1.33	5.13	0.09	4.50	0.90
09/09/94-5b	288	0.94	63.52	0.39	62.91	0.73	3.87	0.04		
09/21/94-5a	453	0.85	33.02	0.66	32.41	0.90	1.40	0.04	1.56	0.22
09/21/94-5b	453	0.91	43.15	0.79	42.55	1.00	1.72	0.04		
10/10/94-5a	220	0.83	21.67	0.39	21.06	0.73	1.92	0.07	1.86	0.09
10/10/94-5b	220	0.94	22.88	0.79	22.27	1.00	1.80	0.08		
10/19/94-5a	216	0.68	18.08	0.74	17.47	0.96	1.99	0.11	1.83	0.22
10/19/94-5b	216	0.85	19.07	0.13	18.46	0.63	1.68	0.06		

Table B.3. HNO_3 Airborne Concentrations on Nylasorb Filters

Sample	Time (h)	Flow rate L/min	NO_3 mass (ug)	NO_3 mass std dev. (ug) [a]	Net NO_3 mass (ug) [b]	Net NO_3 mass std dev. (ug)	HNO_3 conc (ug/m^3)	HNO_3 conc std dev. (ug/m^3)	ave HNO_3 conc (ug/m^3)	ave HNO_3 conc std dev. (ug/m^3)[d]
10/28/94-5a	575	0.85	62.03	0.13	61.42	0.63	2.09	0.02	2.09	0.27
11/21/94-5b	240	1.00	10.41	0.41	9.80	0.74	0.68	0.05	0.68	0.09
12/01/94-5a	431	0.85	10.34	0.47	9.73	0.78	0.44	0.04	0.44	0.06
12/19/94-5a	601	0.85	30.13	1.32	29.53	1.45	0.96	0.05	0.87	0.13
12/19/94-5b	601	0.91	26.23	0.53	25.62	0.81	0.78	0.02		
01/13/95-5a	168	0.91	6.23	0.08	5.62	0.62	0.61	0.07	0.51	0.14
01/13/95-5b	168	0.86	4.18	0.12	3.57	0.63	0.41	0.07		
01/20/95-5a	243	0.89	12.36	0.04	11.75	0.62	0.90	0.05	0.96	0.09
01/20/95-5b	243	0.74	11.63	0.01	11.03	0.61	1.02	0.06		
01/30/95-5b	189	0.95	10.43	0.41	9.82	0.74	0.91	0.07	0.91	0.12
02/07/95-5a	170	0.84	5.85	0.41	5.24	0.74	0.62	0.09	0.67	0.07
02/07/95-5b	170	0.88	7.07	0.42	6.46	0.75	0.72	0.08		
02/14/95-5b	168	0.89	8.66	0.03	8.06	0.62	0.90	0.07	0.90	0.11
02/21/95-5a	168	0.91	3.32	0.83	2.71	1.03	0.29	0.11	0.29	0.04
02/28/95-5a	169	0.91	11.25	0.26	10.65	0.67	1.16	0.07	1.35	0.27
02/28/95-5b	169	0.90	14.64	0.13	14.03	0.63	1.54	0.07		
03/07/95-5a	169	1.23	23.76	1.38	23.15	1.51	1.87	0.12	1.85	0.02
03/07/95-5b	169	0.79	15.35	0.89	14.74	1 .09	1 .83	0.14		
03/14/95-5a	168	0.83	29.65	1.74	29.04	1.84	3.47	0.22	3.47	0.01
03/14/95-5b	168	0.81	28.75	1.43	28.14	1.56	3.46	0.19		
03/21/95-5a	168	1.01	16.41	1.91	15.81	2.00	1.55	0.20	1.55	0.20
03/28/95-5a	168	0.72	14.72	1.01	14.12	1.18	1.94	0.16	1.73	0.31
03/28/95-5b	168	1.07	16.99	1.04	16.38	1.21	1.51	0.11		
04/04/95-5a	168	1.34	29.17	0.42	28.56	0.75	2.12	0.06	2.20	0.11
04/04/95-5b	168	0.87	20.51	0.54	19.91	0.82	2.28	0.09		
04/11/95-5a	193	1.34	30.58	0.56	29.98	0.83	1.93	0.05	1.71	0.45

Table B.3. HNO_3 Airborne Concentrations on Nylasorb Filters

Sample	Time (h)	Flow rate L/min	NO_3 mass (ug)	NO_3 mass std dev. (ug) [a]	Net NO_3 mass (ug) [b]	Net NO_3 mass std dev. (ug)	HNO_3 conc (ugfm^3)	HNO_3 conc std dev. (ug/m^3)	ave HNO_3 conc (ug/m^3)	ave HNO_3 conc std dev. (ug/m^3)[d]
04/11/95-5b	193	0.88	12.84	0.43	12.24	0.75	1.20	0.07		
04/11/95-5c	193	1.01	24.06	0.23	23.45	0.66	2.00	0.06	2.97	0.06
04/19/95-5a	312	0.86	48.85	0.72	48.24	0.94	3.01	0.06		
04/19/95-5c	312	1.00	55.31	0.33	54.70	0.70	2.93	0.04		
05/02/95-5a	192	0.89	34.69	0.36	34.09	0.71	3.33	0.07	3.68	0.49
05/02/95-5c	192	1.00	46.97	0.63	46.37	0.88	4.03	0.08		
05/10/95-5a	169	0.89	36.55	0.35	35.94	0.71	4.00	0.08	4.15	
05/10/95-5b	169	0.97	43.5	0.17	42.89	0.64	4.37	0.06		
05/10/95-5c	169	0.94	39.18	0.78	38.58	0.99	4.07	0.10		0.40
05/17/95-5a	169	0.82	20.8	0.33	20.19	0.70	2.44	0.08	2.89	
05/17/95-5b	169	0.83	27.63	0.22	27.03	0.65	3.21	0.08		
05/17/95-5c	169	1.01	31.49	0.68	30.88	0.92	3.03	0.09		0.04
05/24/95-5a	384	1.12	110.2	2.14	109.58	2.23	4.25	0.09	4.28	
05/24/95-5c	384	0.81	81.25	0.48	80.64	0.78	4.30	0.04		
06/09/95-5a	167	0.82	46.59	1.68	45.98	1.78	5.56	0.22	5.48	0.12
06/09/95-5c	167	0.87	47.87	1.16	47.27	1.32	5.40	0.15		
06/16/95-[e]	263									
06/27/95-5c	213	0.91	45.71	1.18	45.10	1.33	3.88	0.11	3.88	

[a] The % standard deviation from IC replication is 3.7%.
[b] The subtracted blank mass was 0.61 ± 0.61 ug/m^3.
[c] An IC replicate was not performed for this Sample.
[d] The average % standard deviation from adjacent replicates was 12.7%.
[e] Sample was lost due to a power outage at the Cathedral.

Table B.4. SO_2 Airborne Concentrations on Nylasorb Filters

Sample	Time (h)	Flow rate L/min	SO_4 mass (ug)	SO_4 mass std dev. (ug)a	Net SO_4 mass (ug)b	Net SO_4 mass std dev. (ug)	SO_2 conc (ug/m^3)	SO_2 conc std dev. (ug/m^3)	ave SO_2 conc (ug/m^3)	ave SO_2 conc std dev. (ug/m^3)d
06/30/94-5a	166	0.75	65.55	1.38	64.57	1.49	5.75	0.13	5.50	0.35
06/30/94-5b	166	0.80	63.31	1.30	62.32	1.41	5.25	0.12		
07/07/94-5a	193	0.82	65.89	1.72	64.90	1.81	4.59	0.13	4.17	0.59
07/07/94-5b	193	1.24	81.89	2.71	80.91	2.77	3.75	0.13		
07/14/94-5a	146	0.90	.50.75	1.55	49.76	1.64	4.21	0.14	4.11	0.14
07/14/94-5b	146	1.04	55.28	1.24	54.30	1.36	4.00	0.10		
07/21/94-5a	168	0.85	76.79	1.78	75.81	1.86	5.89	0.14	5.33	0.79
07/21/94-5b	168	1.14	83.57	1.55	82.59	1.65	4.78	0.10		
07/28/94-5a	189	1.04	61.46	0.24	60.48	0.61	3.43	0.03	2.65	1.10
07/28/94-5b	189	0.97	31.79	0.76[C]	30.80	0.94	1.87	0.06		
08/05/94-5a	171	0.87	54.70	1.30[C]	53.71	1.42	4.01	0.11	3.29	1.02
08/05/94-5b	171	1.06	42.65	1.02[C]	41.67	1.16	2.57	0.07		
08/12/94-5a	146	0.87	57.62	2.42	56.63	2.48	4.95	0.22	4.56	0.55
08/12/94-5b	146	0.97	54.02	0.99	53.03	1.14	4.17	0.09		
08/18/94-5a	167	1.08	35.58	1.00	34.60	1.15	2.13	0.07	1.98	0.22
08/18/94-5b	167	1.12	31.55	1.00	30.56	1.15	1.82	0.07		
08/25/94-5a	359	0.87	48.11	1.20	47.13	1.32	1.67	0.05	1.61	0.09
08/25/94-5b	359	0.97	49.59	0.45	48.61	0.71	1.55	0.02		
09/09/94-5a	288	0.87	44.08	1.20	43.09	1.33	1 .91	0.06	1.84	0.09
09/09/94-5b	288	0.94	44.22	0.18	43.24	0.59	1.77	0.02		
09/21/94-5a	453	0.85	33.99	0.02	33.01	0.56	0.95	0.02	0.91	0.05
09/21/94-5b	453	0.91	.33.56	0.22	32.58	0.60	0.88	0.02		
10/10/94-5a	220	0.83	25.16	0.58	24.18	0.80	1.47	0.05	1.32	0.22
10/10/94-5b	220	0.94	22.72	0.99	21.73	1.13	1.17	0.06		
10/19/94-5a	216	0.68	33.71	1.21	32.72	1.33	2.48	0.10	2.28	0.29
10/19/94-5b	216	0.85	35.15	1.61	34.16	1.71	2.07	0.10		

Table B.4. SO_2 Airborne Concentrations on Nylasorb Filters

Sample	Time (h)	Flow rate L/min	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_2 conc (ug/m^3)	SO_2 conc std dev. (ug/m^3)	ave SO_2 conc (ug/m^3)	ave SO_2 conc std dev. (ug/m^3)[d]
10/28/94-5a	575	0.85	49.98	1.40	49.00	1 .51	1 .11	0.03	1 .11	0.15
11/21/94-5b	240	1.00	37.52	0.53	36.54	0.77	1.69	0.04	1.69	0.24
12/01/94-5a	431	0.85	44.37	0.43	43.38	0.70	1.31	0.02	1.31	0.18
12/19/94-5a	601	0.85	44.22	1.41	43.24	1.51	0.94	0.03	0.92	
12/19/94-5b	601	0.91	45.09	0.22	44.10	0.60	0.89	0.01		
01/13/95-5a	168	0.91	35.58	0.19	34.60	0.59	2.50	0.04	2.45	0.07
01/13/95-5b	168	0.86	32.12	0.19	31.14	0.59	2.41	0.05		
01/20/95-5a	243	0.89	44.65	2.06	43.67	2.13	2.24	0.11	2.20	0.O5
01/20/95-5b	243	0.74	36.01	2.46	35.03	2.52	2.17	0.16		
01/30/95-5b	189	0.95	44.89	2.79	43.90	2.85	2.71	0.18	2.71	0.38
02/07/95-5a	170	0.84	24.95	4.90	23.97	4.93	1.88	0.39	2.08	
02/07/95-5b	170	0.88	31.72	1.68	30.74	1.77	2.29	0.13		
02/14/95-5b	168	0.89	36.00	0.37	35.01	0.67	2.60	0.05	2.60	0.36
02/21/95-5a	168	0.91	38.79	0.66	37.81	0.86	2.74	0.06	2.74	0.38
02/28/95-5a	169	0.91	23.26	0.38	22.28	0.67	1.61	0.O5	1.70	0.13
02/28/95-5b	169	0.90	25.54	0.13	24.56	0.57	1.80	0.04		
03/07/95-5a	169	1.23	33.50	1.09	32.52	1.22	1.75	0.07	2.26	0.72
03/07/95-5b	169	0.79	34.38	0.66	33.40	0.86	2.77	0.07		
03/14/95-5a	168	0.83	28.02	1.11	27.03	1.24	2.16	0.10	2.38	0.32
03/14/95-5b	168	0.81	32.81	0.84	31.83	1.01	2.61	0.08		
03/21/95-5a	168	1.01	37.81	1.92	36.83	2.00	2.41	0.13	2.41	0.33
03/28/95-5a	168	0.72	41.33	0.61	40.34	0.83	3.71	0.08	3.17	0.75
03/28/95-5b	168	1.07	43.92	0.61	42.94	0.83	2.64	0.05		
04/04/95-5a	168	1.34	38.90	0.02	37.92	0.56	1.88	0.03	2.44	0.80
04/04/95-5b	168	0.87	40.42	0.07	39.44	0.56	3.01	0.04		
04/11/95-5a	193	1.34	46.34	0.46	45.36	0.72	1.95	0.03	2.16	0.31

Table B.4. SO_2 Airborne Concentrations on Nylasorb Filters

Sample	Time (h)	Flow rate L/min	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net So_4 mass std dev. (ug)	SO_4 conc (ug/m^3)	SO_4 conc std dev. (ug/m^3)	ave SO_4 conc (ug/m^3)	ave SO_4 conc std dev. (ug/m^3)[d]
04/11/95-5b	193	0.88	31.83	0.12	30.85	0.57	2.02	0.04		
04/11/95-5c	193	1.01	45.07	2.53	44.09	2.59	2.51	0.15		0.22
04/19/95-5a	312	0.86	49.96	0.17	48.98	0.58	2.04	0.02	1.88	
04/19/95-5c	312	1.00	49.32	0.16	48.33	0.58	1.72	0.02		
05/02/95-5a	192	0.89	37.65	0.72	36.67	0.91	2.39	0.06	2.46	0.10
05/02/95-5c	192	1.00	44.73	1.32	43.75	1.43	2.53	0.08		
05/10/95-5a	169	0.89	43.44	1.01	42.46	1.16	3.15	0.09	3.16	0.03
05/10/95-5b	169	0.97	47.99	0.49	47.01	0.74	3.20	0.O5		
05/10/95-5c	169	0.94	45.44	0.55	44.46	0.78	3.13	0.06		0.78
05/17/95-5a	169	0.82	28.67	0.57	27.69	0.80	2.23	0.06	3.07	
05/17/95-5b	169	0.83	48.79	0.80	47.81	0.97	3.79	0.08		
05/17/95-5c	169	1.01	49.67	0.75	48.69	0.93	3.19	0.06		
05/24/95-5a	384	1.12	73.64	1.35	72.66	1.46	1.88	0.04	2.21	0.46
05/24/95-5c	384	0.81	72.16	1.79	71.18		2.53	0.07		
06/09/95-5a	167	0.82	52.73	0.38	51.75	0.67	4.17	0.05	3.80	0.53
06/09/95-5c	167	0.87	45.96	0.74	44.98	0.92	3.42	0.07		
06/16/95-[e]	263									
06/27/95-5c	213	0.91	65.71	0.43	64.73	0.71	3.71	0.04	3.71	

[a] The % standard deviation from IC replication is 2.4%.

[b] The subtracted blank mass was 0.98 ± 0.56 ug/m^3.

[c] An IC replicate was not performed for this Sample.

[d] The average % standard deviation from adjacent replicates was 13.9%.

[e] Sample was lost due to a power outage at the Cathedral.

Table B.5. SO_2 Airborne Concentrations on Whatman Filters

Sample	Time (h)	Flow rate L/min	SO_4 mass (ug)	SO_4 mass std dev. (ug) a	Net SO_4 mass (ug) b	Net SO_4 mass std dev. (ug)	SO_2 conc (ug/m^3)	SO_2 conc std dev. (ug/m^3)	ave SO_2 conc (uglm^3)	ave SO_2 conc std dev. (ug/m^3)d
06/30/94-5a	166	0.75	169.20	5.91	160.83	14.91	14.31	1.33	15.42	1.57
06/30/94-5b	166	0.80	204.48	0.81	196.11	13.72	16.52	1.16		
07/07/94-5a	193	0.82	303.84	6.11	295.47	15.00	20.89	1.06	19.69	1.69
07/07/94-5b	193	1.24	407.52	2.04	399.15	13.84	18.50	0.64		
07/14/94-5a	146	0.90	348.48	4.07	340.11	14.29	28.75	1.21	31.43	3.79
07/14/94-5b	146	1.04	470.88	30.55	462.51	33.48	34.11	2.47		
07/21/94-5a	168	0.85	400.32	0.00	391.95	13.69	30.44	1.06	30.59	0.22
07/21/94-5b	168	1.14	540.00	10.18	531.63	17.06	30.74	0.99		
07/28/94-5a	189	1.04	705.82	24.74	697.44	28.28	39.52	1.60	34.16	7.58
07/28/94-5b	189	0.97	483.19	3.36	474.82	14.10	28.80	0.86		
08/05/94-5a	171	0.87	738.00	42.97	729.63	45.10	54.42	3.36	42.06	17.48
08/05/94-5b	171	1.06	490.75	13.03	482.38	18.91	29.70	1.16		
08/12/94-5a	146	0.87	160.21	8.71	151.83	16.23	13.27	1.42	11.75	2.14
08/12/94-5b	146	0.97	138.66	3.45	130.29	14.12	10.24	1.11		
08/18/94-5a	167	1.08	587.88	43.89	579.51	45.97	35.69	2.83	32.23	4.89
08/18/94-5b	167	1.12	490.46	15.48	482.09	20.67	28.77	1.23		
08/25/94-5a	359	0.87	817.63	25.66	809.26	29.09	28.75	1.03	24.48	6.03
08/25/94-5b	359	0.97	641.23	9.16	632.86	16.48	20.21	0.53		
09/09/94-5a	288	0.87	699.12	64.15	690.75	65.59	30.54	2.90	26.52	5.68
09/09/94-5b	288	0.94	557.57	10.59	549.19	17.31	22.50	0.71		
09/21/94-5a	453	0.85	362.59	11.81	354.22	18.08	10.21	0.52	11.46	1.77
09/21/94-5b	453	0.91	480.96	8.15	472.59	15.93	12.72	0.43		
10/10/94-5a	220	0.83	523.30	1.22	514.92	13.75	31.37	0.84	30.84	0.75
10/10/94-5b	220	0.94	571.97	55.80	563.59	57.46	30.30	3.09		
10/19/94-5a	216	0.68	570.96	37.67	562.59	40.09	42.70	3.04	35.42	10.31
10/19/94-5b	216	0.85	471.60	3.05	463.23	14.03	28.13	0.85		

Table B.5. SO$_2$ Airborne Concentrations on Whatman Filters

Sample	Time (h)	Flow rate L/min	SO$_4$ mass (ug)	SO$_4$ mass std dev. (ug)[a]	Net SO$_4$ mass (ug)[b]	Net So$_4$ mass std dev. (ug)	SO$_4$ conc (ug/m^3)	SO$_4$ conc std dev. (ug/m^3)	ave SO$_4$ conc (ug/m^3)	ave SO$_4$ conc std dev. (ug/m^3)[d]
10/28/94-5a	575	0.85	1591.63	108.54	1583.26	109.40	35.95	2.48	35.95	7.02
11/21/94-5b	240	1.00	197.06	1.73	188.69	13.80	8.74	0.64	8.74	1.71
12/01/94-5a	431	0.85	757.44	69.24	749.07	70.58	22.67	2.14	22.67	4.43
12/19/94-5a	601	0.85	1760.98	122.80	1752.60	123.56	38.03	2.68	33.97	5.74
12/19/94-5b	601	0.91	1485.22	133.18	1476.84	133.89	29.91	2.71		
01/13/95-5a	168	0.91	339.55	28.10	331.18	31.26	23.93	2.26	21.56	3.35
01/13/95-5b	168	0.86	256.81	7.21	248.44	5.48	19.19	1.20		
01/20/95-5a	243	0.89	257.08	8.70	248.71	16.22	12.74	0.83	15.10	3.33
01/20/95-5b	243	0.74	290.23	25.35	281.86	28.82	17.45	1.78		
01/30/95-5b	189	0.95	307.44	5.09	299.07	14.61	18.45	0.90	18.45	3.61
02/07/95-5a	170	0.84	231.54	1.04	223.16	13.73	17.46	1.07	18.32	1.21
02/07/95-5b	170	0.88	265.97	12.42	257.59	18.49	19.17	1.38		
02/14/95-5b	168	0.89	510.62	2.85	502.25	13.99	37.35	1.04	37.35	7.30
02/21/95-5a	168	0.91	183.62	5.749	175.25	14.85	12.70	1.08	12.70	2.48
02/28/95-5a	169	0.91	129.84	11.75	121.47	18.04	8.79	1.31	11.52	3.86
02/28/95-5b	169	0.90	203.33	8.15	194.95	15.93	14.25	1.17		
03/07/95-5a	169	1.23	357.12	0.00	348.75	13.69	18.75	0.74	19.48	1.03
03/07/95-5b	169	0.79	251.86	3.46	243.48	14.13	20.20	1.17		
03/14/95-5a	168	0.83	266.98	4.89	258.60	14.54	20.63	1.16	20.20	0.61
03/14/95-5b	168	0.81	249.41	1.22	241.03	13.75	19.77	1.13		
03/21/95-5a	168	1.01	180.58	6.11	172.20	15.00	11.25	0.98	11.25	2.20
03/28/95-5a	168	0.72	81.22	3.26	72.84	14.08	6.69	1.29	6.04	0.92
03/28/95-5b	168	1.07	96.05	3.05	87.67	14.03	5.40	0.86		
04/04/95-5a	168	1.34	220.10	8.29	211.73	16.01	10.48	0.79	11.93	2.05
04/04/95-5b	168	0.87	183.81	3.09	175.44	14.04	13.38	1.07		
04/11/95-5a	193	1.34	422.24	5.05	413.86	14.60	17.77	0.63	15.24	6.31

Table B.5. SO$_2$ Airborne Concentrations on Whatman Filters

Sample	Time (h)	Flow rate L/min	SO$_4$ mass (ug)	SO$_4$ mass std dev. (ug)[a]	Net SO$_4$ mass (ug)[b]	Net So$_4$ mass std dev. (ug)	SO$_4$ conc (ug/m^3)	SO$_4$ conc std dev. (ug/m^3)	ave SO$_4$ conc (ug/m^3)	ave SO$_4$ conc std dev. (ug/m^3)[d]
04/11/95-5b	193	0.88	131.70	2.67	123.32	13.95	8.06	0.91		
04/11/95-5c	193	1.01	357.08	8.78	348.70	16.27	19.89	0.93		
04/19/95-5a	312	0.86	81.41	2.45	73.03	13.91	3.04	0.58	2.24	1.13
04/19/95-5c	312	1.00	48.60	1.64	40.22	13.79	1.44	0.49		
05/02/95-5a	192	0.89	183.71	0.22	175.33	13.70	11.44	0.89	15.70	6.02
05/02195-5c	192	1.00	353.02	4.95	344.64	14.56	19.96	0.84		
05/10/95-5a	169	0.89	279.87	4.58	271.50	14.44	20.16	1.07	21.15	0.89
05/10/95-5b	169	0.97	330.49	5.03		14.59	21.91	0.99		
05/10/95-5c	169	0.94	311.72	4.17	303.34	14.32	21.37	1.01		
05/17/95-5a	169	0.82	89.04	1.78	80.66	13.81	6.51	1.11	11.99	4.75
05/17/95-5b	169	0.83	190.87	4.73	182.50	14.49	14.46	1.15		
05/17/95-5c	169	1.01	237.47	4.97	229.10	14.57	14.99	0.95		
05/24/95-5a	384	1.12	482.73	3.73	474.36	14.19	12.26	0.37	15.53	4.62
05/24/95-5c	384	0.81	536.33	6.94	527.95	15.35	18.80	0.55		
06/09/95-5a	167	0.82	252.34	2.64	243.96	13.95	19.68	1.12	20.48	1.13
06/09/95-5c	167	0.87	287.90	3.85	279.52	14.23	21.28	1.08		
06/16/95-[e]	263									
06/27/95-5c	213	0.91	362.53	0.45	354.16	13.70	20.32	0.79	20.32	3.97

[a] The % standard deviation from IC replication is 3.1%.

[b] The subtracted blank mass was 7.8 ± 13.7 ug/m^3.

[c] An IC replicate was not performed for this Sample.

[d] The average % standard deviation from adjacent replicates was 19.5%.

[e] Sample was lost due to a power outage at the Cathedral.

Table B.6. NO_3 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	NO_3 mass (ug)	NO_3 mass std dev. (ug)[a]	Net NO_3 mass (ug)[b]	Net NO_3 mass std dev. (ug)	NO_3 flux (ng/cm^2/day)	NO_3 flux std dev. (ng/cm^2/day)	ave NO_3 flux (ng/cm^2/day)	ave NO_3 flux std dev. (ng/cm^2/day)[f]
06/30/94-ab-1	503.5	9.71	0.21	9.09	0.56	5.00	0.31	9.12	5.83
06/30/94-ab-2	503.5	24.68	0.30	24.06	0.59	13.24	0.33		
06/30/94-ad-2	503.5	19.76	0.34	19.14	0.61	10.54	0.34	10.54	3.47
06/30/94-ae-2	503.5	21.48	0.31	20.86	0.60	11.48	0.33	11.48	3.79
06/30/94-ak-2[c]	503.5	18.50	2.62	17.88	2.67	9.84	1.47	9.84	3.25
07/21/94-ab-1	356.5	2.03	0.03	1.41	0.51	1.10	0.40	0.93	0.24
07/21/94-ab-2	356.5	1.61	0.01	0.98	0.51	0.77	0.40		
07/21/94-ad-1	356.5	4.98	0.33	4.36	0.61	3.39	0.48	4.98	2.25
07/21/94-ad-2	356.5	9.07	0.26	8.45	0.58	6.57	0.45		
07/21/94-ae-1	356.5	6.34	0.29	5.72	0.59	4.45	0.46	3.72	1.04
07/21/94-ae-2	356.5	4.45	0.18	3.83	0.54	2.98	0.42		
07/21/94-ak-1	356.5	2.39	0.03	1.77	0.51	1.38	0.40	3.06	2.38
07/21/94-ak-2	356.5	6.73	0.23	6.11	0.56	4.75	0.44		
07/21/94-am-1	356.5	13.56	0.04	12.94	0.51	10.06	0.40	7.71	3.32
07/21/94-am-2	356.5	7.52	0.29	6.90	0.59	5.36	0.46		
08/05/94-ab-1[d]	316.5	0.09	0.04	0[e]	0[e]	0[e]	0[e]	1.52	2.14
08/05/94-ab-2	316.5	4.08	0.01	3.46	0.51	3.03	0.45		
08/05/94-ad-1	316.5	2.82	0.06	2.20	0.52	1.92	0.45	1.34	0.83
08/05/94-ad-2	316.5	1.47	0.01	0.85	0.51	0.75	0.45		
08/05/94-ae-1	316.5	5.27	0.28	4.65	0.58	4.07	0.51	2.81	1.79
08/05/94-ae-2	316.5	2.38	0.14	1.76	0.53	1.54	0.47		
08/05/94-ak-1[d]	316.5	1.25	0.08	0.63	0.52	0.55	0.45	1.08	0.75
08/05/94-ak-2	316.5	2.46	0.10	1.84	0.52	1.61	0.46		
08/05/94-am-1[d]	316.5	0.18	0.01	0[e]	0[e]	0[e]	0[e]	1.03	1.46
08/05/94-am-2	316.5	2.98	0.05	2.36	0.52	2.07	0.45		
08/18/94-ab-1[d]	525	0.92	0.18	0.30	0.54	0.16	0.29	0.08	0.11

Table B.6. NO_3 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	NO_3 mass (ug)	NO_3 mass std dev. (ug)a	Net NO_3 mass (ug)b	Net NO_3 mass std dev. (ug)	NO_3 flux (ng/cm2/day)	NO_3 flux std dev. (nglcm2/day)	ave NO_3 flux (ng/cm2/day)	ave NO_3 flux std dev. (ng/cm2/day)t
08/18/94-ab-2[d]	525	0.33	0.14	0[e]	0[e]	0[e]	0[e]		
08/18/94-ad-1[d]	525	1.36	0.00	0.74	0.51	0.39	0.27	0.20	0.28
08/18/94-ad-2[d]	525	0.23	0.05	0[e]	0[e]	0[e]	0[e]		
08/18/94-ae-1[d]	525	0.45	0.02	0[e]	0[e]	0[e]	0[e]	0.03	0.04
08/18/94-ae~2[d]	525	0.72	0.20	0.10	0.55	0.05	0.29		
08/18/94-ak-1[d]	525	0.61	0.10	0[e]	0[e]	0[e]	0[e]	0.00	0.00
08/18/94-ak-2[d]	525	0.39	0.04	0[e]	0[e]	0[e]	0[e]		
08/18/94-am-1[d]	525	0.23	0.05	0[e]	0[e]	0[e]	0[e]	0.00	0.00
08/1 8/94-am-2[d]	525	0.41	0.01	0[e]	0[e]	0[e]	0[e]		
09/09/94-ab-1[d]	741	0.25	0.18	0[e]	0[e]	0[e]	0[e]	0.00	0.00
09/09/94-ab-2[d]	741	0.34	0.05	0[e]	0[e]	0[e]	0[e]		
09/09/94-ad-1[d]	741	1.25	0.07	0.63	0.52	0.24	0.19	0.12	0.17
09/09/94-ad-2[d]	741	0.26	0.06	0[e]	0[e]	0[e]	0[e]		
09/09/94-ae-1[d]	741	0.09	0.05	0[e]	0[e]	0[e]	0[e]	0.25	0.36
09/09/94-ae-2	741	1.97	0.10	1.35	0.52	0.51	0.20		
09/09/94-ak-1[d]	744	0.24	0.06	0[e]	0[e]	0[e]	0[e]	0.17	0.24
09/09/94-ak-2	741	1.51	0.10	0.89	0.52	0.33	0.20		
09/09/94-am-1	741	1.90	0.14	1.28	0.53	0.48	0.20	0.36	0.16
09/09/94-am-2[d]	741	1.28	0.05	0.66	0.52	0.25	0.19		
10/10/94-ab-1[d]	1249.75	0.34	0.09	0[e]	0[e]	0[e]	0[e]	0.00	0.00
10/10/94-ab-2[d]	1249.75	0.21	0.13	0[e]	0[e]	0[e]	0[e]		
10/10/94-ak-1[d]	1249.75	0.20	0.26	0[e]	0[e]	0[e]	0[e]	0.00	0.00
10/10/94-ak-2[d]	1249.75	0.39	0.20	0[e]	0[e]	0[e]	0[e]		
10/10/94-am-2[d]	1249.75	0.16	0.09	0[e]	0[e]	0[e]	0[e]	0.00	0.00
12/01/94-ab-1[d]	431	0.05	0.02	0[e]	0[e]	0[e]	0[e]	0.00	0.00
12/01/94-ab-2[d]	431	0.12	0.01	0[e]	0[e]	0[e]	0[e]		

Table B.6. NO_3 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	NO_3 mass (ug)	NO_3 mass std dev. (ug)a	Net NO_3 mass (ug)b	Net NO_3 mass std dev. (ug)	NO_3 flux (ng/cm^2/day)	NO_3 flux std dev. (ng/cm^2/day)	ave NO_3 flux (ng/cm^2/day)	ave NO_3 flux std dev. (ng/cm^2/day)[f]
12/01/94-ad-1[d]	431	0.01	0.02	0[e]	0[e]	0[e]	0[e]	0.00	0.00
12/01/94-ad-2[d]	431	0.15	0.12	0[e]	0[e]	0[e]	0[e]		
12/01/94-ae-1[d]	431	0.15	0.11	0[e]	0[e]	0[e]	0[e]	0.22	0.31
12/01/94-ae-2[d]	431	1.31	0.13	0.69	0.53	0.44	0.34		
12/01/94-ak-1[d]	431	1.41	0.03	0.79	0.51	0.51	0.33	0.51	0.00
12/01/94-ak-2[d]	431	1.41	0.07	0.79	0.52	0.51	0.33		
12/01/94-am-1[d]	431	0.20	0.00	0[e]	0[e]	0[e]	0[e]	0.00	0.00
12/01/94-am-2[d]	431	0.11	0.01	0[e]	0[e]	0[e]	0[e]		
12/19/94-ab-1	1012.25	7.56	0.39	6.94	0.64	1.90	0.18	0.95	1.34
12/19/94-ab-2[d]	1012.25	0.25	0.20	0[e]	0[e]	0[e]	0[e]		
12/19/94-ad-1	1012.25	11.73	0.06	11.11	0.52	3.04	0.14	4.67	2.30
12/19/94-ad-2	1012.25	23.59	0.16	22.97	0.54	6.29	0.15		
12/19/94-ae-1	1012.25	16.07	0.83	15.45	0.98	4.23	0.27	4.40	0.25
12/19/94-ae-2	1012.25	17.34	0.86	16.72	1.00	4.58	0.27		
12/19/94-ak-1	1012.25	18.49	0.71	17.87	0.88	4.89	0.24	4.28	0.87
12/19/94-ak-2	1012.25	14.02	0.00	13.40	0.51	3.67	0.14		
12/19/94-am-1	101225	17.76	0.49	17.14	0.71	4.69	0.19	2.35	3.32
12/19/94-am-2[d]	1012.25	0.14	0.06	0[e]	0[e]	0[e]	0[e]		
01/30/95-ab-1	694	59.68	0.10	59.06	0.52	23.59	0.21	23.25	0.48
01/30/95-ab-2	694	57.97	0.58	57.35	0.78	22.91	0.31		
01/30/95-ad-1	694	42.94	0.03	42.32	0.51	16.90	0.21	17.27	0.52
01/30/95-ad-2	694	44.77	0.19	44.15	0.55	17.63	0.22		
01/30/95-ae-1	694	47.96	0.57	47.34	0.77	18.90	0.31	22.84	5.57
01/30/95-ae-2	694	67.68	0.29	67.06	0.59	26.78	0.23		
01/30/95-ak-1	694	48.60	0.48	47.98	0.70	19.16	0.28	18.07	1.55
01/30/95-ak-2	694	43.12	1.32	42.50	1.42	16.97	0.57		

Table B.6. NO_3 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	NO_3 mass (ug)	NO_3 mass std dev. (ug)[a]	Net NO_3 mass (ug)[b]	Net NO_3 mass std dev. (ug)	NO_3 flux (ng/cm^2/day)	NO_3 flux std dev. (ng/cm^2/day)	ave NO_3 flux (ng/cm^2/day)	ave NO_3 flux std dev. (ng/cm^2/day)[f]
01/30/95-am-1	694	40.95	0.31	40.33	0.60	16.11	0.24	17.22	1.58
01/30/95-am-2	694	46.52	0.31	45.90	0.60	18.33	0.24		
02/28/95-ab-1	673	19.32	1.24	18.70	1.34	7.70	0.55	7.43	0.39
02/28/95-ab-2	673	17.98	1.28	17.36	1.38	7.15	0.57		
02/28/95-ad-1	673	15.65	0.66	15.03	0.83	6.19	0.34	6.11	0.12
02/28/95-ad-2	673	1524	0.10	14.62	0.52	6.02	0.22		
02/28/95-ae-1	673	17.32	0.28	16.70	0.58	6.88	0.24	7.20	0.45
02/28/95-ae-2	673	18.87	0.22	18.25	0.56	7.52	0.23		
02/28/95-ak-1	673	15.71	0.65	15.09	0.83	6.21	0.34	6.18	0.04
02/28/95-ak-2	673	15.56	0.46	14.94	0.69	6.15	0.28		
02/28/95-am-1	673	14.16	0.28	13.54	0.59	5.58	0.24	5.11	0.67
02/28/95-am-2	673	11.88	0.31	11.26	0.60	4.64	0.25		
03/28/95-ab-1	840	80.87	2.46	80.25	2.51	26.48	0.83	25.15	1.88
03/28/95-ab-2	840	72.82	2.32	72.20	2.38	23.82	0.78		
03/28/95-ad-1	840	65.32	1.55	64.70	1.63	21.35	0.54	20.68	0.95
03/28/95-ad-2	840	61.26	1.47	60.64	1.56	20.01	0.51		
03/28/95-ae-1	840	85.59	0.73	84.97	0.89	28.04	0.30	24.14	5.52
03/28/95-ae-2	840	61.95	0.49	61.33	0.71	20.24	0.23		
03/28/95-ak-1	840	52.65	0.56	52.03	0.76	17.17	0.25	13.88	4.65
03/28/95-ak-2	840	32.74	1.98	32.12	2.05	10.60	0.68		
03/28/95-am-1	840	63.56	2.89	62.94	2.93	20.77	0.97	22.18	2.00
03/28/95-am-2	840	72.15	3.50	71.53	3.53	23.60	1.17		
05/02/95-ab-1	913.5	119.91	0.01	119.29	0.51	36.19	0.16	34.13	2.92
05/02/95-ab-2	913.5	106.30	1.94	105.68	2.01	32.06	0.61		
05/02/95-ad-1	913.5	71.39	0.08	70.77	0.52	21.47	0.16	12.69	12.43
05/02/95-ad-2	913.5	13.47	1.86	12.85	1.93	3.90	0.58		

Table B.6. NO3 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	NO_3 mass (ug)	NO_3 mass std dev. (ug)[a]	Net NO_3 mass (ug)[b]	Net NO_3 mass std dev. (ug)	NO_3 flux (ng/cm^2/day)	NO_3 flux std dev. (ng/cm^2/day)	ave NO_3 flux (ng/cm^2/day)	ave NO_3 flux std dev. (ng/cm^2/day)[f]
05/02/95-ae-1	913.5	87.90	0.67	87.28	0.84	26.48	0.26	22.65	
05/02/95-ae-2	913.5	62.65	3.63	62.03	3.67	18.82	1.11		
05/02/95-ak-1	913.5	56.14	1.29	55.52.	1.39	16.85	0.42	15.97	1.24
05/02/95-ak-2	913.5	50.38	1.31	49.76	1.41	15.10	0.43		
05/02/95-am-1	913.5	51.77	1.72	51.15	1.79	15.52	0.54	14.31	1.70
05/02/95-am-2	913.5	43.83	4.48	43.21	4.51	13.11	1.37		11.58
06/09/95-ab-1	643	65.95	3.98	65.33	4.01	28.16	1.73	19.98	
06/09/95-ab-2	643	27.98	0.81	27.36	0.96	11 .79	0.41		
06/09/95-ad-1	643	13.51	0.25	12.89	0.57	5.56	0.25	4.31	1.77
06/09/95-ad-2	643	7.71	0.78	7.09	0.93	3.06	0.40		
06/09/95-ae-1	643	13.86	1.07	13.24	1.19	5.71	0.51	10.76	7.15
06/09/95-ae-2	643	37.31	0.03	36.69	0.51	15.82	0.22		
06/09/95-ak-1	643	37.37	3.77	36.75	3.80	15.84	1.64	9.68	8.72
06/09/95-ak-2	643	8.77	0.59	8.15	0.78	3.51	0.34		
06/09/95-am-1	643	14.69	0.52	14.07	0.73	6.07	0.31	5.30	1.08
06/09/95-am-2	643	11.14	0.21	10.52	0.55	4.54	0.24		

a Average % standard dev1ation from IC replication is 14.1%.
b The subtracted blank mass is 0.62 ± 0.51 ug.
c An IC replicate was not performed for this sample.
d Sample contaminant mass is less than 1.64 times the sample contaminant mass standard deviation.
e Sample contaminant mass is less than the subtracted blank mass, resulting in a negative value for net contaminant mass. If these were reported as upper limit values the zeroes would be replaced by $<1.64\sigma_n$, which is <0.86 ug NO_3 on average.
f The average % standard deviation from adjacent samples is 33.0%.

Table B.7. SO4 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux st dev. (ng/cm^2/day)[e]
06/30/94-ab-1	504	65.30	2.32	60.15	3.68	33.11	2.02	30.06	4.32
06/30/94-ab-2	504	54.20	0.00	49.05	2.85	27.00	1.57		
06/30/94-ad-2	504	34.37	0.27	29.21	2.86	16.08	1.58	16.08	3.25
06/30/94-ae-2	504	39.38	0.21	34.23	2.86	18.84	1.57	18.84	3.81
06/30/94-ak-2[c]	504	69.71	4.68	64.56	5.48	35.54	3.02	35.54	7.18
07/21/94-ab-1	357	24.19	1.63	19.04	3.28	14.80	2.55	14.32	0.68
07/21/94-ab-2	357	22.95	0.90	17.80	2.99	13.84	2.32		
07/21/94-ad-1	357	13.46	0.56	8.31	2.90	6.46	2.26	7.57	1.56
07/21/94-ad-2	357	16.31	0.47	11.15	2.89	8.67	2.25		
07/21/94-ae-1	357	16.73	0.48	11.58	2.89	9.00	2.25	8.78	0.32
07/21/94-ae-2	357	16.15	0.73	11.00	2.94	8.55	2.29		
07/21/94-ak-1	357	16.22	0.65	11.07	2.92	8.61	2.27	9.63	1.45
07/21/94-ak-2	357	18.86	0.36	13.71	2.87	10.66	2.23		
07/21/94-am-1	357	20.77	0.06	15.62	2.85	12.14	2.22	9.31	4.00
07/21/94-am-2	357	13.49	0.37	8.34	2.87	6.48	2.23		
08/05/94-ab-1	317	17.17	0.55	12.02	2.90	10.53	2.54	.9.51	1.44
08/05/94-ab-2	317	14.85	0.46	9.70	2.89	8.49	2.53		
08/05/94-ad-1[d]	317	8.74	0.19	3.58	2.86	3.14	2.50	3.74	0.85
08/05/94-ad-2	317	10.11	0.18	4.96	2.86	4.34	2.50		
08/05/94-ae-1	317	14.02	0.60	8.87	2.91	7.77	2.55	7.81	0.06
08/05/94-ae-2	317	14.l1	0.51	8.96	2.90	7.84	2.54		
08/05/94-ak-1	317	12.22	0.34	7.07	2.87	6.19	2.51	6.33	0.20
08/05/94-ak-2	317	12.54	0.16	7.39	2.85	6.47	2.50		
08/05/94-am-1[d]	317	8.94	0.37	3.79	2.87	3.32	2.52	6.00	3.79
08/05/94-am-2	317	15.06	0.05	9.90	2.85	8.67	2.50		
08/18/94-ab-1	525	79.69	0.59	74.54	2.91	39.35	1.54	29.08	14.52

Table B.7. SO_4 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[e]
08/18/94-ab-2	525	40.79	0.98	35.64	3.01	18.81	1.59		
08/18/94-ad-1	525	20.33	0.64	15.18	2.92	8.01	1.54	10.25	3.16
08/18/94-ad-2	525	28.79	0.81	23.64	2.96	12.48	1.56		
08/18/94-ae-1	525	22.13	0.52	16.98	2.90	8.96	1.53	9.65	0.97
08/18/94-ae-2	525	24.74	0.32	19.59	2.87	10.34	1.51		
08/18/94-ak-1	525	28.17	0.60	23.02	2.91	12.15	1.54	9.95	3.11
08/18/94-ak-2	525	19.84	0.20	14.69	2.86	7.76	1.51		
08/18/94-am-1	525	23.70	0.52	18.54	2.90	9.79	1.53	9.44	0.50
08/18/94-am-2	525	22.37	0.65	17.21	2.92	9.09	1.54		
09/09/94-ab-1	741	28.01	1.22	22.86	3.10	8.55	1.16	9.11	0.79
09/09/94-ab-2	741	31.01	1.49	25.86	3.22	9.67	1.20		
09/09/94-ad-1	741	25.59	0.89	20.44	2.99	7.64	1.12	8.97	1.88
09/09/94-ad-2	741	32.70	0.49	27.55	2.89	10.31	1.08		
09/09/94-ae-1	741	28.09	0.50	22.94	2.89	8.58	1.08	10.33	2.48
09/09/94-ae-2	744	37.47	0.49	32.32	2.89	12.09	1.08		
09/09/94-ak-1	7411	33.11	0.64	27.96	2.92	10.46	1.09	10.08	0.54
09/09/94-ak-2	741	31.06	0.60	25.91	2.91	9.69	1.09		
09/09/94-am-1	741	34.36	0.76	29.21	2.95	10.93	1.10	12.77	2.60
09/09/94-am-2	741	44.21	0.14	39.06	2.85	14.61	1.07		
10/10/94-ab-1	1250	199.50	2.28	194.35	3.65	43.10	0.81	44.68	2.23
10/10/94-ab-2	1250	213.73	4.56	208.58	5.38	46.26	1.19		
10/10/94-ak-1	1250	70.65	1.12	65.50	3.06	14.53	0.68	12.92	2.27
10/10/94-ak-2	1250	56.16	0.53	51.01	2.90	11.31	0.64		
10/10/94-am-2	1250	37.68	0.44	32.53	2.88	7.21	0.64	7.21	1.46
12/01/94-ab-1	431	46.29	2.67	41.14	3.91	26.46	2.51	19.98	9.16
12/01/94-ab-2	431	26.15	1.17	21.00	3.08	13.51	1.98		

Table B.7. SO4 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[e]
12/01/94-ad-1[d]	431	6.18	8.57	1.03	9.03	0.66	5.81	1.98	1.87
12/01/94-ad-2	431	10.29	0.13	5.14	2.85	3.31	1.84		
12/01/94-ae-1[d]	431	8.41	11.77	3.25	12.11	2.09	7.79	1.95	0.20
12/01/94-ae-2[d]	431	7.97	11.13	2.81	11.48	1.81	7.39		
12/01/94-ak-1	431	18.78	0.33	13.63	2.87	8.77	1.85	7.68	1.54
12/01/94-ak-2	431	15.40	0.66	10.25	2.92	6.59	1.88		
12/01/94-am-1	431	16.48	0.11	11.32	2.85	7.28	1.83	10.85	5.05
12/01/94-am-2	431	27.57	1.63	22.42	3.28	14.42	2.11		
12/19/94-ab-1	1012	128.33	1.21	123.17	3.10	33.73	0.85	28.32	7.65
12/19/94-ab-2	1012	88.83	0.27	83.68	2.86	22.91	0.78		
12/19/94-ad-1	1012	53.69	0.58	48.54	2.91	13.29	0.80	10.39	4.10
12/19/94-ad-2	1012	32.52	0.43	27.37	2.88	7.49	0.79		
12/19/94-ae-1	1012	49.57	0.76	44.42	2.95	12.16	0.81	12.55	0.55
12/19/94-ae-2	1012	52.42	1.25	47.26	3.11	12.94	0.85		
12/19/94-ak-1	1012	26.16	0.51	21.01	2.90	5.75	0.79	9.26	4.96
12/19/94-ak-2	1012	51.80	0.04	46.64	2.85	12.77	0.78		
12/19/94-am-1	1012	25.16	0.15	20.01	2.85	5.48	0.78	6.22	1.04
12/19/94-am-2	1012	30.55	0.11	25.40	2.85	6.95	0.78		
01/30/95-ab-1	694	143.60	0.62	138.44	2.92	55.29	1.17	51.86	4.86
01/30/95-ab-2	694	126.39	1.35	121.24	3.16	48.42	1.26		
01/30/95-ad-1	694	74.07	0.58	68.92	2.91	27.52	1.16	28.53	1.42
01/30/95-ad-2	694	79.09	0.77	73.94	2.95	29.53	1.18		
01/30/95-ae-1	694	129.44	0.24	124.29	2.86	49.64	1. 4	43.93	8.07
01/30/95-ae-2	694	100.86	0.69	95.71	2.93	38.22	1.17		
01/30/95-ak-1	694	86.46	1.64	81.31	3.29	32.47	1.31	32.81	0.48
01/30/95-ak-2	694	88.15	0.19	83.00	2.86	33.15	1.14		

Table B.7. SO_4 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[e]
01/30/95-am-1	694	58.65	0.67	53.50	2.93	21.37	1.17	22.71	1.90
01/30/95-am-2	694	65.38	0.77	60.23	2.95	24.05	1.18		
02/28/95-ab-1	673	112.55	1.29	107.40	3.13	44.23	1.29	43.23	1.42
02/28/95-ab-2	673	107.67	3.60	102.52	4.59	42.22	1.89		
02/28/95-ad-1	673	58.48	1.22	53.33	3.10	21.96	1.28	20.95	1.43
02/28/95-ad-2	673	53.56	3.14	48.41	4.24	19.94	1.75		
02/28/95-ae-1	673	60.22	0.11	55.07	2.85	22.68	1.17	22.08	0.84
02/28/95-ae-2	673	57.32	2.44	52.17	3.75	21.49	1.55		
02/28/95-ak-1	673	46.34	0.10	41.18	2.85	16.96	1.17	18.46	2.12
02/28/95-ak-2	673	53.63	1.01	48.48	3.02	19.96	1.25		
02/28/95-am-1	673	41 .92	1.13	36.77	3.07	15.14	1.26	12.01	4.44
02/28/95-am-2	673	26.69	0.56	21.54	2.90	8.87	1.20		
03/28/95-ab-1	840	103.55	1.61	98.39	3.27	32.47	1.08	42.14	13.68
03/28/95-ab-2	840	162.17	1.68	157.02	3.31	51.81	1.09		
03/28/95-ad-1	840	97.27	0.24	92.12	2.86	30.40	0.94	32.39	2.82
03/28/95-ad-2	840	109.35	0.68	104.20	2.93	34.38	0.97		
03/28/95-ae-1	840	119.21	0.57	114.06	2.91	37.64	0.96	36.18	2.06
03/28/95-ae-2	840	110.40	1.59	105.25	3.27	34.73	1.08		
03/28/95-ak-1	840	114.30	0.18	109.15	2.86	36.01	0.94	30.61	7.65
03/28/95-ak-2	840	81.52	0.49	76.37	2.89	25.20	0.95		
03/28/95-am-1	840	91.33	4.63	86.18	5.44	28.44	1 .79	28.08	0.51
03/28/95-am-2	840	89.17	5.17	84.01	5.91	27.72	1.95		
05/02/95-ab-1	914	132.90	0.29	127.75	2.86	38.76	0.87	51.70	18.30
05/02/95-ab-2	914	218.18	8.48	213.03	8.94	64.64	2.71		
05/02/95-ad-1	914	65.30	2.65	60.14	3.89	18.25	1.18	15.95	3.26
05/02/95-ad-2	914	50.11	1.32	44.96	3.14	13.64	0.95		

Table B.7. SO_4 deposition fluxes to greased Teflon sheets

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[e]
05/02/95-ae-1	914	80.42	4.89	75.27	5.66	22.84	1.72	23.76	1.30
05/02/95-ae-2	914	86.47	0.89	81.32	2.99	24.67	0.91		
05/02/95-ak-1	914	96.80	0.26	91.64	2.86	27.81	0.87	31.59	5.34
05/02/95-ak-2	914	121.71	0.78	116.56	2.96	35.37	0.90		
05/02/95-am-1	914	117.73	0.64	112.58	2.92	34.16	0.89	33.08	1.53
05/02/95-am-2	914	110.61	2.24	105.46	3.62	32.00	1.10		
06/09/95-ab-1	643	204.99	3.89	199.84	4.83	86.14	2.08	63.42	32.13
06/09/95-ab-2	643	99.57	1.78	94.42	3.36	40.70	1.45		
06/09/95-ad-1	643	24.61	0.58	19.46	2.91	8.39	1.25	7.81	0.82
06/09/95-ad-2	643	21.93	0.82	16.78	2.97	7.23	1.28		
06/09/95-ae-1	643	29.23	1.21	24.08	3.10	10.38	1.34	13.02	3.73
06/09/95-ae-2	643	41.47	0.30	36.31	2.87	15.65	1.24		
06/09/95-ak-1	643	42.40	3.02	37.25	4.15	16.06	1.79	13.59	3.48
06/09/95-ak-2	643	30.97	0.46	25.82	2.89	11.13	1.24		
06/09/95-am-1	643	21.77	1.80	16.62	3.37	7.16	1.45	7.26	0.13
06/09/95-am-2	643	22.20	1.09	17.05	3.05	7.35	1.32		

[a] Average % standard deviation from IC replication is 6.7%.

[b] The subtracted blank mass was 5.15 ± 2.85 ug.

[c] An IC replicate was not performed for this sample.

[d] The net contaminant mass was less than 1.64 times the net contaminant mass standard deviation.

[e] The average % standard deviation from adjacent samples is 20.2%.

Table B.8. SO2 deposition fluxes to Whatman filters

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[e]
06/30/94-ab-3	503.5	5885.2	335.0	5845.0	337.1	2146	124	2133	19
06/30/94-ab-4	503.5	5812.6	509.4	5772.3	510.8	2119	188		
06/30/94-ak-4	503.5	4765.3	150.0	4725.1	154.6	1735	57	1735	63
06/30/94-am-3	503.5	4406.3	264.9	4366.0	267.6	1603	98	1588	22
06/30/94-am-4	503.5	4322.7	277.1	4282.4	279.7	1572	103		
07/21/94-ab-3	356.5	4433.4	319.5	4393.1	321.7	2278	167	2191	123
07/21/94-ab-4	356.5	4096.8	60.3	4056.5	71.1	2104	37		
07/21/94-ad-3	356.5	3800.8	2.0	3760.6	37.6	1950	20	2156	291
07/21/94-ad-4	356.5	4595.3	5.7	4555.1	38.0	2362	20		
07/21/94-ae-3	356.5	4375.1	286.1	4334.9	288.6	22i18	150	2304	79
07/21/94-ae-4	356.5	4591.3	252.7	4551.0	255.5	2360	132		
07/21/94-ak-3	356.5	4051.2	217.6	4011.0	220.9	2080	115	2021	84
07/21/94-ak-4	356.5	3821.8	93.7	378 6	101.0	1961	52		
07/21/94-am-3	356.5	3748.6	61.9	3708.4	72.5	1923	38	1869	76
07/21/94-am-4	356.5	3540.6	61.1	3500.3	71.8	1815	37		
08/05/94-ab-3	316.5	3070.8	151.6	3030.6	156.2	1770	91	1757	18
08/05/94-ab-4	316.5	3027.3	46.1	2987.1	59.4	1745	35		
08/05/94-ad-3	316.5	2680.4	68.9	2640.1	78.5	1542	46	1451	129
08/05/94-ad-4	316.5	2367.7	120.6	2327.4	126.4	1359	74		
08/05/94-ae-3	316.5	2523.0	121.9	2482.8	127.5	1450	74	1564	160
08/05/94-ae-4	316.5	2911.2	2.4	2870.9	37.7	1677	22	.	
08/05/94-ak-3	316.5	2635.1	88.0	2594.9	95.7	1516	56	1544	40
08/05/94-ak-4	316.5	2733.1	197.3	2692.8	200.8	1573	117		
08/05/94-am-3	316.5	2244.9	56.2	2204.7	67.6	1288	40	1202	121
08/05/94-am-4	316.5	1951.0	118.2	1910.7	124.0	1116	72		
08/18/94-ab-3	525.0	4569.7	95.8	4529.4	102.9	1595	36	1572	32

Table B.8. SO2 deposition fluxes to Whatman filters

Sample	Time (hr)	SO$_4$ mass (ug)	SO$_4$ mass std dev. (ug)[a]	Net SO$_4$ mass (ug)[b]	Net SO$_4$ mass std dev. (ug)	SO$_4$ flux (ng/cm^2/day)	SO$_4$ flux std dev. (ng/cm^2/day)	ave SO$_4$ flux (ng/cm^2/day)	ave SO$_4$ flux std dev. (ng/cm^2/day)[d]
08/18/94-ab-4	525.0	4441.4	216.8	4401.2	220.1	1550	77		
08/18/94-ad-3	525.0	4183.8	201.3	4143.5	204.8	1459	72	1455	6
08/18/94-ad -4	525.0	4159.9	74.6	4119.6	83.5	1451	29		
08/18/94-ae-3	525.0	4321.5	241.3	4281.3	244.2	1508	86	1511	4
08/18/94-ae-4	525.0	4338.8	234.7	4298.6	237.7	1514	84		
08/18/94-ak-3	525.0	4171.1	323.6	4130.9	325.8	1455	115	1429	36
08/18/94-ak-4	525.0	4024.7	214.4	3984.5	217.6	1403	77		
08/18/94-am-3	525.0	3852.4	215.2	3812.1	218.4	1342	77	1328	21
08/18/94-am-4	525.0	3768.0	24.0	3727.7	44.6	1313	16		
09/09/94-ab-3	741.0	6491.0	303.2	6450.7	305.5	1609	76	1607	3
09/09/94-ab-4	741	6471.7	274.3	6431.4	276.8	1605	69		
09/09/94-ad-3	741.0	6162.7	222.1	6122.5	225.3	1527	56	1544	23
09/09/94-ad-4	741.0	6294.4	282.8	6254.2	285.3	1560	71		
09/09/94-ae-4	741.0	5915.2	43.2	5874.9	57.3	1466	14	1466	53
09/09/94-ak-3	741.0	6076.6	312.2	6036.3	314.4	1506	78	1457	69
09/09/94-ak-4	741.0	5683.5	405.1	5643.2	406.8	1408	102		
09/09/94-am-4	741.0	5369.4	35.9	5329.1	52.0	1330	13	1330	48
12/01/94-ab-3	431.0	5635.1	388.8	5594.8	390.6	2400	168	2258	201
12/01/94-ab-4	431.0	4971.7	81.5	4931.4	89.8	2115	39		
12/01/94-ad-3	431.0	4720.4	546.1	4680.1	547.4	2007	235	2009	2
12/01/94-ad-4[c]	431.0	4726.2	176.0	4685.9	180.0	2010	77		
12/01 /94-ae-3	431 0	4927.3	339.9	4887.0	342.0	2096	147	2103	10
12101/94-ae-4	431.0	4960.2	70.1	4919.9	79.5	2110	34		
12/01/94-ak-3	431.0	4567.1	50.5	4526.8	63.0	1942	27	1939	4
12101/94-ak-4	431.0	4553.8	147.5	4513.6	152.2	1936	65		
12/01/94-am-3	431.0	4471.4	300.0	4431.1	302.3	1901	130	1861	56

Table B.8. SO2 deposition fluxes to Whatman filters

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[d]
12/01/94-am-4	431.0	4285.2	44.8	4245.0	58.5	1821	25		
12/19/94-ab-3	1012.3	11481.1	456.5	11440.8	458.0	2089	84	2021	97
12/19/94-ab-4	1012.3	10733.6	100.3	10693.3	107.1	1953	20		
12/19/94-ad-3	1012.3	9764.7	308.1	9724.4	310.4	1776	57	1822	65
12/19/94-ad-4	1012.3	10265.0	317.9	10224.7	320.1	1867	58		
12/19/94-ae-3	1012.3	10985.4	586.9	10945.2	588.1	1999	107	2014	21
12/19/94-ae-4	1012.3	11150.8	444.2	11110.6	445.8	2029	81		
12/19/94-ak-3	1012.3	9452.3	114.1	9412.0	120.1	1719	22	1838	168
12/19/94-ak-4	1012.3	10755.5	82.3	10715.2	90.5	1957	17		
12/19/94-am-3	1012.3	10673.0	432.0	10632.8	433.6	1942	79	1869	104
12/19/94-am-4	1012.3	9871.3	69.3	9831.1	78.8	1795	14		
01/30/95-ab-3	694.0	7495.6	232.3	7455.3	235.3	1986	63	2092	149
01/30/95-ab-4	694.0	8288.6	114.9	8248.4	120.9	2197	32		
01/30/95-ad-3	694.0	7812.6	338.3	7772.3	340.3	2070	91	2015	79
01/30/95-ad-4	694.0	7394.7	275.5	7354.4	278.1	1959	74		
01/30/95-ae-3	694.0	8335.3	115.7	8295.1	121.7	2210	32	2091	168
01/30/95-ae-4	694.0	7442.0	242.9	7401.7	245.8	1972	65		
01/30/95-ak-3	694.0	7488.1	247.8	7447.8	250.6	1984	67	1745	339
01/30/95-ak-4	694.0	5691.0	200.5	5650.7	204.0	1505	54		
01/30/95-am-3	694.0	7952.0	406.7	7911.8	408.5	2108	109	2095	18
01/30/95-am-4	694.0	7858.1	355.4	7817.8	357.4	2083	95		
02/28/95-ab-3	673.0	5769.4	301.6	5729.1	303.9	1574	83	1566	11
02/28/95-ab-4	673.0	5711.7	122.3	5671.5	127.9	1558	35		
02/28/95-ad-4	673.0	5579.2	130.4	5538.9	135.7	1522	37	1522	55
02/28/95-ae-3	673.0	5602.2	130.4	5562.0	135.7	1528	37	1544	24
02/28/95-ae-4	673.0	5723.3	138.6	5683.0	143.6	1561	39		

Table B.8. SO2 deposition fluxes to Whatman filters

Sample	Time (hr)	SO_4 mass (ug)	SO_4 mass std dev. (ug)[a]	Net SO_4 mass (ug)[b]	Net SO_4 mass std dev. (ug)	SO_4 flux (ng/cm^2/day)	SO_4 flux std dev. (ng/cm^2/day)	ave SO_4 flux (ng/cm^2/day)	ave SO_4 flux std dev. (ng/cm^2/day)[d]
02/28/95-ak-3	673.0	4897.3	84.0	4857.1	92.0	1334	25	1318	23
02/28/95-ak-4	673.0	4778.0	138.6	4737.8	143.6	1301	39		
02/28/95-am-3	673.0	4703.1	179.3	4662.8	183.2	1281	50	1283	3
02/28/95-am-4	673.0	4720.4	122.3	4680.1	127.9	1286	35		
03/28/95-ab-3	840	6324.3	247.1	6284.0	250.0	1383	55	1343	57
03/28/95-ab-4	840	5958.9	221.8	5918.7	225.0	1303	50		
03/28/95-ad-3	840	5706.4	211.7	5666.1	215.0	1247	47	1252	7
03/28/95-ad-4	840	5752.1	203.4	5711.9	206.8	1257	46		
03/28/95-ae-3	840	5892.4	215.2	5852.1	218.4	1288	48	1288	47
03/28/95-ak-3	840	5307.5	159.8	5267.3	164.2	1159	36	1161	2
03/28/95-ak-4	840	5320.8	176.4	5280.6	180.3	1162	40		
03/28/95-am-3	840	5062.4	171.7	5022.1	175.7	1105	39	1095	15
03/28/95-am-4	840	4964.5	39.9	4924.3	144.8	1084	32		
05/02/95-ab-3	913.5	5455.8	108.9	5415.6	115.2	1096	23	1148	73
05/02/95-ab-4	913.5	5968.7	182.3	5928.4	186.1	1200	38		
05/02/95-ad-3	913.5	5573.9	173.3	5533.6	177.3	1120	36	1131	15
05/02/95-ad-4	913.5	5679.4	179.7	5639.1	183.6	1141	37		
05/02/95-ae-3	913.5	5622.0	84.0	5581.7	92.1	1130	19	1142	17
05/02/95-ae-4	913.5	5742.2	197.7	5701.9	201.3	1154	41		
05/02/95-ak-3	913.5	5238.6	163.4	5198.3	167.7	1052	34	1029	32
05/02/95-ak-4	913.5	5015.1	129.2	4974.8	134.6	1007	27		
05/02/95-am-3	913.5	4820.7	139.1	4780.4	144.0	967	29	962	8
05/02/95-am-4	913.5	4763.3	118.4	4723.0	124.2	956	25		
06/09/95-ab-3	643	3506.1	143.3	3465.9	148.1	996	43	1033	51
06/09/95-ab-4	643	3757.2	157.2	3717.0	161.7	1069	46		
06/09/95-ad-3	643	3541.2	135.0	3500.9	140.1	1007	40	1007	1

Table B.8. SO2 deposition fluxes to Whatman filters

Sample	Time (hr)	SO$_4$ mass (ug)	SO$_4$ mass std dev. (ug)[a]	Net SO$_4$ mass (ug)[b]	Net SO$_4$ mass std dev. (ug)	SO$_4$ flux (ng/cm^2/day)	SO$_4$ flux std dev. (ng/cm^2/day)	ave SO$_4$ flux (ng/cm^2/day)	ave SO$_4$ flux std dev. (ng/cm^2/day)[d]
06/09/95-ad-4	643	3546.7	132.0	3506.5	137.2	1008	39		
06/09/95-ae-3	643	3577.8	123.7	3537.5	129.2	1017	37	1026	12
06/09/95-ae-4	643	3637.6	121.5	3597.3	127.2	1034	37		
06/09/95-ak-3	643	3155.0	77.1	3114.7	85.8	896	25	881	21
06/09/95-ak-4	643	3051.9	107.9	3011.7	114.3	866	33		
06/09/95-am-3	643	3431.0	134.6	3390.8	139.7	975	40	952	33
06/09/95-am-4	643	3268.8	81 .2	3228.5	89.5	928	26		

a Average % standard deviation from IC replication is 3.6%.
b The subtracted blank mass was 40.3 ± 37.6 ug.
c An IC replicate was not performed for this sample.
d The average % standard deviation from adjacent samples is 3.6%.

Appendix C

Computer Analysis of Architectural Features on the Cathedral of Learning:

CROSSES

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INTRODUCTION

For the past several years there has been an increasing interest in the study of the deterioration of limestone monuments and buildings. One part of this study is the assessment of the patterns of visible damage that occur on these structures. This project focuses on documenting the soiling of repeated architectural features on the Cathedral of Learning. The repeated features, in this case, are stone carvings in the shape of a large “X”, which will be referred to as crosses. One of the working hypotheses is that the deposition of carbon particles causes a black discoloration on the surface of the building. The goal of this project is to determine the percent-area soiled of each of the crosses on the different faces of the building.

PROBLEM DEFINITION

In order to calculate the percentage soiled on the different faces of the building, sketches of the crosses were obtained. These sketches were shaded in the regions corresponding to the soiled areas on each cross. After the sketches were completed, the images were scanned into a computer. A computer program which calculates the percent-area soiled had already been developed for quatrefoils (See Appendix F of of previous years Progress Report, Lutz et al. 1994). This program was adapted for use with the crosses.

SKETCHING AND SCANNING

The procedures used here were similar to those used for the quatrefoils. Blueprints for the design of the crosses were obtained from Facilities Management at the University of Pittsburgh. These blueprints were then photocopied onto letter sized paper.

In representing the positions of the crosses on the building, a plan view of each face of the building is used. Each cross is labeled on the plan view. The label for each cross contains four fields: the reference number, the building face number, the column location, and the elevation. The reference number (1-226) is used for bookkeeping purposes. The building face number represents the side of the building on which the cross is located: 1 is for Forbes Aye, 2 is for Bellefield, 3 is for Fifth Aye, and 4 is for Bigelow. The third field represents the horizontal position on the plan view. Finally, the fourth field designates the elevation. The labels for the crosses are given in Figure C-l.

In order to sketch the soiling patterns, black charcoal pencils were used to shade in the templates of the crosses. To prepare the sketches for scanning, a black marker was used to darken the areas shaded with the charcoal pencil. For lower elevations, the soiling on the crosses was clearly visible. However, for the crosses at higher elevations, it was necessary to use a spotting scope. With the help of the spotting scope, the crosses at higher elevations were sketched with ease.

Once the sketches were completed, they were scanned into a computer. The sketches were scanned by using Silverscan on a Macintosh IIci with the aid of Silverscan software. The resolution was set to 360 dots per inch. The image size was changed to insure that all crosses were the same length, 720 pixels. Since the crosses were not all geometrically similar, the width varies. The crosses were saved as Macpaint bitmap files. The scanned images for the 226 crosses are shown in Figure C-2.

DATA ANALYSIS

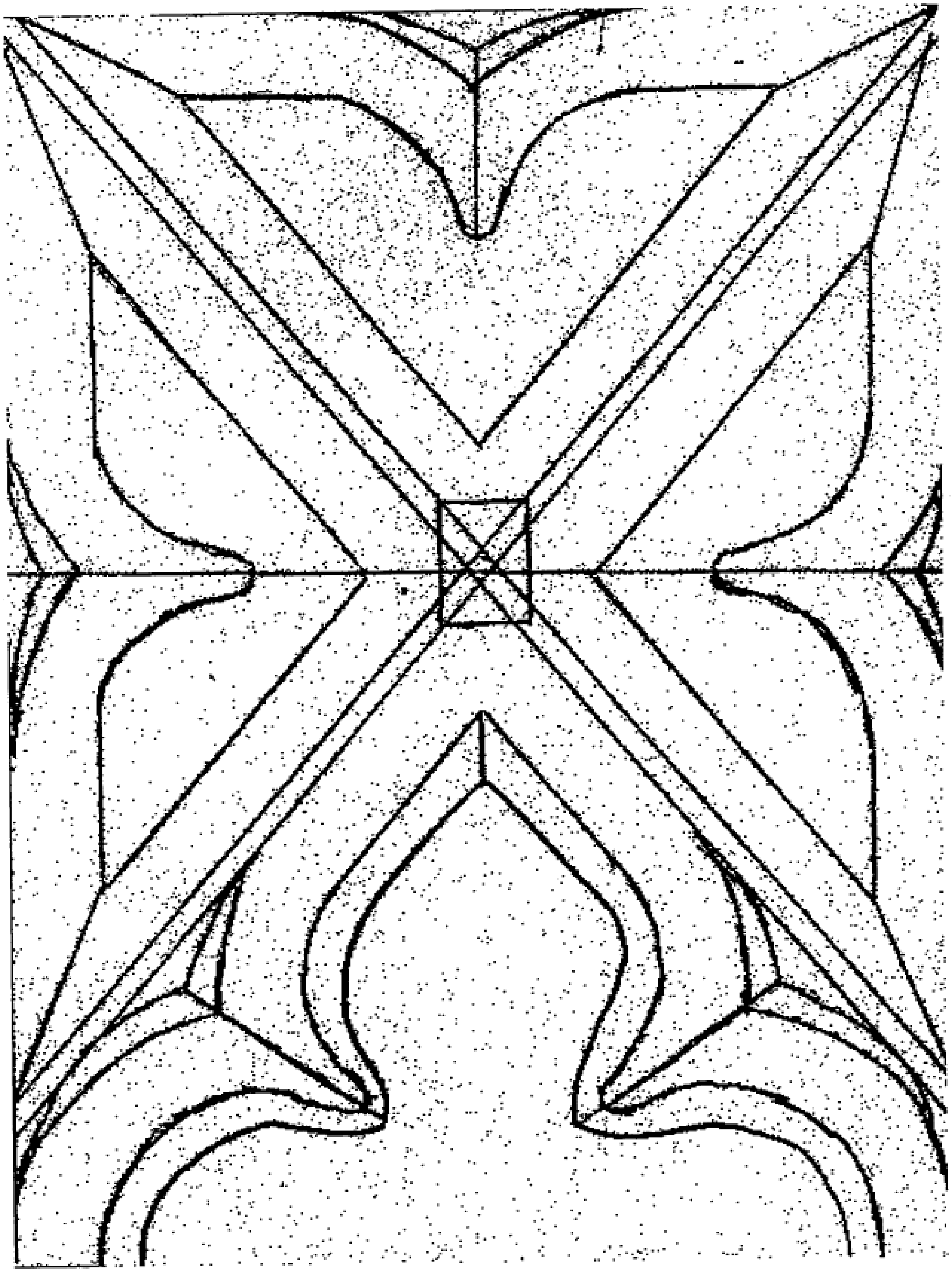
Once the scanning was completed, the computer program was used to find the percent area soiled of each cross. The heights and widths of the crosses were used to determine the area of each individual cross. This information was used to find the average area of all the crosses. This average area was used in the program (refer to Appendix F in the 1994 report). Because the lines on the blank templates were black, the computer program evaluated them as soiling marks. In order to correct for the blank template, the following formula was used:

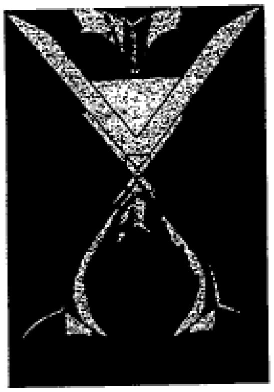
$$CF = [(l00-S\%)/l00]*T\%$$

where
CF = Correction Factor
S = Percent Soiled
T = Percent Black of the blank Template

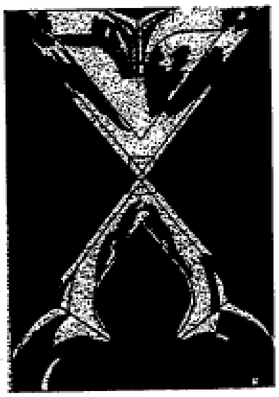
In order to determine the distribution of soiled crosses, a scatter plot was created for each face of the building (Figure C-3). From these plots, it was noted that the percent area soiled on the Forbes side and the Bellefield side crosses was uniform with elevation. However the percent area soiled on the Fifth and Bigelow side crosses decreased with elevation. The percent area soiled for each cross, as well as values of CF, are listed in Table C-1. The values are plotted in Figure C-3.

Blank Template

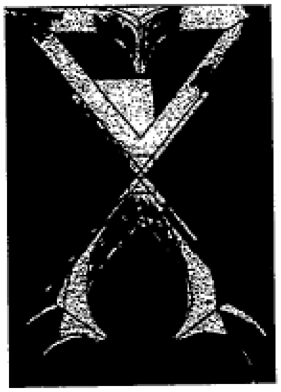




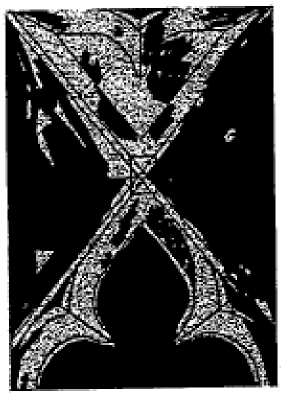
25-1-f-6



26-1-g-6



27-1-h-6



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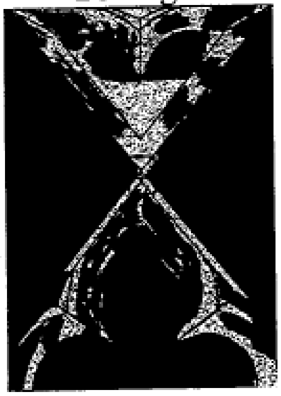

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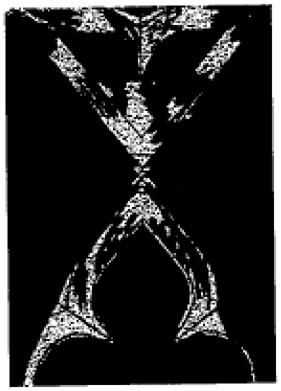

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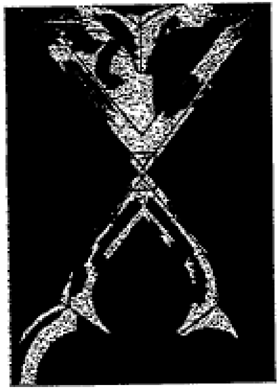

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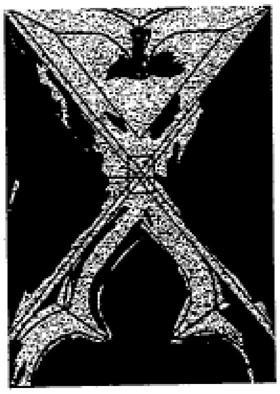

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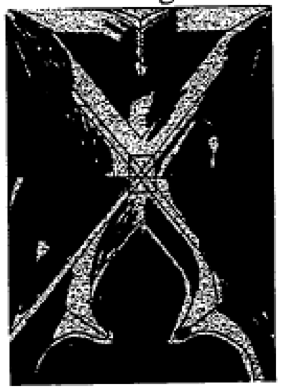

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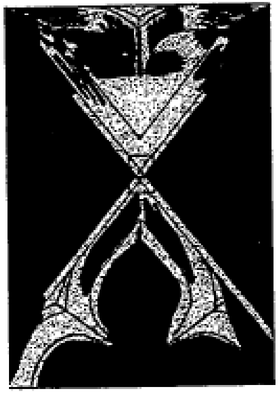

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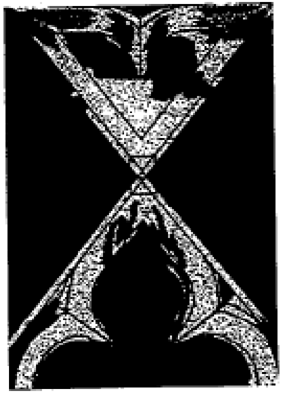

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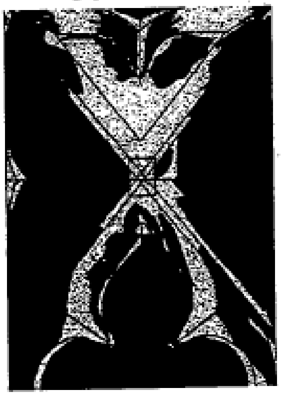
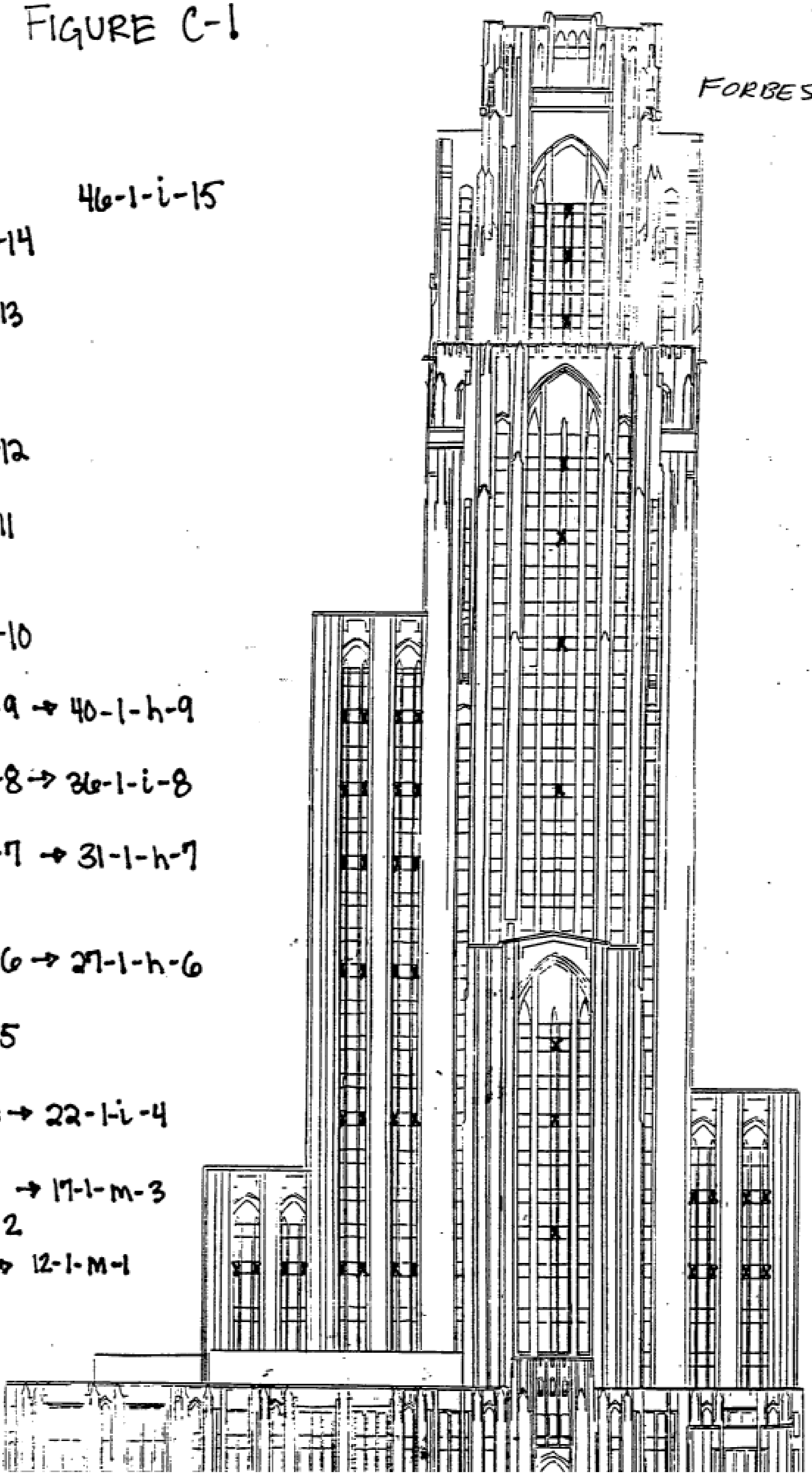
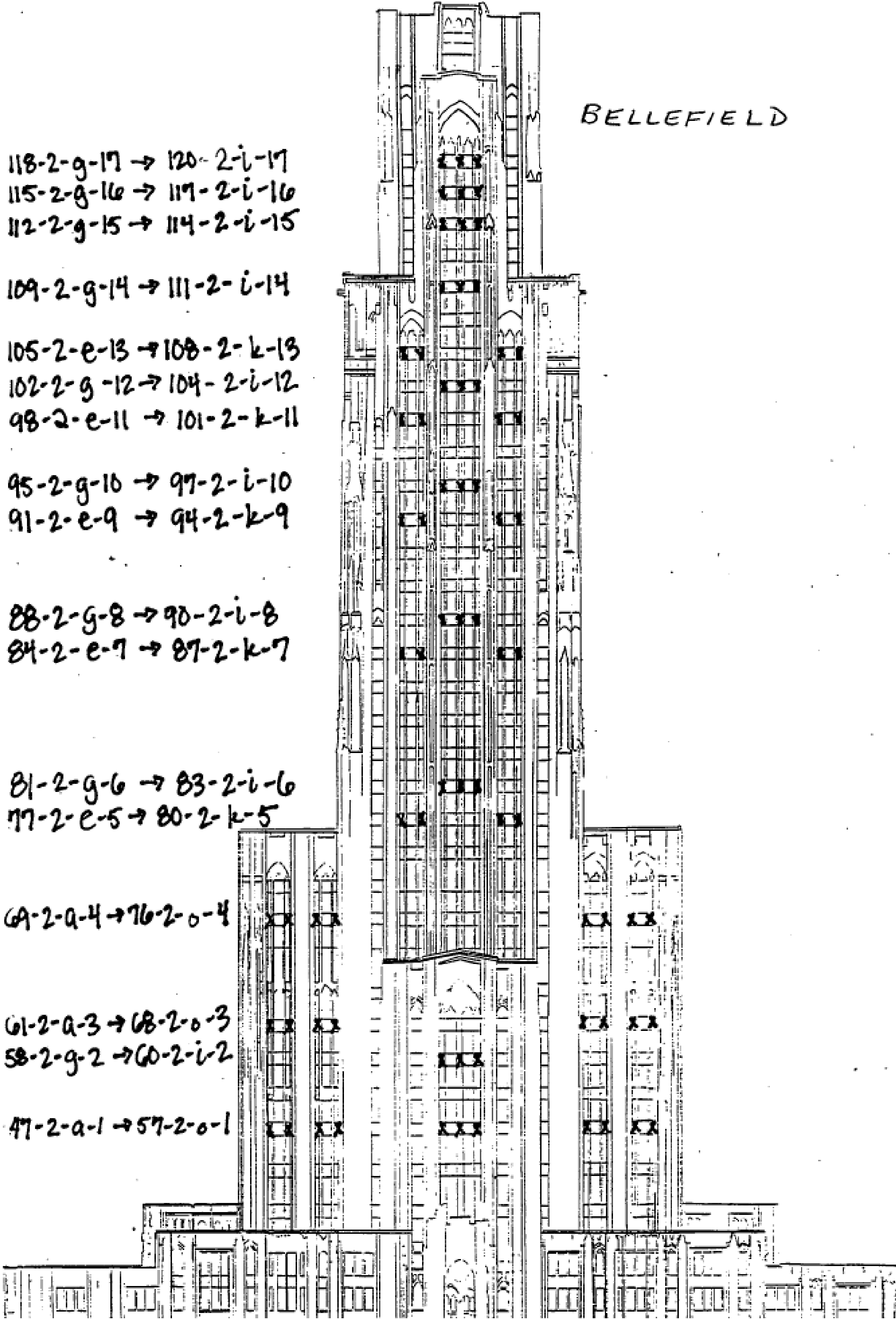


36-1-i-8

FIGURE C-1

37TH	46-1-i-15
36TH	45-1-i-14
34TH	44-1-i-13
30TH	43-1-i-12
28TH	42-1-i-11
25TH	41-1-i-10
23RD	37-1-e-9 → 40-1-h-9
21ST	32-1-e-8 → 36-1-i-8
19TH	28-1-e-7 → 31-1-h-7
16TH	24-1-e-6 → 27-1-h-6
14TH	23-1-i-5
12TH	18-1-e-4 → 22-1-i-4
10TH	14-1-j-3 → 17-1-m-3
9TH	13-1-i-2
8TH	1-1-a-1 → 12-1-M-1





37TH 118-2-g-17 → 120-2-i-17
36TH 115-2-g-16 → 117-2-i-16
35TH 112-2-g-15 → 114-2-i-15

33RD 109-2-g-14 → 111-2-i-14

31ST 105-2-e-13 → 108-2-k-13
30TH 102-2-g-12 → 104-2-i-12
29TH 98-2-e-11 → 101-2-k-11

27TH 95-2-g-10 → 97-2-i-10
26TH 91-2-e-9 → 94-2-k-9

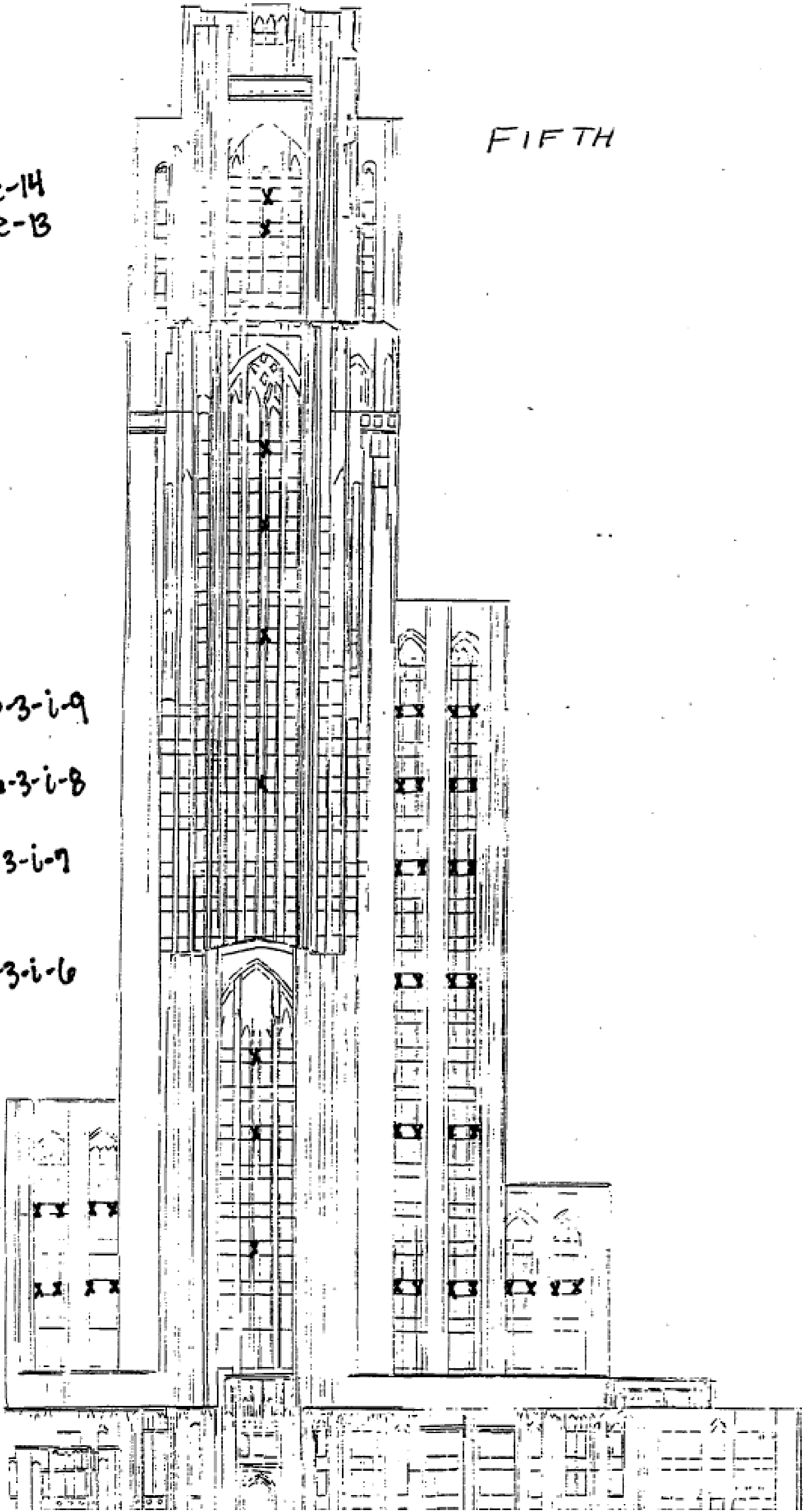
23RD 88-2-g-8 → 90-2-i-8
22ND 84-2-e-7 → 87-2-k-7

18TH 81-2-g-6 → 83-2-i-6
17TH 77-2-e-5 → 80-2-k-5

14TH 69-2-a-4 → 76-2-o-4

12TH 61-2-a-3 → 68-2-o-3
11TH 58-2-g-2 → 60-2-i-2

9TH 47-2-a-1 → 57-2-o-1



37 165-3-e-14
36 164-3-e-13

30 163-3-e-12

28 162-3-e-11

25 161-3-e-10

23 157-3-f-9 → 160-3-i-9

21 152-3-e-8 → 156-3-i-8

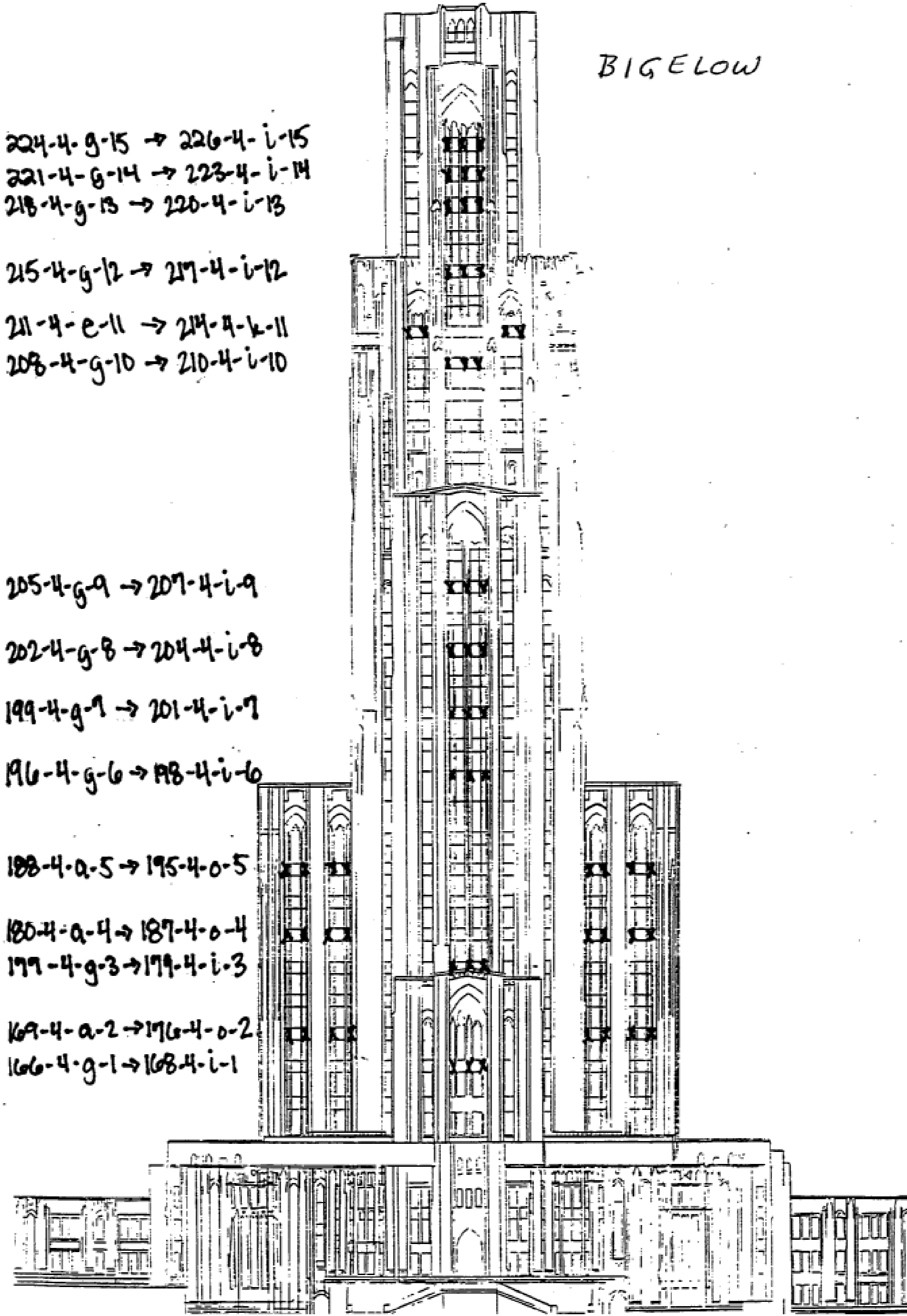
19 148-3-f-7 → 151-3-i-7

16 144-3-f-6 → 147-3-i-6

14 143-3-e-5

12 138-3-e-4 → 142-3-i-4

10 134-3-a-3 → 157-3-[illegible]-3
9 133-3-e-2
8 121-3-a-1 → 132-3-m-1



37 224-4-g-15 → 226-4-i-15
36 221-4-g-14 → 223-4-i-14
35 218-4-g-13 → 220-4-i-13

33 215-4-g-12 → 217-4-i-12

31 211-4-e-11 → 214-4-k-11
30 208-4-g-10 → 210-4-i-10

23 205-4-g-9 → 207-4-i-9

21 202-4-g-8 → 204-4-i-8

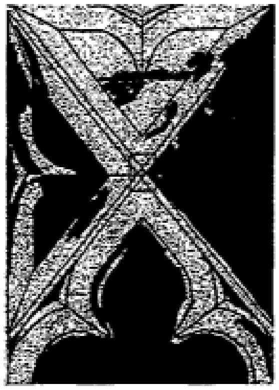
19 199-4-g-7 → 201-4-i-7

17 196-4-g-6 → 198-4-i-6

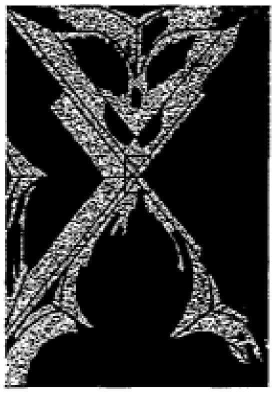
14 188-4-a-5 → 195-4-o-5

12 180-4-a-4 → 187-4-o-4
11 177-4-g-3 → 179-4-i-3

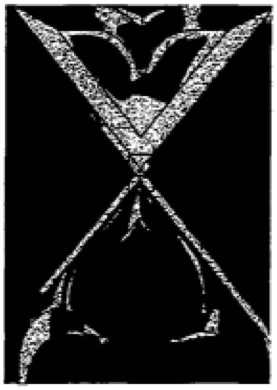
9 169-4-a-2 → 176-4-o-2
8 166-4-g-1 → 168-4-i-1



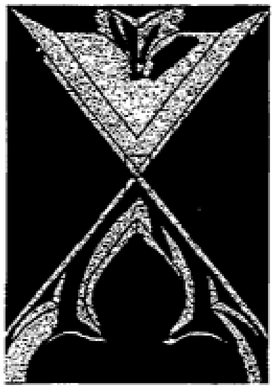
37-1-e-9



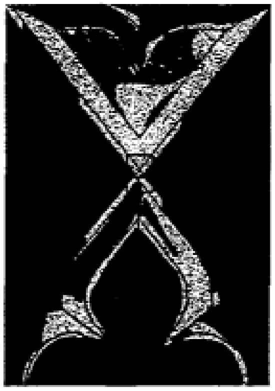
38-1-f-9



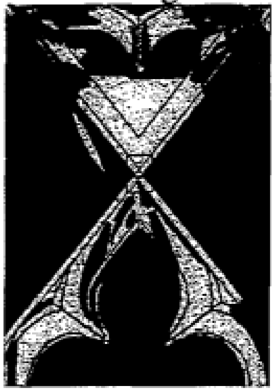
39-1-g-9



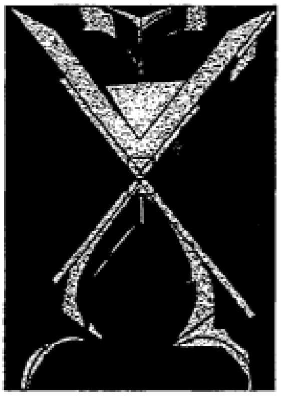
40-1-h-9



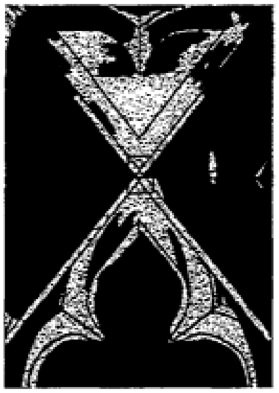
41-1-i-10



42-1-i-11



43-1-i-12



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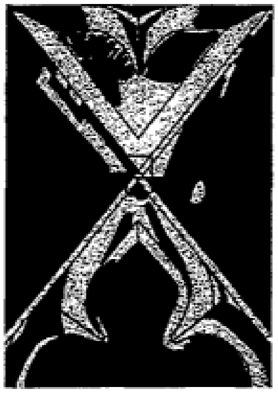

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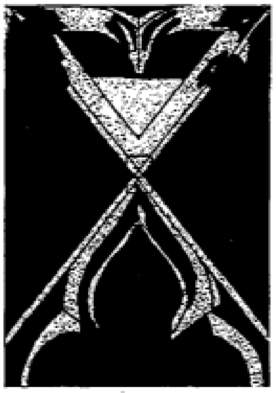

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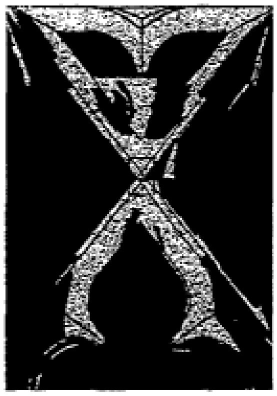
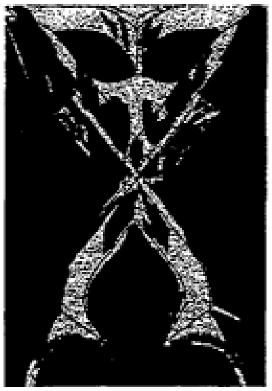
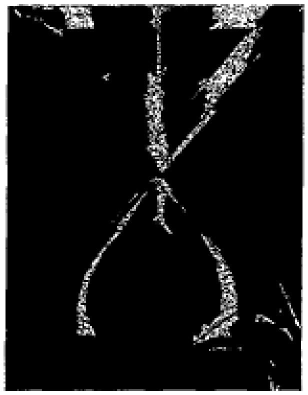


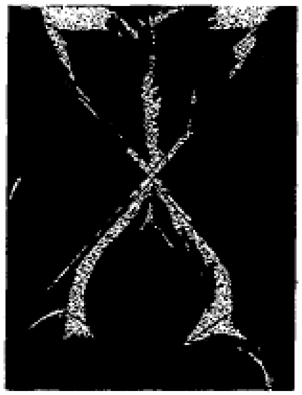
47-2-a-1



48-2-b-1



49-2-c-1



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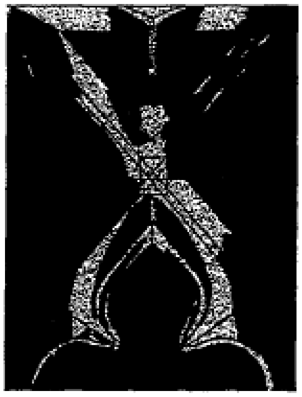
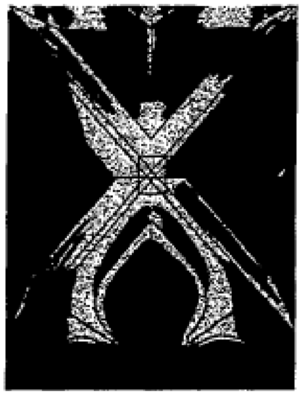


51-2-g-1



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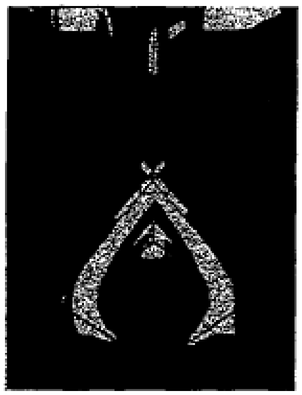

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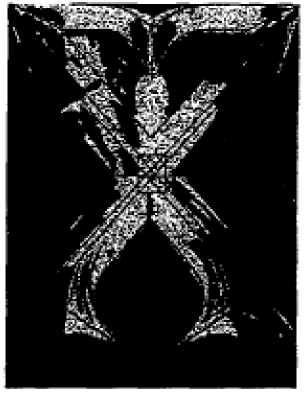

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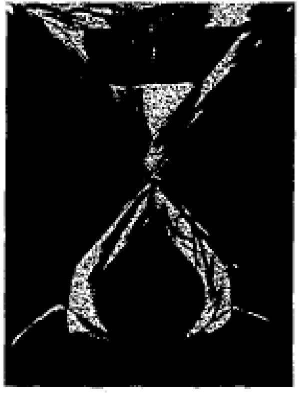

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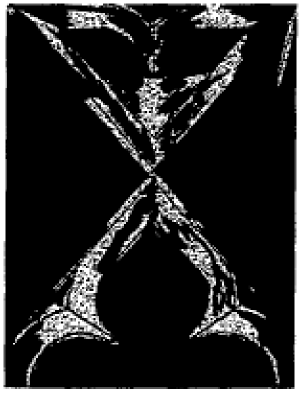

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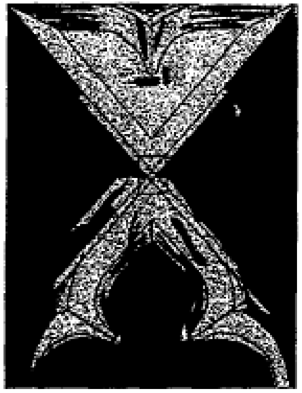

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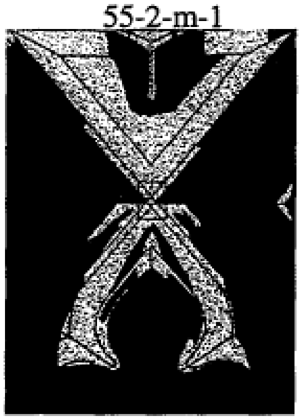

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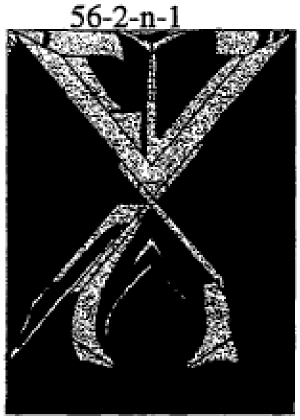

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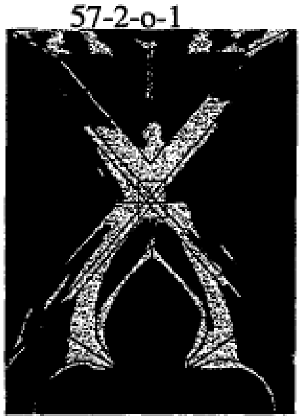

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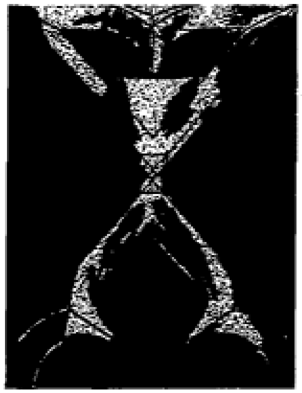
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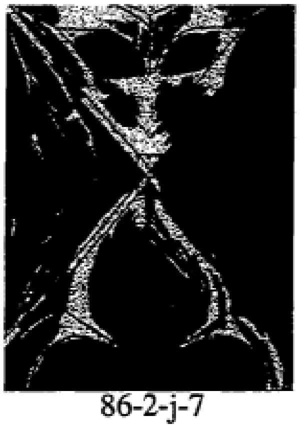
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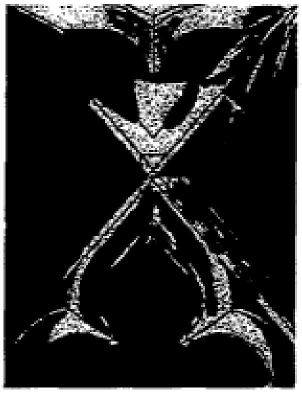
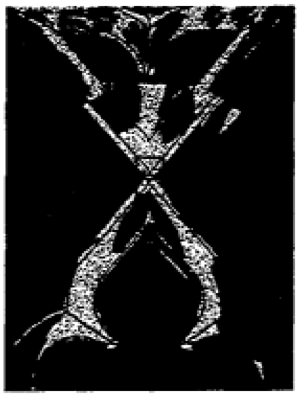

87-2-k-7


88-2-g-8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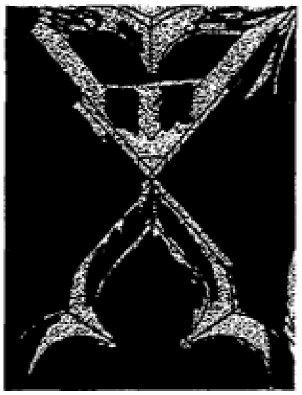
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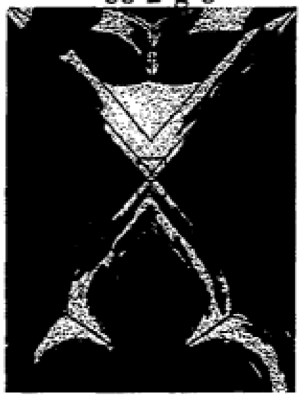
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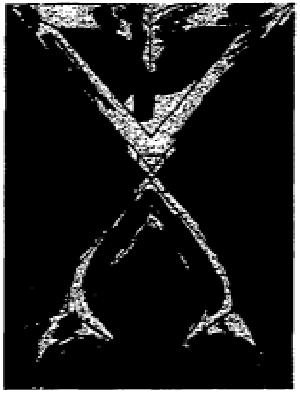
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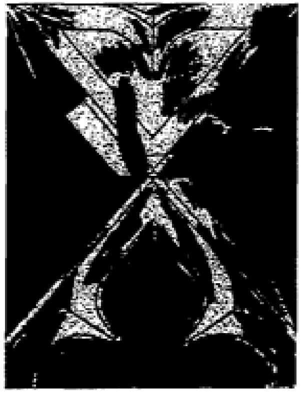
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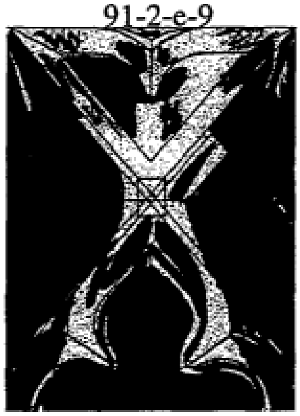
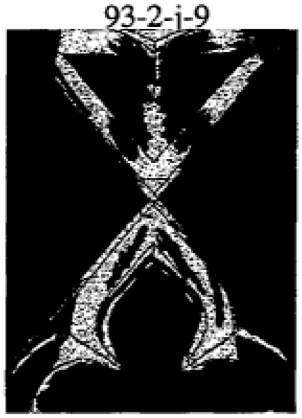

94-2-k-9


95-2-g-10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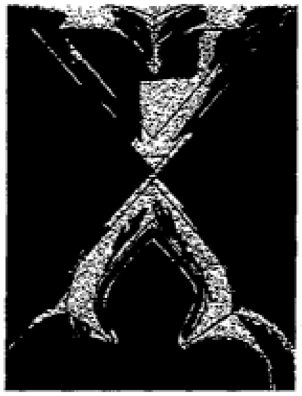
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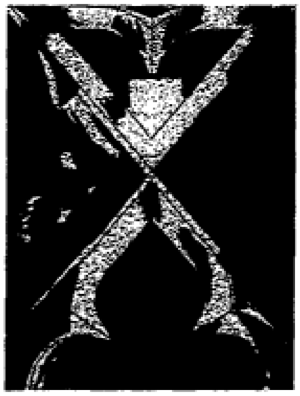
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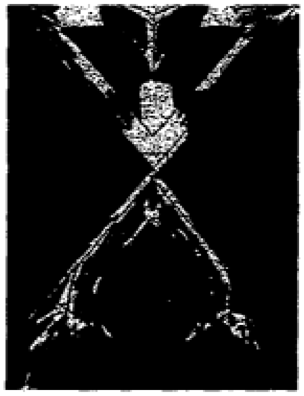
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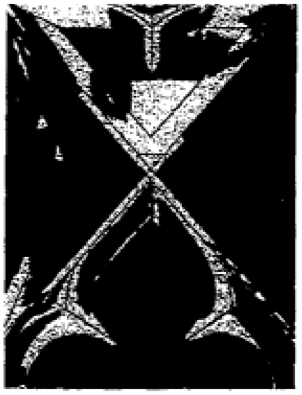
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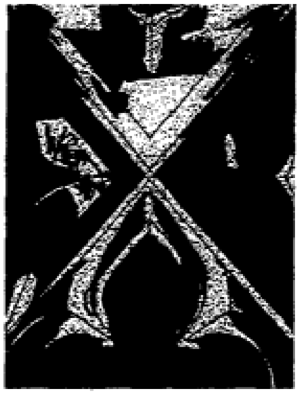
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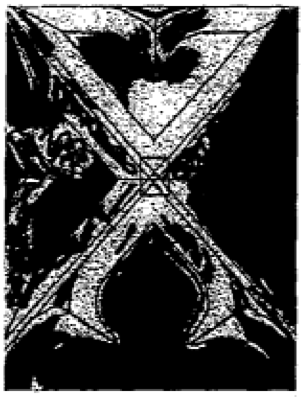
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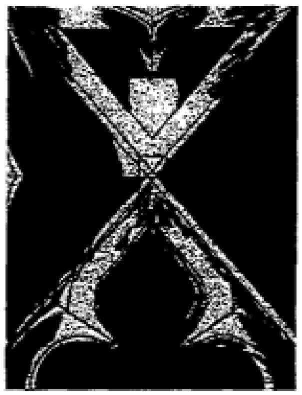
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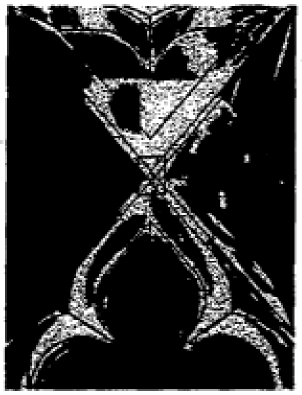
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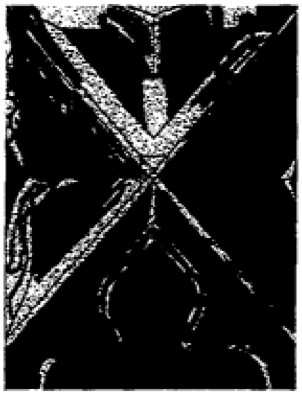
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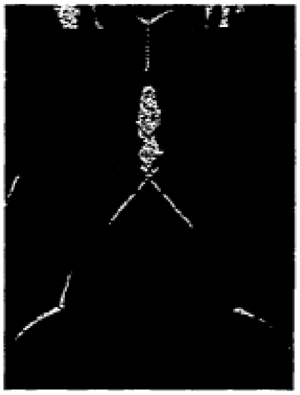
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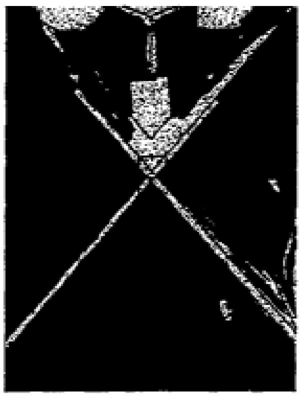
107-2-j-13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