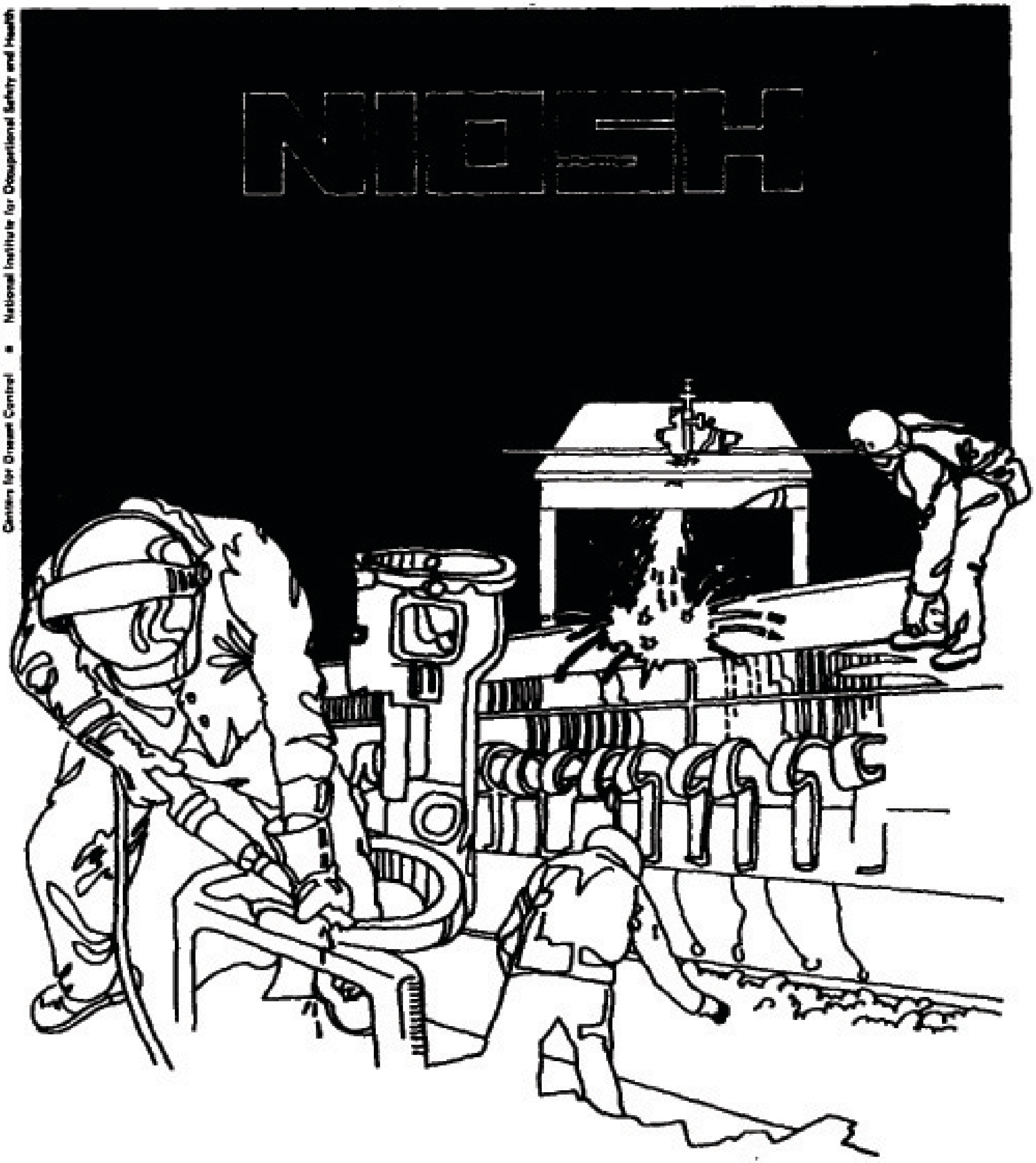
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 88-364-2103 - VOL. II
LIBRARY OF CONGRESS
MADISON BUILDING
WASHINGTON, D.C.

INDOOR AIR QUALITY AND WORK ENVIRONMENT STUDY

Library of Congress
Madison Building

Volume II:

Results of Indoor Air Environmental Monitoring

National Institute for Occupational Safety and Health

U.S. Environmental Protection Agency

John B. Pierce Foundation Laboratory at Yale University

National Institute of Standards and Technology

HETA 88-364-2103
July 1990

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Volume II: Environmental Survey
Library of Congress
Madison Building

TECHNICAL TEAMS

This study of indoor air quality and work environment was conducted by three technical teams representing multiple organizations. It was jointly developed and carried out at the Library of Congress Madison Building and the EPA headquarters under the auspices of these teams working independently of both management and unions at both the Library of Congress and the EPA.

Overall project coordination was provided by two technical team leaders: Lawrence Fine at NIOSH and Kevin Teichman at EPA.

ENVIRONMENTAL MONITORING TEAM

NIOSH

Michael Crandall, Industrial Hygiene Engineer
Richard Gorman, Industrial Hygiene Engineer
Rebecca Stanevich, Industrial Hygienist
Gregory Burr, Industrial Hygienist
Teresa Seitz, Industrial Hygienist
G.E. Burroughs, Industrial Hygienist
Matthew Klein, Mechanical Engineer
Eugene Kennedy, Chemist

John B. Pierce Foundation at Yale University

Brian Leaderer, Environmental Scientist
Oliver John Selfridge, Environmental Scientist

EPA

Ross Highsmith, Chemist
Lance Wallace, Environmental Scientist
Tom Lumpkin, Chemist
Steve Hern, Biologist
Vinson Thompson, Chemist
Ken McLauchlin, Professional Engineer*
Linda Stetzenbach, Microbiologist

NIST

Andrew Persily, Mechanical Engineer

QUESTIONNAIRE SURVEY DESIGN TEAM

NIOSH

Anne Fidler, Epidemiologist
Thomas Wilcox, Physician
Joseph Hurrell, Psychologist
Richard Hornung, Statistician

John B. Pierce Foundation at Yale University

Brian Leaderer, Environmental Scientist
Oliver John Selfridge, Environmental Scientist

EPA

Mel Kollander, Senior Survey Statistician
Lance Wallace, Environmental Scientist
F. Cecil Brenner, Statistician

Westat

Robert Clickner, Senior Statistician
Stephen Dietz, Senior Statistician

REPORTING AND ANALYSIS TEAM, VOLUME II

NIOSH

Michael Crandall, Industrial Hygiene Engineer
Rebecca Stanevich, Industrial Hygienist
Matthew Klein, Mechanical Engineer

John B. Pierce Foundation at Yale University

Brian Leaderer, Environmental Scientist

EPA

Ross Highsmith, Chemist
C. J. Nelson, Statistician
Ken McLauchlin, Professional Engineer*
Linda Stetzenbach, Microbiologist

NIST

Andrew Persily, Mechanical Engineer

*Consultant

ACKNOWLEDGEMENT

We wish to thank all those whose efforts contributed to the success of this study. First, we appreciate the technical support during the environmental monitoring at the LOC Madison Building of Ross Highsmith and Thomas Lumpkin of the Atmospheric Research and Exposure Assessment Laboratory, EPA, Teresa Seitz and Greg Burr of the Hazard Evaluations and Technical Assistance Branch, NIOSH, Ed Burroughs and Gene Kennedy of the Division of Physical Sciences and Enginering, NIOSH, and Becky Stanevich of the Division of Respiratory Disease Studies, NIOSH. We also appreciate the ventilation evaluations performed by Andy Persily of the Center for Building Technology, NIST, and Matt Klein of the Hazard Evaluations and Technical Assistance Branch, NIOSH.

We also wish to thank Joachim Pleil of the Methods Research and Development Division, EPA, for the total VOC analysis and Howard Crist of the Quality Assurance Division, EPA, for the QA samples. Thanks go to Roy Zweidinger and Silvestre Tejada for the aldehyde analysis.

A special thanks to Andy Lindstrom and Matt Somerville of NSI Technology Services Corporation for the statistical summaries, figures, and tables. They were very helpful in a short time frame. Thanks to C.J. Nelson for his support in reporting the statistical results, and to Jan Parsons for her editorial review and many helpful suggestions as to format and style.

Thanks to Brian Leaderer and his staff of the John B. Pierce Foundation at Yale University for the nicotine analysis.

We appreciate the NIOSH management support of Dawn Tharr, Rick Gorman, Dave Sundin, Bob Rinsky, and Larry Fine. They have worked closely with the project team to ensure the success of this study.

Volume II: Environmental Survey
Library of Congress
Madison Building

CONTENTS

Appendices

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

1. Background

In recent years, employees in the James Madison Memorial Building of the Library of Congress (LOC) in Washington, DC, have reported health symptoms and discomfort concerns which they have attributed to the building indoor environment. As a result, a systematic study was undertaken to determine if associations exist between these symptoms and concerns and workplace conditions. This evaluation of the Madison Building has been performed by the National Institute for Occupational Safety and Health (NIOSH), the Environmental Protection Agency (EPA), the John B. Pierce Foundation at Yale University, the National Institute of Standards and Technology (NIST), and Westat, Inc., a health consulting firm.

The research effort at the LOC was integrated with a parallel study of three headquarters buildings at the EPA in Washington, D.C. Both the LOC and EPA surveys made use of similar study designs and survey instruments. While certain features of the study are specific to the particular buildings involved, the survey was designed to be applicable to any building suspected of environmental problems.

The objectives of the study were to survey health symptoms and comfort concerns of employees; characterize the indoor air environment in selected building locations; and analyze possible associations between health or comfort symptoms and conditions in the building environment. The study results are being presented in three successive reports. Volume I, released in December 1989, summarized the employees' health symptoms and comfort concerns. This report, Volume II, summarizes the environmental measurements in the Madison Building. Volume III, to be published in the second half of 1990, will analyze any associations between health or comfort and the building environment.

The Hazard Evaluations and Technical Assistance Branch (HETAB) of NIOSH's Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS) and the Atmospheric Research and Exposure Assessment Laboratory (AREAL) of EPA's Office of Research and Development (ORD) planned, directed, and carried out most of the environmental monitoring performed at the LOC. The Environmental Investigations Branch (EIB) of the Division of Respiratory Disease Studies (DRDS), NIOSH, conducted the biological sampling and analysis. NIST conducted a study of the LOC ventilation systems and air quality.

2. Study Design

A survey questionnaire was given to each employee in the Madison Building prior to environmental monitoring. The questionnaire was designed to collect information pertaining to the workers' health, comfort, and perception of odors, as well as their job characteristics and workstation environment. This questionnaire was analyzed to select locations for environmental monitoring. An equal proportion (1:1) of high-complaint level and low-complaint level locations was selected. Information regarding which category the monitoring site was in was not revealed to any LOC employee or member of the monitoring team, in order to avoid possible bias. A supplementary questionnaire was administered to the employees in the vicinity of the sampling site on the day of monitoring that included the same questions on health, comfort and odors.

The basic concept of the monitoring study was to measure a series of comfort and environmental variables in selected locations for a single day. About 20 locations were sampled in a day, allowing the total monitoring effort to be completed in one week (February 27 through March 3, 1989).

Available resources allowed for a complete set of environmental samples to be collected in 51 locations inside the Madison Building and one outdoor location. These "primary sites" were supplemented by an additional set of 40 "secondary sites" and ten "special sites", where a less complete set of environmental samples were collected.

Environmental parameters monitored at all sites included the "comfort variables" (temperature and relative humidity), an indicator for the amount of fresh air in a space (carbon dioxide [CO_2]), and a measure of dust levels (respirable suspended particulates [RSP]). Each was instantaneously monitored during four separate site visits (morning, late-morning, early afternoon, and late-afternoon) on the day monitoring was conducted. Additional variables measured at the 51 primary sites included indicators of potential chemical contamination (formaldehyde and 27 other volatile organic compounds, or VOCs), an indicator of smoking activity (nicotine), and an integrated (time-weighted average) measurement of RSP. The formaldehyde, VOCs, and RSP measurements were integrated over a 9-h period; the nicotine measurement was integrated over the entire five-day workweek. Microbiological aerosols (bacteria and fungi) were also sampled at the primary sites and some of the secondary sites. At a few sites (about three per day), integrated air samples were collected and analyzed for 15 aldehydes and 33 pesticides. One fixed indoor site and one fixed outdoor site were established and evaluated over all five days, to obtain an idea of the daily variability of the environmental parameters.

Whole-building air exchange rates were measured using the tracer gas decay technique (sulfur hexafluoride). Qualitative measurements of local air exchange effectiveness were performed at 56 locations. Other qualitative evaluations of ventilation system operational parameters were directed at the 27 air handlers serving the air monitoring locations.

Quality control samples, including duplicates, blanks, and spiked controls, were collected for the VOCs. All monitoring instruments were calibrated periodically according to the study protocol.

3. Results

Table ES-1 summarizes the total number of sites sampled at the LOC for each environmental parameter. Results are presented as overall mean values for the building for the week (Tables ES-2 and ES-3).

Comfort Parameters

The mean temperature for the building was 73.1 °F (Table ES-2). There was a general trend for the temperature to increase from morning to afternoon throughout the building, on all days. A majority (>75%) of the measured temperatures were between 70 and 75 °F. The minimum measured indoor temperature was 61.5 °F (recorded in the morning on the subground level), and the maximum was 77.5 °F.

The mean relative humidity was 49.2%. More than 80% of the individual measurements fell between 40 and 60%. Variability beween time periods, days, and sample sites was not great. The maximum indoor value was 72% and the minimum was 34%.

Ventilation Parameters

Mean carbon dioxide concentrations increased at all sampling locations throughout the morning, with the maximum mean values observed near midday, and decreased somewhat toward the end of the day. The mean CO_2 concentraiton overall was 491 parts per million (ppm). The range of values was 300-675 ppm (Table A.32). All values were below the guideline value of 1000 ppm.

Whole-building air exchange rates were relatively constant, with day- and night-time averages being 0.85 and 0.79 air changes per hour (ACH) respectively. The minimum ventilation recommendation by ASHRAE (20 CFM/person) corresponds to an air exchange rate of roughly 0.72 ACH. Local measurements indicated good distribution of the outdoor air at measurement locations. All outdoor air dampers inspected were believed to be in the maximum open position. Some minor problems were noted with operation of individual air handler filter systems and control gages, as well as with individual variable air volume distribution systems and room thermostats.

Particles

The real-time RSP measurement mean value was 5.5 $\mu g/m^3$. Integrated samples, collected at primary sites only, averaged 19.5 $\mu g/m^3$. The difference in real-time and integrated values is probably due to different measurement techniques. The real-time device employs optical scattering, which depends on the aerodynamic diameter of the particles, whereas the integrating monitor measures the mass of the particles. An instantaneous value of 50 $\mu g/m^3$ was observed on one occasion. The highest 9-h integrated average was 37.3 $\mu g/m^3$.

Nicotine

Nicotine was measured in the smoking area of the ground floor snack bar (18.5 $\mu g/m^3$), as well as in several lounges (range 0.6-11.7 $\mu g/m^3$). Nicotine was also measured in 4 of the 51 primary sampling locations (range 0.4-0.7 $\mu g/m^3$).

Formaldehyde and other aldehydes

The mean formaldehyde concentration in this building (Table ES-3), 9.2 $\mu g/m^3$ (<0.01 ppm), was very low. The mean acetaldehyde concentration, 16.1 $\mu g/m^3$ (<0.01 ppm), was similarly low, and the mean acetone concentration was 32.5 $\mu g/m^3$ (0.01 ppm). Other aldehyde concentrations ranged from 0.1 to 2.1 $\mu g/m^3$.

Volatile Organic Compounds

Tetrachloroethylene (31 μg/m^3, 5 parts per billion [ppb]), 1,1,1-trichloroethane (23 μg/m^3, 4 ppb), toluene (15.9 μg/m^3, 4 ppb), and the xylene isomers (o-xylene, 3.2 μg/m^3 [<1 ppb], and p-xylene, 7.2 μg/m^3 [2 ppb]) were the predominant VOC species measured (Table ES-3). The highest values were measured on the ground floor. Most of the targeted chlorinated compounds were found in all of the indoor samples. The mean indoor benzene concentration (6.8 μg/m^3, 2 ppb) was minimally greater than the measured outdoor concentration (6.0 μg/m^3). With the exception of benzene, indoor sources appear to be the principal contributors the VOCs.

Total VOCs, measured using gas chromatography and flame ionization detection (GC-FID), averaged 1.1 ppm carbon (Table D.16). The mean of the sum of the 27 VOCs, measured using GC and mass spectrometry (GC-MS), was 95.8 μg/m^3. Outdoor concentrations for the 27 VOCs added up to 16.7 μg/m^3.

There was no 4-PC (4-phenylcyclohexene) measured above the analytical limit of quantitation.

Pesticides

Chlorpyrifos was the only targeted pesticide observed above the analytical limit of detection, and was found in only one indoor air sample (0.004 μg/m^3).

Carbon Monoxide

Whole-building average CO concentrations, measured by NIST in the building air return system, averaged between one and two ppm.

Biological Aerosols

Overall mean counts of airborne fungi inside the Madison Building, 35 colony forming units per cubic meter (CFU/m^3), were lower than mean counts in the outdoor samples, 102 CFU/m^3. The most commonly seen organisms indoors were Penicillium, Aspergillus, Sporobolomyces, and Cladosporium. Only indoor Penicillium concentrations exceeded ambient concentrations. Fungal spore counts were low and consisted of common airborne spores.

Generally, human source bacterial counts (HSB) were low (44 CFU/m^3 indoors, 80 CFU/m^3 outdoors) with Staphylococcus sp. being seen most frequently both indoors and outdoors. Micropolyspora sp. and Proteus sp. counts were higher at some locations indoors than outdoors.

Thermophylic actinomycetes colonies (Micropolyspora sp.) averaged 7 CFU/m^3 outdoors and 13 CFU/m^3 indoors.

Concentrations of microorganisms found in water-spray humidification system water samples were orders of magnitude greater than those found in the steam humidification system water samples. No thermophylic organisms were identified in any of the water samples.

Table ES.1 Number of Sites Sampled at the Madison Building

Parameter	Total Inside	Total Outside
Temperature	101	1
Relative Humidity	101	1
CO_2	101	1
RSP (real-time)	101	1
RSP (integrated)	51	1
VOCs	51	1
Aldehydes	11	0
Nicotine	64	0
Pesticides	11	0
Microbiological	92	1

Table ES.2 Summary Statistics for Real-Time Environmental Measurements and Respirable Particles

Environmental Parameter	
Temperature (°F)	
Mean	73.1
Standard Error	0.2
Minimum	61.5
Median	73.1
Maximum	77.5
Relative Humidity (%)	
Mean	49.2
Standard Error	0.9
Minimum	34.0
Median	49.5
Maximum	72.0
CO_2 (ppm)	
Mean	491
Standard Error	15
Minimum	300
Median	501
Maximum	675
RSP: Real-time ($\mu g/m^3$)	
Mean	5.5
Standard Error	0.8
Minimum	0.0
Median	5.4
Maximum	50.0
RSP: Integrated ($\mu g/m^3$)	
Mean	19.5
Standard Error	1.3
Minimum	10.1
Median	18.0
Maximum	37.3

Table ES.3 Mean Values for Major Aldehydes and VOCs (μg/m^3)

Chemical	Indoors	Outdoors
Aldehydes (total)	32.1	NM[a]
Formaldehyde	9.2	NM
Acetaldehyde	16.1	NM
Acetone	32.5	NM
VOCs (total of 27 targets)	95.8	16.7
Toluene	15.9	8.0
p-Xylene	7.2	3.2
o-Xylene	3.2	1.2
Benzene	6.8	6.0
Methylene chloride	4.4	1.3
Tetrachloroethylene	31.0	3.9
1,1,1-trichloroethane	23.0	1.7
Trichloroethylene	1.0	ND[b]

[a] Not Measured

[b] Not Detected

Volume II: Environmental Survey
Library of Congress
Madison Building

1. INTRODUCTION

1.1 Background and Purpose

The indoor air quality of the work environment is increasingly becoming a significant factor influencing job satisfaction and office productivity. Occupants in many apparently well-designed office buildings, modern as well as newly renovated, are reporting increasing numbers of health symptoms and comfort concerns that are being attributed to the overall quality of the work environment. The most typical symptoms reported include eye, nose, and throat irritation, headaches, and lethargy.

Investigating large office buildings and relating worker concerns to indoor air quality are complex tasks. Health symptoms reported for work-related illnesses are not unique. These same symptoms are also frequently reported for common illnesses or result from other causes and exposures that are not work related. As with individual workers, large buildings are unique. Although buildings may be comparably designed, the actual operating conditions may differ significantly. The investigative process is complicated by the influence of the building's physical characteristics (windows, building materials, etc.); the design and operation of its heating, ventilating, and air-conditioning systems (HVAC); workstation ergonomic factors; indoor sources; and outside sources. Relationships between these components must be evaluated and understood before they can be directly related to the most significant factor influencing this complex investigative process, the individual workers themselves.

In recent years, employees of the Library of Congress (LOC) at the James Madison Memorial Building in Washington, DC, have reported numerous health and discomfort symptoms which they attributed to the building indoor air environment. Because of these worker concerns, the National Institute for Occupational Safety and Health (NIOSH) set out to systematically evaluate the nature and spatial distribution of the employees' health symptoms and comfort concerns, characterize the indoor levels and spatial distribution of environmental pollutants, and where possible, relate the worker symptoms and concerns to the physical and environmental conditions of the building. The U.S. Environmental Protection Agency (EPA) was requested to assist NIOSH in this investigation. The John B. Pierce Foundation at Yale University, and Westat, Incorporated, were contracted to assist the participating federal agencies in the development and administration of a questionnaire survey of employees and to assist in the building environment study. At the time of this investigation, the National Institute of Standards and Technology (NIST) was in the process of conducting a long-term study of ventilation and air quality in the Madison Building under contract to the U.S. Department of Energy.

A multidimensional indoor air investigation protocol integrating resources and participating organizational expertise was developed and implemented. A detailed employee survey questionnaire instrument was developed and administered to all LOC employees during February 1989. The questionnaire is divided into five sections. Parts I, II, and III address the spatial distribution of health symptoms and comfort concerns throughout the building. Part IV contains questions addressing job characteristics and satisfaction, as well as indicators of stress in work and nonwork activities. Part V includes demographic and other miscellaneous questions.

The survey results were summarized by worker locations and analyzed for trends and uniformity in response rates to select areas of high and low incidence of worker health symptoms and comfort concerns for environmental monitoring and evaluation. Environmental monitoring was conducted at selected indoor and outdoor locations during February 27 through March 3, 1989. A supplemental survey questionnaire was concurrently administered to employees located near the environmental sampling sites.

Three reports will result from this investigation. The first report summarized the design, conduct, and descriptive statistics of the employee survey.[1] This second report summarizes the environmental monitoring study and results. A third report comparing the employee and supplemental questionnaire survey responses along with the environmental results will follow.

This report is the second of the three scheduled reports and summarizes the design and conduct of the cooperative LOC environmental monitoring study. A brief description of the LOC Madison Building, including design and operating features that may contribute to overall indoor air quality, is presented in Chapter 2. Chapter 3 provides an overview of the criteria for selecting monitoring sites, the monitoring study design, the basis for the parameters monitored, and the study monitoring and analytical methodologies. Environmental monitoring study results are summarized in Chapter 4. Ventilation evaluation results are presented in Chapter 5.

A parallel investigation was conducted at the three EPA Headquarters Building facilities located in the Washington, DC, area. The LOC and EPA study objectives, protocols, survey instruments, monitoring methods, and analytical methods were similar. The activities of NIST were unique to the LOC study and are described in this report where appropriate. A detailed discussion of the measurement techniques employed by NIST and results obtained is presented elsewhere.[2]

1.2 Study Objectives

Four major objectives were defined for the LOC investigation:

1. Survey the nature, magnitude, and spatial distribution of health symptoms and comfort concerns.

2. Characterize selected physical, chemical, and biological aspects of the building in selected locations during the survey period.

3. Generate hypotheses regarding associations between observed health and comfort effects and environmental factors, while taking into account factors that would confound or modify such associations.

4. Identify areas not in compliance with standards or guidelines.

The employee questionnaire survey was conducted to meet the first objective. Monitoring for selected environmental and comfort parameters was conducted during the normal working hours for one week to meet the second objective. A supplemental questionnaire survey of selected workers in the vicinity of the monitoring stations was conducted simultaneously with the monitoring program. The environmental monitoring, employee survey, and supplemental survey data bases will be integrated and statistically analyzed in support of the third and fourth study objectives, and results will be provided in the third report.

2. DESCRIPTION OF THE LIBRARY OF CONGRESS MADISON BUILDING

The LOC James Madison Memorial Building is located on Capitol Hill, bounded on the north by Independence Avenue, on the south by C Street, on the west by First Street, and on the east by Second Street (Square 732) in Southeast Washington, DC. Construction of the building began in June 1971 and was completed in December 1979. Occupation of the building was completed in February 1983. There are greater than one and one-half million square feet of assignable interior space in the Madison Building and approximately 3100 workers.

2.1 Building Description

Figure 2.1 is a photograph of the LOC Madison Building, a nine-floor concrete and steel structure with a marble and granite exterior. Except for fire walls and special feature walls, the building interior partitions are movable metal, floor to ceiling, 5-ft-wide panels. Remarkable interior features include a parking garage for 330 cars and mechanical equipment rooms located in the basement (sub-ground); preservation laboratories, restoration shop, fumigation area, print shop, computer systems area, snack bar, and the loading and trash docks on the ground floor; the James Madison Memorial Hall and a glass enclosed interior court, with a water fountain and plant life (extending from the first through the third floors) on the first floor; a large cafeteria on the sixth floor (1000-person capacity); and a mechanical penthouse above the ninth floor. Remaining areas are made up of libraries of varying size, office space, and storage.

There are four main service cores, which run vertically through the building near each corner. These contain the elevators, rest rooms, trash chutes, electrical and communications closets, ventilation ductwork, public telephones, and lounges. Another core in the north center contains the front elevators, and at the rear, two freight elevators.

Typical office space is multiple occupancy, carpeted, lighted by fluorescent systems, and divided into individual spaces with 4-ft-high partitions. Ceiling height is 9 ft, 3 in. There are some single-occupant offices. Some of the exterior wall space contains windows which do not open.

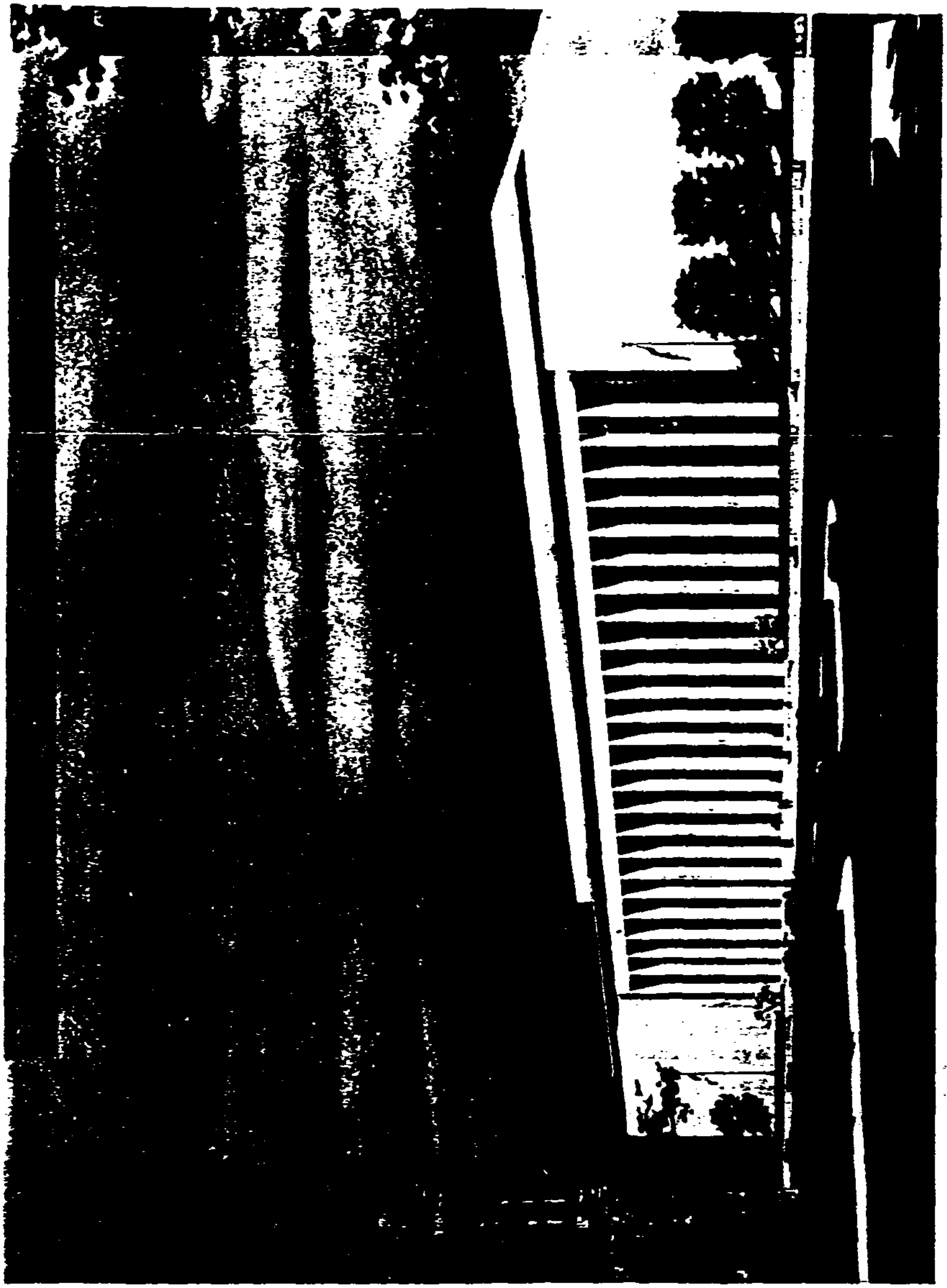


FIGURE 2.1 THE JAMES MADISON MEMORIAL BUILDING

2.2 Ventilation System Description

The mechanical ventilation system consists of 44 air handlers in the penthouse mechanical room (located above the sixth floor) and 10 air handlers in four basement mechanical rooms. The penthouse air handlers provide ventilation air predominantly to the upper eight floors of the building, while the air handlers in the basement serve only the lower three floors, a small fraction of the building volume, most of which is unoccupied. The air-handling systems are divided into eight zones within the building, as shown in Figure 2.2. The figure also contains the building column designations. Each zone is associated with a bank of air handlers in the penthouse mechanical room and has its own return and supply air shafts. The eight zones are designated A, B, C, D, EE, EW, FE, and FW. These zones are not isolated from each other in terms of airflow, and interior air can flow between these zones through hallways, from room to room, and open office spaces that are in more than one zone.

Figure 2.3 is a schematic of a typical air handling system within the eight building zones. Each zone's system is associated with a separate outdoor air (OA) intake plenum in the penthouse, and each plenum is connected to an OA intake grille located on the roof of the building. There are four to eight air handlers associated with the system in each zone (only three are shown in the figure), and any given air handler serves from one to nine of the building floors. These air handlers all have variable air volume (VAV) supply fans and maintain constant OA intake rates through the control of dampers in the OA intake ducts of each fan. The control of these dampers is based on airflow monitors in the OA intake ducts. The ventilation air from the air handlers is delivered to the occupied space through a network of supply air ducts that run down the building's supply air shafts and through the suspended ceiling plenum on each floor. The return air from the occupied space flows into a plenum above the suspended ceiling system on each floor via return air openings in the suspended ceiling. This return air then flows through the ceiling plenum and into the vertical return air shafts. Each zone's return shaft is connected to a return air plenum in the penthouse (shown in Figure 2.3) that serves the air handlers for that zone, enabling the recirculation of return air. There are no return fans in the building and no provisions for spilling excess return air; therefore, all of the return air is recirculated, and the return airflow rate is equal to the supply airflow rate minus the OA intake rate. Any excess of supply airflow over the return airflow

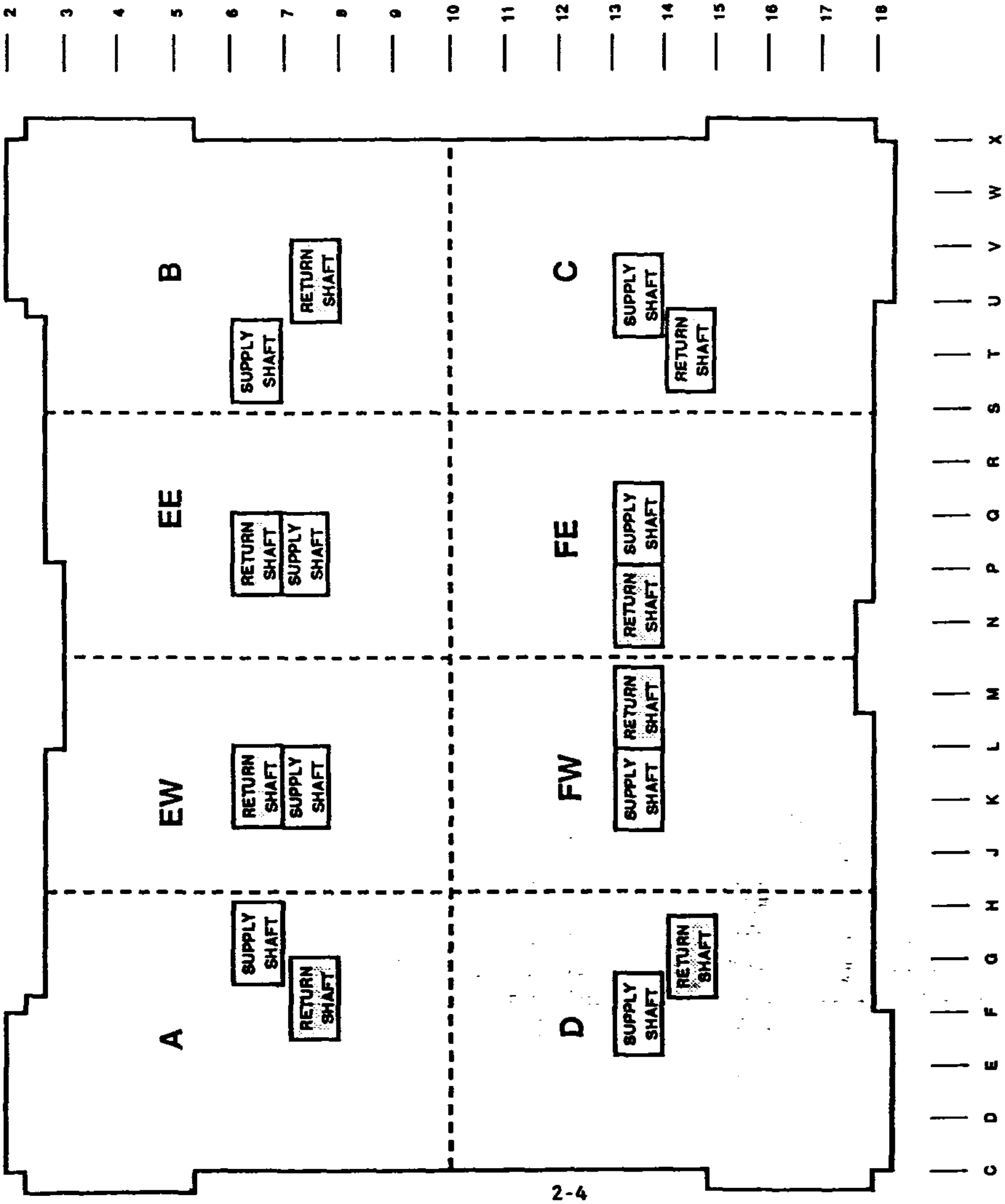


Figure 2.2 Schematic of Madison Building Floor Plan

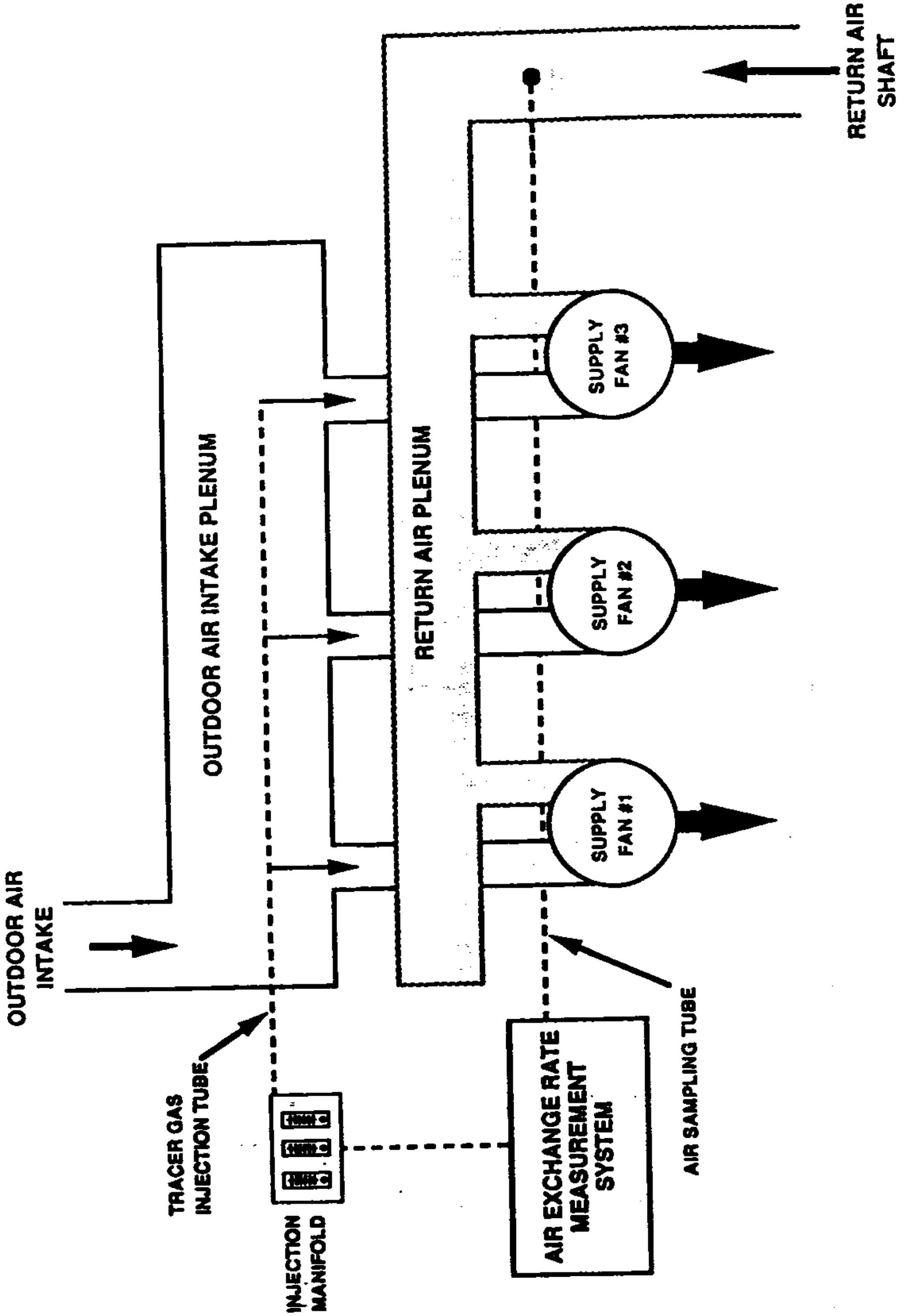


Figure 2.3 Schematic of Air Handling System

leaves the building by exfiltration through leaks in the building envelope and airflow into the ground floor tunnel and local exhaust systems. The air handling systems in the Madison Building operate 24 h a day, every day of the year. There is a nighttime setback in the supply air static pressure setpoint, but the OA intake rate is constant.

The air handling systems in the Madison Building are somewhat unusual in that the controls are designed to maintain a constant OA intake rate. In addition, OA intake rates are not usually monitored in office building ventilation systems as they are in the Madison Building. The ventilation systems in most office buildings are designed to bring in minimum levels of outdoor air during very cold and very hot weather to reduce the costs associated with conditioning the air. Large amounts of outdoor air are brought in during mild weather for cooling, employing a so-called economizer cycle. Therefore, in typical office buildings the OA ventilation rate can vary by a factor of 5 or more, depending on the outdoor weather, time of day, and season of the year.

Table 2.1 describes the air handlers in the Madison Building. The first column in the table is the air handler designation, and the second column is the supply airflow rate capacity in cubic feet per minute (CFM). The design value of the outdoor air intake rate for each air handler is also given in CFM units and as a percentage of the supply airflow rate. The supply airflow rates are the total capacities of the air handlers; the actual supply rates will generally be lower in these VAV systems. The design percent of outdoor air intake for almost all of the air handlers is 20% of the supply air capacity.

The total supply airflow rate capacity for the building's air handlers is about 1.8 million CFM, or 850 m^3/s, and the total design minimum outdoor air intake rate is 362,000 CFM (170 m^3/s). These airflow rates are converted to air changes per hour (ACH) by dividing by the building volume. The supply airflow rate capacity then corresponds to about 5 ACH, and the design outdoor air intake rate corresponds to 1.05 ACH. When the volume associated with interior partitions, furniture, and other items is accounted for, the corresponding air change rates will increase, but the correction to the air change rates is probably no more than 10 or 20%.

Table 2.1 Mechanical Ventilation System Design Airflow Rates

Air Handlers	Supply Airflow Capacity (cfm)	Outdoor Air Intake Rate (cfm)	Percent Outdoor Air Intake	Airflow Rates by Floor (cfm)								
				SB	B	G	1	2	3	4	5	6
Penthouse												
A-1	55730	11145	20			4605	11060	19765	20300			
A-2	47220	9445	20							19205	19235	8780
A-3	31940	6390	20		10985		20950					
A-4	52790	10560	20		8220	6205	5370	8665	8510	9965	9255	2805
E1W	37680	7525	20						7961	11551	10171	9080
E2W	22715	4545	20		9295	5960	4755		2550			
E3W	47785	9555	20		11280	11885	14400	10220				
E4W	42565	8515	20		830	830	1580	11380	1580	4205	1580	19980
NZW	7500	1500	20				1200	1200	1700	1700	1700	
SZWI	3345	1000	30									3345
WZ	14105	2820	20			930	2635	2635	2635	2635	2635	
WZI	5490	1465	27									5490
D-1	55410	11080	20				4590	11530	11415	11470	12010	4395
D-2	38150	7630	20		17635	10185	8655					
D-3	60665	12135	20			16435	9880	9120	8730	8605	7895	
D-4	38375	7680	20	400	1990		6795	6005	5910	5955	6135	5205
F1W	54980	10995	20		17440	4975		18815	13750			
F2W	45910	8780	19		12070	7020	18995		5825			
F3W	49405	9881	20							22530	22500	4375
ASSY	6970	1395	20									6970
CAW	35020	7020	20									35020
KIT	17800	3560	20									17800
FIE	61165	12235	20		26360	4035	3560	21290	5920			
F2E	52935	10585	20							23950	23800	5025
F3E	53045	10610	20		9980	11210	19050		12805			
SZ	15600	3120	20			600	3000	3000	3000	3000	3000	
NZI	4580	1850	40									4580
CAE	24490	5025	21									24490
C-1	64885	12980	20				15640	11060	4390	11260	11275	11260
C-2	61815	12365	20		29755	3965	7625		18825			
C-3	47990	9600	20			9185	11045	6250	5670	6690	6030	3120
C-4	43695	8740	20	400	6080	9535		8710		8835	9795	
E1E	48740	9750	20						11815	14175	13875	8835
E2E	57765	11555	20		15430	9005	8850	22370	2130			
E3E	41210	8240	20		10070	14295	13420	6615				
E4E	26550	5310	20					4275	2095	3800	2000	13698
NZE	6000	1200	20				1200	1200	1200	1200	1200	
SZEI	3195	985	31								3195	
B-1	51685	10335	20		3150	7860	9170	22005	9500			
B-2	54130	10830	20							19450	19580	15100
B-3	57800	11576	20		20745	12955	13395		10785			
B-4	39255	7847	20			8891	2490	3990	6490	9025	9030	
EZ	13175	2635	20				2635	2635	2635	2635	2635	
EZI	3650	1460	40									3650
Basement												
W-1	18405	3680	20		10730	7675						
W-2	25515	5105	20	16530		8985						
NW-1	24075	4815	20	24075								
NW-2	14085	2815	20			14085						
NW-3	15935	3190	20		15935							
NE-1	22310	4460	20	22310								
NE-2	15465	3130	20		15645							
NE-3	11465	2295	20			11465						
E-1	11815	2365	20		11815							
E-2	34175	6835	20	15185		18990						

Totals	1798150	362144	20

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in its Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends a minimum ventilation rate in the office space of 20 CFM, or 10 L/s, per person for offices.[3] This value can be converted to air changes per hour by dividing by the volume associated with a single person. Assuming an occupant density in office space of 7 people per 1000 ft^2 (the default value contained in ASHRAE Standard 62), 20 CFM per person converts to about 0.72 ACH. This conversion should also be corrected to account for the volume occupied by interior furnishings, but the correction is probably not large. The OA intake rate specified in the mechanical ventilation system design for this building (1.05 ACH) is almost 50% greater than the ASHRAE recommendation.

2.2.1 Filter Systems

The air filtration systems used on all of the air handlers include a primary coarse filter followed by much more efficient secondary filters. These filters are intended to remove only particulate contaminants from the air. The primary filters are made of an oiled fibrous glass material supplied in a wide roll. A section of the filter is exposed to the airstream, and as it becomes loaded (indicated by the measured pressure drop across the filter), it is advanced onto a take-up roll to expose a fresh portion. These roll filters are intended as prefilters. This allows the more efficient secondary system of bag filters to last longer. The bag filters are made of a tightly-woven fibrous glass fabric. The filters are shaped like bags to increase the area through which air passes and decrease the pressure drop.

According to ASHRAE's Particle/Particle Removal Systems Technical Committee, a "rule of thumb" recommendation is that roll filters be changed when the pressure drop reaches about 0.5 in. water gage (w.g.). The recommendation for bag filters is 1.0 in. w.g.

2.2.2 Humidifier Systems

Two methods of humidification are used in the air handlers, a water spray system and a steam system. In the first method, tap water is sprayed onto the cooling coils and picked up by the air passing through the system. Water not taken up by the air flows back into a reservoir beneath the coils. The second method of humidification is injection of steam into the supply air. The steam is obtained from the boiler in the central Architect of the Capitol (AOC) power plant. This same steam is used in the heating coils for the system.

3. LIBRARY OF CONGRESS ENVIRONMENTAL MONITORING DESIGN

3.1 Selection of Environmental Monitoring Sites

Findings from the employee survey were used to select potential sites for environmental monitoring. By using a protocol developed for this purpose, sites were selected for monitoring by the technical team. A detailed description of this procedure can be found in Section IV of Volume I.

Briefly, a health symptom index was computed for each employee from the questionnaire responses, and a standardized mean symptom score was computed for each room in the building. Similarly, a comfort index was computed for each employee from the questionnaire responses, and a standardized mean comfort score was computed for each room in the building. Rooms were independently ranked according to the standardized health and comfort indices. Sample locations were selected by NIOSH, EPA, and Yale University for environmental monitoring; the first locations chosen were the those with the highest values for both indices and the lowest values for both indices. Results of these rankings were not revealed to the monitoring team. In the selection of locations, greater priority was given to the health symptom index than to the comfort index.

Each potential site was visited and evaluated for number of workers, availability of electrical and space requirements, and the presence of obvious indoor pollutant sources.

One of the survey-identified indoor locations was selected by Yale University and Westat for monitoring throughout the entire five-day sampling period to assess possible changes over the week. In addition, an outdoor roof location was selected for monitoring on each of the five days to assess the influence of outdoor contaminants on the indoor environment.

In addition to the sites chosen in the manner described above, some special study sites were selected in two other manners:

1. To be responsive to the persons who work in the Madison Building who have particular concerns about certain areas of the building, representatives of management and each of the three unions were asked to provide a list of sites where employees were thought to have experienced problems (either health or

comfort related). These sites were compared with the list generated by analysis of the comprehensive questionnaire, and, if a site reported by management or unions was not included in that list, every effort was made to perform environmental monitoring at the suggested site.

2. Single-person offices were not eligible for selection for environmental monitoring. However, because they are an area of concern for employees, a list of such offices was requested from union representatives, and environmental sampling was performed in seven one-person and three two-person offices. The results from these locations are reported in the special site summaries, which are separate from the results from the sites chosen according to the selection procedure described above.

Detailed descriptions of the site selection process, including algorithms used in the ranking and selection process, are provided in the Volume I.

3.2 Environmental Monitoring Study Design

Comfort and environmental parameters were monitored at selected areas with high and low (approximate ratio 1:1) symptom and comfort index scores during routine employee working hours (between 7:00 a.m. and 5:00 p.m.) during the week of February 27 through March 3, 1989. Four categories of monitoring locations were identified: primary, secondary, fixed, and special. Except where noted, monitoring was conducted on only one day at each primary, secondary, and special study location. Samples were collected during all five daytime sampling periods at the fixed indoor and fixed outdoor monitoring locations.

3.2.1 Primary Study Locations

Extensive monitoring was conducted at each primary site to characterize the magnitude and spatial differences of the comfort and environmental parameters and included the following.

1. Real-time temperature (T), relative humidity (RH), carbon dioxide (CO_2), respirable suspended particle (RSP) measurements 4 times during the monitoring period: morning, mid-morning, early afternoon, and late afternoon.

2. Viable and nonviable microbiological samples.

3. Integrated 9-hour RSP, volatile organic compounds (VOCs), and passive formaldehyde samples.

4. Passive nicotine badges installed over the 5-day study period.

5. Integrated 9-h aldehyde and pesticide samples at selected sites daily.

3.2.2 Secondary Study Locations

Real-time T, RH, CO_2, and RSP measurements were collected 4 times (morning, mid-morning, early afternoon, and late afternoon) at each secondary site.

3.2.3 Fixed Study Locations

Integrated particle and VOC samples were collected daily to determine daily changes in concentrations and the influence of the outside air on the indoor air quality. Integrated aldehyde samples and real-time T, RH, CO_2, and RSP measurements (morning, mid-morning, early afternoon, and late afternoon) were also made daily at the fixed indoor site.

3.2.4 Special Study Locations

Viable and nonviable microbiological parameters were monitored in various components of the LOC HVAC system. When possible, individual parameters were monitored in selected areas not identified through the design criteria to support management, union, and concerned individual worker requests.

3.2.5 NIST Study

The National Institute of Standards and Technology (NIST) made measurements of whole building air exchange rates and building average concentrations of carbon dioxide and carbon monoxide. NIST also measured ventilation effectiveness at 56 locations, including some primary and some secondary monitoring locations. These measurements were conducted over a 2-h period, and each location was monitored only once, either in the morning or the afternoon.

3.3 Bases for Monitoring Environmental Pollutants

Standards for indoor air quality in office buildings do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards and recommended limits for occupational exposures.[4-6] ASHRAE has published recommended building design criteria.[3] With few exceptions, pollutant concentrations observed in office work environments fall well below these published standards or recommended exposure limits. Scientists suspect that work-related complaints may be attributable not to individual environmental species, but to the cumulative effect resulting from exposures to low concentrations of multiple pollutants. The monitoring study protocol measured individual species concentrations to provide the data base necessary to investigate relationships between worker concerns, health symptoms, and low-level exposures to the multiple contaminants measured.

The bases for monitoring individual or classes of environmental parameters are presented below in the following subsections.

3.3.1 Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. American National Standards Institute (ANSI)/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[7]

3.3.2 Carbon Dioxide

CO_2 is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 CFM per person for office spaces and 15 CFM per person for reception areas, classrooms, libraries, auditoriums, and corridors and provides estimated maximum occupancy figures for each area.[3]

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. Maintaining the recommended ASHRAE outdoor air supply rates should provide for acceptable indoor air quality in the absence of unusual sources.

3.3.3 Respirable Suspended Particles and Inhalable Particles

Respirable suspended particles (smaller than 2.5 μm) are associated with combustion source emissions. The greatest contributor to indoor RSP is environmental tobacco smoke (ETS). In buildings where smoking is not allowed, RSP levels are influenced by outdoor particle concentrations and by minor contributions from other indoor sources. In buildings with oil, gas, or kerosene heating systems, increased RSP concentrations associated with the heating source may be important. Inhalable particles, particles smaller than 10 μm in diameter (PM_{10}), are a combined result of combustion, soil, dust, and mechanical source particle contributions. The larger particles are associated with outdoor particle concentrations, mechanical processes, and human activity. When indoor combustion sources are not present, indoor particle concentrations generally fall well below the EPA ambient PM_{10} standard (150 $\mu g/m^3$ averaged over 24 h).[8]

3.3.4 Volatile Organic Compounds, Formaldehyde, and Other Aldehydes

VOCs, including formaldehyde and other aldehydes, are emitted in varying concentrations from numerous indoor sources (e.g., carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, kerosene heaters, and other combustion heating products). Studies in newly constructed office buildings have identified hundreds of these organic compounds present in the indoor air (reference). Some organic species (e.g., formaldehyde and benzene) have been determined to be carcinogenic in animal studies. NIOSH and the ACGIH have established compound-specific Recommended Exposure Limits (RELs) and Threshold Limit Values (TLVs) for many organic compounds.[4,6] Total indoor VOCs and aldehyde concentrations typically exceed corresponding outdoor levels except in locations immediately impacted by industrial or combustion source emissions. In the absence of cigarette smoke, indoor combustion appliances, new building materials, new office furnishings, glues and adhesives, solvents, paints, or cleaning products, individual species concentrations are well below the corresponding RELS and TLVs. Recent laboratory studies evaluating human responses to controlled exposures to varying VOC mixtures reported test subject health symptoms similar to those reported by workers in large office buildings.[9-11]

The list of targeted VOCs for this study were selected on the basis of previous indoor air studies, suspected indoor sources, common occurrence in the environment, available health data, as well as the monitoring and analytical methodologies employed.[12-16]

3.3.5 Pesticides

Pesticides, a special family of VOCs, are commonly found indoors as a result of applications of household insecticides, termiticides, general purpose lawn and building insecticides, and the transport of contaminated outdoor dust. TLVs have been established for most commercially available insecticides. Indoor pesticide concentrations generally fall well below the TLVs except in situations where the pesticide may have been misapplied or misused. Pesticide exposures may result in worker symptoms similar to those typically observed in indoor air quality studies.

3.3.6 Nicotine

Recent reports from the Surgeon General and the National Research Council have concluded that exposure to environmental tobacco smoke (ETS) may be associated with a wide range of health (e.g., lung cancer) and comfort (eye, nose, and throat irritation and odor) effects.[17-22] Vapor phase nicotine has been identified as a proxy or tracer for the presence of ETS, because it is unique to tobacco and occurs in easily measured air concentrations in indoor spaces where smoking takes place.

3.3.7 Viable and Nonviable Microbiological Contaminants

Microbiological contaminants are ubiquitous. Biological concentrations increase dramatically in the presence of warm, humid conditions, fleecy surfaces for growth, and the presence of dust, combustion aerosols, or other organic nutrients. Warm, wet areas (e.g., HVAC ducts, condensate pans, and humidification systems) may enhance biological growth. Water-damaged ceiling tiles, walls, carpets, or other indoor surfaces can serve as excellent growth media for biologicals. However, scientists generally recommend that indoor concentrations be no higher than ambient concentrations. Microbiological contaminant exposures may result in allergic reactions and/or flu-like symptoms. The potency of the microbiological contaminant is dependent on the individual species present.

There are currently no standards to be used for interpretating the results of microbiological monitoring in indoor air. However, the ACGIH[23] states that "A situation can be considered unusual when overall levels of the bioaerosol are at least an order of magnitude (10^x) higher than those that commonly occur in control environments, or if the organism (or other bioaerosols) differ between the control environment and the complaint environment." With regard to fungi, specifically, they state, "In general, indoor levels should be lower than those outdoors, and taxa should be similar indoors and out." In mechanically ventilated interiors, fungal counts should be less than half of outdoor levels. Other researchers propose four major points to consider when interpreting bioaerosol data: the presence of pathogens and toxigenic fungi (i.e., Stachybotrys atra) is unacceptable, counts of greater than 50 colony forming units (CFU)/m^3 with a single species present are of concern and should be investigated further, counts of less than 150 CFU/m^3 with a mixture of species is acceptable if no pathogens or toxigenic species are found, and counts up to 300 CFU/m^3 when Cladosporium or other phylloplane fungi are the predominant species are acceptable.

Human-source bacteria (e.g., Micrococcus and Staphyloccus) are used as surrogates for adequate ventilation because office occupants serve as the primary source of these bacteria via breathing, talking, sneezing, etc. One must consider local contaminant reservoirs and amplifiers, as well as the building's humidification system, as other possible sources of airborne bacteria. The presence of gram-negative organisms, for example, might be suggestive of contamination from the buildings's toilet exhaust. A recommended upper limit for the "normal" indoor bacterial aerosol in subarctic homes is 4500 CFU/m^3.[24]

Although unusual in nonfarm, indoor environments, thermophilic actinomycetes have been implicated in many cases of allergic alveolitis. For this reason, some indoor air monitoring protocols include sampling for this group of organisms. Farmer's lung is the classic form of allergic alveolitis. The thermophilic species grow prolifically up to temperatures 65-70° C, and their size (< 5μm) allows them to be easily dispersed. Micropolyspora faeni is considered to be the principal source of antigens in the United States.

Inhalation of either live or dead mold spores, both considered potential allergens, may cause illness. Both are commonly included in indoor air monitoring protocols.

Other microorganisms such as Pseudomonas, a leaf surface organism, are more abundant outdoors.

Reports of building illness frequently cite water spray humidification systems as a source, amplifier, and dissemination system for microbial organisms in office buildings.

3.4 Environmental Monitoring and Analytical Procedures

A detailed sampling and analysis protocol was developed and implemented for the LOC Madison Building study (Tables 3.1 and 3.2). The monitoring and analytical procedures used are described below.

3.4.1 Temperature and Relative Humidity

Real-time temperature and relative humidity measurements were conducted by using a Vista Scientific, Model 784, battery-operated psychrometer. Dry and wet bulb temperature readings were monitored, and the corresponding relative humidity was determined via the manufacturer-supplied curve.

3.4.2 Carbon Dioxide

Real-time CO_2 levels were determined with Gastech Model RI-411A, portable CO_2 indicators. This portable, battery-operated instrument monitors CO_2 (range 0-4975 ppm) via nondispersive infrared absorption with a sensitivity of 25 ppm. Instrument zeroing and calibration were performed daily prior to use with zero air and a known CO_2 span gas (800 ppm). Confirmations were conducted throughout the instrument use period.

TABLE 3.1 MONITORING AND ANALYTICAL METHODOLOGY

ANALYTE/ PARAMETER	COLLECTION METHOD	ANALYTICAL METHOD*
Temperature	Direct measurement	Psychrometer
Relative Humidity	Direct measurement	Psychrometer
Carbon Monoxide	Direct measurement	Infrared analyzer
Carbon Dioxide	Direct measurement	Infrared analyzer
Respirable and Inhalable Particles	Direct measurement - RSP	Light scattering
RSP/PM_{10}	Microenvironmental monitor - RSP	Gravimetric
	Dichotomous sampler - PM_{10}	Gravimetric
VOCs	SUMMA canister	GC/MS, GC/FID
Formaldehyde	Passive badge	Crystal growth
Aldehydes	2,4-dinitrophenylhydrazine	HPLC
Pesticides	Polyurethane foam	GC/MS, GC/ECD
Nicotine	Passive badge	GC/nitrogen detector
Viable Microbiologicals	Agar	Incubation/ spore count
Nonviable Microbiologicals	Impaction onto greased tape	Spore count

* - GC = gas chromatography, MS = mass spectrometry, FID = flame ionization detector, HPLC = high performance liquid chromatography, ECD = electron capture detector.

TABLE 3.2 ANALYTE LIMIT OF DETECTION (LOD) OR LIMIT OF QUANTITATION (LOQ)

PARTICULATE MATTER

Sampler	Flowrate	LOQ
Personal	1.67 L/min	10 $\mu g/m^3$
Microenvironmental	4.00 L/min	5 $\mu g/m^3$
Microenvironmental	10.0 L/min	2 $\mu g/m^3$
PM_{10} Dichotomous	16.7 L/min	2 $\mu g/m^3$

REAL-TIME MEASUREMENTS

Real-Time Parameter	Measurement Limits
Temperature	± 1 °C
Relative Humidity	± 2% RH
Carbon Dioxide	± 25 ppm CO_2
Particulate Matter	± 1 $\mu g/m^3$

FORMALDEHYDE

Passive Badge	34.5 $\mu g/m^3$ over 8-h exposure period

NICOTINE

Passive Badge	0.0001 $\mu g/m^3$ nicotine over 5-day period

VIABLE MICROBIOLOGICAL ORGANISMS

Impactor Sampler	Seven viable organisms/m^3, 28 L/min for 5 min

(continued)

TABLE 3.2 ANALYTE LOD OR LOQ (cont'd)

ALDEHYDES

Compound	LOQ ($\mu g/m^3$)
Formaldehyde	0.07
Acetaldehyde	0.07
Acrolein	0.06
Acetone	0.06
Propionaldehyde	0.06
Crotonaldehyde	0.06
Butyraldehyde	0.06
Benzaldehyde	0.05
Isovaleraldehyde	0.06
Valeraldehyde	0.06
o-Tolualdehyde	0.05
m-Tolualdehyde	0.05
p-Tolualdehyde	0.05
Hexanaldehyde	0.05
2,5-Dimethylbenzaldehyde	0.05

(continued)

TABLE 3.2 LOD OR LOQ (cont'd)

VOLATILE ORGANIC COMPOUNDS

Organic Compound	LOD ($\mu g/m^3$)	LOQ ($\mu g/m^3$)
Vinyl chloride	2.02	8.08
Vinylidene chloride	0.73	2.93
Methylene chloride	0.32	1.27
trans-1,2-Dichloroethene	0.15	0.59
1,1-Dichloroethane	0.20	0.81
cis-1,2-Dichloroethene	0.25	0.98
Chloroform	0.25	0.98
1,1,1-Trichloroethane	0.14	0.56
Carbon tetrachloride	1.71	6.85
Benzene	0.96	3.84
Trichloroethylene	0.18	0.70
Toluene	1.72	6.89
n-Octane	0.15	0.59
Tetrachloroethylene	0.24	0.95
1,2-Dibromomethane	0.38	1.53
Chlorobenzene	0.09	0.35
Ethylbenzene	0.24	0.96
p-Xylene	0.59	2.36
o-Xylene	0.25	0.99
Styrene	0.37	1.47
1,1,2,2-Tetrachloroethane	0.64	2.55
n-Decane	0.70	2.82
m-Dichlorobenzene	0.44	1.76
p-Dichlorobenzene	0.43	1.70
o-Dichlorobenzene	0.54	2.14
n-Dodecane	1.11	4.42
4-Phenylcyclohexene	1.23	4.90

TABLE 3.2 ANALYTE LOD OR LOQ (cont'd)

PESTICIDES

Compound	LOD µg/m³
Dichlorvos (DDVP)	0.93
alpha-BHC	0.02
Hexachlorobenzene	0.01
Pentachlorophenol	1.85
gamma-BHC (Lindane)	0.02
Chlorothalonil	0.02
Heptachlor	0.13
Ronnel	0.03
Chlorpyrifos	0.03
Aldrin	0.02
Dacthal	0.02
Heptachlor Epoxide	0.02
Oxychlordane	0.03
Captan	0.14
Folpet	0.09
2,4-D Butoxyethyl ester	0.46
Dieldrin	0.04
Methoxychlor	0.05
Dicofol	0.46
cis-Permethrin	0.19
trans-Permethrin	0.19
Chlordane	0.37
4,4'-DDT	0.03
4,4'-DDD	0.03
4,4'-DDE	0.03
ortho-Phenylphenol	0.09
Propoxur	0.05
Bendiocarb	0.12
Atrazine	0.12
Diazinon	0.14
Carbaryl	0.12
Malathion	0.12
Resmethrin	0.23

3.4.3 Respirable Suspended Particles and Inhalable Particles

Real-time RSP and integrated RSP/PM_{10} concentrations were monitored as follows.

1. Real-time RSP concentrations were measured by using GCA Environmental Instruments Model RAM-1 monitors. This portable,battery-operated instrument assesses changes in particle concentrations via an infrared detector, centered on a wavelength of 940 nm. Indoor air is sampled (2 L/min) first through a cyclone preselector, which restricts the penetration of particles greater than 9 μm. The air stream then passes through the detection cell. Operating on the 0-2 mg/m^3 range with a 32-s time constant yields a resolution of 0.001 mg/m^3.

2. Integrated RSP samples were collected at the primary sites by passing representative air samples (1.67 L/min) through a preweighed 37-mm Teflon filter media loaded in a Millipore cassette. The cassette flow orifices prevent the collection of large particles.

Fixed indoor site RSP and PM_{10} concentrations were measured by using two, 10 L/min particle samplers, each with an independent particle size selective inlet (one RSP and one PM_{10}). The air sample enters the inlet and is directed into an acceleration jet nozzle with a diameter that is engineer-designed for maximum collection of the appropriate sample size fraction. The accelerated airstream leaves the nozzle and is focused toward a lightly oiled impaction plate. Particles larger than the designated size cannot make the critical turn and are collected on the oiled impaction plate. Particles equal to and smaller than the designated size pass around the oiled plate and are collected on preweighed 37-mm Teflon filter media.

Outdoor RSP and PM_{10} concentrations were measured by using a Sierra PM_{10} Dichotomous Sampler (total flow 16.7 L/min). The air sample enters the inlet where particles larger than 10 μm are removed. The sample stream then passes downward into an acceleration nozzle inside the virtual impactor assembly, where particles are separated by size fraction. The RSP sample stream (15 L/min) is redirected perpendicular to the original flow direction while the coarse stream (particles 2.5-10.0 μm in diameter) continues its downward motion. The two distinct size fractions are collected independently onto preweighed 37-mm

Teflon filter media.

The 37-mm Teflon filters are returned to the laboratory for gravimetric analysis following standard procedures.[25] The laboratory quality assurance weighing limits for Teflon filter media are ± 10 μm for both pre- and post-sample weighings. Primary and fixed indoor site particle collections with a net gain of less than 10 μm are considered within the experimental error and are not reported by the laboratory.

3.4.4 Volatile Organic Compounds

Two independent methods were used to monitor and analyze for VOCs. VOCs were collected in precleaned, evacuated (29 in. Hg) SUMMA-polished canisters by using standard EPA monitoring procedures.[26-27] Randomly selected precleaned canisters were analyzed for the target VOCs compounds prior to canister shipment and sample collection. Evacuated canisters were loaded into a sampler downstream of a flow controller calibrated for an inlet flow of 8-10 cm^3/min. At the beginning of the sampling period, the canister valve was opened, and the canister vacuum recorded, and the indoor air was sampled over the 9-hour monitoring period (approximately a 5-L sample). At the completion of sampling, the canister final vacuum reading and time were recorded, and the valve was closed. Sampled canisters were returned to the laboratory for analysis. Representative aliquots of each canister were analyzed for targeted compounds via GC/MS. Additional aliquots were drawn and analyzed by GC/FID without a separation column for total nonmethane VOCs.[28]

VOCs were also collected via an experimental method in which indoor air was sampled (20 cm^3/min) through Carbotrap 300 multiple-bed sorbent tubes (Supelco, Inc.). Prior to sampling, the tubes were precleaned via thermal desorption (300 °C, 8 min) and thermal conditioning (400 °C, 25 min). When not being used, the tubes were stored in an aluminum container which had a double O-ring seal cap to prevent contamination. Following sampling, the tubes were returned to the laboratory for thermal desorption and qualitative GC/MS analysis.

3.4.5 Formaldehyde and Other Aldehydes

1. **Passive Formaldehyde Monitors.** Passive formaldehyde badges (Crystal Diagnostics Airscan Passive Monitors) were installed and exposed

at each primary site on the day of sampling. The badges sampled formaldehyde via diffusion and were analyzed on-site by a proprietary technique to determine cumulative formaldehyde exposures. At the completion of the sampling period, the badges were removed, the developing solution was injected, the badges were analyzed via the manufacturer's instructions, and the corresponding formaldehyde concentrations were recorded.

2. Aldehydes. At selected primary sites (two each day), samples for aldehyde analysis were collected by passing air (200 cm^3/min) through 2,4-dinitrophenylhydrazine-coated silica gel cartridges.[29] At the completion of the monitoring period, the cartridges were sealed, refrigerated, and shipped to the laboratory for targeted compound analysis via HPLC.

3.4.6 Pesticides

Pesticides were collected on precleaned polyurethane foam (PUF) cartridges (4.0 L/min) at one primary site each day. At the completion of the sampling period, the PUF cartridge was sealed in aluminum foil, placed in a Teflon sealed glass jar, immediately stored on dry ice (-40 °C), and shipped to the laboratory. The samples remained frozen until extracted by the laboratory within five working days following sample collection. The sample extracts were analyzed for targeted pesticides via GC/ECD and/or GC/MS as outlined in the Non-Occupational Pesticide Exposure Study.[30]

3.4.7 Nicotine

Nicotine was collected over the entire 5-day monitoring period by using passive, sodium bisulfate-coated filter media contained in Millipore cassettes. At each sampling location, the cassettes were opened, and the start time was recorded on Sunday, February 26, prior to the initiation of the environmental monitoring study. The passive nicotine monitors sampled at a rate of 24 mL/min. Upon completion of the study, the cassettes were sealed, the ending times recorded, and the samples returned to the laboratory for analysis. The filter media was removed, extracted in heptane, and analyzed by using GC with a nitrogen-specific detector.[31]

3.4.8 Viable and Nonviable Microbiological Agents

1. Viables. Viable microbiological samples were collected at each primary site, the fixed indoor and outdoor sites, selected locations in the HVAC system, as well as other sites where biological growth was suspected. Samples were collected according to a duplicate sampling protocol onto appropriate growth media by using Andersen Viable Air Samplers modified to employ only the sixth stage.[32] The Andersen sampler employs inertial impaction at a flow of 1.0 CFM for organism collection into standard 100-mm plastic petri dishes filled with 45 cm^3 of the appropriate agar to ensure adequate plate to agar distance. Mesophilic fungi, human source bacteria, and thermophilic bacteria were collected on malt extract agar (MEA), trypticase-soy agar (TSA), and TSA, respectively. Samples were collected over a 5-min time period. Fungal samples were stored at room temperature. Bacterial and thermophilic samples were refrigerated. Samples were shipped to the laboratory within 2 days following collection. The mesophilic, human-source bacteria, and thermophilic samples were incubated (25, 37, and 56 °C, respectively). Fungal spores were counted after 3-5 days of incubation whereas the bacteria samples were counted after 1-2 days of incubation. Colony types were identified initially by number, and the most common were identified by genus.

2. Nonviables. Nonviable samples (fungal spores) were collected using a Burkard Recording Air sampler.[33] Samples were collected for a 24 h period at four sites per day, Monday through Thursday. Indoor air passes through the sampler (10 L/min) with particles impacting on a greased tape attached to a rotating drum turning at a constant speed. Upon completion of the monitoring study, the samples were returned to the laboratory for spore counting and the determination of 8-h averaged values.

3.4.9 NIST Carbon Dioxide and Carbon Monoxide

NIST made measurements of building average carbon dioxide and carbon monoxide concentrations by using an automated measuring system. This system monitored the concentrations in the eight return shafts and an outdoor location every 10 min and was operated continuously throughout the week of monitoring and for several months thereafter. These measurements employed air sample tubes and pumps that were used in the tracer gas decay tests discussed below. The measuring system employed two infrared absorption analyzers for determining carbon dioxide and carbon monoxide concentrations and a microcomputer to control the air sampling and to record the data. The carbon dioxide monitor had a range of 0 to 2500 ppm and is accurate to within 0.5% of full scale. The carbon monoxide monitor had a range of 0 to 50 ppm and is accurate to within 1% of full scale.

3.5 Ventilation Evaluation

The Madison Building investigation involved the measurement of whole building ventilation rates and local ventilation effectiveness as part of the NIST study[2] and a qualitative evaluation by NIOSH of how the ventilation systems were operating during the survey period.

3.5.1 Whole-Building Air Exchange Rate Measurements

Whole-building air exchange rates were measured by NIST in the Madison Building by using the tracer gas decay technique (Standard Test Method E741-83, American Society for Testing and Materials), which yields the net rate at which outdoor air enters a building, including both intentional outdoor air intake through the air handling systems and unintentional infiltration through leaks in the building envelope. The air exchange rate of a building depends on a variety of factors including the design, installation and operation of the mechanical ventilation system, the airtightness of the building envelope, the interior configuration of the building, outdoor weather conditions, and the manner in which the ventilation control system responds to weather and time of day.

In the tracer gas decay technique, a harmless and nonreactive tracer gas is released into a building and mixed thoroughly with the interior air. Once the tracer gas concentration within the building is spatially uniform, the decay in tracer gas concentration is monitored over time. The rate of decay of the logarithm of concentration is equal to the air exchange rate of the building during the test period, in units of building volumes per unit time (generally ACH).

The tracer gas measurements of air exchange in the Madison Building employed an automated measuring system with sulfur hexafluoride (SF_6) used as the tracer gas. The microcomputer-based system controls the tracer gas injection and air sampling, records the SF_6 concentration, and monitors and records the outdoor weather, indoor temperature and fan operation status. SF_6 was measured with a GC equipped with an ECD that determines SF_6 concentrations in a range of about 5 to 300 ppb with an accuracy of roughly 1%.

In tracer gas tests, the manner in which the tracer gas is injected into the building and the locations at which the tracer gas concentrations are measured are necessarily based on the layout of the building and its air handling systems. In the Madison Building both the tracer gas injection and the air sampling strategy were based on the division of the building into the eight zones shown in Figure 2.2. Figure 2.3 depicts the injection and sampling scheme for an individual air handling zone. A tracer gas injection tube carried a metered amount of tracer gas from the automated system to each of the eight outdoor air intake plenums, where the injection tube was connected to an injection manifold containing a flow meter for each air handler in that zone. The automated tracer gas decay system injected SF_6 into 39 of the 44 penthouse air handlers. The SF_6 concentration in the building was determined from air sampled in each of the eight return air shafts. The SF_6 concentration in the outdoor air was also monitored.

Figure 3.1 shows a schematic of the SF_6 measurement system, along with the CO/CO_2 system discussed earlier. Air sample tubes of 3/8 in. outside diameter (OD) polyethylene were connected to a series of air sample pumps which pull air from the air sample locations described above. The output of these pumps was connected to the 10-channel SF6 analyzer, which was controlled by the microcomputer-based data acquisition and control system. This system also controlled the tracer gas injection system, which releases SF_6 into the building air handlers through 1/8-in. OD nylon tubing.

During the automated, whole-building air exchange measurements, tracer gas was injected into the building air handlers every 3 h. The tracer was injected at a rate that was based on achieving an initial concentration of about 150 ppb in the building. After the injection, the tracer gas concentration was monitored at the nine air sample locations, each location being sampled once every 10 min. During the measurement period the system monitors and recorded the outdoor air temperature, the air temperatures in the eight return air shafts, and the fan operation status. In this building, the fans operated 24 h a day, except during servicing, and the tracer gas testing was conducted continuously with eight separate decays each day. The tracer gas concentration data were analyzed

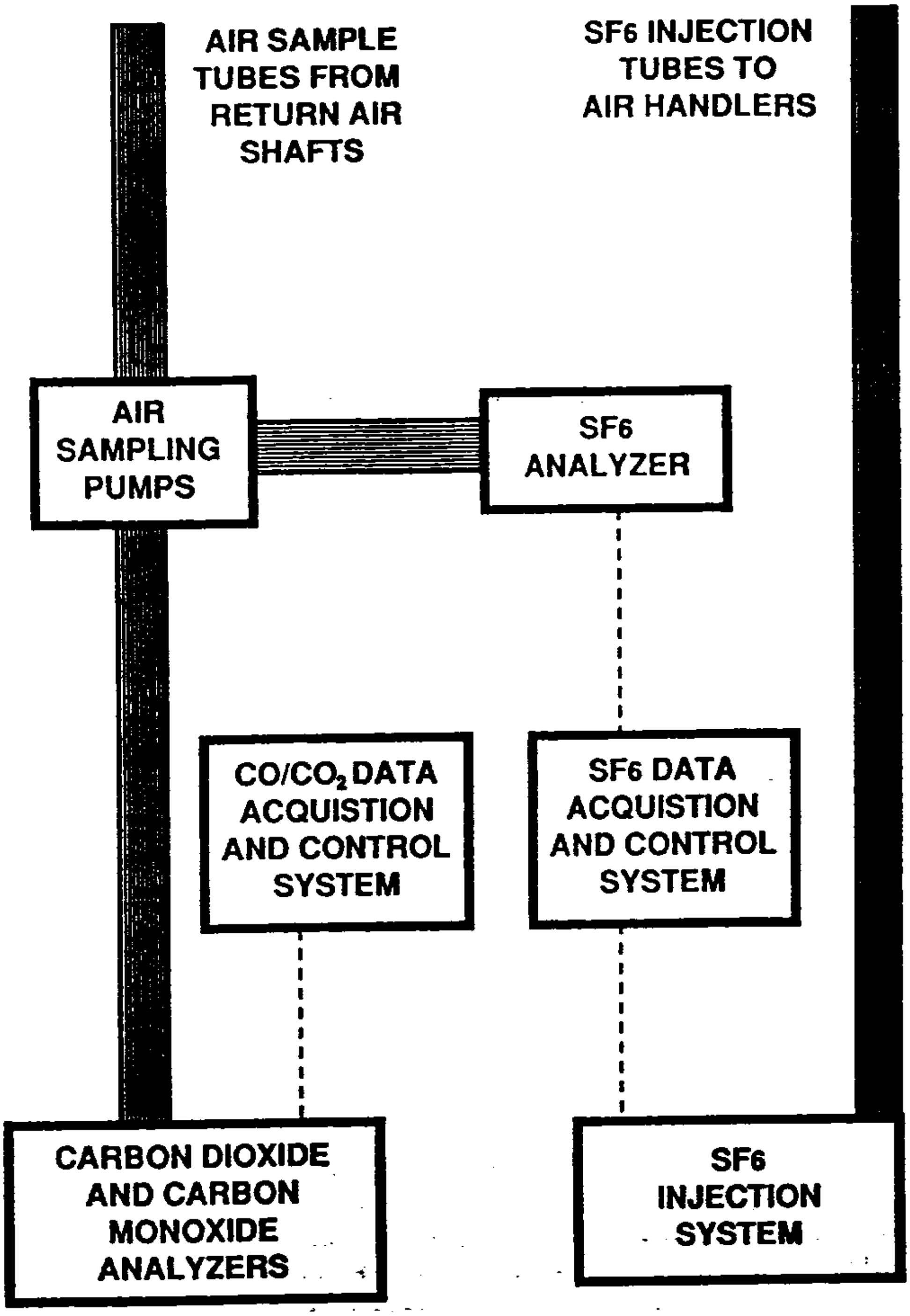


Figure 3.1 Schematic of SF_6 and CO/CO_2 Measurement System

to determine the decay rate for each of the eight returns, and these eight decay rates were averaged to determine an estimate of the whole-building air exchange rate. The accuracy of this air exchange rate determination is a function of the uniformity of tracer gas concentration within the building and was estimated to be about 10%.

Measurements of whole-building air exchange rates started during January 1989 and continued for several months. The results in this report constitute a data set consisting of about 650 air exchange rates, along with the corresponding weather and fan operation conditions. Analysis of the measurement results enables the determination of how the building air exchange rates compare to the design ventilation rates and how they are affected by weather, time of day, and season of the year.

3.5.2 Local Ventilation Effectiveness

Measured values of whole-building air exchange rates can be compared to design rates and ventilation standards, but they do not provide any information on the distribution of this ventilation air to individual locations within the occupied space of the building. Although the ventilation rate may be adequate on a whole-building scale, if this air is not well distributed there may be areas within the building with inadequate outdoor air supply. Nonuniformities in air distribution (i.e., rooms or locations within rooms that are less well ventilated than other portions of the building) have been suspected as being responsible for some air quality complaints. There are no accepted measurement techniques for quantifying the uniformity of air distribution or ventilation effectiveness in mechanically ventilated office buildings, and therefore the air quality impacts of nonuniformities in air distribution have not been demonstrated. Measurements of local air exchange effectiveness were performed at 56 locations in the Madison Building by NIST. These local evaluations consisted of measurements of local tracer gas decay rates and mean local ages of air. Although these techniques provide a qualitative indication of ventilation effectiveness, they have not yet been demonstrated to yield reliable measurements of ventilation effectiveness in the field. These measurement techniques and their application are described in detail in the NIST report on the Madison Building study.[2]

3.5.3 Ventilation Systems Evaluation

The qualitative evaluation was directed at observing and recording operational parameters of the ventilation systems supplying areas of the Madison Building where environmental monitoring was being conducted. The following methods were used:

a. Color-coded drawings of the ventilation system were consulted to identify the air handling units (AHUs) that supply air to the sample sites being monitored. Each of these air handlers was visited to perform a visual check and record operating parameter data. First, the outside air dampers were checked for position, and the damper motor was by-passed to see whether the damper could operate. Second, the main filters were checked for loading and the roll filters were checked to see if they would advance. Third, the pressure drop across the filters showing on the AHU gauge was recorded. Fourth, a check was made to see whether humidification was being used, and if so, what type (steam or water spray). Finally, the data showing on the gauges in the control panel for the AHU were recorded as a check for any unusual operating problems.

b. Throughout the study week, operating parameter data were provided to the Building Management Systems computer from sensors on the AHUs. Print-outs of these half-hourly data contained recordings of dry bulb temperature, discharge static pressure, and air monitoring device (AMD) outside air percentage. This information indicated any appreciable changes in operating conditions for the AHU throughout the day.

c. A copy of the maintenance log for the week was obtained as a record of work performed on the AHUs supplying air to the sample sites.

d. At several sampling sites each day, the thermostat which controlled the airflow to the supply air diffuser closest to the sampling site was located. For each thermostat, the temperature at the thermostat, the thermostat setpoint, the branch-line pressures at the lower and upper limits of the throttling range, and the supply air temperature from the diffuser were recorded. In addition, observations about conditions in the space which could be causing worker concerns were recorded.

e. On every floor in the building, smoke tubes were used to visualize the airflow direction in the hallways and at the doorways of offices, closets, and elevator doors. Airflow directions were indicated on floor plans to show how air travels within the building.

4. SUMMARY OF ENVIRONMENTAL MONITORING RESULTS

This section presents summarized data by floor collected at the LOC Madison Building during the environmental monitoring study. These descriptive results reflect conditions found in a generalized fashion and do not define conditions or make inferences based on specific sample data. All of the summary results are presented in Appendices A-G.

4.1 Number of Monitoring Sites

With the exception of the microbiological contaminants, environmental monitoring was conducted in 50 primary, 40 secondary, 10 special, one fixed indoor, and one fixed outdoor sites. Biological samples were collected at 91 indoor locations, 28 HVAC units, and at the outdoor sample location.

4.2 Real-Time Indoor Measurements

4.2.1 Method for Summarizing Real-Time Indoor Measurements

4.2.1.1 Mean Floor Value for a Single Time Period. Mean floor values for real-time measurements were calculated for each of the four monitoring time periods (morning, mid-morning, early afternoon, and late afternoon) by using individual or averaged location values. If only one measurement was made for a given location in the time period, this individual value was considered the mean location value. If a sampling location other than the fixed indoor site was monitored more than once during the study for any time period, a mean location value for that time period was calculated by adding the various observations and dividing by the number of observations. The fixed indoor site data were treated slightly differently; only the observations collected on the day the questionnaire was administered were included in the primary site data. The remaining fixed indoor site data were used in the calculation of the summary data for all locations. A mean floor value was then calculated by adding the individual mean location values for that time period and dividing by the number of locations monitored during the time period.

4.2.1.2 Average Mean Floor Values for the Entire Monitoring Day. An average mean floor value representing the parameter over the four time periods was calculated by first calculating average location values within the floor over the four time periods, adding these average location values, and dividing by the actual number of locations monitored in the floor.

4.2.1.3 Building Means over Floors. Building means for each of the four time periods, regardless of floor, were calculated by using the eight mean floor values (4.2.1.1, above) for the specific time period.

4.2.1.4 Grand Building Means. A grand building mean for each real-time parameter was calculated by using the eight average mean floor values for the entire monitoring period (4.2.1.2, above).

4.2.1.5 Individual Maximum and Minimum Values. The individual maximum and minimum values reflected in the real-time summary tables represent individual observations and not location mean values.

4.2.2 Temperature

There was a general trend for mean indoor temperature (Tables A.1 - A.4) to slightly increase (Figure 4.1) from morning to afternoon throughout the building, regardless of sampling day. The calculated building grand mean temperature was 73.1 °F. More than 75% of the individual temperature measurements (Figure 4.2) were between 70 and 75 °F, suggesting that the building mean temperature was relatively constant. The maximum indoor temperature measured was 77.5 °F, and the second-highest temperature measured was 77.0 °F. The single lowest temperature measured (61.5 °F) was recorded in the morning in the basement floor. Ten additional individual temperature measurements (<3% of all measurements) fell below 70 °F. The lowest temperature measured on ground or any above-ground floors was 68.0 °F. Temperature gradients between floors were small as was the variability in mean temperature among the primary, secondary, and special study sites. The largest within-day temperature variation occurred on Friday, at sampling locations having a large visitor population (first and second floors) and the basement.

4.2.3 Relative Humidity

Mean building relative humidities (Tables A.5-- A.8) varied from 45 to 55% RH over the monitoring period, the building grand mean being 49.2% RH. Relative humidity did not vary greatly between time periods or from day to day

Figure 4.1. Plot of Temperature Maximum, Mean, and Minimum, Across Floors at The Library of Congress by Earliest Sample Start Time

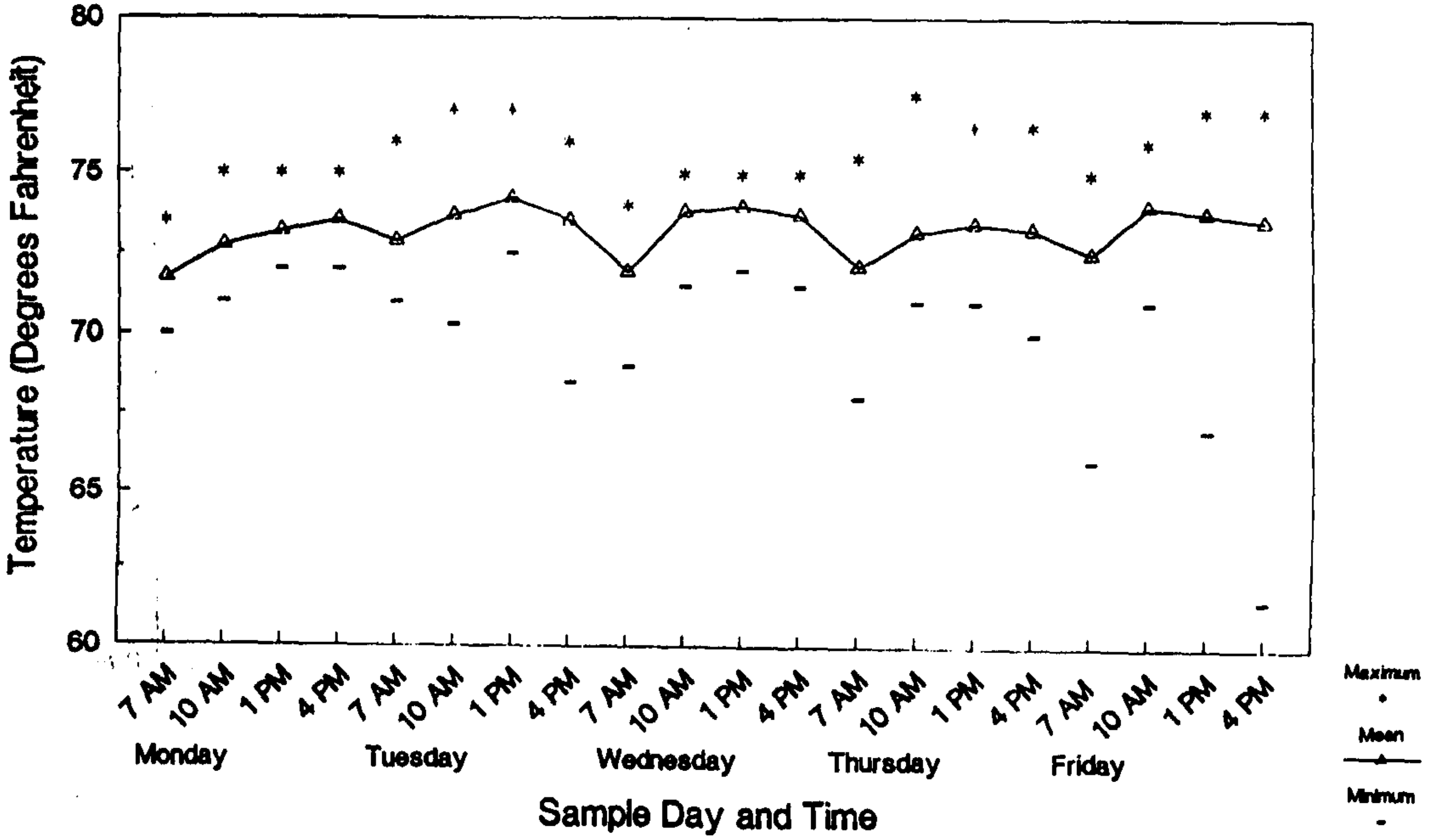
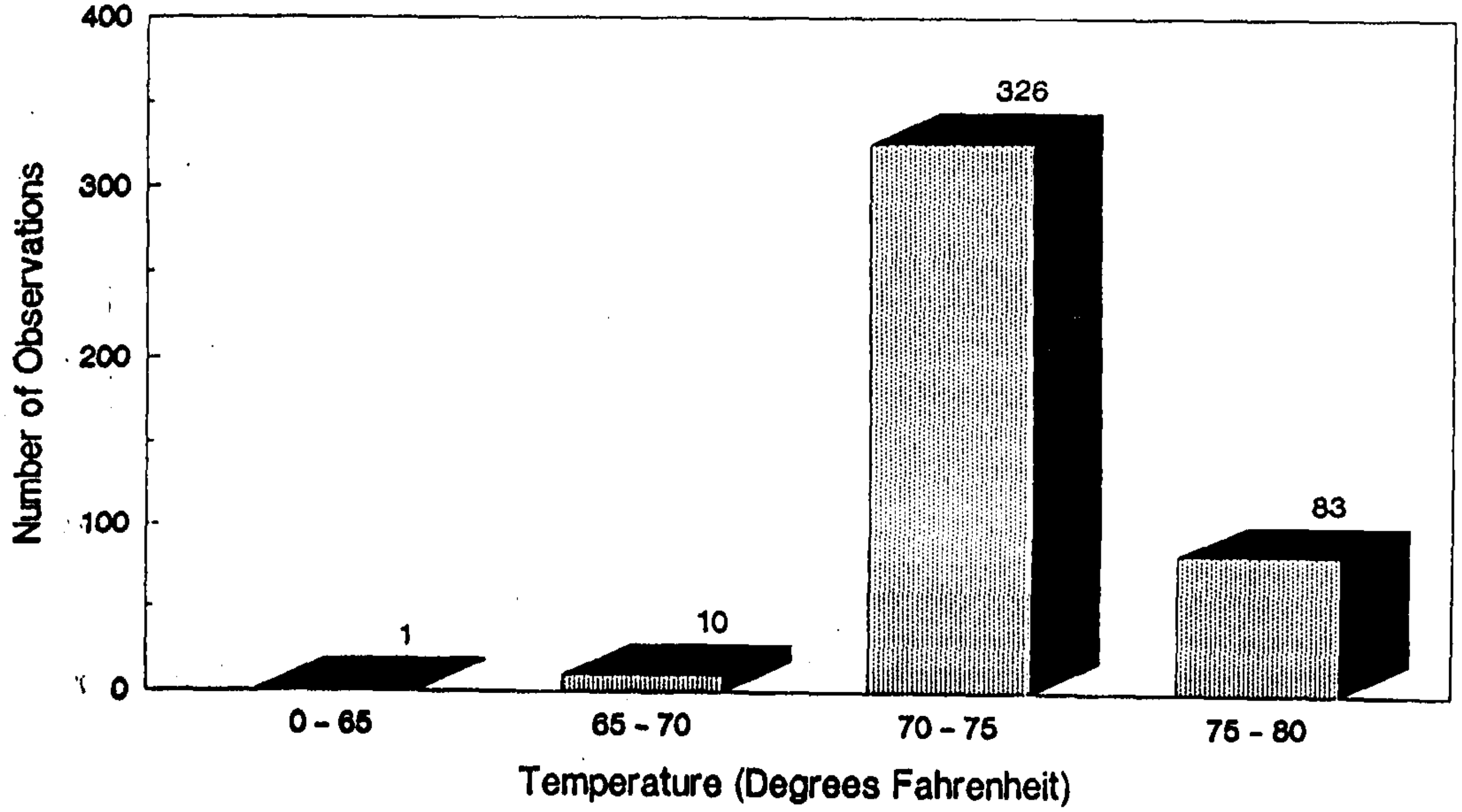


Figure 4.2. Frequency Distribution of Observed Temperatures Across Floors at The Library of Congress



(Figure 4.3). More than 80% of the individual RH measurements (Figure 4.4) fell between 40 and 60%. The observed single value and calculated mean relative humidities fell within the comfort zone. There was little variability in the relative humidities observed among the mean primary, secondary, and special study sites. The maximum indoor single value was 72.0%, and the minimum value observed was 34.0%.

4.2.4 Carbon Dioxide

Mean indoor carbon dioxide concentrations increased at all sampling locations throughout the morning, the maximum mean values were observed near midday, and concentrations decreased somewhat toward the end of each day (Figure 4.5). The largest within-day CO_2 variation occurred on Thursday, when sampling was conducted on floors with the highest potential for exchange in outside air (ground and first floors) and also at various fourth floor locations. The building grand mean was 491 ppm CO_2, and floor mean CO_2 values ranged from above 300 ppm to below 700 ppm (Tables A.9 - A.12). Less than 6% of the individual CO_2 values were greater than 650 ppm (Figure 4.6). The maximum CO_2 concentration observed (675 ppm) was measured in more than one location. These mean and individual values are much less than the ASHRAE guideline of 1000 ppm.

4.2.5 Respirable Particulate Matter

Mean respirable particle concentrations were less than 16 $\mu g/m^3$ (Tables A.13 - A.16) throughout the building and the building grand mean value for real-time particle concentration was 5.5 $\mu g/m^3$. The maximum individual value (50 $\mu g/m^3$) doubles the second-highest individual measurement (24 $\mu g/m^3$). For the sixth floor, the mean real-time particle concentration (10.6 $\mu g/m^3$) was nearly double the other mean floor values. The largest difference between within-day maximum and minimum values (Figure 4.7) occurred on Friday and most probably reflects the mechanical and human-related activities associated with the larger public and LOC employee population located in the selected monitoring locations that day (basement, first and second floors). Nearly 87% of the individual measurements indicated that indoor respirable particle concentrations were <10 $\mu g/m^3$ (Figure 4.8).

Figure 4.3. Plot of Relative Humidity Maximum, Mean, and Minimum Across Floors at The Library of Congress by Earliest Sample Start Time

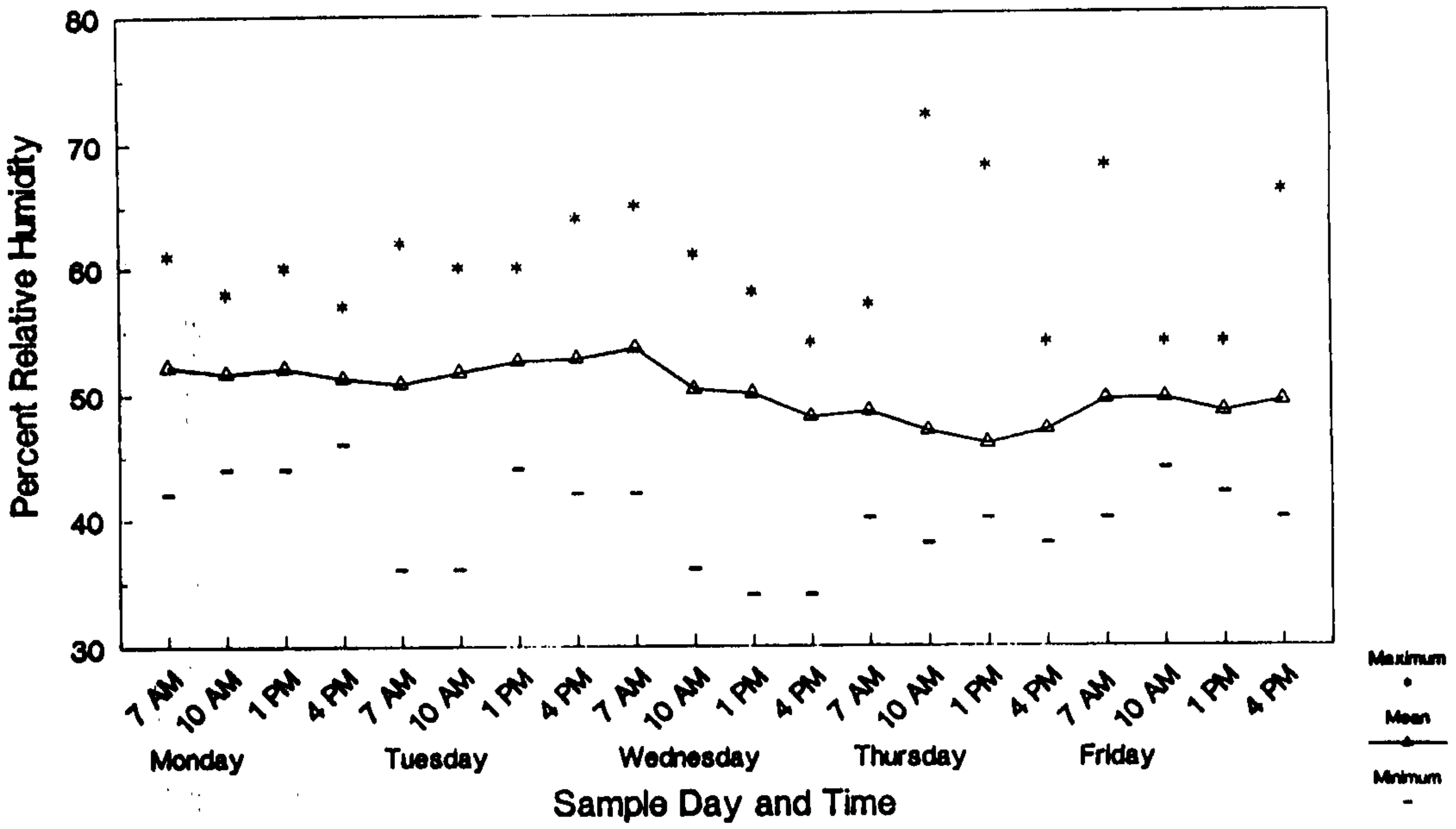


Figure 4.4. Frequency Distribution of Observed Relative Humidity Across Floors at The Library of Congress

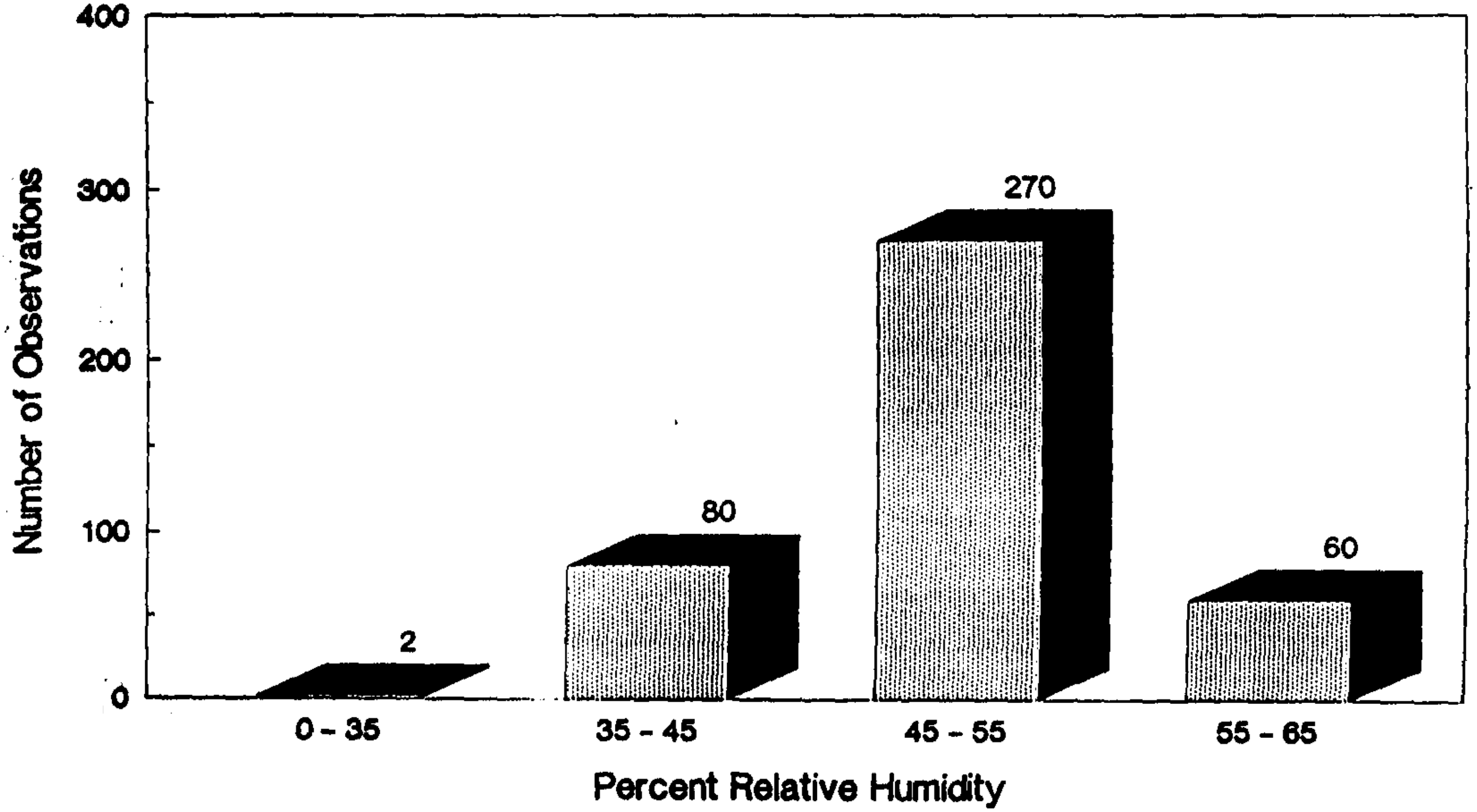


Figure 4.5. Plot of Carbon Dioxide Maximum, Mean, and Minimum Across Floors at The Library of Congress by Earliest Sample Start Time

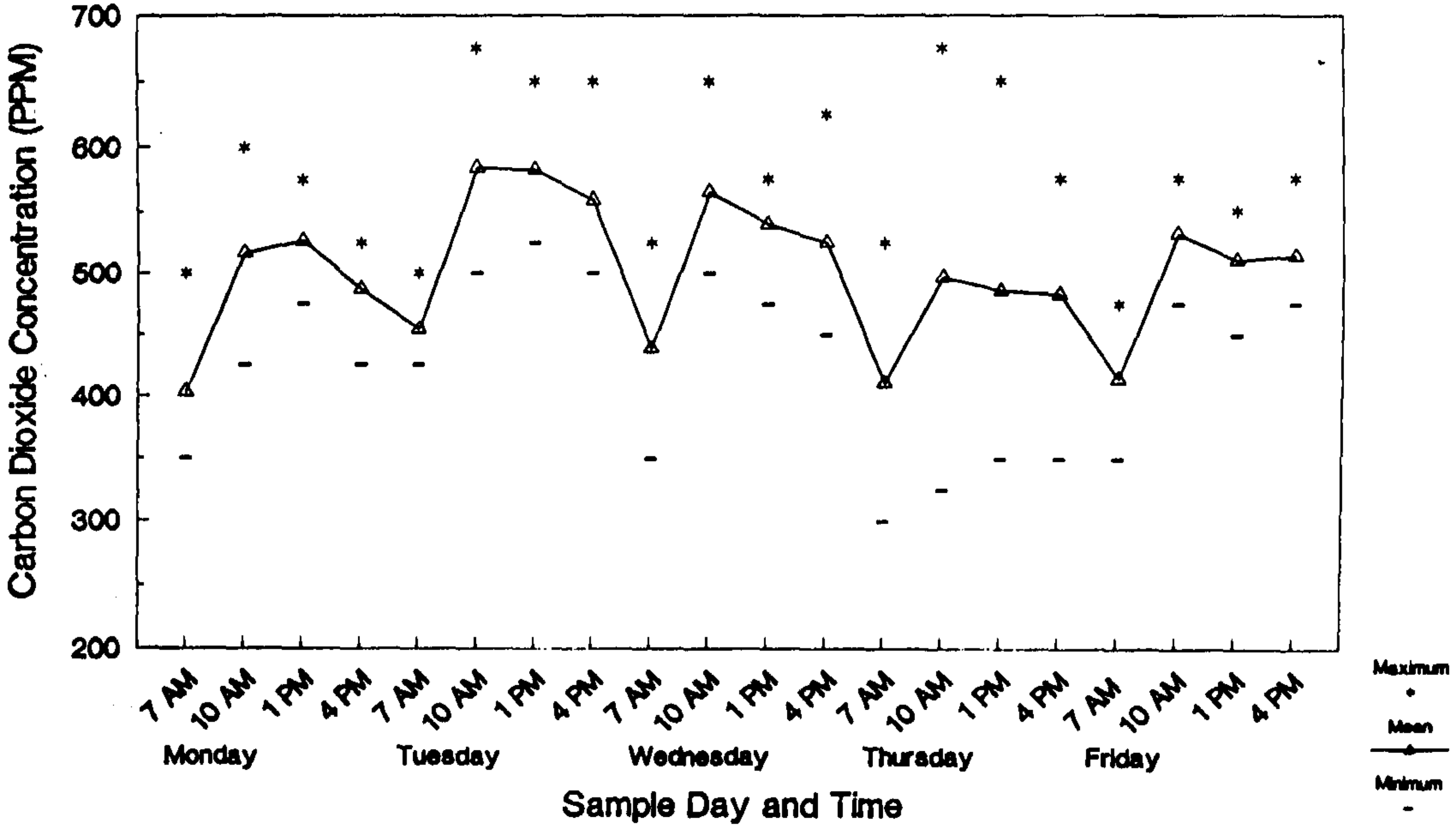


Figure 4.6. Frequency Distribution of Observed Carbon Dioxide Concentrations Across Floors at The Library of Congress

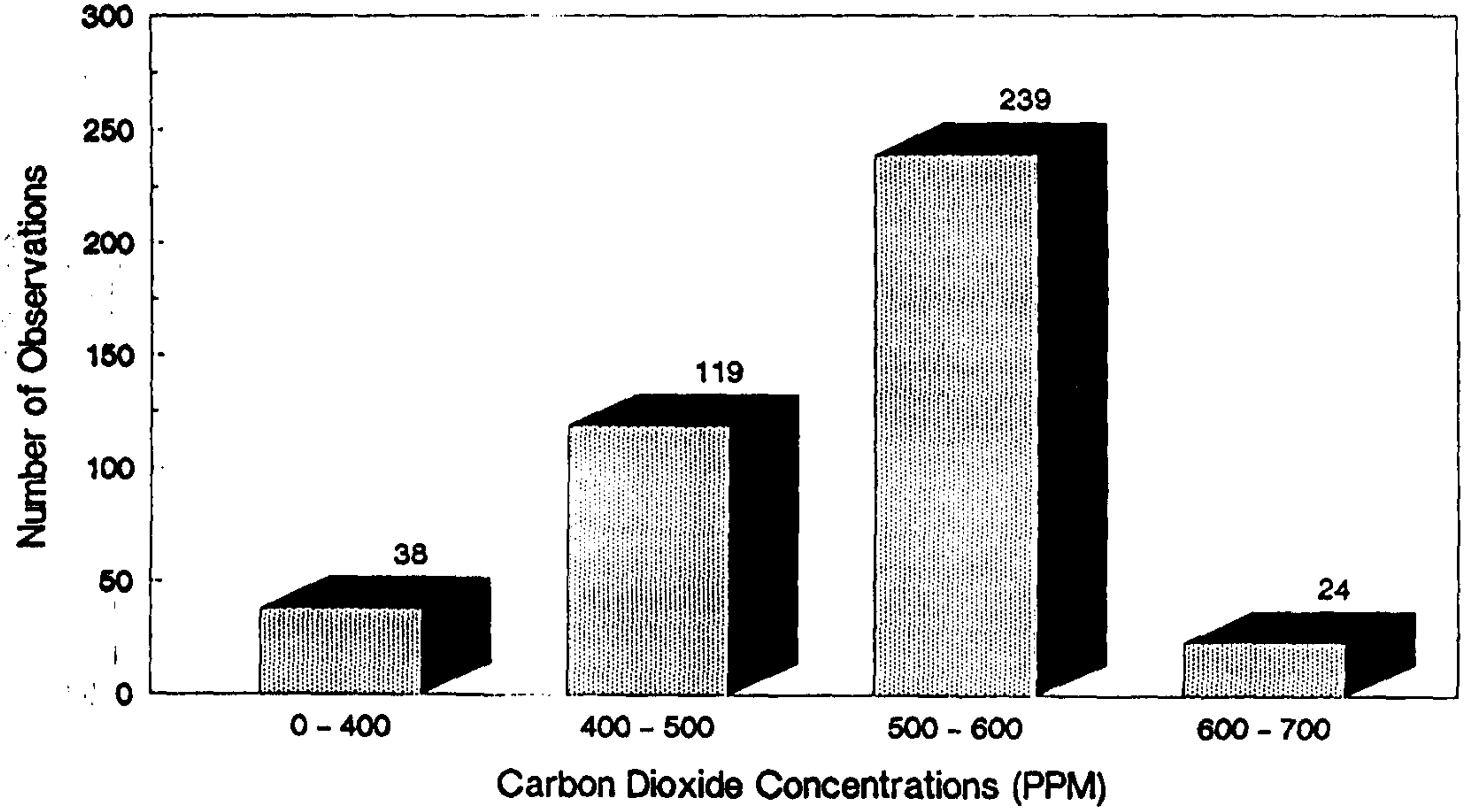


Figure 4.7. Plot of Respirable Particulate Maximum, Mean, and Minimum Across Floors at The Library of Congress by Earliest Sample Start Time

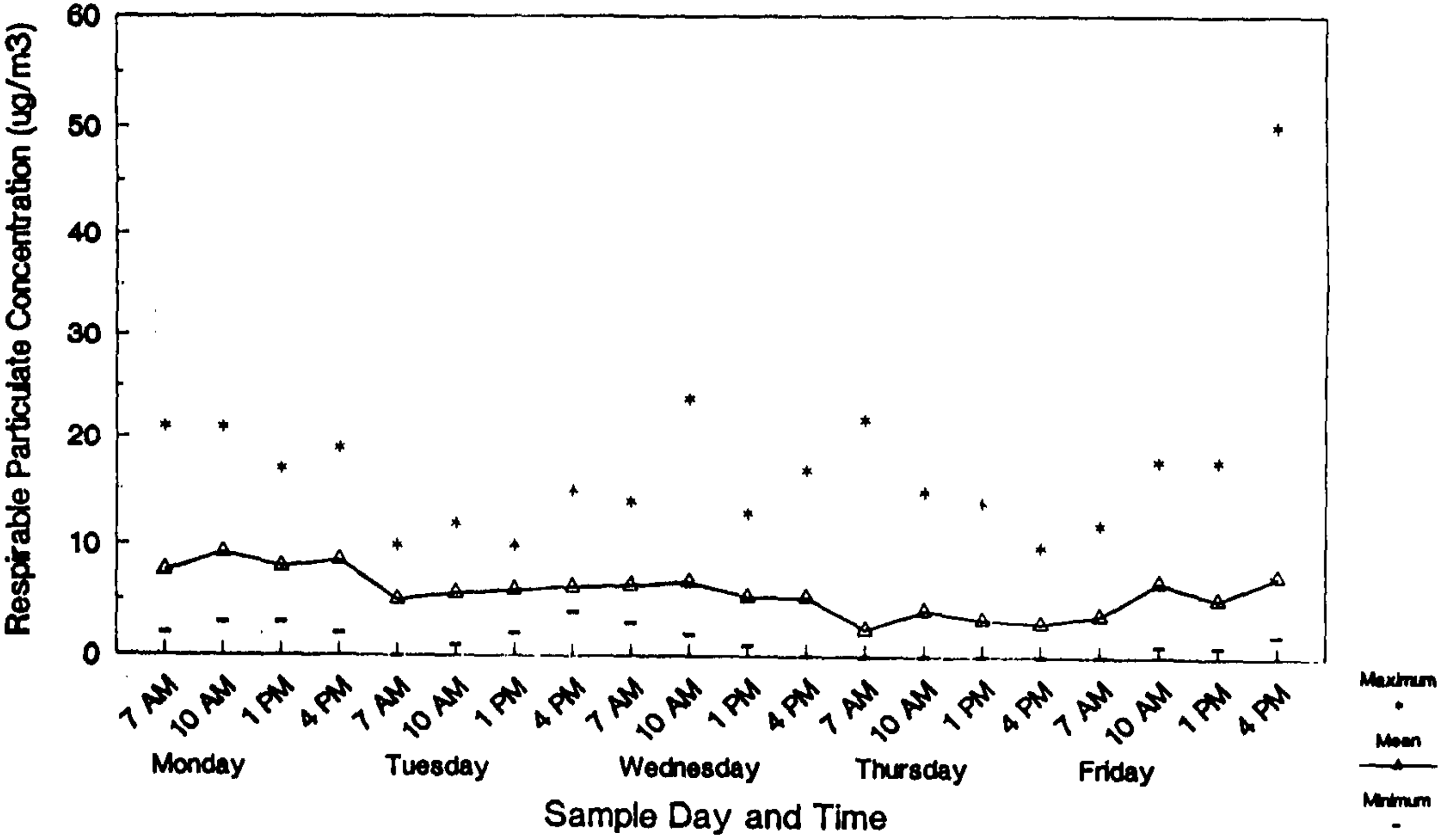
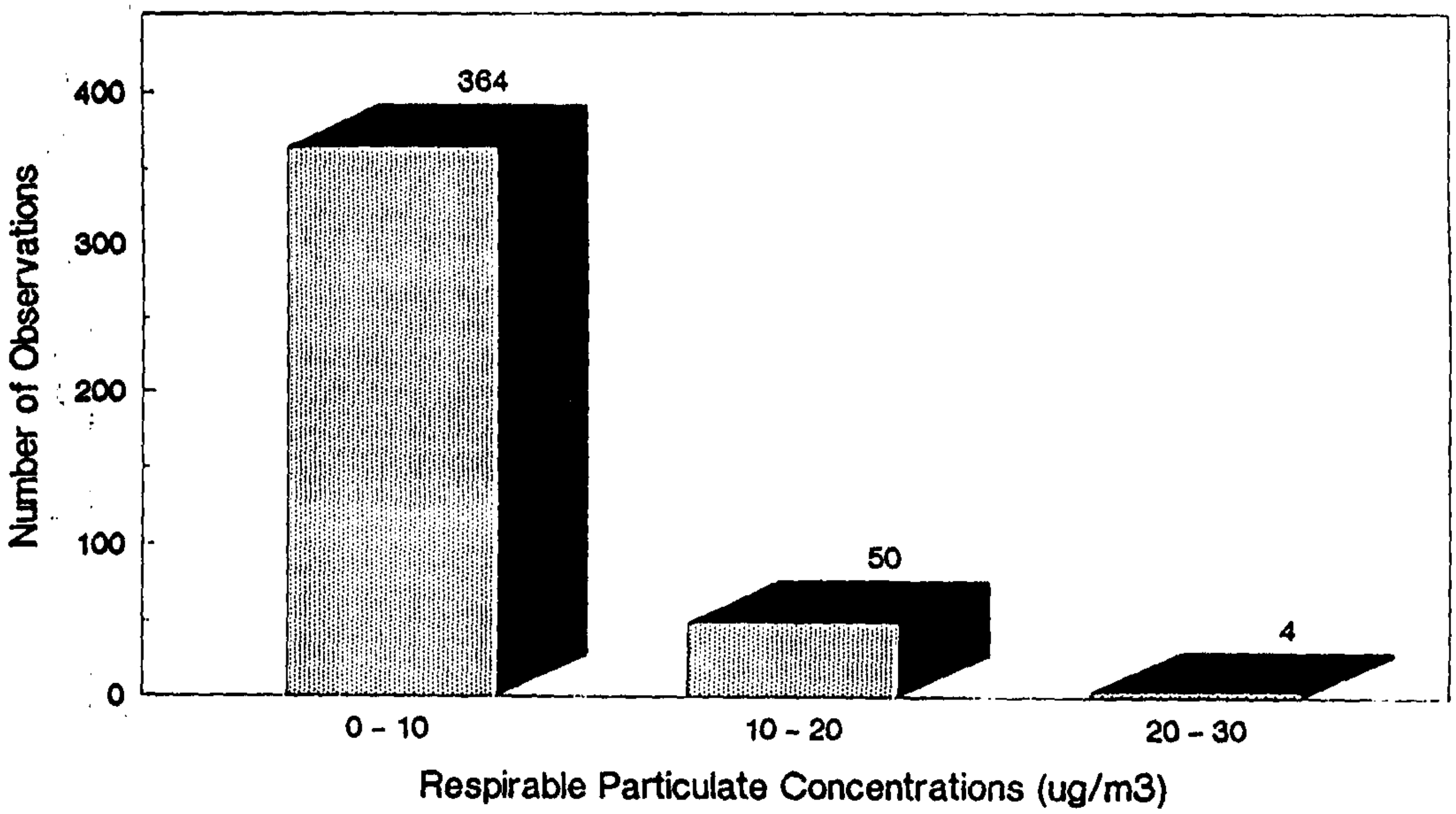


Figure 4.8. Frequency Distribution of Observed Respirable Particulate Concentrations Across Floors at The Library of Congress



4.2.6 NIST Measurements of Carbon Dioxide and Carbon Monoxide

NIST made continuous measurements of building average carbon dioxide and carbon monoxide concentrations, beginning at the time of the LOC study and continuing through September 1989. Figure 4.9 shows the building average and outdoor carbon dioxide concentrations during the week of testing. The indoor concentration increased when the building occupants arrived, reaching a peak in the late morning. There was a slight decrease in the middle of the day, due to decreased occupancy during lunch, followed by a second peak in the afternoon. When the occupants left at the end of the working day, the concentration decreased. During unoccupied periods, the indoor concentration was driven by variations in the outdoor concentration. During this week of monitoring, the daily peak of the building average concentration was between 500 and 525 ppm. Considering all of the data collected by NIST from February through September, the average value of the daily peak concentration was 501 ppm, the standard deviation was 20 ppm, and the largest value for a daily peak was 545 ppm.

NIST also made measurements of whole-building average carbon monoxide concentrations during July, August, and September of 1989, and as in the case of carbon dioxide, these concentrations were based on the average of the concentrations in the eight return shafts. The measured concentrations were all very low, at the most 1 or 2 ppm. The indoor concentrations appeared to track the outdoor levels, which increased in the early morning, presumably because of motor vehicle exhaust, and decreased late in the day. This increase in outdoor concentration was also on the order of 1 or 2 ppm during the work week. On Saturdays and Sundays, no increase in outdoor or indoor concentrations was observed.

4.3 Integrated Sample Results

4.3.1 Method for Summarizing Integrated Sample Measurements

Mean species concentrations for each floor were calculated by adding the individual values that were above the limit of quantitation (LOQ) for those samples collected from the corresponding floor monitoring locations and dividing this number by the number of samples above the LOQ. Trace quantities of selected VOCs, concentrations above the limit of detection (LOD) but below the LOQ, were

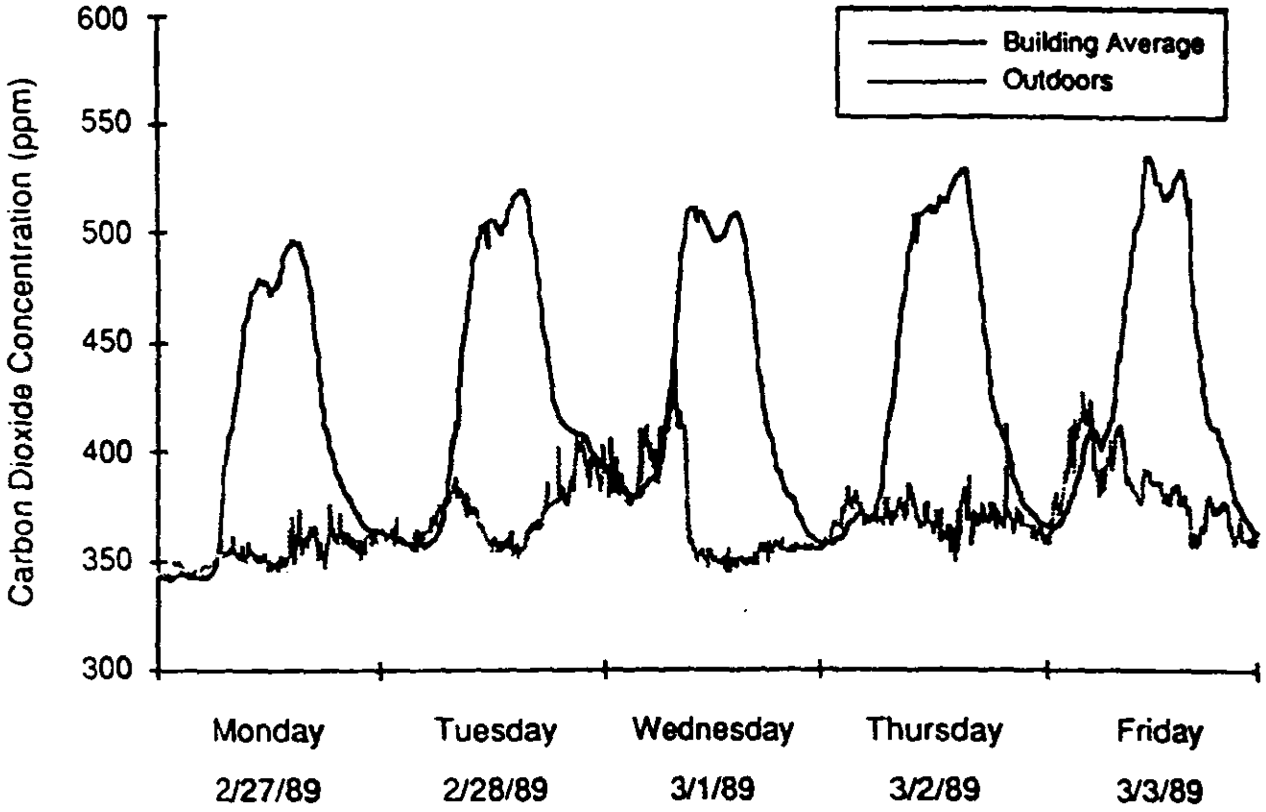


Figure 4.9 Building Average and Outdoor Carbon Dioxide Concentrations at the Library of Congress

also observed when the Summa canister VOC method was used but were not included in the summarized data other than by indicating the number of trace measurements that were reported by individual species. This qualitative measurement approach indicates that through the use of the highly sophisticated mass spectrometer analytical technique, the presence of individual species can be confirmed (i.e., if it is above the LOD). However, the concentration of these species is below the LOQ. Again, samples having trace concentrations of a specific organic compound were not used in the calculation of the floor means for that compound.

4.3.2 Respirable Particulate Matter

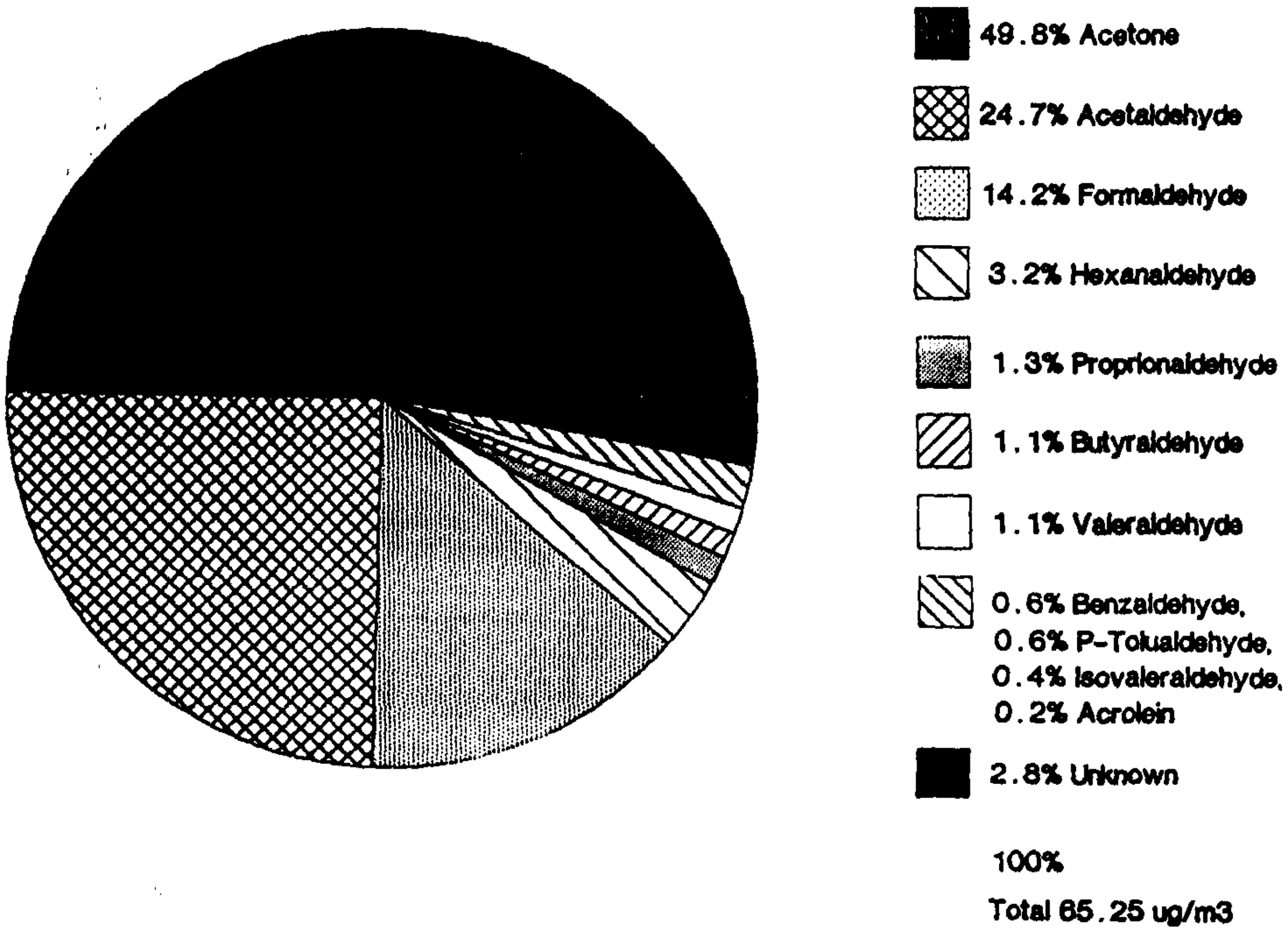
The results of the integrated RSP samples (Table B.1) are consistently higher (5-25 $\mu g/m^3$) than the mean corresponding real-time values calculated over all monitoring locations (Table A.16). Integrated sampler particle means ranged from 10.6 to 30.6 $\mu g/m^3$, and the grand building mean was 19.5 $\mu g/m^3$. The difference between the integrated and real-time particle mean values most probably results from the increased sensitivity of the light-scattering method, the integrated method limit of detection, the real-time versus integrated methodology, and the omission of below LOQ values in the integrated mean. The difference in values may also have resulted from difference in the activities that occurred over the entire sampling period versus those occurring during the short time required for the real-time monitoring method. Regardless, both methods suggest that indoor LOC RSP particle concentrations are low (<50 $\mu g/m^3$).

4.3.3 Formaldehyde and Other Aldehydes

4.3.3.1 Passive Formaldehyde Badges. The results of analysis of the 54 passive formaldehyde badges were all below the analytical limit of detection (34.5 $\mu g/m^3$).

4.3.3.2 Integrated Aldehyde Samples. Figure 4.10 shows the mean building distribution of formaldehyde as well as other targeted carbonyls (Table 3.2) having concentration values greater than 1% of the total carbonyl concentration (mean total carbonyl = 65.3 $\mu g/m^3$). Four target carbonyls, each individually representing <1% of the total carbonyl concentration (Table C.11),

Figure 4.10. Mean Carbonyl Specie Distribution Across Floors at The Library of Congress



were combined (<2%) and graphically represented as was the unknown carbonyls (Table C.10) sample component (<3%). Formaldehyde and other carbonyls were nearly uniformly distributed across the selected building monitoring locations. Formaldehyde (mean - 9.2 μg/m^3), acetaldehyde (mean - 16.1 μg/m^3), and acetone (mean - 32.5 μg/m^3) were the primary constituents found in all samples and constituted 14.2%, 24.7%, and 49.8% of the mean total carbonyl sample. Nontargeted carbonyls accounted for less than 4% of the mean total carbonyl sample. Seven of the 15 targeted species (Tables C.1-C.11) were measured in all indoor samples, and the maximum values for these seven species observed in three fourth-floor samples (acetaldehyde, hexanaldehyde, and butyraldehyde), two fifth-floor samples (acetone and propionaldehyde), one basement sample (formaldehyde) and one ground floor sample (valeraldehyde). Isovaleraldehyde and p-tolualdehyde were each measured at one monitoring location at concentrations 5-8 times the limit of quantitation. o-Tolualdehyde, m-tolualdehyde, and 2,5-dimethylbenzaldehyde were not detected in any indoor samples. No outdoor aldehyde samples were collected during the monitoring study.

4.3.4 Volatile Organic Compounds

4.3.4.1 Volatile Organic Compounds Samples Collected in Summa Canisters. Figure 4.11 summarizes the mean outdoor, mean indoor, and the maximum observed value (identified by floor) for the targeted VOCs observed above the limit of quantitation. With the exception of benzene, toluene, ethylbenzene, and o- and p-xylene, indoor sources appear to be the dominant contributors for these VOCs; that is, the mean indoor concentration more than doubles the mean outdoor concentration. 1,1,1-Trichloroethane, tetrachloroethylene, toluene, and the xylene isomers were the dominant species measured across the building (Figure 4.12).

Most of the targeted chlorinated organic compounds were found in all the indoor samples. Methylene chloride (Table D.1) was detected above the LOQ in 54 of the 55 indoor samples but only one outdoor sample, the mean indoor concentrations nearly tripling the outdoor value. The highest floor mean and the highest individual sample value were observed on the fourth floor (7.3 and 25.7 μg/m^3, respectively). Trichloroethylene (Table D.2) was detected in all indoor samples but quantified in only 29 of the 55 samples. Little variability in trichloroethylene mean concentrations was observed between floors, and the maximum concentration (2.9 μg/m^3) was observed on the fourth

Figure 4.11. Mean Indoor and Outdoor VOC Concentrations and Maximum VOC Concentration Observed at the Library of Congress

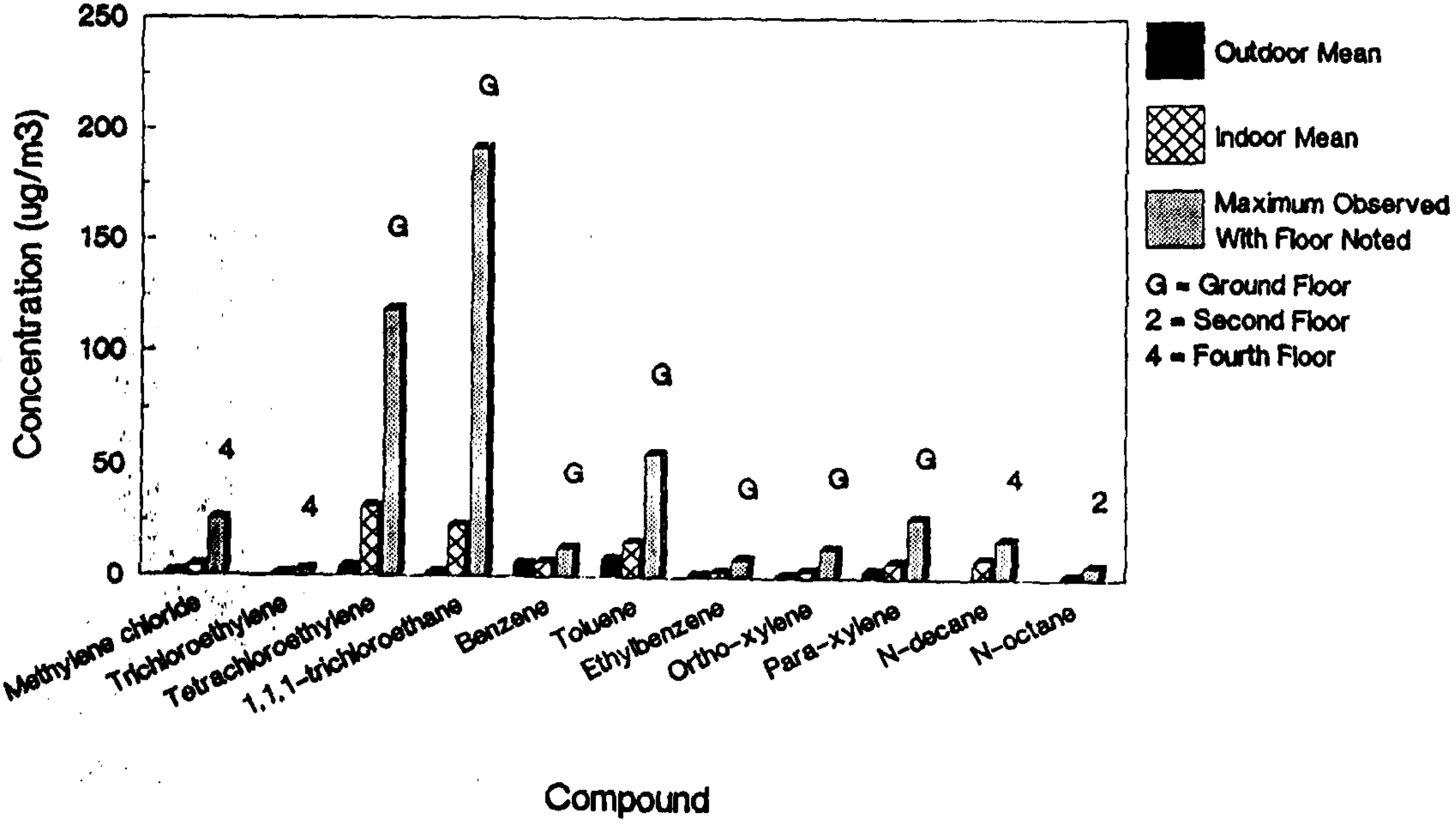
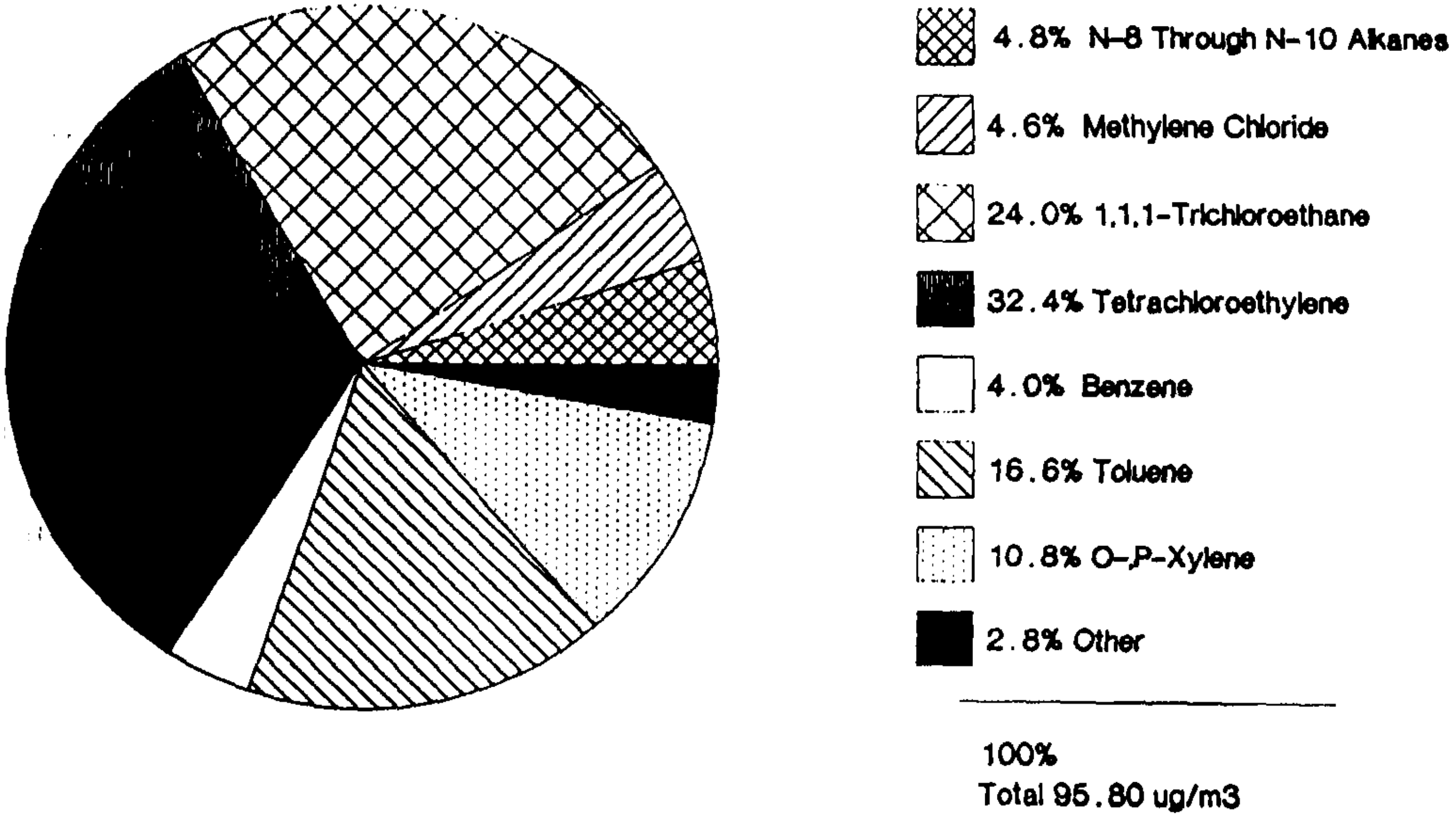


Figure 4.12. Average Volatile Organic Compound Concentrations Based on All Observations Above the Limit of Quantitation at the LOC Primary Sites



floor. Tetrachloroethylene (Table D.3) was quantified in all the indoor samples (mean = 31.0 $\mu g/m^3$). The mean building tetrachloroethylene concentration was 8 times the outdoor concentration. The mean ground and first floor concentrations were 2-3 times greater than the other floor mean values, and the single sample maximum value (118 $\mu g/m^3$) was reported on the ground floor. Chloroform was detected in all the indoor samples, but quantified in only four (range 1.1-1.6 $\mu g/m^3$). Indoor mean 1,1,1-trichloroethane (Table D.4) was more than 10 times the ambient concentration (23 $\mu g/m^3$ vs 1.8 $\mu g/m^3$). With the exception of the first and second floors which are approximately twice the mean building value, floor mean concentrations are about equal to or less than the mean building value. The highest 1,1,1-trichloroethane value (191.2 $\mu g/m^3$) observed was collected on the second floor.

Benzene, toluene, and ethylbenzene (Tables D.6, D.7, and D.8, respectively), organics commonly associated with gasolines and other solvents, were detected in all indoor samples. The mean indoor benzene concentration (6.8 $\mu g/m^3$), calculated by using the 31 samples with levels greater than the LOQ was slightly higher than the ambient benzene concentration (6.0 $\mu g/m^3$). Ground-, first-, and second-floor mean and maximum concentrations were approximately 50% higher than the corresponding benzene values reported for the other floors. Toluene and ethylbenzene mean indoor concentrations (15.9 $\mu g/m^3$ and 2.2 $\mu g/m^3$, respectively) were double the ambient concentrations. Basement and ground floor mean toluene concentrations (32.0 and 33.7 $\mu g/m^3$, respectively) were 2-3 times greater than the other floor mean values. Ground-floor mean ethylbenzene (4.3 $\mu g/m^3$) was nearly double the mean concentrations for all other floors.

o- and p-Xylene (Tables D.9 and D.10, respectively) were quantified in all indoor samples (mean = 3.2 and 7.2 $\mu g/m^3$, respectively) at concentrations more than twice the ambient concentration. The ground-floor mean values for both isomers was nearly double the mean values reported for the other floors. The maximum observed species concentrations (o-xylene = 13.0 $\mu g/m^3$ and p-xylene = 26.9 $\mu g/m^3$) were also reported on the ground floor. Trace styrene concentrations (Table D.11) were detected in less than 50% of the indoor samples.

n-Decane (Table D.12) was detected in 30 of the indoor samples but not in the ambient samples. Third- and fifth-floor mean concentrations were <50% of the mean concentration for any other floors and of the mean building value (8.5 $\mu g/m^3$). n-Dodecane (Table D.13) was detected in only 14 indoor samples. n-Octane (Table D.14) was detected in all indoor and four outdoor samples and quantified in 50 indoor samples. With the exception of the second and sixth floors, the floor mean concentration approximated the mean building n-octane concentration (1.4 $\mu g/m^3$). The maximum value (5.9 $\mu g/m^3$) was observed on the second floor (mean = 2.6 $\mu g/m^3$). Only trace concentrations of n-octane were observed on the sixth floor.

The sum of the targeted compounds (Table D.15) measured indoors, calculated by summing the concentration of the individual target compound concentrations, was nearly six times the corresponding outdoor concentration. The mean values observed for the lower four floors were nearly double the concentrations of the upper four floors. The qualitative measurement of total VOCs (Table D.16) suggests that the indoor VOC concentrations are approximately 3 times the mean outdoor concentrations and that floors 1 and 2 have higher VOC concentrations.

Vinylidene chloride, carbon tetrachloride, chlorobenzene, m-, p-, and o-dichlorobenzene, 1,2-dibromomethane, 1,1,2,2-tetrachloroethane, vinyl chloride, cis-1,2-dichloroethene, trans-1,2-dichloroethene, 1,1-dichloroethane, and 4-phenylcyclohexene were not measured above the limit of quantitation in any indoor or outdoor sample. Trace indoor concentrations, above the LOD but below the LOQ, of chlorobenzene were found in 11 samples, of m- and p-dichlorobenzene in one and six samples, respectively, and of 1,1,2,2-tetrachloroethane and 4-phenylcyclohexene in two and one sample, respectively.

4.3.4.2 Volatile Organic Compounds Collected on Solid Sorbents. The qualitative results for this VOC monitoring and analytical method are summarized by floor in Table 4.1. Several of the species observed via this technique were also identified and quantitatively determined in the Summa canister method.

4.3.5 Pesticides

Chloropyrifos was the only targeted pesticide (Table 3.2) observed above the limit of detection and was found in only one indoor air sample (0.004 $\mu g/m^3$).

Table 4.1 Compounds Identified in Thermally-Desorbed Samples Collected At Library of Congress, Madison Building

	Floor Number					
Compound	G	1	2	3	4	5
Freon			X		X	X
Methyl Ethyl Ketone	X[A]					
1,1,1-Trichloroethane	X	X	X	X	X	X
Hexene or Isomer					X	X
Heptane					X	
Toluene	X	X	X	X	X	X
Tetrachloroethylene	X	X	X	X	X	X
Xylenes	X	X	X	X	X	X
Decane or Isomer		X	X			
Hydrocarbons			X	X	X	X
Limonene						X
Dipropylene Glycols	X[A]					
Glycol	X[A]					
Phenyl Phenol	X[A]		X	X	X	

An "X" indicates the presence of a compound.

[A] - Only found in the print shop for ground floor. This area was not sampled by using the canister method.

4.3.6 Nicotine

Nicotine (18.5 $\mu g/m^3$) was measured in the smoking area of the ground-floor snack bar (Table E.1), as well as in the samples collected in several lounges (range 0.6-11.7 $\mu g/m^3$). Nicotine was measured in four of the primary sampling locations (range 0.4 - 0.7 $\mu g/m^3$).

4.3.7 Fixed Indoor and Fixed Outdoor Monitoring Locations

Tables F.1 - F.4 present the particulate statistics. The mean fine-particle (<2.5 μm) concentration measured over the five day period at the fixed indoor site (5.9 $\mu g/m^3$) was less than one-third the corresponding outdoorconcentration and approximates the building real-time RSP grand mean (5.5 $\mu g/m^3$). The mean indoor PM10 measured at the fixed indoor site (11.7 $\mu g/m^3$) was slightly greater than one-third the corresponding mean outdoor value (31.5 $\mu g/m^3$).

Figures 4.13 and 4.13 graphically shows changes in T, RH, CO_2, and RSP over the entire five-day monitoring period at the fixed indoor and outdoor locations. The outdoor temperature stayed relatively constant between 40 and 50 °F, whereas the relative humidity varied from less than 10% to 65%, a large change in RH occurring on Wednesday morning. The fixed indoor site data are consistent with the mean floor values discussed above and demonstrate small day-to-day variability at this single location.

Figure 4.15 shows the variability of selected organic species over the five-day monitoring period at the fixed indoor site. Integrated aldehyde samples were not collected at the fixed outdoor site. Outdoor VOC concentrations were consistently lower than corresponding indoor values with small daily variation in concentrations. The large day-to-day variations in selected indoor sample VOC species concentrations probably result from building-or worker-related processes.

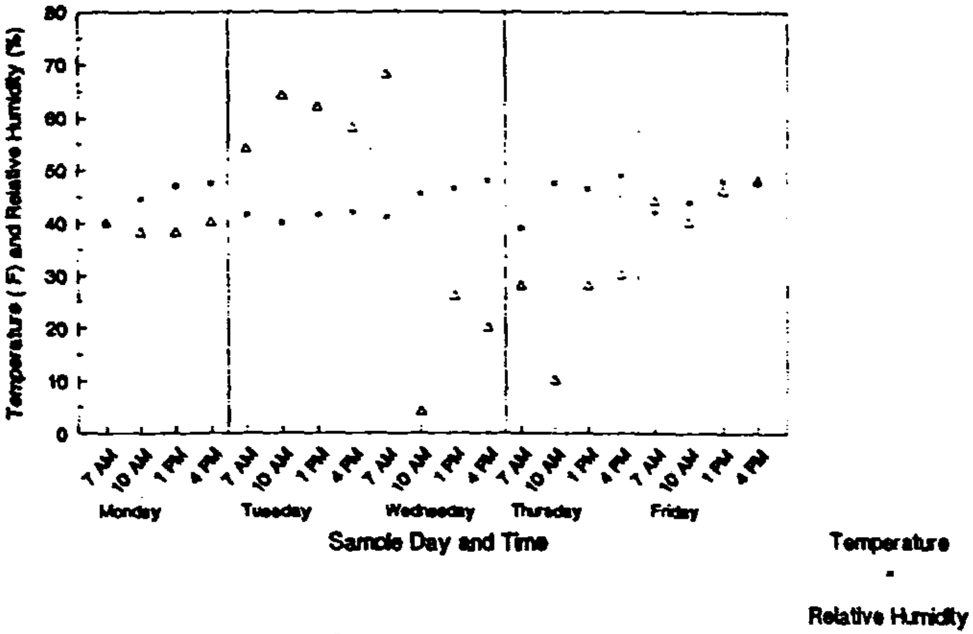
4.4 Microbiological Contaminants

4.4.1 Sampling for Airborne Fungi

In general, airborne fungal concentrations (Table G.1) were low,

Figure 4.13. Indoor and Outdoor Fixed Site Temperature and Relative Humidity by Earliest Sample Start Time

LOC Outdoor Fixed Site



LOC Indoor Fixed Site

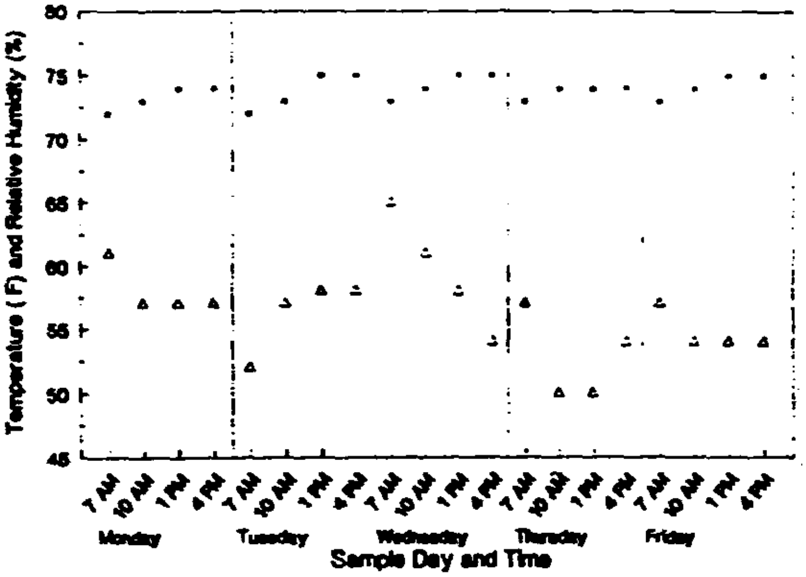
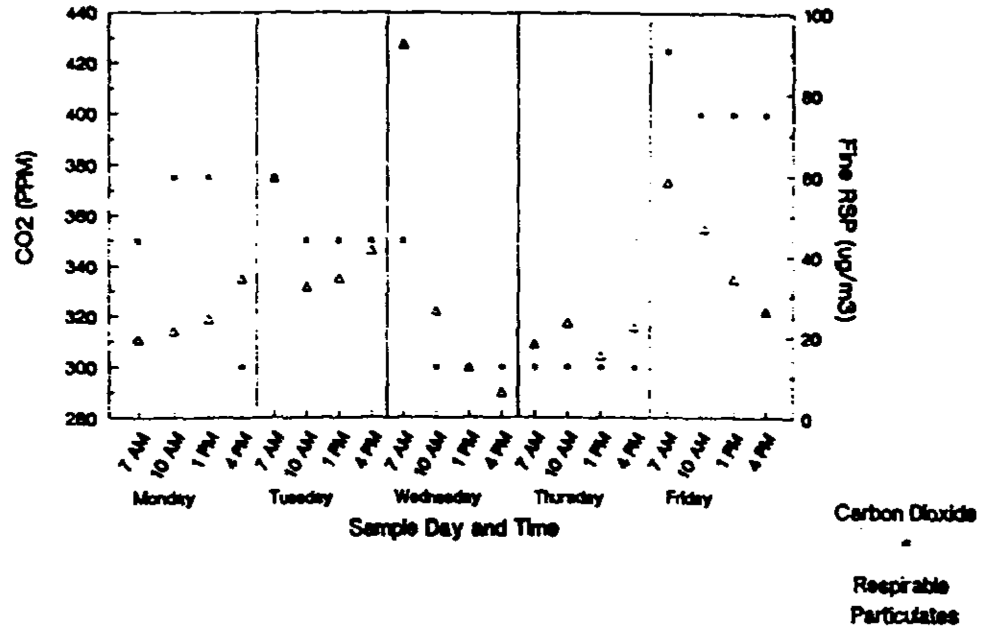


Figure 4.14. Indoor and Outdoor Fixed Site Carbon Dioxide and Respirable Particulate Concentration by Earliest Sample Start Time

LOC Outdoor Fixed Site



LOC Indoor Fixed Site

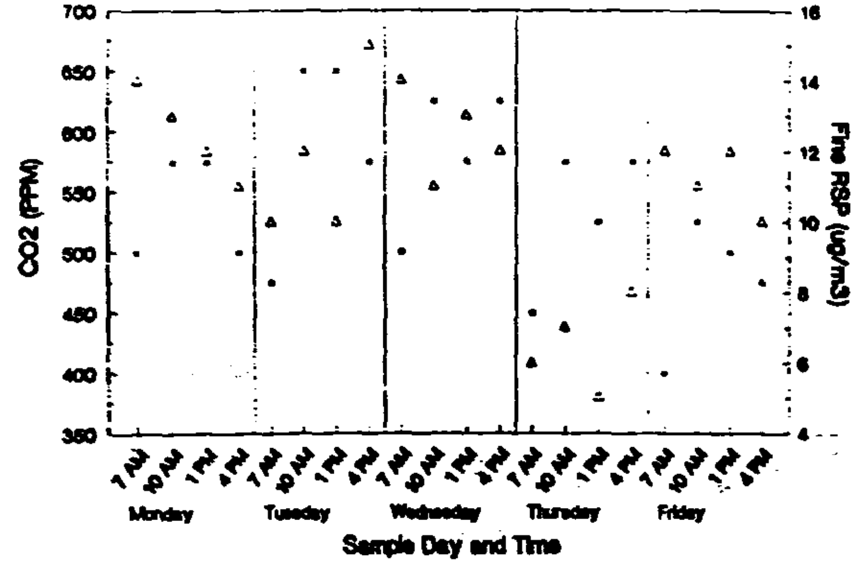
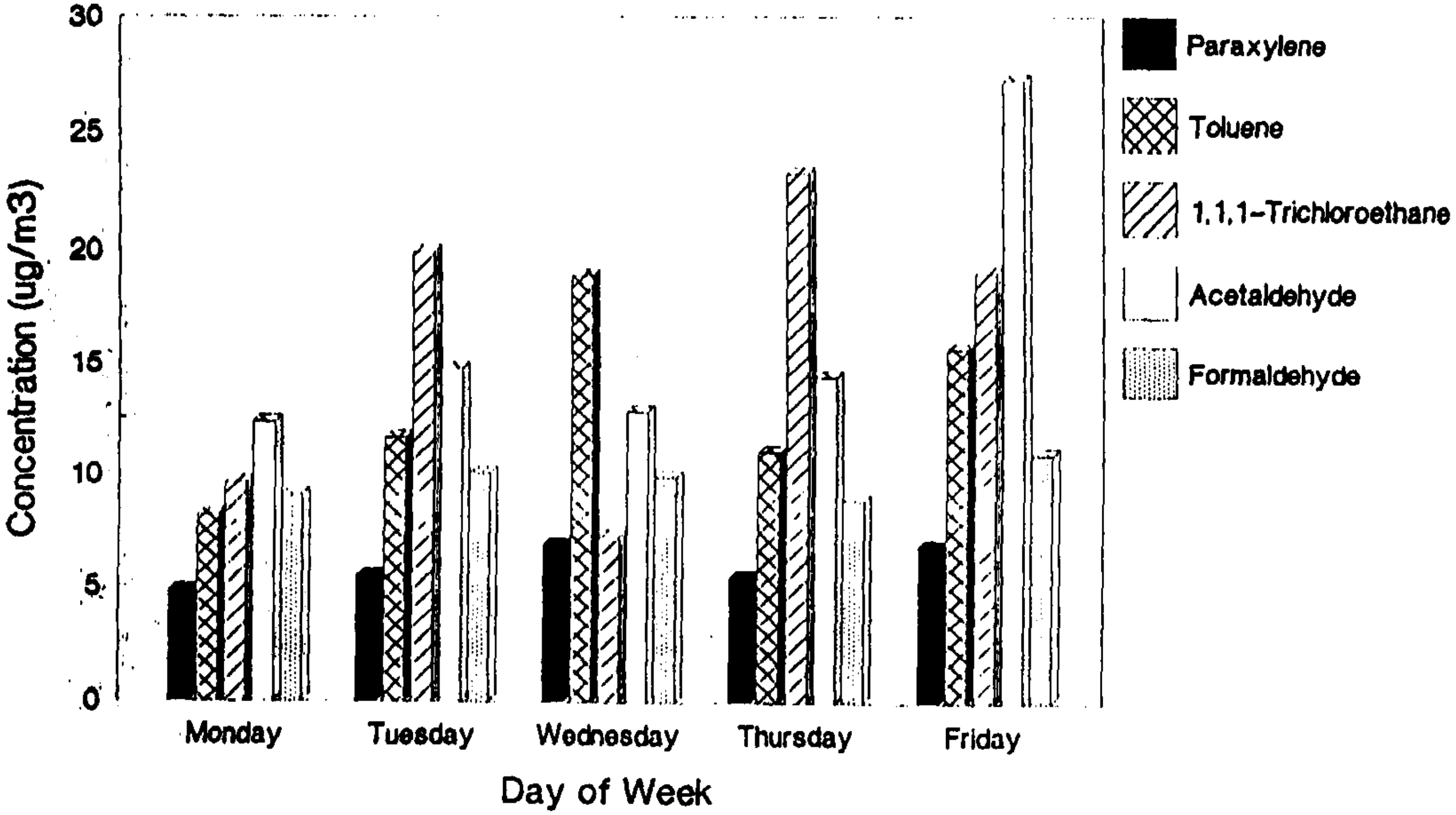


Figure 4 . 15 Concentrations of Selected Volatile Organic Compounds and Aldehyde Species Measured at The Library of Congress Indoor Fixed Site



ranging from an average of three CFU/m^3, in the basement to 110 CFU/m^3 on the fourth floor. The mean building airborne fungal concentration (35 CFU/m^3) was one-third the mean ambient concentration (102 CFU/m^3). Many plates had no fungal growth. No-growth plates more commonly resulted from samples collected on the lower floors, and the percentage of no-growth plates decreased as the floor level increased (Table 4.2).

Table 4.2 Percentage of Airborne Fungal Plates with No Fungal Growth
Library of Congress, Madison Building

Floor	6	5	4	3	2	1	ground	subground
% No-Growth Plates	17	24	24	38	50	63	47	71
	Outside - 10							

The maximum average airborne fungi concentration measured at a sample location was on the fourth floor (1637 CFU/m^3). This elevated count (primarily Penicillium) was likely due to a localized fungal spore source (plant soil, old books, vacuum cleaner effluent, etc.), because sampling in the four nearby locations all showed fungal counts that were less than 15 CFU/m^3, as were fungal counts at two other sampling sites supplied by the same air handling unit.

During repeat sampling at two locations on Friday, the measured fungal concentrations much greater than those in the Monday samples (497 and 345 CFU/m^3 vs. 7 and 11 CFU/m^3, respectively). The minimum and maximum in Table G.1 are average values for all samples collected at a particular location and do not reflect these individual values.

Thirty-nine visually different fungal colony types were cultured from the indoor air samples. Sixteen of these were also observed during analysis of the outdoor samples, and 23 were unique to the indoor air samples. Table 4.3 presents the 10 genera identified, their outside concentrations, and their concentrations by floor. The organisms seen in the highest concentrations

Table 4.3 Average Floor Airborne Fungal Concentrations by Genus
Library of Congress, Madison Building

		Fungal Air Concentration by Floor, CFU/m^3							
Genus	Outside	6	5	4	3	2	1	Ground	Subground
Alternaria	35	7	7	7					
Aspergillus	138	14	56	63	42	6		92	
Cladosporium	91	14	14		14	26	14	7	
Mucor	0			7				7	
Penicillium	70	14	24	287	193	15	14	30	28
Phoma	35	7	7						
Rhizopus	0	7		7	7				
Sporobolmyces	89	8	16	11	13	14	14	11	
Verticillum	0				7				
Yeast	0			7		10	7	7	7
Un-identified	201		28	28	64	28	28	49	

outdoors, in descending order, were Aspergillus, Cladosporium, and Sporobolomyces. Indoors the concentration rank order varies by floor. The most commonly seen organisms indoors were Penicillium, Aspergillus, Sporobolmyces, and Cladosporium. Only indoor Penicillium concentrations exceeded ambient concentrations. The organism seen most frequently throughout the building was Sporobolomyces, but at low concentrations.

4.4.2 Sampling for Airborne Human-Source Bacteria

The building average airborne concentration of human-source bacteria (44 CFU/m^3) was slightly more than half of the outdoor average concentration of 80 CFU/m^3 (Table G.2). Indoor concentrations ranged from 10 to 115 CFU/m^3, and the greatest average floor concentration was measured on the sixth floor. The maximum sample location concentration was found in the sub-ground area (370 CFU/m^3).

Nineteen bacteria colony types were visually identified from the indoor air samples. Nine of these colony types were identified in the outdoor air and 10 were unique to the indoor samples. A rank ordering of identified bacteria species is presented in Table 4.4, comparing indoor concentrations, by floor, to outdoor concentrations. Staphylococcal species were seen most frequently both indoors and outdoors. Indoor Micropolyspora concentrations are elevated on the ground and sixth floors, Proteus on the fourth and fifth floors, and Bacteria "12" on the third floor.

Table 4.4 Average Floor Airborne Bacterial Concentrations by Genus
Library of Congress, Madison Building

		Bacterial Air Concentration by Floor, CFU/m^3							
Genus	Outside	6	5	4	3	2	1	Ground	Subground
Aeromonas	0	0	0	7	0	0	0	7	0
Alcaligenes	0	28	0	0	0	7	0	42	7
Klebsiella	53	0	16	9	7	0	0	0	11
Micrococcus	53	7	10	11	14	18	20	14	53
Micropolyspora	36	95	8	13	13	61	7	110	12
Proteus	35	7	99	141	7	21	0	7	0
Serratia	35	0	0	7	18	0	7	7	7
Staphylococcus	70	54	32	27	33	49	20	31	22
Streptococcus	71	0	21	7	7	0	0	0	0
Un-identified	35	21	39	75	347	37	0	62	14

4.4.3 Sampling for Airborne Thermophilic Organisms

Thermophilic actinomycetes colonies were identified in indoor air samples at concentrations ranging from 1 to 110 CFU/m^3 (Table G.3). The average outdoor and indoor air concentrations were 7 and 13 CFU/m^3 respectively. Airborne concentrations of thermophilic organisms greater than 100 CFU/m^3 were measured at four locations (two on the second floor and two on the sixth floor). The only thermophilic organism identified during this survey was a Micropolyspora species.

4.4.4 Sampling for Spores

Airborne indoor spore concentrations throughout the building were extremely low (Table 4.5). Average floor concentrations for 24-h samples ranged from 9 to 20 spores/m^3. Sample location 24-h averages ranged from <5 to 34 spores/m^3 (not presented). Penicillium/Aspergillus and Cladosporium spores were the only genera classified.

Table 4.5 Average Floor Spore Concentrations
Library of Congress, Madison Building

Floor	24-Hour Average Spores/m^3	# of Samples
5	13	4
4	16	3
1	20	2
Ground	9	2

4.4.5 HVAC System Water Samples

HVAC system water samples were analyzed for human source bacteria, heterotrophic bacteria, thermophilic organisms, and fungi (Table G.4 and Table 4.6). A comparison of microorganism concentrations found between the water-spray and the steam humidification systems is displayed in Table 4.6. The concentrations of all organisms in the steam units were very low (near zero), whereas, except for the thermophilic types, all organisms in the water spray units were orders of magnitude higher.

Eleven human-source bacteria were identified among the samples. Colony type #4 (not identified) and a Streptococcus were most commonly identified. Fourteen different heterotrophic organisms were identified. Organisms #4 and #11 (not identified), Pseudomonas, and Streptococcus were the most frequently distinguished colonies. No thermophilic organisms were identified in any of the water samples. Only one fungal species, a Phoma, was identified in the samples.

Table 4.6 Average Humidification System Water Microorganism Concentrations
Library of Congress, Madison Building

	Organism Concentration, CFU/mL			
Organism	Steam	n=	Water	n=
Human-source Bacteria	0	11	2896	27
Heterotrophic Bacteria	75	10	444,179	27
Thermophilic Organisms	0	1	<1	6
Fungi	0	1	353	6

5. ENVIRONMENTAL MONITORING AND ANALYSIS QUALITY ASSURANCE

5.1 Quality Control Procedures

Considerable care was taken to characterize the quality of the environmental measurements and analytical results. Time and other resource limitations necessitated that different levels of quality assurance procedures be implemented for the monitoring of individual compound classes in this field study. The most sophisticated quality assurance procedures were implemented for those species determined in the initial study design considerations to be of primary concern. The identical analytical laboratories were contracted to support both the Library of Congress Madison Building and the EPA Headquarters Building indoor air quality investigations. Because of the closeness in time for the two monitoring programs (one week) and the extensive laboratory support resources required for these two studies, the sampling media for both studies were prepared by the contractors at the same time. Likewise, the environmental and quality control samples collected from the two studies were simultaneously analyzed by the contractors.

5.1.1 Real-Time Serial Measurements

Each instrument was calibrated in accordance with the manufacturer's specifications immediately before and after each of the four daily monitoring periods for each day sampling was conducted.

5.1.2 Integrated Samples

5.1.2.1 Respirable Suspended Particles and Inhalable Particles. Duplicate low-flow (1.67 L/min) RSP samples were collected at two primary sampling locations. Only one indoor and one outdoor PM_{10} (inhalable particulate) sampler were operated during the study. Therefore, no duplicate PM_{10} duplicate samples were collected. Ten percent of all the tared or final weighed filters were reweighed by an independent operator at the conclusion of each weighing session. If the difference in independent operator weighings exceeded 10 μm for one or more individual filters, all the filters weighed during the weighing session were reweighed. External performance evaluation samples were not available for this method. The RSP and PM_{10} samplers flows were checked at the beginning and end of each sampling period.

5.1.2.2 Volatile Organic Compounds.

The most sophisticated quality control procedures were implemented for VOCs sampling and analysis. Grab VOC samples were collected in two locations one month prior to the monitoring study to assist in the selection of the target VOCs. The sites selected for the grab sample collection were determined on the basis of documented employee concerns recorded by the Safety Office. Cleaned, evacuated canisters were manually opened in the two locations and allowed to come to atmospheric conditions. The canisters were then closed and returned to the laboratory for GC/MS analysis. A full-scan analysis of these samples was conducted, and the compound peaks were identified. In addition, full-scan analysis was conducted on two integrated VOC samples collected during the monitoring study to evaluate potential changes in VOC sources before and during the monitoring period.

Numerous laboratory quality assurance procedures were implemented for VOC analysis. A series of field blanks, spiked control samples, and external performance evaluation samples was provided to characterize the quality of the VOC analysis. The laboratory also conducted duplicate analyses on selected canisters to estimate the representativeness of the aliquot removed from the canister for analysis.

Field quality assurance procedures for VOC sampling included duplicate canister sample collection at two monitoring locations. Each sampler flow controller was checked immediately before and after the monitoring period to ensure proper flow rate. Canister vacuum gauges were checked periodically (two to three times a day) to ensure proper sampler operation.

5.1.2.3 Formaldehyde and Other Aldehydes.

Duplicate passive formaldehyde badge samples were collected at four monitoring locations. Duplicate integrated aldehyde samples were collected at one monitoring site. Passive and integrated sample field blanks were also collected to evaluate biases resulting from storage and shipment of the samples. Aldehyde sampler flows were checked at the beginning and end of each sampling period. External quality control samples were not available for this study.

5.1.2.4 Pesticides.

Because of the limited number of available samples, duplicate pesticide samples were not collected. Field blanks were collected to evaluate potential biases resulting from storage and shipment of the samples. External quality control samples were not available for this study. Pesticide sampler flows were checked at the beginning and end of each sampling period.

5.1.2.5 Nicotine.

Duplicate passive nicotine badge samples were collected at four monitoring locations. Field blanks were also collected to evaluate biases resulting from storage and shipment of the samples. External quality control samples were not available for this study.

5.1.2.6 Viable and Nonviable Microbiological Agents.

Duplicate samplers containing the same growth medium for the retrieval of each group of organisms (fungi, human source bacteria, and thermophilic bacteria) were operated in tandem. To minimize the effects of inherent biological variability, these duplicate plates were averaged to record the concentration of organisms at a particular site. Repeat sampling runs were also performed at randomly selected sites during the same sampling day.

Quality control of the media consisted of incubation of nonexposed plates for sterility checks and incubation of plates inoculated with an appropriate test organism for growth checks. Internal laboratory quality assurance and quality control measures were conducted by the analytical laboratory to ensure accurate identification of the fungal and bacterial isolates and by the University of Michigan Medical Center laboratory for the accurate identification of fungal spores.

5.1.3 Other Quality Control Procedures

Additional administrative procedures were instituted by the field monitoring personnel to ensure data quality. Site environmental samples were physically inventoried against the site log sheet prior to each sampling period and rechecked by an independent operator. Computer-entered data was checked (100%) by an independent operator. At least twice each day, visual and physical checks were conducted at the primary monitoring sites to ensure that the instruments were operating. At the completion of each sampling period, a physical inventory of the site sampling log sheets, the real-time monitoring log sheets, and the samples collected at that site was conducted.

5.2 Quality Control Results

5.2.1 Real-time Serial Measurements

The monitors met the manufacturer's specifications prior to and following each measurement period.

5.2.2 Integrated Samplers

5.2.2.1 Respirable Suspended Particles and Inhalable Particles.

Duplicate personal RSP concentrations differed by 24.1% at one site (18.7 and 14.2 $\mu g/m^3$). No data is available for the second collocated sampling site, as one sample was voided by the operator as the result of a failed pump. Comparisons of the filter weighing performed by the two independent operators revealed that no filter weight exceeded the acceptable weighing limits for either the tare or final weighing sessions.

5.2.2.2 Volatile Organic Compounds.

The results of the full-scan VOC analyses conducted on the samples prior to and following the monitoring period are shown in Appendix H. Few differences are seen in the VOC peak areas between sites, and the major organic compounds identified had already been selected as targeted VOCs. Numerous alkanes and selected Freons were present in the full-scan samples. The GC scan for the field blank and the calibration standards are shown for reference.

The results of analysis on the collocated VOC canisters collected at the two sites are summarized in Table 5.1. Excellent agreement is observed for the VOCs measured at these two locations, which suggests no significant bias in the sampling and analysis procedures.

The results from laboratory duplicate analysis on selected canisters and the results of analysis on field blank, spiked, and external audit VOC samples analyses are shown in Appendix I. These data confirm the high quality of the VOC sample data reported.

TABLE 5.1 RESULTS OF DUPLICATE SAMPLE ANALYSIS

VOLATILE ORGANIC COMPOUNDS

Organic Compound	Site 1		Site 2	
	%Diff [a]	Mean	%Diff [a]	Mean
Methylene chloride	-0.3	3.3	NA [b]	T [c]
1,1,1-Trichloroethane	-7.4	22.4	16.2	13.1
Benzene	* [d]	*	NA	T
Toluene	-0.9	11.0	4.0	10.6
N-Octane	-1.0	1.0	NA	T
Tetrachloroethylene	-5.1	28.4	37.1	18.9
Ethylbenzene	-0.6	1.8	13.6	1.1
p-Xylene	-0.9	5.4	9.5	3.3
o-Xylene	0.0	2.5	12.4	1.4
N-Decane	1.8	9.4	NA	T

ALDEHYDES

Compound	Mean Blank Concentration[e] ($\mu g/m^3$)	%Diff[a]	Mean
Formaldehyde	0.92	2.1	9.0
Acetaldehyde	0.75	0.4	14.4
Acetone	1.62	-7.3	31.2
Propionaldehyde	0.29	-21.1	0.6
Butyraldehyde	0.19	56.5	0.6
Benzaldehyde	0.00	*	NA
Valeraldehyde	0.00	-23.4	0.7
Hexanaldehyde	0.00	-5.1	2.1
Unknown Carbonyls	0.17	7.8	2.0
Total Carbonyls	3.93	-4.0	60.8

[a] % Difference = ((Canister 1 - Canister 2)* 100) / Canister 1.

[b] NA = Not applicable.

[c] T = Trace concentrations were measured in both canisters, above limit of detection but below limit of quantitation.

[d] * = Only one sample was above the limit of quantitation.

[e] Other aldehyde mean blank sample concentrations were 0.0 $\mu g/m^3$.

The analysis of the canister samples for total VOCs using the more qualitative GC method yielded results suggesting potential sample contamination. Some of the laboratory-prepared zero air field blanks and low-VOC-concentration quality control samples had total VOC concentrations equal to or slightly above the concentrations measured in some outdoor samples. As discussed above, the canister samples were cleaned, and selected samples were analyzed by the laboratory prior to shipment for targeted VOCs only. The results of the analysis of selected "clean" canisters for the target VOCs (Appendix I) indicated this sampling medium was cleaned properly for the collection and analysis of the targeted VOCs. Only after the canisters had been shipped to the field and the study already initiated was the total VOC canister analysis included in the study protocol.The canister GC/MS scan data was subsequently reviewed with emphasis placed on the m/z peaks located at 43 and 91, the two major peaks associated with non-aromatic and aromatic hydrocarbon identification, respectively. On the basis of the review of the m/z 43 and 91 peak areas for the seven laboratory-supplied blank samples, the cleaned canisters could be expected to contain 40-102 $\mu g/m^3$ of nontargeted, nonaromatic hydrocarbons and 0-2 $\mu g/m^3$ of nontargeted aromatic hydrocarbons. The environmental sample m/z 43 and 91 peak areas suggest that nonaromatic compound concentrations ranged from 24 to 996 $\mu g/m^3$, whereas the aromatic compound concentrations ranged from 9 to 137 $\mu g/m^3$. This suggests that the non-aromatic hydrocarbons were the dominant class of hydrocarbons collected in the environmental samples.

5.2.2.3 Formaldehyde and Other Aldehydes.

Analysis of the passive formaldehyde badges indicated that all the samples were below the limit of detection. Table 5-1 summarizes the mean blank aldehyde sample concentrations and the results from the analysis of duplicate aldehyde samples.

5.2.2.4 Pesticides.

The results of laboratory matrix spike sample recovery data are shown in Appendix I. No individual pesticide compounds were observed in any of the individual field blank pesticide samples.

5.2.2.5 Nicotine.

Duplicate passive nicotine badge samples differed by 26.9% and 10.8% at two of the four monitoring sites (mean - 5.0 $\mu g/m^3$ and 1.8 $\mu g/m^3$, respectively). Analysis of the duplicate nicotine samples collected at the other two sites were below the limit of detection.

5.2.2.6 Microbiological Samples.

No contamination was recorded on the nonexposed plates, and all of the positive growth plates supported the growth of the test organism(s).

6. VENTILATION EVALUATION RESULTS

6.1 Ventilation Measurement Results

This section presents the results of the measurements of whole-building air exchange rates and discusses the measurements of ventilation effectiveness.

6.1.1 Whole-Building Air Exchange Rates

Whole-building air exchange rates were measured in the Madison Building from the end of January through August 1989, with a total of about 650 individual measurements. Figures 6.1 and 6.2 are plots of the building air exchange rates versus the indoor-outdoor air temperature difference measured during the day and night, respectively. These data indicate that the building air exchange rates are essentially constant over a wide range of temperature differences. The mean daytime air exchange rate is 0.85 ACH with a standard deviation of 0.05 ach. The nighttime mean is 0.79 ACH with the same standard deviation. These standard deviations are similar in magnitude to the measurement uncertainty. Therefore, the outdoor air intake controls are performing as intended; that is, the building air exchange rate is constant. The small variation in the air exchange rates may exist for two reasons. There are small variations in the air exchange rate over the year as discussed below. There are also slight variations over the day that may be related to the supply airflow rate. The VAV air handling systems in this building increase the supply airflow rate as the occupied space requires more cooling. As the cooling load and the supply airflow rate builds up during the day, the air exchange rate increases slightly. This effect may be due to a slight static pressure dependence of the outdoor air intake control system. The difference between the day and night air exchange rates may then be due to the difference in the day and night supply airflow rates caused by the nighttime setback in the supply air static pressure setpoint. Figure 6.3 shows the daytime air exchange rates plotted against Julian date, showing slight variations in the ventilation rate over the year. The amount of variation is small relative to the measurement uncertainty of roughly 10%. This figure contains two horizontal lines, one associated with the minimum ventilation recommendation in ASHRAE Standard 62-1989, which is, 20 CFM (10 L/s) per person, and which corresponds to an air exchange rate of roughly 0.72 ACH. The other horizontal line corresponds to the minimum outdoor air intake rate in the building's

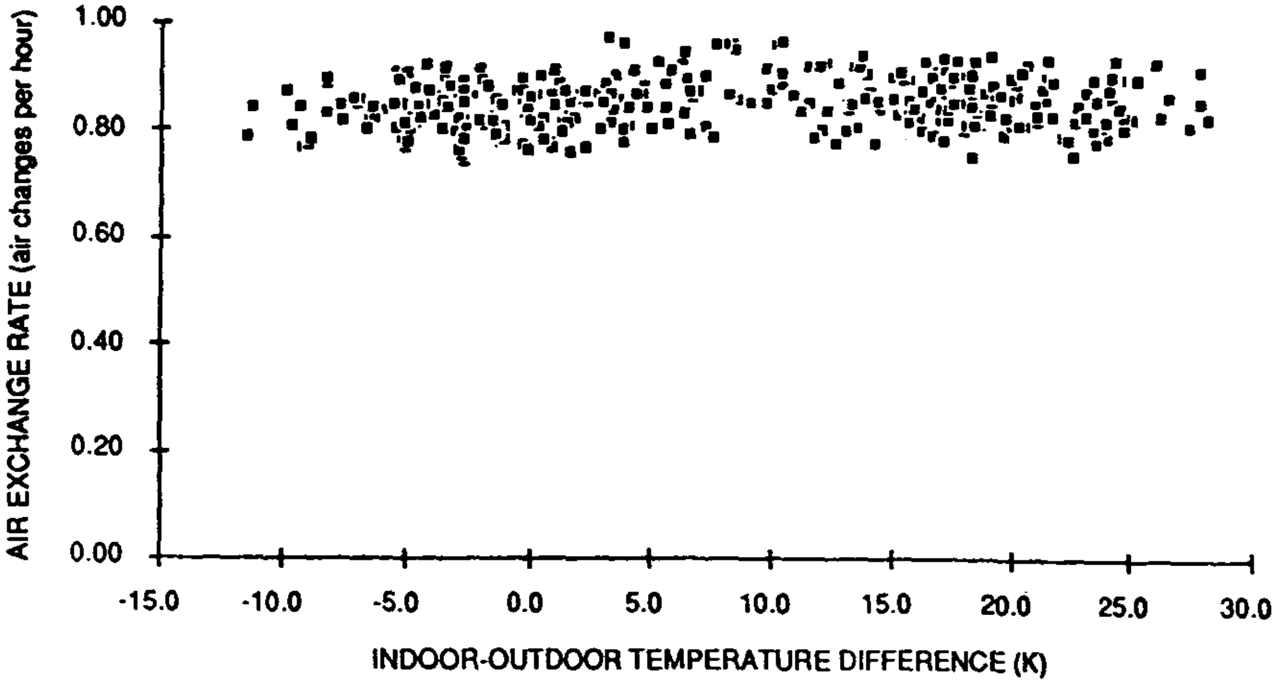


Figure 6.1 Daytime Air Exchange Rates versus Temperature Difference

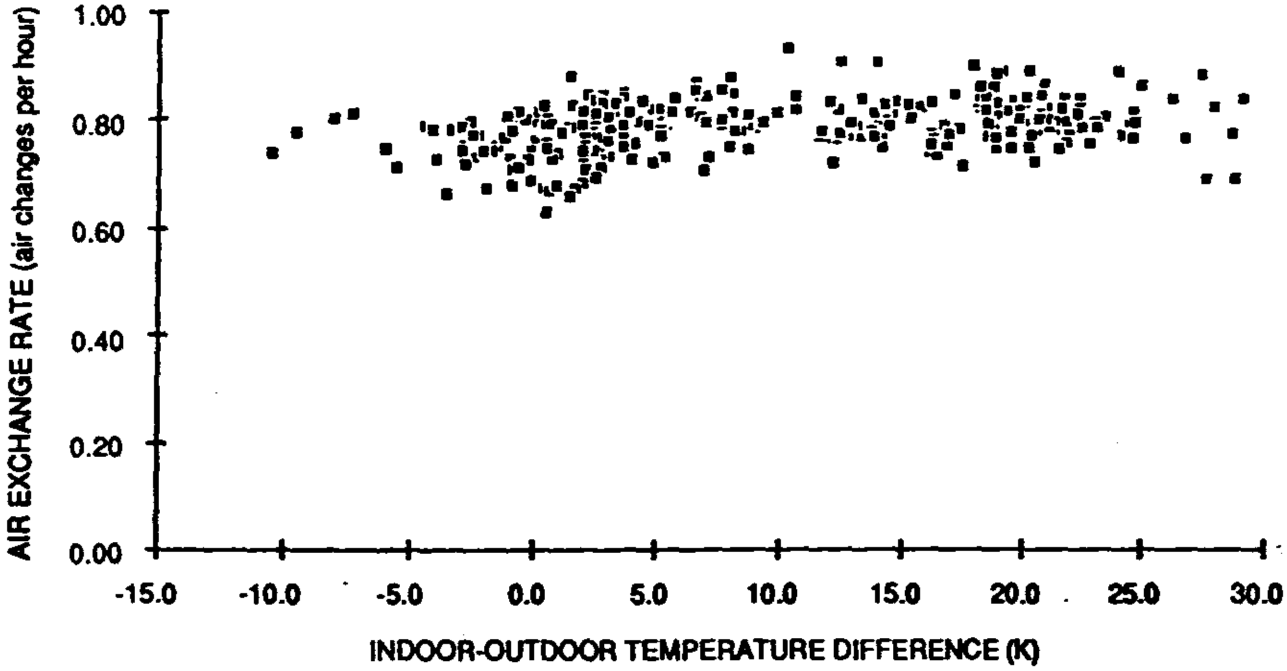


Figure 6.2 Nighttime Air Exchange Rates versus Temperature Difference

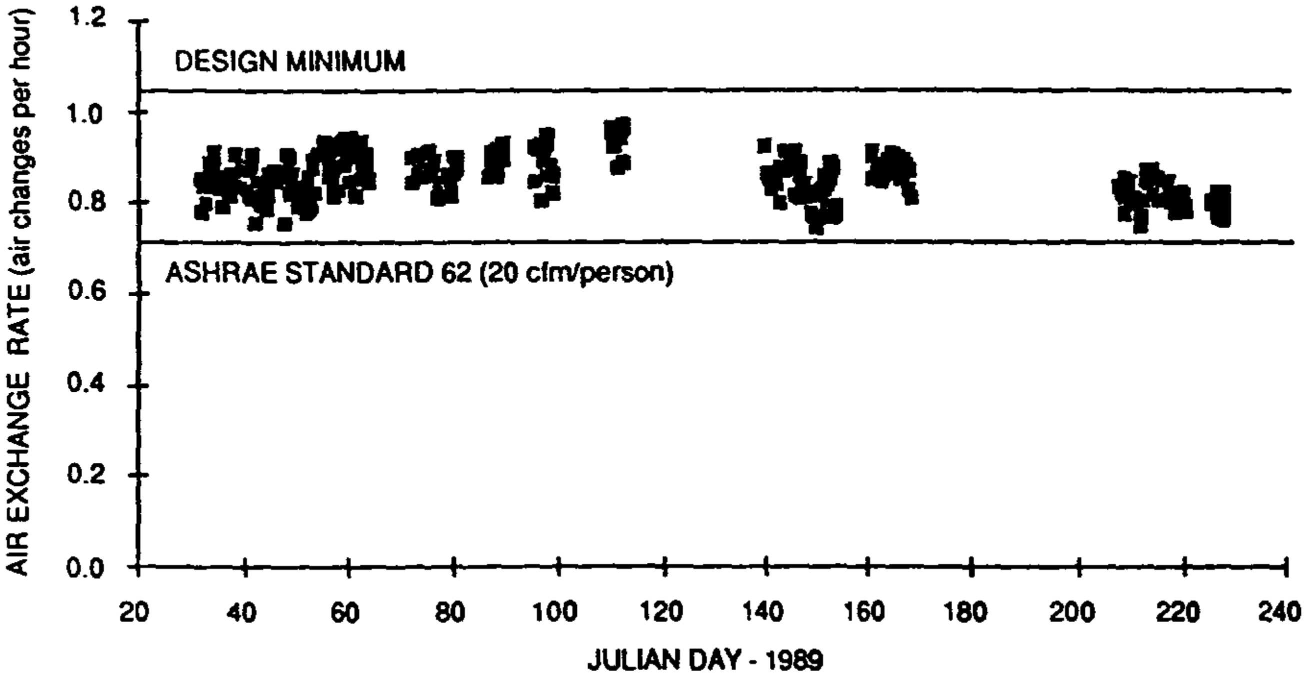


Figure 6.3 Daytime Air Exchange Rate versus Julian Day

ventilation system design, which is about 1.05 ACH. Both the higher and lower limits may be somewhat low since they are based on gross volumes, uncorrected for the volume occupied by interior furnishings and other items. All of the measured air exchange rates are below the design value and above the ASHRAE-recommended value.

The long-term measurements of whole-building air exchange rates and carbon dioxide concentrations in the Madison Building enable the determination of whether the building ventilation rates measured during the week of monitoring are typical for the building. The air exchange rates in Figure 6.3 exhibit variations over the year, but as discussed earlier the variations are not very large relative to the 10% measurement uncertainty. Table 6.1 lists weekly average air exchange rates over the period of the NIST testing of the building. These averages are based on the air exchange rates measured during the occupied hours of each week, from Monday through Friday. Based on the 10% measurement uncertainty in the individual air exchange rates, these weekly averages have an uncertainty of about 0.03 ACH. Therefore, the weekly average air exchange rate during the week of monitoring is only slightly higher than the average of the weeks preceding the test week and no different from the following weeks. The table also lists averages of daily peak carbon dioxide concentrations for the working days of each week, and no significant differences exist between the test week average and the other weeks in the table. Therefore, the whole-building air exchange rates and the building average carbon dioxide concentrations during the test week were not significantly different from the conditions in the building during other weeks of the NIST testing.

6.1.2 Ventilation Effectiveness

NIST made measurements of local tracer gas decay rates and local mean ages of air at 56 locations within the occupied space in order to quantify the uniformity of air distribution, or the ventilation effectiveness, in the building. Although the applicability of these measurement techniques in mechanically ventilated office buildings is not yet well established, the results of these measurements are consistent with good distribution of the outdoor air by the ventilation system to these particular locations. These measurements are described in detail in the NIST report on the Madison Building study.

Table 6.1 Weekly Air Exchange Rates and Carbon Dioxide Concentrations

Week Starting	Average Air Exchange Rate (ach)	Average Peak Carbon Dioxide Concentration (ppm)
30-Jan-89	0.86	**
6-Feb-89	0.85	**
13-Feb-89	0.85	**
20-Feb-89	0.87	**
27-Feb-89*	0.90	516
6-Mar-89	**	505
13-Mar-89	0.88	517
20-Mar-89	0.86	520
27-Mar-89	0.89	**
3-Apr-89	0.90	**
17-Apr-89	0.94	**
22-May-89	0.87	**
29-May-89	0.82	507
12-Jun-89	0.87	510
19-Jun-89	**	516
26-Jun-89	**	504
26-Jul-89	0.82	**
31-Jul-89	0.84	**

* Week of cooperative testing.
** Insufficient data to calculate weekly average.

6.2 Ventilation System Evaluation Results

This section presents results of the qualitative ventilation evaluation conducted during the week of the environmental survey. Tables and figures presenting the data are in Appendix J.

6.2.1 Air Handler Systems

Information collected at the air handlers included the outside air damper position, pressure drop across the filter systems (indicating filter loading), humidification method and condition of humidification systems, control panel gage readings, and AMD gage readings (Table J.1). The AMD instrumentation is inside the outside air intake and continually measures airflow. Twenty-seven penthouse air handlers were inspected. Since the inspections corresponded to environmental sample locations, some air handlers were inspected more than once, but only once per day.

Sensors on the AHUs supplied information to the LOC Building Management System's computer. Printouts of the gage data were obtained which provided information at half-hour intervals between the times of 2:40 p.m. and 5:10 p.m. on February 27 and between 7:10 a.m. and 5:10 p.m. on February 28, March 1, and March 3. Only one-half day's data were obtained for February 27 because of programming setup time for the computer. Data for March 2 were not available because of computer maintenance.

Information from the AHU computer printouts included the AHU discharge dry bulb temperature, the discharge static pressure, and the outside airflow. For these three parameters, means and standard deviations were calculated for each AHU on a daily and weekly basis (Tables J.2 - J.4). Additionally, all of the data were plotted on line graphs to show the trends over the survey week for each parameter, for all of the AHUs (Figures J.1 - J.3).

6.2.1.1 Outside Air Supply. Outside air (OA) dampers on all air handlers were visually inspected and estimated to be between 90 and 100% open. For 62 observations, 53 (85%) were 100% open, five were 98% open, three were 90% open, and one was not recorded. The OA damper positions on the inspected AHUs did not vary between observations and were believed to be in the maximum-open positions on the basis of the AMD readings.

Table J.1 and Figure J.1 present data showing how the outside airflow rates supplied to the AHUs varied over the survey period. These were calculated from the AMD gage information. These OA airflows can be compared to the specifications in Table 2.1.

These trends in the outside airflow can be used to reveal the AHU supply air trends, since the OA dampers were fully open; as the unit supplies more air to the building, the AMD reflects this as an increase in sensed outside airflow. The line graphs also allow observation of certain phenomena associated with AHU operation. The supply airflow to the building for each unit should remain relatively constant or show a gradual rise or fall throughout the day (Figure 6.4). However, some erratic behavior was observed (Figure 6.5). This behavior could indicate a control malfunction (searching), or that the unit is not sized to handle its assigned thermal load.

6.2.1.2 Filter Systems. The roll filters are advanced whenever the sum of the pressure drops measured across both AHU filter systems (roll and bag filters) is equal to 1.5 in. w.g. The greatest pressure drop across the filters recorded during the week of the environmental survey was 0.85 in. w.g. AOC staff change the bag filters annually, or more often if visual inspection shows that the change is needed.

Problems with air handler roll filters were noted. On 13 of the 30 AHUs, all roll filters advanced properly when tested. All other units had one or more roll filter that would not advance with the motorized system. AOC maintenance staff reported that inoperable filters were rotated by hand when the pressure drop across the filter indicated sufficient loading.

Some of the bag filters become thoroughly wetted from spilled water during coil cleaning. Continual wetting and drying will cause this type of filter material to harden and decompose, which can cause glass fibers to be released in the airstream. It will also cause the filters to become less efficient because of the hardening of the filter cake.

Figure 6.4. Normal Outside Air Flow Trends Occurring During Survey Week

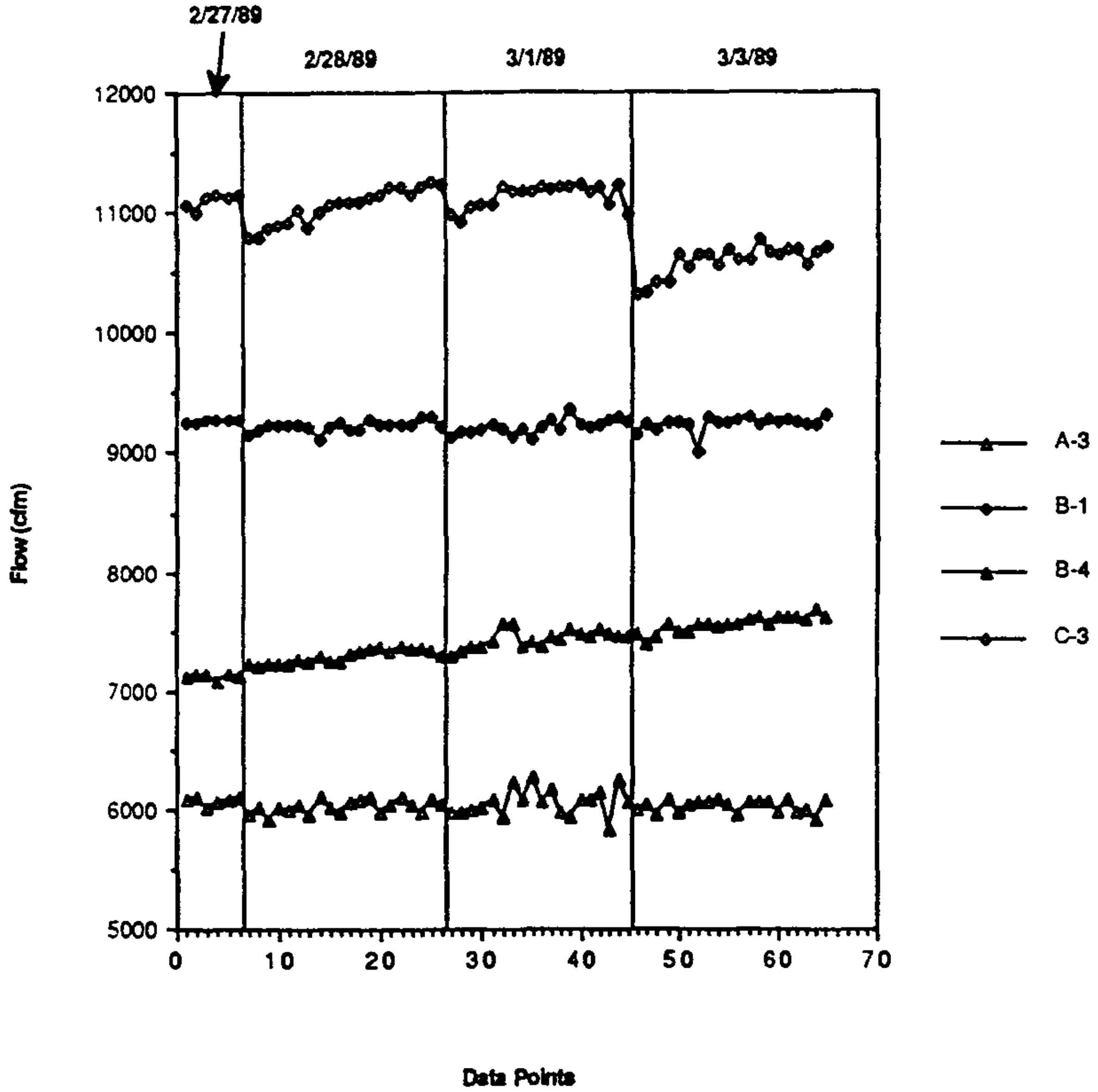
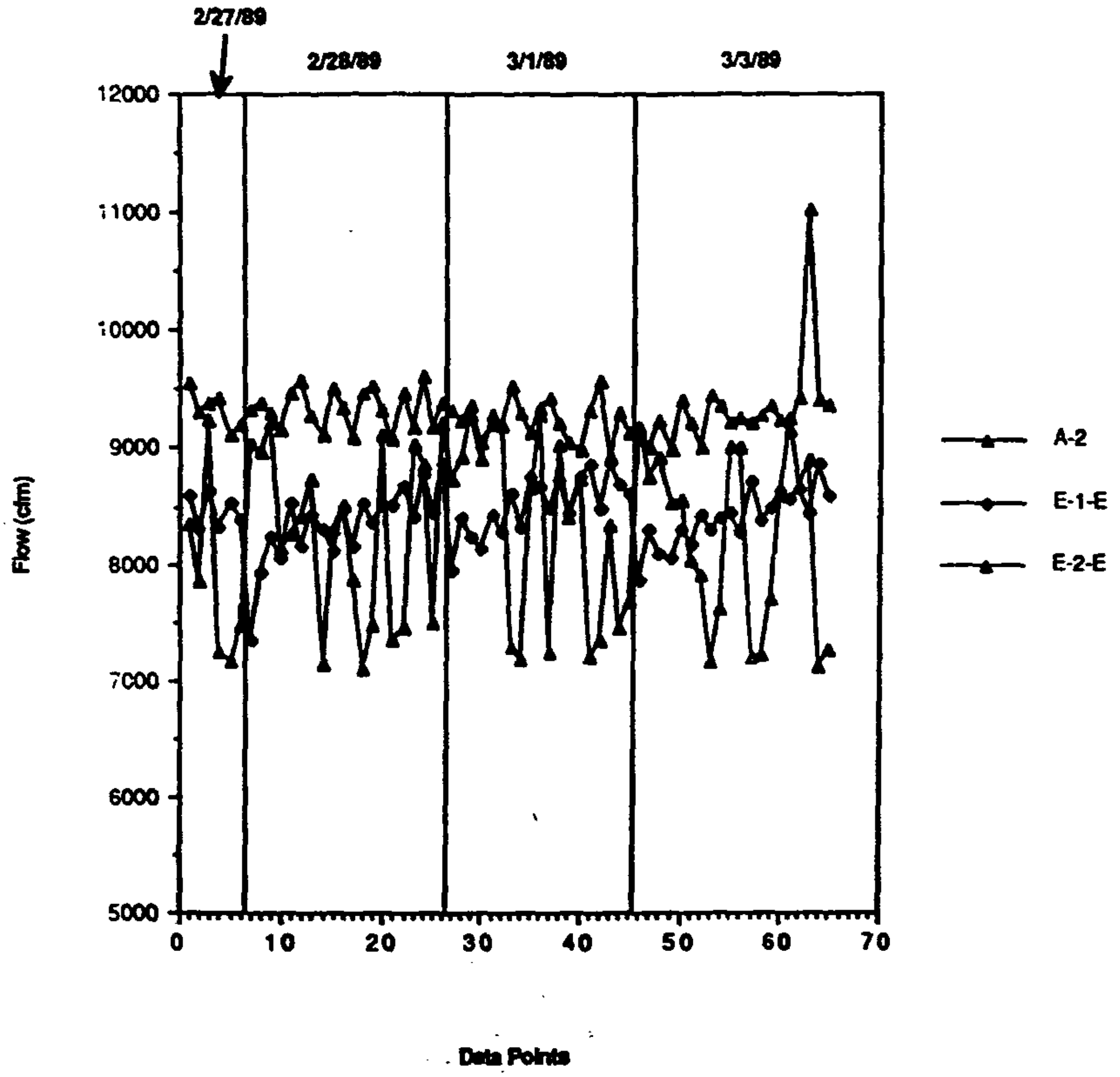


Figure 6.5. Erratic Outside Air Flow Trends Occurring During Survey Week



6.2.1.3 Humidifier Systems. Eighteen of the inspected air handlers had spray humidification, seven had steam humidification, and no humidification was noted on two units. One of the steam units had very light steam injection and two had no steam injection when inspected.

During the survey, spray-wash cleaning of the cooling coils on an air handling unit with spray humidification was observed. On average, AHUswith water spray humidifiers reportedly receive a spray wash every two weeks, and a more thorough cleaning less frequently. The primary difference between the thorough wash and the routine spray washing is descaling. Scale is formed on AHU surfaces from minerals in the tap water and algae. Spray washing entails shutting down the AHU during the evening, draining the reservoir, and spraying the coils for one to two hours with pressurized hot water. After washing, all of the water in the coil reservoir and in the air handling unit is vacuumed, and the reservoir is refilled with tap water.

Two AHUs cleaned the previous day were inspected. A frothy foam was observed on the reservoir water downstream of the coils, and some foam was on the floor of the air handler. The foam was slimy and had a foul smell. Reportedly, this foam results from the dead algae on the coils and dissipates after a few days. AOC personnel reported that most complaints about "fishy odors" normally occur in the time just after a coil is cleaned, and only when the spray humidifiers are working.

6.2.1.4 Gage Information. Control panel gage readings recorded at the time of inspection were mostly unremarkable, except for "off-scale" readings. The off-scale readings appeared only on the outside air dew point temperature gages. These gages are linked to the control systems for the outside air preheat coils on the air handling units. Their possible malfunction may impact the operation of the preheat coil. Several gages on AHU E-2-W exhibited a phenomenon called searching (the gage needle continually oscillated up and down the scale).

For comfort, one important parameter is the relative humidity of the supply air, reflected, in part, in the readings on the supply air dew point temperature gage. This gage is important since its sensor's operation affects the humidity of the supply air and the thermal comfort of the building occupants. The supply air dew point temperature stayed relatively constant for each air handling unit from day to day.

6.2.1.5 Air Delivery Parameters. The AHU discharge dry bulb temperature is the temperature of the supply air (air being supplied to cool the Library spaces) as it leaves the air handlers. The discharge static pressure is the static pressure maintained in the main supply ducts (the ducts up to the VAV boxes). Changes in the discharge static pressure reflect proportional changes in the amount of airflow through the VAV box for a given damper position. The AHU discharge dry bulb temperature and static pressure are parameters which can be controlled by the system operators to alter the characteristics of the air supplied to the office spaces. For example, a slight increase in the discharge dry bulb temperature can cause the VAV boxes in a zone to stay open longer in response to a signal from a local thermostat. Also, by increasing the static pressure in the main supply duct, the air handling unit can push more air into a space for a given VAV damper position.

Inspection of the temperature data (Table J.3) and the static pressure data (Tables J.4) indicates that there were no abnormal alterations in the operation of the AHUs. The standard deviation of the overall temperature and static pressure data was small compared to the mean, which indicated that no large changes were taking place during the survey.

Normally, for a VAV system, the temperature would be expected to remain relatively constant (Figure 6.6). However, some trends were seen which may indicate control problems (Figure 6.7) such as "searching". The graph for NE-2 (Figure 6.8) shows an instability in the temperature setpoint. Most of the graphs showed alterations in the supply air temperature, some more than others. This could correspond to areas of increased comfort complaints where the AOC personnel change the temperature setpoint more often. This could also indicate that some of the AHUs are not sized properly, there is a mechanical problem, or some other type of problem.

Static pressure for a VAV system would also be expected to remain constant (Figure 6.9). However, some setpoint instability was observed (Figure 6.10). These graphs show frequent alterations in the setpoint, as do the temperature graphs, which indicates problems similar to those discussed for the temperature graphs.

Figure 6.6. Normal Supply Air Dry Bulb Temperature Trends

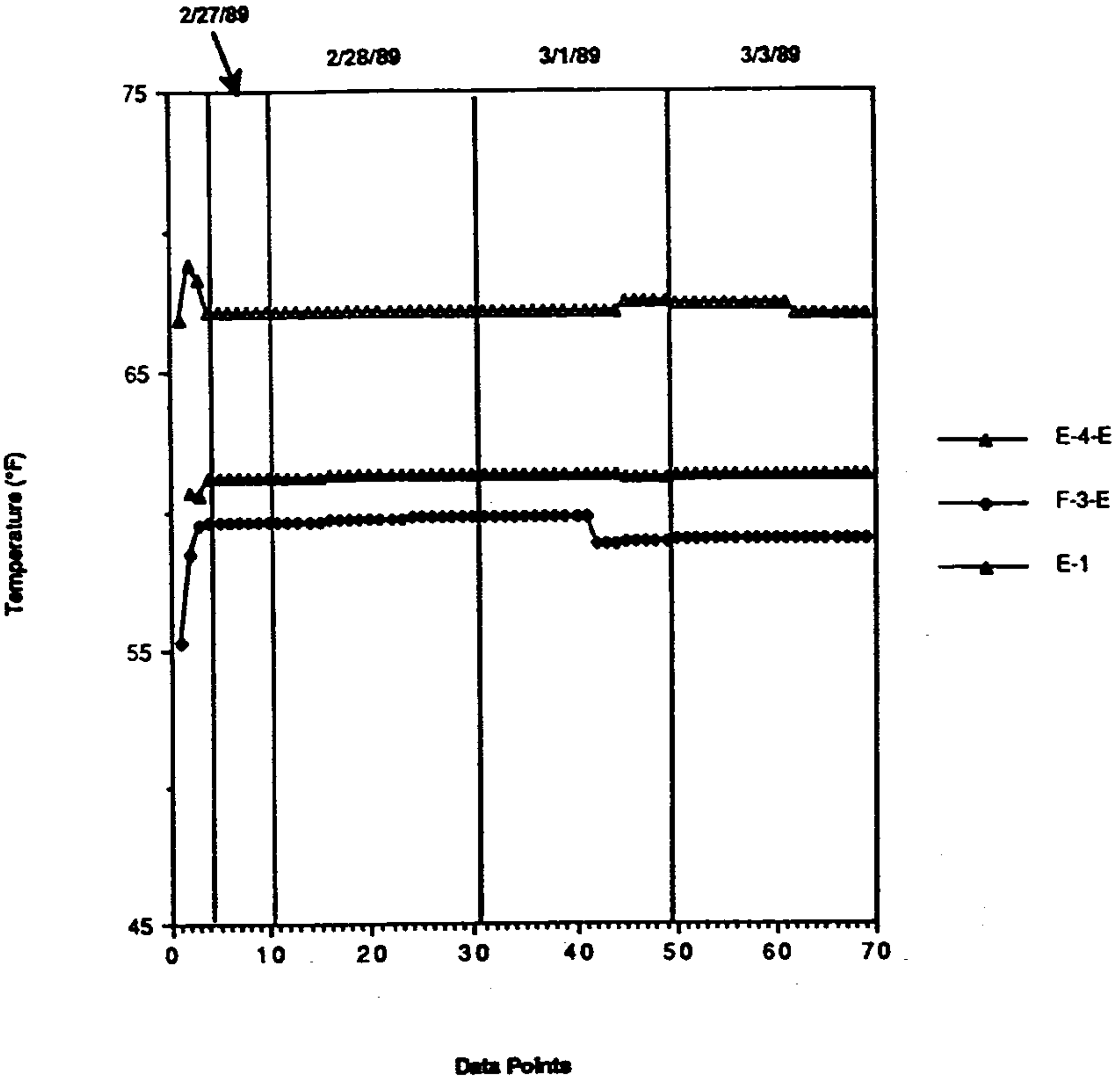


Figure 6.7. Supply Air Dry Bulb Temperature Trends Showing Searching

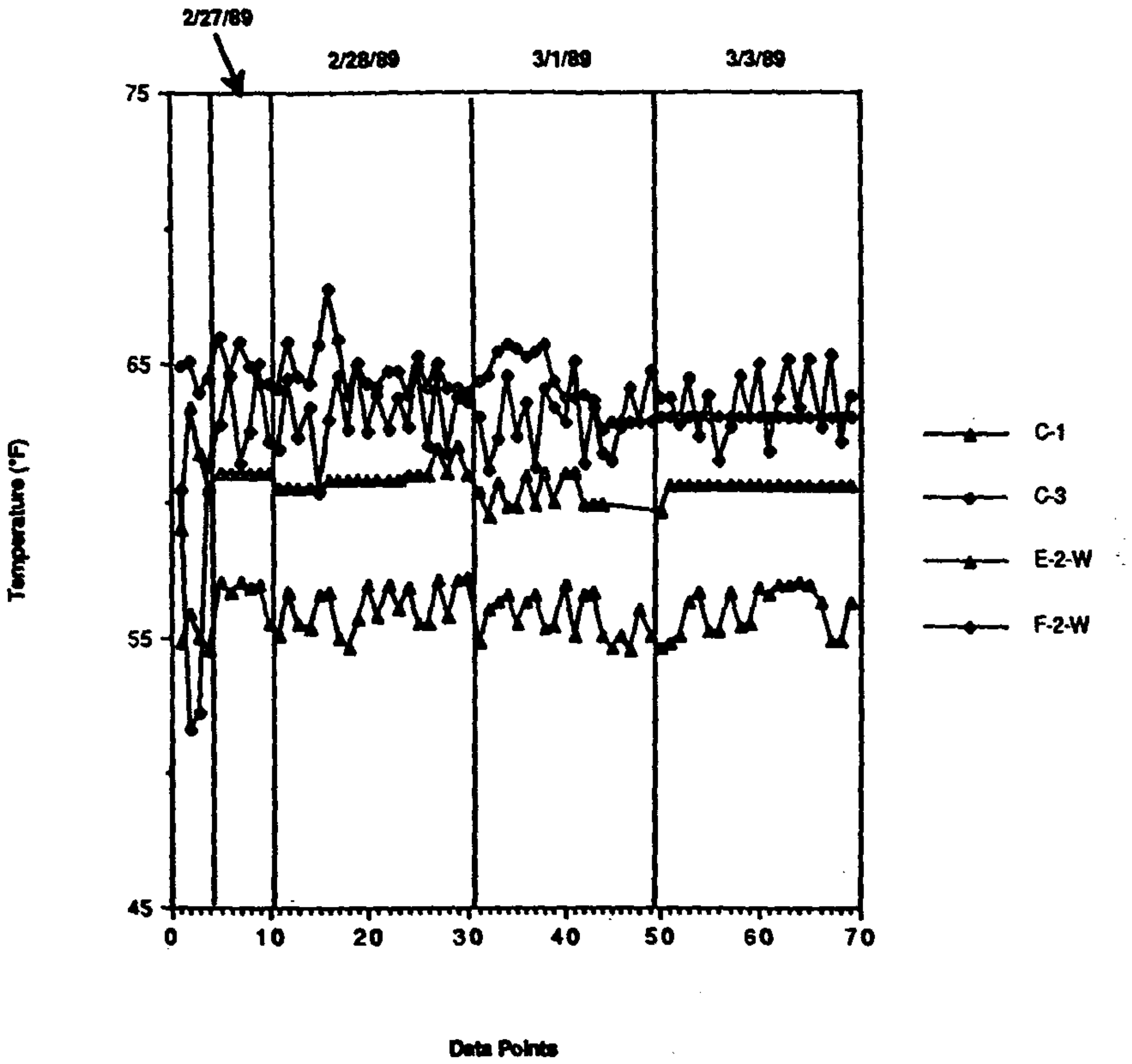


Figure 6.8. Supply Air Dry Bulb Temperature Trends Showing Unstable Setpoint

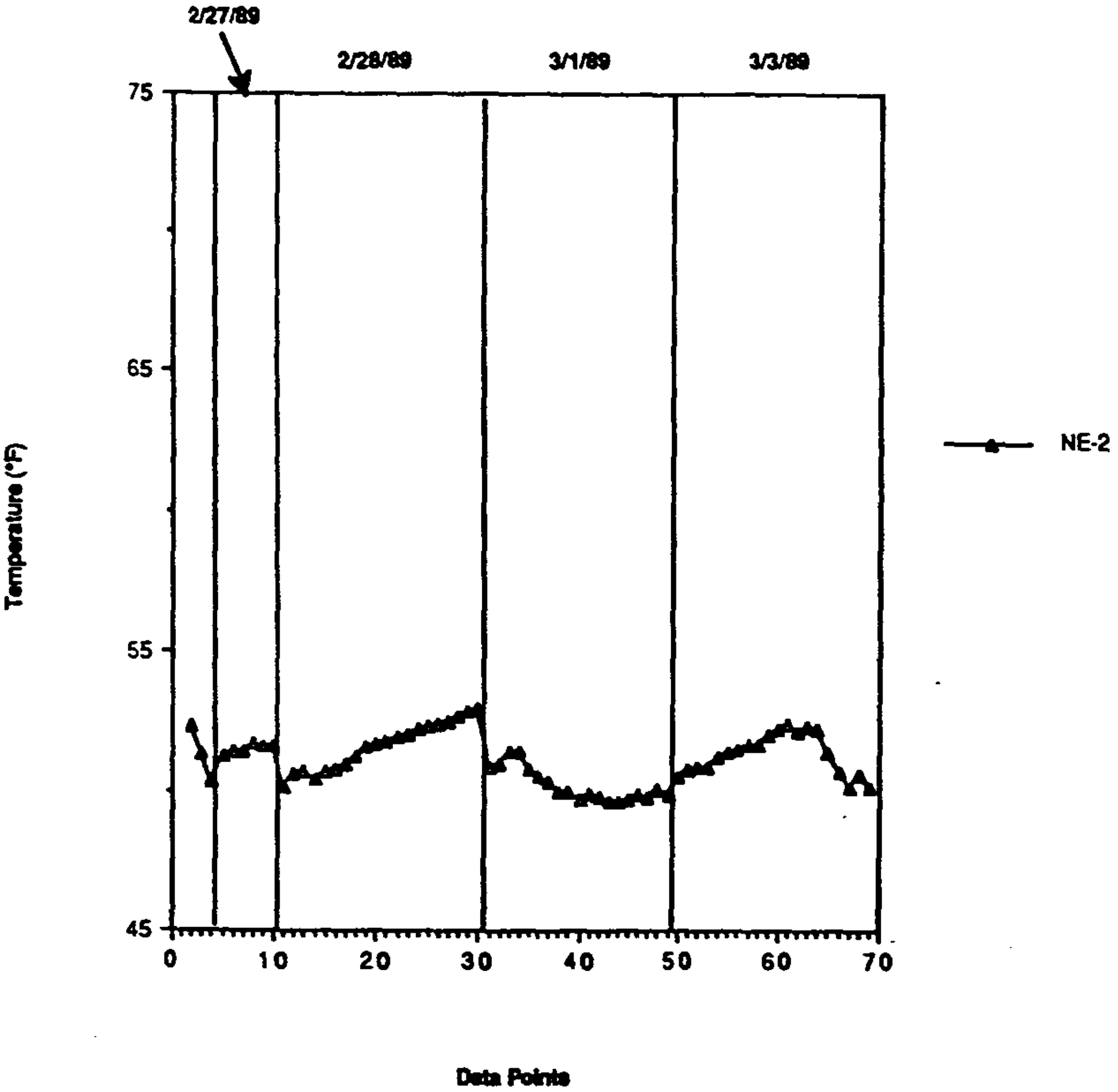


Figure 6.9. Normal Supply Air Main Duct Static Pressure Trends

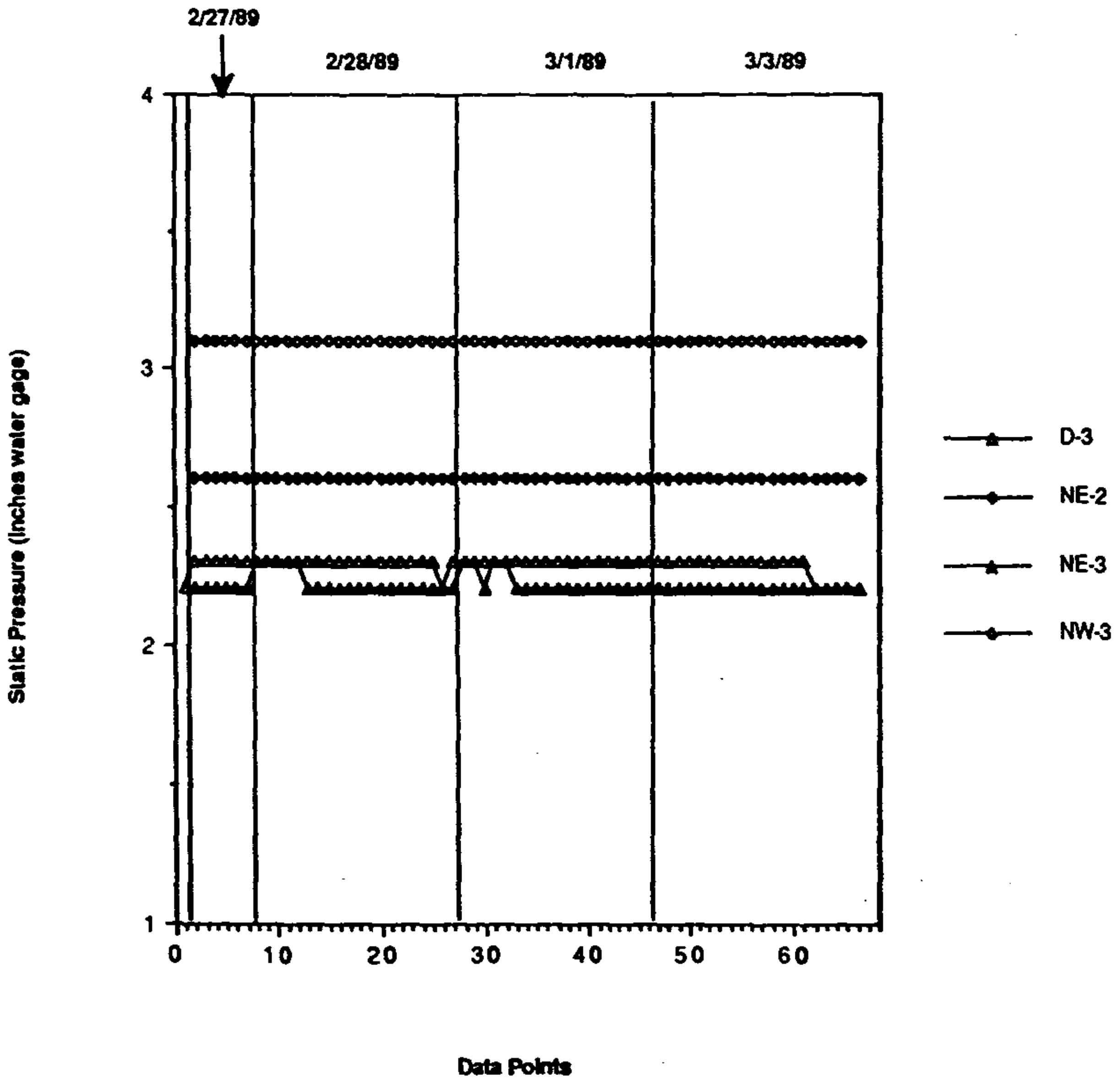
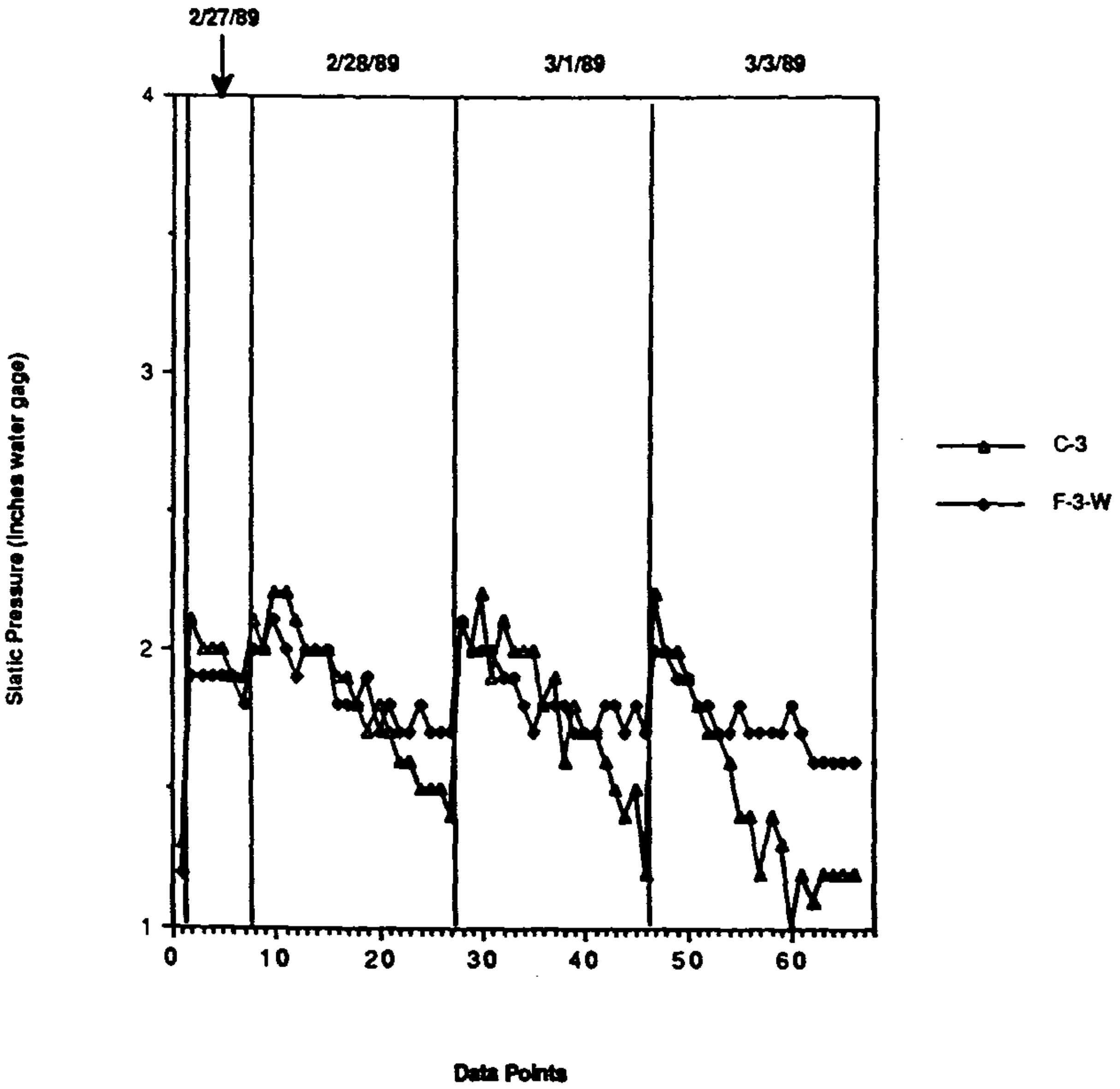


Figure 6.10. Abnormal Supply Air Main Duct Static Pressure Trends



6.2.2 Office Thermal Control and Air Delivery Systems

The operations of thermostats and VAV boxes are coupled by using a pneumatic control system. The thermostats control the opening and closing of the VAV box damper, which increases or decreases airflow to the room, for heating or cooling effects. Data collected from the thermostats is summarized in Table J.5. Data for all of the thermostats serving the general area of a sample site were averaged and are listed in the table.

Important aspects of the inspection of the office environment included (1) the calibration status of thermostats serving the area, (2) placement of the thermostats, and (3) the operation of the VAV boxes.

Measurements at the thermostats showed temperatures ranging from 71 to 77 °F. Normally, the temperature strived for in the space was 74 to 75 °F. The broad range of setpoints recorded (64 to 75 °F) indicated that adjustments had been made in various areas to obtain comfort.

As checks on the calibration of the thermostats, measurable parameters of the pneumatic control system were recorded, such as the "as found" branch line pressure (BLP) and the main line pressure. These indicated whether or not the proper setpoints were being maintained and whether line pressures measured were as designed for proper coordination of function between the thermostats and VAV boxes.

In Table J.5, the "Mean BLP When SP-RT" column shows that some of the thermostats checked may need to be recalibrated. Branch line pressures should have been near 13 pounds per square inch (psi), ± 1 psi error on the measuring gage (11.6-14.5 psi). Twelve of the 22 means are out of this range. When a thermostat is off calibration, the VAV box cannot open or close when it is supposed to. When the thermostat calls for cooling, the box may not respond and thus cause an artificial shift in the thermostat setpoint. This shift in setpoint can be seen by comparing the "Mean Setpoint on Stat" column with the "Mean VAV Box Opening Temperature" column (Table J.5).

Other comments on the thermostats and VAV boxes are listed below.

1. Of the 65 thermostats checked, 30 had low main pressures (less

than 20 psi), which can affect the temperature at which the VAV box opens.

2. Three of the 65 thermostats appeared to control supply air diffusers in areas remote to the thermostat. For two of these cases, the diffusers were in areas on the other side of a wall. In at least one other case, the thermostat controlling diffusers at a survey site could not be located.

3. Twelve of the 65 thermostats were located so that they were isolated from the environment which they were to control, or they were located near a heat source. In some cases, the thermostat was located between shelves on a shelving unit, or between a shelf and a wall. In other cases, the thermostat was located behind office furnishings. In one case, the thermostat was located near a coffee urn. Any obstacle affecting the free flow of air past the thermostat, or affecting temperature sensed by the thermostat, can cause the thermostat to operate incorrectly.

4. Eight of the thermostats had mechanical problems, primarily leaking at the upper limit of the throttling range. In one case, the thermostat was torn from the wall and the throttling lever bent severely.

5. There were several problems with ducting or supply diffusers, including a duct disconnected from a supply diffuser, a diffuser unseated from a luminaire, and perceptively little change in the airflow from a diffuser when the thermostat setpoint was changed. The latter indicates that a VAV damper was malfunctioning.

6.2.3. Airflow Movement in the Building

Airflow movement and direction in the building was studied by using smoke tubes. The following observations were made from this study.

1. Air is pulled into the building from outside through all of the doors, including the doors to the parking garage and the loading dock.

2. Air from the Madison Building is pushed out through a tunnel on the ground floor to the other LOC buildings, and air is pulled into the Madison Building from a tunnel on the basement floor.

3. Air from certain contaminant source areas (e.g., the print shop) was pulled from those areas into the hallway and dispersed to other areas.

4. Air migrated between floors via stairwells and elevator shafts.

5. Air migrated between some rooms (open doors accentuated this movement).

6. Air flowed out of nearly every room.

7. Out of 99 restrooms and lounges, which are supposed to have dedicated exhausts, 32 had air exfiltrating (flowing out) to other rooms.

These observations indicate that the various ventilation systems in the building were not balanced (the airflow from the diffusers and VAVs are not set to design specifications). Each time the system is changed, all or part of the system needs to be rebalanced. If the VAVs are not balanced, either more air or less air than intended flows through them. This could cause some areas to be too hot or too cold. Unbalanced VAVs can also cause "searching" by the thermostat as a result of rapid heating and/or cooling which then causes overshooting of the thermostat setpoint. Unbalanced diffusers can cause uneven air distribution within an office space.

6.2.4 Other Observations

Observations on the roof of the building showed that the stacks for the exhaust systems in the building were not as tall as recommended by ASHRAE, and there was standing water on the roof. If OA intakes are located on the roof, as some are for the Madison Building, reentrainment of exhausted air can occur when stack heights are too low. Standing water on the roof can be an amplifier for microbiological agents, which can also be entrained in the OA supplied to the building.

7. REFERENCES

1. National Institute for Occupational Safety and Health, "Indoor air quality and work environment study: Library of Congress James Madison Memorial Building volume I - employee survey," National Institute for Occupational Safety and Health, Cincinnati, OH, 1989.

2. Persily A.K., and Dols W.S., Ventilation and air quality investigation of the Madison Building phase I report. NISTIR 89-4219. National Institute of Standards and Technology, Gaithersburg, MD, 1989

3. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., "Ventilation for acceptable indoor air quality," ASHRAE standard 62-1989, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA, 1989.

4. National Institute for Occupational' Safety and Health. "NIOSH Recommendatiuons for Occupational Safety and Health Standards, 1988". Morbididty and Mortality Weekly Report, August 26, 1988, 37(5-7). Centers for Disease Control, Atlanta, GA.

5. Occupational Safety and Health Administration. OSHA air contaminants - permissible exposure limits. 29 CFR 1910.1000. Occupational Safety and Health Administration, Washington, DC, 1989.

6. American Conference of Governmental Industrial Hygienists, "Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH for 1988-1989," American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1988.

7. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., "Thermal Environmental Conditions for Human Occupancy", ANSI/ASHRAE Standard 55-1981, American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA, 1981.

8. Fed. Regist., 1987, 52, 24634.

9. Molhave, L., Bach, B., Pedersen, O.F., "Human reactions during controlled exposures to low concentrations of organic gases and vapours known as normal indoor air pollutants," Environ. Int., 1986, 12, 167-175.

10. Bach, B., Molhave, L., Pedersen, O.F., "Human reactions during controlled exposures to low concentrations of organic gases and vapours known as normal indoor air pollutants: Performance tests," Proceedings of the 3d international indoor air quality and climate conference, World Health Organization, Stockholm, Sweden, 1984, 397-402.

11. Skov, P., Valbjorn, O., "The "sick" building syndrome in the office environment: The Danish town hall study," Environ. Inter., 1987, 13, 339-349.

12. Sheldon, L.S., Handy, R.W., Hartwell, T.D., Whitmore, R.W., Zelon, H.S., Pellizzari, E.D., "Indoor air quality in public buildings: Volume I," EPA/600/S6-88/009a (NTIS PB 89-102 503/AS), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1988.

13. Sheldon, L., Zelon, H., Sickles, J. Eaton, C., Hartwell, T., Wallace, L., "Indoor air quality in public buildings: Volume II," EPA/600/S6-88/009b (NTIS PB 89-102 511/AS), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1988.

14. Pellizzari, E.D., Thomas, K.W., Smith, D.J., Perritt, R.L., Morgan, M.A., "Total exposure assessment methodology (TEAM): 1987 study in New Jersey," U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

15. Pellizzari, E.D., Michael, L.C., Perritt, R.L., Smith, D.J., Hartwell, T.D., Sebestik, J., "Comparison of indoor and outdoor toxic air pollutant levels in several southern California communities," U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

16. Pellizzari, E.D., Hartwell, T.D., Zelon, H. Perritt, R., Sebestik, J., Williams, W., Smith, D.J., Keever, J., Decker, C.E., Jayanty, R.K.M., Thomas, K.W., Whitaker, D.A., Michael, L.C., "Baltimore total exposure assessment methodology (TEAM) study," U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

17. U.S. Department of Health, Education, and Welfare, Office on Smoking and Health. Smoking and health: A report of the Surgeon General. U.S. Government Printing Office, Washington, DC, 1979.

18. U.S. Department of Health and Human Services, Office on Smoking and Health. The health consequences of smoking -- cancer: A report of the Surgeon General. U.S. Government Printing Office, Washington, DC, 1982.

19. U.S. Department of Health and Human Services, Office on Smoking and Health. The health consequences of smoking -- Chronic obstructive lung disease: A report of the Surgeon General. U.S. Government Printing Office, Washington, DC, 1984.

20. U.S. Department of Health and Human Services, Office on Smoking and Health. The health consequences of smoking -- Cardiovascular disease: A report of the Surgeon General. U.S. Government Printing Office, Washington, DC, 1983.

21. U.S. Department of Health and Human Services, Office on Smoking and Health. The health consequences of involuntary smoking: A report of the Surgeon General. U.S. Government Printing Office, Washington, DC, 1986.

22. National Research Council Committee on Indoor Air Quality, "Policies and procedures for control of indoor air quality," National Academy Press, Washington, DC, 1987, 75 pages.

23. American Conference of Governmental Industrial Hygienists, "Guidelines for the assessment of bioaerosols in the indoor environment," American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1989.

24. Miller et. al.

25. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, "Inhalable particulate network operations and quality assurance manual," U.S. Environmental Protection Agency, Research Triangle Park, NC, 1983.

26. Oliver, K.D., Pleil, J.D., McLenny, W.A., "Sample integrity of trace level volatile organic compounds in ambient air stored in SUMMA polished canisters," Atmos. Environ., 1986, 20, 1403.

27. Winberry, W.T., Forehand, L., Murphy, N.T., Ceroli, A., Phinney, B, Evans, A., "Compendium of methods for the determination of air pollutants in indoor air," in press, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1990.

28. Winberry, W.T., Murphy, N.T., "Compendium of methods for the determination of toxic organic compounds in ambient air, Method TO-12" EPA/600/4-89/017, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1988.

29. Tejada, S.B., "Evaluation of silica gel cartridges coated in-situ with acidified 2,4-dinitrophenylhydrazine for sampling aldehydes and ketones in air," Int. J. Environ. Anal. Chem. 1986, 26, 167-185.

30. Hsu, J.P., Wheeler, H.G., Camann, D.E., Schattenberg, H.J., Lewis, R.G., Bond, A.E., "Analytical methods for detection of nonoccupational exposure to pesticides," J. Chromatogr. Sci., 1988, 26, 181-189.

31. Hammond, S.K., Leaderer, B.P., "A diffusion monitor to measure exposure to passive smoking," Environ. Sci. Technol., 1987, 21, 494-497.

32. Jones, W., Morring, K., Morey, P., Sorenson, W. "Evaluation of the Andersen Viable Impactor for single stage sampling," J. Am. Ind. Hygiene, 1985, 46(5), 294-298.

33. Nevalainen, A., "Bacterial aerosols in indoor air", National Public Health Institute, Helsinki, Finland, 1989.

APPENDIX A

Summary Statistics for Real-Time Indoor Measurements

Table A.1. Summary statistics for temperature (degrees F.) measured at the LOC Madison building Primary sites.

		Floor									
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means	
7-9am	N	3	11	14	7	8	3	3	2	8	
	Mean	71.0	72.5	71.9	71.9	72.3	70.8	74.0	71.5	72.0	
	Std. error	0.6	0.4	0.5	0.4	0.4	1.5	0.6	0.5	0.4	
9-12am	N	3	11	14	7	8	3	3	2	8	
	Mean	72.0	73.4	73.8	72.8	73.9	72.5	74.0	73.5	73.2	
	Std. error	0.6	0.5	0.3	0.5	0.5	0.9	0.6	0.5	0.3	
12-3pm	N	3	11	14	7	8	3	3	2	8	
	Mean	72.7	73.8	74.0	73.1	74.1	72.8	75.0	72.0	73.4	
	Std. error	0.3	0.3	0.3	0.4	0.6	0.6	0.6	0.5	0.3	
3-5pm	N	3	11	14	7	8	3	3	2	8	
	Mean	73.0	72.7	73.8	73.7	74.4	72.5	74.0	72.0	73.3	
	Std. error	0.0	0.8	0.3	0.3	0.5	1.3	0.6	0.5	0.3	
											Grand
Average Daily Statistics	N	3	11	14	7	8	3	3	2		8
	Mean	72.2	73.1	73.4	72.9	73.7	72.2	74.3	72.3		73.0
	Std. error	0.4	0.5	0.3	0.3	0.5	1.0	0.4	0.2		0.3
	Median	72.3	73.3	74.0	73.1	73.5	72.5	74.5	72.3		73.0
Individual values	First maximum	73.0	76.0	75.0	75.0	77.0	74.0	76.0	74.0		77.0
	Second maximum	73.0	76.0	75.0	75.0	77.0	74.0	75.0	73.0		77.0
	First minimum	70.0	68.5	69.0	70.0	71.0	68.0	73.0	71.0		68.0
	Second minimum	71.0	69.0	69.0	71.0	71.0	70.0	73.0	71.5		68.5

Table A.2. Summary statistics for temperature (degrees F.) measured at the LOC Madison building Secondary sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	1	5	5	4	5	6	9	5	8
	Mean	72.0	73.8	72.2	71.6	73.6	72.4	72.2	72.2	72.5
	Std. error	-	0.7	0.7	0.6	0.5	0.9	0.5	1.7	0.3
9-12am	N	1	5	5	4	5	6	9	5	8
	Mean	73.0	74.4	73.9	73.4	74.8	73.5	73.1	73.7	73.7
	Std. error	-	0.7	0.3	0.6	0.2	0.9	0.4	0.4	0.2
12-3pm	N	1	5	5	4	5	6	9	5	8
	Mean	73.0	75.0	73.8	73.6	75.0	73.4	73.4	72.6	73.7
	Std. error		0.5	0.4	0.6	0.3	0.8	0.2	1.5	0.3
3-5pm	N	1	5	5	4	5	6	9	5	8
	Mean	73.0	75.0	73.4	73.6	74.6	73.2	73.4	71.5	73.5
	Std. error	-	0.4	0.2	0.6	0.4	0.8	0.2	2.6	0.4
										Grand
Average Daily Statistics	N	1	5	5	4	5	6	9	5	8
	Mean	72.8	74.5	73.3	73.1	74.5	73.1	73.1	72.5	73.4
	Std. error	nc	0.6	0.2	0.5	0.3	0.9	0.3	1.6	0.3
	Median	nc	74.5	73.5	73.1	74.8	73.1	73.3	74.5	73.1
Individual values	First maximum	73.0	77.0	75.0	74.5	76.0	77.5	75.0	75.0	77.5
	Second maximum	73.0	77.0	75.0	74.5	75.0	76.5	74.0	75.0	77.0
	First minimum	72.0	72.0	70.0	71.0	72.0	69.0	69.0	61.5	61.5
	Second minimum	73.0	73.0	72.0	71.0	73.0	71.0	71.0	66.0	66.0

Table A.3. Summary statistics for temperature (degrees F.) measured at the LOC Madison building Special sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	72.0	71.0	71.7	73.5	-	-	72.0
	Std. error	-	-	-	0.8	0.3	-	-	-	0.5
9-12am	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	74.0	73.0	72.3	72.5	-	-	73.0
	Std. error	-	-	-	0.4	0.7	-	-	-	0.4
12-3pm	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	74.0	73.4	73.0	71.5	-	-	73.0
	Std. error	-	-	-	0.4	0.6	-	-	-	0.5
3-5pm	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	74.0	73.2	73.0	72.0	-	-	73.0
	Std. error	-	-	-	0.4	0.6	-	-	-	0.4
										Grand
Average Daily Statistics	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	73.5	72.6	72.5	72.4	-	-	72.8
	Std. error	-	-	nc	0.5	0.5	nc	-	-	0.3
	Median	-	-	nc	72.5	72.8	nc	-	-	72.6
Individual values	First maximum	-	-	74.0	74.0	74.0	73.5	-	-	74.0
	Second maximum	-	-	74.0	74.0	74.0	72.5	-	-	74.0
	First minimum	-	-	72.0	69.0	71.0	71.5	-	-	69.0
	Second minimum	-	-	74.0	70.0	71.0	72.0	-	-	70.0

Table A.4. Summary statistics for temperature (degrees F.) measured at the LOC Madison building Primary & Secondary & Special sites.

		Floor								Building
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Means
7-9am	N	4	16	20	16	15	10	12	7	8
	Mean	71.3	72.9	72.0	71.6	72.7	72.0	72.7	72.0	72.1
	Std. error	0.5	0.4	0.4	0.3	0.3	0.7	0.4	1.2	0.2
9-12am	N	4	16	20	16	15	10	12	7	8
	Mean	72.3	73.7	73.8	73.0	74.1	73.1	73.3	73.6	73.4
	Std. error	0.5	0.4	0.2	0.3	0.3	0.6	0.3	0.3	0.2
12-3pm	N	4	16	20	16	15	10	12	7	8
	Mean	72.8	74.2	74.0	73.3	74.4	73.0	73.8	72.4	73.5
	Std. error	0.2	0.3	0.2	0.2	0.3	0.5	0.3	1.1	0.2
3-5pm	N	4	16	20	16	15	10	12	7	8
	Mean	73.0	73.4	73.7	73.5	74.3	72.8	73.6	71.6	73.3
	Std. error	0.0	0.6	0.2	0.2	0.3	0.6	0.2	1.8	0.3
										Grand
Average Daily Statistics	N	4	16	20	16	15	10	12	7	8
	Mean	72.3	73.6	73.4	72.9	73.9	72.8	73.4	72.4	73.1
	Std. error	0.3	0.4	0.2	0.2	0.3	0.6	0.3	1.1	0.2
	Median	72.5	73.6	73.5	73.1	73.5	72.5	73.4	72.5	73.1
Individual values	First maximum	73.0	77.0	75.0	75.0	77.0	77.5	76.0	75.0	77.5
	Second maximum	73.0	77.0	75.0	75.0	77.0	76.5	75.0	75.0	77.0
	First minimum	70.0	68.5	69.0	69.0	71.0	68.0	69.0	61.5	61.5
	Second minimum	71.0	69.0	69.0	70.0	71.0	69.0	71.0	66.0	66.0

Table A.5. Summary statistics for relative humidity (%) measured at the LOC Madison building Primary sites.

		Floor									
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means	Grand
7-9am	N	3	11	14	7	8	3	3	2	8	
	Mean	56.0	50.4	53.8	51.4	50.8	47.3	45.3	47.0	50.2	
	Std. error	2.3	2.1	1.5	1.6	1.9	3.5	3.5	1.0	1.3	
9-12am	N	3	11	14	7	8	3	3	0	7	
	Mean	50.0	51.5	50.4	51.4	50.5	51.3	47.3	-	50.3	
	Std. error	1.2	2.0	1.5	1.0	1.2	10.3	5.5	-	0.5	
12-3pm	N	3	11	14	7	8	3	3	2	8	
	Mean	52.0	52.4	50.4	50.9	50.0	50.0	44.7	48.0	49.8	
	Std. error	1.2	1.5	1.7	0.6	1.4	9.0	4.7	0.0	0.9	
3-5pm	N	3	10	14	7	8	3	3	2	8	
	Mean	52.7	54.0	48.3	49.7	49.0	44.0	48.0	49.0	49.3	
	Std. error	1.3	2.1	1.3	0.8	1.2	4.2	4.2	1.0	1.1	
Average Daily Statistics	N	3	11	14	7	8	3	3	2		8
	Mean	52.7	51.9	50.7	50.9	50.1	48.2	46.3	48.0		49.8
	Std. error	0.4	1.6	1.4	0.6	1.3	6.7	4.3	0.0		0.8
	Median	52.5	52.0	50.5	51.5	50.3	43.0	44.5	48.0		50.4
Individual values	First maximum	60.0	64.0	65.0	60.0	60.0	72.0	58.0	50.0		72.0
	Second maximum	56.0	62.0	62.0	56.0	56.0	68.0	54.0	48.0		68.0
	First minimum	48.0	36.0	34.0	46.0	42.0	38.0	40.0	46.0		34.0
	Second minimum	50.0	36.0	34.0	48.0	42.0	40.0	40.0	48.0		34.0

Table A.6. Summary statistics for relative humidity (%) measured at the LOC Madison building Secondary sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	1	5	5	4	5	6	9	5	8
	Mean	48.0	51.6	52.4	50.5	48.4	46.0	48.9	48.0	49.2
	Std. error	-	2.1	3.4	3.0	1.5	1.5	1.3	5.2	0.8
9-12am	N	1	5	5	4	5	6	9	0	7
	Mean	54.0	51.2	51.2	50.0	47.2	43.0	46.9	-	49.1
	Std. error	-	2.7	2.7	3.2	1.4	1.1	1.8	-	1.4
12-3pm	N	1	5	5	4	5	6	9	5	8
	Mean	58.0	52.0	50.0	49.5	48.8	43.7	44.7	44.8	48.9
	Std. error	-	2.4	2.3	3.8	0.5	1.1	0.9	1.0	1.7
3-5pm	N	1	5	5	4	5	6	9	5	8
	Mean	54.0	49.2	48.4	49.0	50.0	44.3	46.9	48.4	48.8
	Std. error	-	2.0	1.6	2.6	1.1	1.0	1.1	4.7	1.0
										Grand
Average Daily Statistics	N	1	5	5	4	5	6	9	5	8
	Mean	53.5	51.0	50.5	49.8	48.6	44.3	46.8	47.1	48.9
	Std. error	nc	2.1	2.3	2.5	1.0	1.1	1.1	3.5	1.0
	Median	nc	52.0	51.0	50.0	49.5	44.0	46.5	43.3	49.2
Individual values	First maximum	58.0	58.0	64.0	60.0	54.0	50.0	58.0	68.0	68.0
	Second maximum	54.0	58.0	58.0	58.0	52.0	50.0	54.0	66.0	66.0
	First minimum	48.0	42.0	44.0	42.0	44.0	38.0	42.0	40.0	38.0
	Second minimum	54.0	42.0	44.0	44.0	44.0	40.0	42.0	40.0	40.0

Table A.7. Summary statistics for relative humidity (%) measured at the LOC Madison building Special sites.

		Floor								
Time	**Statistic**	6	5	4	3	2	1	Grd	SubGrd	**Building Means**
7-9am	**N**	-	-	1	5	3	1	-	-	4
	Mean	-	-	56.0	51.2	47.3	48.0	-	-	50.6
	Std. error	-	-	-	1.7	0.7	-	-	-	2.0
9-12am	**N**	-	-	1	5	3	1	-	-	4
	Mean	-	-	50.0	48.0	46.7	46.0	-	-	47.7
	Std. error	-	-	-	1.4	0.7	-	-	-	0.9
12-3pm	**N**	-	-	1	5	3	1	-	-	4
	Mean	-	-	50.0	46.8	46.7	48.0	-	-	47.9
	Std. error	-	-	-	1.9	0.7	-	-	-	0.8
3-5pm	**N**	-	-	1	5	3	1	-	-	4
	Mean	-	-	54.0	49.6	46.7	45.0	-	-	48.8
	Std. error	-	-	-	1.6	0.7	-	-	-	2.0
										Grand
Average Daily Statistics	**N**	-	-	1	5	3	1	-	-	4
	Mean	-	-	52.5	48.9	46.8	46.8	-	-	48.7
	Std. error	-	-	nc	0.5	0.6	nc	-	-	1.3
	Median	-	-	nc	49.5	46.5	nc	-	-	47.9
Individual values	**First maximum**	-	-	56.0	56.0	48.0	48.0	-	-	56.0
	Second maximum	-	-	54.0	54.0	48.0	48.0	-	-	56.0
	First minimum	-	-	50.0	42.0	46.0	45.0	-	-	42.0
	Second minimum	-	-	50.0	44.0	46.0	46.0	-	-	44.0

Table A.8. Summary statistics for relative humidity (%) measured at the LOC Madison building Primary & Secondary & Special sites.

		Floor									
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means	Grand
7-9am	N	4	16	20	16	15	10	12	7	8	
	Mean	54.0	50.8	53.5	51.1	49.5	46.6	48.0	47.7	50.2	
	Std. error	2.6	1.5	1.3	1.1	1.1	1.3	1.3	3.6	1.0	
9-12am	N	4	16	20	16	15	10	12	0	7	
	Mean	51.0	51.4	50.5	50.0	48.7	45.8	47.0	-	49.2	
	Std. error	1.3	1.6	1.2	1.0	0.9	3.0	1.7	-	0.8	
12-3pm	N	4	16	20	16	15	10	12	7	8	
	Mean	53.5	52.3	50.3	49.3	48.9	46.0	44.7	45.7	48.8	
	Std. error	1.7	1.2	1.3	1.1	0.8	2.6	1.2	0.9	1.1	
3-5pm	N	4	15	20	16	15	10	12	7	8	
	Mean	53.0	52.4	48.6	49.5	48.9	44.3	47.2	48.6	49.1	
	Std. error	1.0	1.6	1.0	0.8	0.8	1.2	1.2	3.3	1.0	
Average Daily Statistics	N	4	16	20	16	15	10	12	7		8
	Mean	52.9	51.6	50.8	50.0	49.0	45.7	46.7	47.3		49.2
	Std. error	0.4	1.3	1.1	0.7	0.8	1.9	1.2	2.4		0.9
	Median	53.0	52.0	50.8	49.8	49.5	44.0	46.0	48.0		49.5
Individual values	First maximum	60.0	64.0	65.0	60.0	60.0	72.0	58.0	68.0		72.0
	Second maximum	58.0	62.0	64.0	60.0	56.0	68.0	58.0	66.0		68.0
	First minimum	48.0	36.0	34.0	42.0	42.0	38.0	40.0	40.0		34.0
	Second minimum	48.0	36.0	34.0	42.0	42.0	38.0	40.0	40.0		34.0

Table A.9. Summary statistics for carbon dioxide (ppm) measured at the LOC Madison building Primary sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	3	11	14	7	8	3	3	2	8
	Mean	433	455	445	393	400	408	450	450	429
	Std. error	22	8	17	13	12	58	14	25	9
9-12am	N	3	11	14	7	8	3	3	2	8
	Mean	542	568	563	514	522	467	492	525	524
	Std. error	17	14	9	22	12	58	8	25	12
12-3pm	N	3	11	14	7	8	3	3	2	8
	Mean	567	568	541	514	513	467	467	525	520
	Std. error	8	11	8	12	8	46	8	0	14
3-5pm	N	3	11	14	7	8	3	3	2	8
	Mean	492	561	530	493	513	458	458	525	504
	Std. error	22	12	10	13	11	30	8	0	13
										Grand
Average Daily Statistics	N	3	11	14	7	8	3	3	2	8
	Mean	508	538	520	479	487	450	467	506	494
	Std. error	13	9	9	11	10	48	2	12	10
	Median	506	544	522	481	494	481	469	506	496
Individual values	First maximum	575	675	625	600	575	525	500	550	675
	Second maximum	575	650	625	575	550	525	500	525	650
	First minimum	400	425	350	350	350	300	425	425	300
	Second minimum	425	425	350	350	350	350	450	475	350

Table A.10. Summary statistics for carbon dioxide (ppm) measured at the LOC Madison building Secondary sites.

		Floor									
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means	Grand
7-9am	N	1	5	5	4	5	6	9	5	8	
	Mean	425	450	440	356	390	329	431	450	409	
	Std. error	-	14	28	6	10	21	7	8	16	
9-12am	N	1	5	5	4	5	6	9	5	8	
	Mean	500	605	585	488	535	396	497	550	519	
	Std. error	-	9	23	26	13	30	8	16	23	
12-3pm	N	1	5	5	4	5	6	9	5	8	
	Mean	550	600	550	488	495	392	483	520	510	
	Std. error	-	16	16	12	15	28	16	5	22	
3-5pm	N	1	5	5	4	5	6	9	5	8	
	Mean	475	550	525	463	520	400	483	515	491	
	Std. error	-	16	18	22	18	23	14	6	17	
Average Daily Statistics	N	1	5	5	4	5	6	9	5		8
	Mean	488	551	525	448	485	379	474	509		482
	Std. error	nc	9	10	9	13	24	9	7		19
	Median	nc	544	525	450	469	353	469	519		486
Individual values	First maximum	550	650	650	550	575	525	525	575		650
	Second maximum	500	625	625	525	575	525	525	575		650
	First minimum	425	425	350	350	375	300	400	425		300
	Second minimum	475	425	425	350	375	300	425	450		300

Table A.11. Summary statistics for carbon dioxide (ppm) measured at the LOC Madison building Special sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	400	440	458	300	-	-	400
	Std. error	-	-	-	23	33	-	-	-	35
9-12am	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	625	550	608	400	-	-	546
	Std. error	-	-	-	18	33	-	-	-	51
12-3pm	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	600	565	575	375	-	-	529
	Std. error	-	-	-	23	29	-	-	-	52
3-5pm	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	525	555	558	400	-	-	510
	Std. error	-	-	-	9	17	-	-	-	37
										Grand
Average Daily Statistics	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	538	528	550	369	-	-	496
	Std. error	-	-	nc	14	14	nc	-	-	43
	Median	-	-	nc	519	550	nc	-	-	533
Individual values	First maximum	-	-	625	650	675	400	-	-	675
	Second maximum	-	-	600	600	625	400	-	-	650
	First minimum	-	-	400	400	425	300	-	-	300
	Second minimum	-	-	525	400	425	375	-	-	375

Table A.12. Summary statistics for carbon dioxide (ppm) measured at the LOC Madison building Primary & Secondary & Special sites.

Time	Statistic	Floor								Building Means
		6	5	4	3	2	1	Grd	SubGrd	
7-9am	N	4	16	20	16	15	10	12	7	8
	Mean	431	453	441	398	409	350	435	450	421
	Std. error	16	7	13	12	11	23	6	8	12
9-12am	N	4	16	20	16	15	10	12	7	8
	Mean	531	580	571	519	543	418	496	543	525
	Std. error	16	11	9	14	12	25	6	13	18
12-3pm	N	4	16	20	16	15	10	12	7	8
	Mean	563	578	546	523	519	413	479	521	518
	Std. error	7	9	7	12	11	23	12	4	18
3-5pm	N	4	16	20	16	15	10	12	7	8
	Mean	488	558	529	505	523	418	477	518	502
	Std. error	16	10	8	12	8	18	11	5	15
										Grand
Average Daily Statistics	N	4	16	20	16	15	10	12	7	8
	Mean	503	542	522	486	499	399	472	508	491
	Std. error	10	7	7	10	9	22	6	6	15
	Median	497	544	528	488	506	363	469	519	501
Individual values	First maximum	575	675	650	650	675	525	525	575	675
	Second maximum	575	650	625	600	625	525	525	575	675
	First minimum	400	425	350	350	350	300	400	425	300
	Second minimum	425	425	350	350	350	300	425	425	300

Table A.13. Summary statistics for real-time particulate concentration ($\mu g/m^3$) measured at the LOC Madison building Primary sites.

		Floor									
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means	Grand
7-9am	N	3	11	14	7	8	3	3	2	8	
	Mean	10.0	4.9	6.5	7.7	3.6	0.7	4.7	4.0	5.3	
	Std. error	5.5	0.3	0.8	2.0	0.9	0.7	1.2	0.0	1.0	
9-12am	N	3	11	14	7	8	3	3	2	8	
	Mean	13.3	4.8	7.4	8.7	7.0	4.0	4.3	3.0	6.6	
	Std. error	4.1	0.6	1.4	1.7	1.3	0.6	0.3	2.0	1.2	
12-3pm	N	3	11	14	7	8	3	3	2	8	
	Mean	9.7	5.2	5.5	7.4	6.9	4.7	5.3	2.0	5.8	
	Std. error	3.7	0.6	1.0	1.1	1.8	2.0	0.9	0.0	0.8	
3-5pm	N	3	11	14	6	8	3	3	2	8	
	Mean	8.3	5.5	5.9	9.3	5.9	4.7	4.0	5.5	6.1	
	Std. error	1.9	0.3	1.2	2.7	1.2	1.8	0.6	3.5	0.6	
Average Daily Statistics	N	3	11	14	7	8	3	3	2		8
	Mean	10.3	5.1	6.3	8.4	5.8	3.5	4.6	3.6		6.0
	Std. error	3.7	0.4	0.8	1.6	1.2	0.9	0.2	1.4		0.8
	Median	7.5	5.3	5.6	6.8	5.0	3.5	4.8	3.6		5.5
Individual values	First maximum	21.0	8.0	24.0	19.0	18.0	8.0	7.0	9.0		24.0
	Second maximum	21.0	8.0	17.0	16.0	13.0	8.0	7.0	5.0		21.0
	First minimum	4.0	1.0	0.0	2.0	0.0	0.0	3.0	1.0		0.0
	Second minimum	5.0	2.0	1.0	3.0	1.0	0.0	3.0	2.0		0.0

Table A.14. Summary statistics for real-time particulate concentration ($\mu g/m^3$) measured at the LOC Madison building Secondary sites.

					Floor					
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	1	5	5	4	5	6	9	5	8
	Mean	7.0	4.4	6.0	4.0	3.6	1.0	5.1	2.4	4.2
	Std. error	-	1.2	1.6	1.1	0.5	0.4	2.4	0.7	0.7
9-12am	N	1	5	5	4	5	6	9	5	8
	Mean	10.0	6.2	5.0	5.5	9.8	4.5	5.6	4.0	6.3
	Std. error	-	0.5	1.3	0.6	3.1	1.4	0.4	0.7	0.8
12-3pm	N	1	5	5	4	5	6	9	5	8
	Mean	13.0	6.8	4.2	6.0	5.8	3.3	5.2	2.2	5.8
	Std. error	-	0.7	0.4	1.5	1.0	1.0	1.4	0.5	1.2
3-5pm	N	1	5	5	4	5	6	9	5	8
	Mean	16.0	6.0	4.2	4.0	13.6	3.5	3.6	3.8	6.8
	Std. error	-	0.4	0.9	0.8	9.2	1.4	0.8	1.1	1.8
										Grand
Average Daily Statistics	N	1	5	5	4	5	6	9	5	8
	Mean	11.5	5.8	4.8	4.9	8.2	3.1	4.9	3.1	5.8
	Std. error	nc	0.4	0.9	0.7	3.2	0.6	0.9	0.4	1.0
	Median	nc	5.3	4.0	4.4	6.8	2.4	4.0	3.0	4.9
Individual values	First maximum	16.0	9.0	12.0	10.0	50.0	11.0	22.0	8.0	50.0
	Second maximum	13.0	8.0	10.0	7.0	18.0	10.0	14.0	6.0	22.0
	First minimum	7.0	0.0	1.0	2.0	2.0	0.0	0.0	0.0	0.0
	Second minimum	10.0	4.0	2.0	2.0	2.0	0.0	0.0	1.0	0.0

Table A.15. Summary statistics for real-time particulate concentration (μg/m^3) measured at the LOC Madison building Special sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	0.0	0.0	0.0	5.0	-	-	1.3
	Std. error	-	-	-	0.0	0.0	-	-	-	1.2
9-12am	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	1.0	4.0	0.7	2.0	-	-	1.9
	Std. error	-	-	-	2.8	0.3	-	-	-	0.8
12-3pm	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	0.0	0.2	0.0	4.0	-	-	1.0
	Std. error	-	-	-	0.2	0.0	-	-	-	1.0
3-5pm	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	1.0	1.6	0.0	2.0	-	-	1.1
	Std. error	-	-	-	1.0	0.0	-	-	-	0.4
										Grand
Average Daily Statistics	N	-	-	1	5	3	1	-	-	4
	Mean	-	-	0.5	1.4	0.2	3.3	-	-	1.3
	Std. error	-	-	nc	1.0	0.1	nc	-	-	0.7
	Median	-	-	nc	0.3	0.3	nc	-	-	1.0
Individual values	First maximum	-	-	1.0	15.0	1.0	5.0	-	-	15.0
	Second maximum	-	-	1.0	5.0	1.0	4.0	-	-	5.0
	First minimum	-	-	0.0	0.0	0.0	2.0	-	-	0.0
	Second minimum	-	-	0.0	0.0	0.0	2.0	-	-	0.0

Table A.16. Summary statistics for real-time particulate concentration ($\mu g/m^3$) measured at the *LOC Madison* building Primary & Secondary & Special sites.

		Floor								
Time	Statistic	6	5	4	3	2	1	Grd	SubGrd	Building Means
7-9am	N	4	16	20	16	15	10	12	7	8
	Mean	9.3	4.8	6.0	4.4	3.1	1.3	5.0	2.9	4.6
	Std. error	4.0	0.4	0.8	1.2	0.6	0.5	1.8	0.6	0.8
9-12am	N	4	16	20	16	15	10	12	7	8
	Mean	12.5	5.3	6.4	6.4	7.0	4.1	5.3	3.7	6.3
	Std. error	3.0	0.5	1.1	1.2	1.4	0.8	0.4	0.7	1.0
12-3pm	N	4	16	20	16	15	10	12	7	8
	Mean	10.5	5.7	4.9	4.8	5.5	3.8	5.3	2.1	5.3
	Std. error	2.7	0.5	0.7	1.0	1.2	0.8	1.1	0.3	0.8
3-5pm	N	4	16	20	15	15	10	12	7	8
	Mean	10.3	5.7	5.2	5.3	7.5	3.7	3.7	4.3	5.7
	Std. error	2.3	0.3	0.9	1.4	3.2	1.0	0.6	1.1	0.8
										Grand
Average Daily Statistics	N	4	16	20	16	15	10	12	7	8
	Mean	10.6	5.3	5.6	5.4	5.8	3.2	4.8	3.3	5.5
	Std. error	2.7	0.3	0.7	1.1	1.4	0.4	0.7	0.4	0.8
	Median	9.5	5.3	5.3	4.5	4.3	2.9	4.5	3.0	5.4
Individual values	First maximum	21.0	9.0	24.0	19.0	50.0	11.0	22.0	9.0	50.0
	Second maximum	21.0	8.0	17.0	16.0	18.0	10.0	14.0	8.0	24.0
	First minimum	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Second minimum	5.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0

APPENDIX B

Summary Statistics for
Respirable Particulate Matter (RSP)

Table B.1. Descriptive statistics for PEM particle concentration (μg/m^3) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	55
Number of samples above LOQ	30
Sample mean	19.5
Standard error of the mean	1.3
Median	18.0
Maximum	37.3
Minimum	10.1

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	2	5	9	4	4	2	2	1	2
Sample mean	30.6	21.8	19.1	18.0	14.1	22.8	19.6	10.6	18.2
Standard error of the mean	6.7	4.0	2.4	1.9	2.0	4.4	3.7	nc	0.5
Median	30.6	20.7	17.7	16.3	13.4	22.8	19.6	nc	18.2
Maximum	37.3	37.1	35.6	23.7	19.6	27.3	23.3	nc	18.7
Minimum	23.9	14.6	10.6	15.8	10.1	18.4	15.9	nc	17.7

APPENDIX C

Summary Statistics for Formaldehyde and Other Aldehydes

Table C.1. Descriptive statistics for formaldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	9.2
Standard error of the mean	0.4
Median	9.1
Maximum	13.0
Minimum	6.7

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	9.2	9.3	8.2	8.2	7.2	10.2	7.9	13.0	9.8
Standard error of the mean	nc	0.8	0.7	nc	nc	nc	nc	nc	0.4
Median	nc	9.3	8.7	nc	nc	nc	nc	nc	9.9
Maximum	nc	10.1	9.1	nc	nc	nc	nc	nc	10.9
Minimum	nc	8.5	6.7	nc	nc	nc	nc	nc	8.9

Table C.2. Descriptive statistics for acetaldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	16.1
Standard error of the mean	1.1
Median	14.8
Maximum	27.2
Minimum	11.3

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	12.6	16.7	14.3	11.3	22.8	17.2	14.2	18.5	16.3
Standard error of the mean	nc	2.4	1.0	nc	nc	nc	nc	nc	2.8
Median	nc	16.7	15.3	nc	nc	nc	nc	nc	14.4
Maximum	nc	19.1	15.3	nc	nc	nc	nc	nc	27.2
Minimum	nc	14.4	12.3	nc	nc	nc	nc	nc	12.3

Table C.3. Descriptive statistics for propionaldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	0.8
Standard error of the mean	0.1
Median	0.9
Maximum	1.3
Minimum	0.3

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	0.9	1.0	0.6	0.3	1.2	1.0	1.2	1.1	0.7
Standard error of the mean	nc	0.3	0.2	nc	nc	nc	nc	nc	0.1
Median	nc	1.0	0.6	nc	nc	nc	nc	nc	0.7
Maximum	nc	1.3	0.9	nc	nc	nc	nc	nc	1.2
Minimum	nc	0.6	0.3	nc	nc	nc	nc	nc	0.3

Table C.4. Descriptive statistics for butyraldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	0.7
Standard error of the mean	0.0
Median	0.7
Maximum	1.1
Minimum	0.5

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	0.5	0.8	0.8	0.8	0.6	0.8	0.8	0.7	0.8
Standard error of the mean	nc	0.1	0.1	nc	nc	nc	nc	nc	0.1
Median	nc	0.8	0.7	nc	nc	nc	nc	nc	1.0
Maximum	nc	0.9	1.0	nc	nc	nc	nc	nc	1.1
Minimum	nc	0.7	0.6	nc	nc	nc	nc	nc	0.5

Table C.5. Descriptive statistics for benzaldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	9
Sample mean	0.4
Standard error of the mean	0.0
Median	0.4
Maximum	0.6
Minimum	0.2

Statistic	Floor 6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	1	1	0	1	1	1	1	2
Sample mean	0.4	0.5	0.2	-	0.4	0.4	0.4	0.6	0.3
Standard error of the mean	nc	nc	nc	-	nc	nc	nc	nc	0.0
Median	nc	nc	nc	-	nc	nc	nc	nc	0.3
Maximum	nc	nc	nc	-	nc	nc	nc	nc	0.4
Minimum	nc	nc	nc	-	nc	nc	nc	nc	0.3

Table C.6. Descriptive statistics for valeraldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	0.7
Standard error of the mean	0.1
Median	0.7
Maximum	1.5
Minimum	0.4

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	0.6	0.6	0.7	0.4	0.7	0.8	1.5	0.5	0.7
Standard error of the mean	nc	0.1	0.1	nc	nc	nc	nc	nc	0.1
Median	nc	0.6	0.7	nc	nc	nc	nc	nc	0.7
Maximum	nc	0.7	0.9	nc	nc	nc	nc	nc	0.9
Minimum	nc	0.5	0.5	nc	nc	nc	nc	nc	0.5

Table C.7. Descriptive statistics for hexanaldehyde ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	2.1
Standard error of the mean	0.1
Median	2.1
Maximum	2.6
Minimum	1.5

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	2.1	2.2	2.0	1.7	2.1	2.0	2.2	1.8	2.1
Standard error of the mean	nc	0.2	0.3	nc	nc	nc	nc	nc	0.1
Median	nc	2.2	2.0	nc	nc	nc	nc	nc	2.3
Maximum	nc	2.4	2.6	nc	nc	nc	nc	nc	2.3
Minimum	nc	2.0	1.5	nc	nc	nc	nc	nc	1.5

Table C.8. Descriptive statistics for acrolein ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	8
Sample mean	0.1
Standard error of the mean	0.0
Median	0.1
Maximum	0.2
Minimum	0.1

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	1	1	0	1	1	1	1	1
Sample mean	0.1	0.2	0.1	-	0.1	0.1	0.1	0.1	0.1
Standard error of the mean	nc	nc	nc	-	nc	nc	nc	nc	nc
Median	nc	nc	nc	-	nc	nc	nc	nc	nc
Maximum	nc	nc	nc	-	nc	nc	nc	nc	nc
Minimum	nc	nc	nc	-	nc	nc	nc	nc	nc

Table C.9. Descriptive statistics for acetone ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	32.5
Standard error of the mean	2.6
Median	32.4
Maximum	55.7
Minimum	13.2

Statistic	Floor								Fixed Site
	6	5	4	3	2	1	Grd	SubGrd	
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	33.3	42.2	35.6	28.0	13.2	28.1	31.1	24.8	34.9
Standard error of the mean	nc	13.4	7.5	nc	nc	nc	nc	nc	0.8
Median	nc	42.2	36.6	nc	nc	nc	nc	nc	34.8
Maximum	nc	55.7	48.1	nc	nc	nc	nc	nc	36.6
Minimum	nc	28.8	22.0	nc	nc	nc	nc	nc	32.4

Table C.10. Descriptive statistics for unknown carbonyls ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	2.6
Standard error of the mean	0.2
Median	2.4
Maximum	5.1
Minimum	1.7

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	3.1	3.4	2.3	2.5	2.8	2.3	2.2	3.7	2.3
Standard error of the mean	nc	1.7	0.3	nc	nc	nc	nc	nc	0.1
Median	nc	3.4	2.5	nc	nc	nc	nc	nc	2.2
Maximum	nc	5.1	2.7	nc	nc	nc	nc	nc	2.7
Minimum	nc	1.7	1.8	nc	nc	nc	nc	nc	1.9

Table C.11. Descriptive statistics for total carbonyls ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	15
Number of samples above LOQ	15
Sample mean	65.2
Standard error of the mean	2.6
Median	63.8
Maximum	84.3
Minimum	51.1

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	1	2	3	1	1	1	1	1	5
Number of samples above LOQ	1	2	3	1	1	1	1	1	5
Sample mean	63.1	76.7	64.7	53.2	51.1	63.0	61.6	64.7	67.7
Standard error of the mean	nc	7.7	7.8	nc	nc	nc	nc	nc	3.4
Median	nc	76.7	64.1	nc	nc	nc	nc	nc	64.1
Maximum	nc	84.3	78.5	nc	nc	nc	nc	nc	80.8
Minimum	nc	69.0	51.5	nc	nc	nc	nc	nc	62.0

APPENDIX D

Summary Statistics for
Volatile Organic Compounds

Table D.1. Descriptive statistics for Methylene chloride ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	1	54
Sample mean	1.3	4.4
Standard error of the mean	nc	0.5
Median	nc	3.2
Maximum	nc	25.7
Minimum	nc	1.8
Number of trace values	4	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	2	2	5
Sample mean	1.9	4.7	7.2	2.6	3.2	2.8	2.7	3.6	4.1
Standard error of the mean	0.1	0.6	1.8	0.2	0.1	0.3	0.1	0.7	0.5
Median	1.9	4.5	4.3	2.6	3.2	2.7	2.7	3.6	3.6
Maximum	2.0	9.1	25.7	3.8	3.6	3.4	2.8	4.3	5.6
Minimum	1.8	2.4	2.6	1.9	2.6	2.2	2.6	3.0	3.2
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.2. Descriptive statistics for Trichloroethylene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	0	29
Sample mean	-	1.0
Standard error of the mean	-	0.1
Median	-	0.8
Maximum	-	2.9
Minimum	-	0.7
Number of trace values	1	26

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	0	8	6	2	8	2	1	2	0
Sample mean	-	1.0	1.2	0.8	0.9	0.8	1.3	0.8	-
Standard error of the mean	-	0.2	0.3	0.1	0.1	0.1	nc	0.1	-
Median	-	0.8	0.8	0.8	0.8	0.8	nc	0.8	-
Maximum	-	1.9	2.9	0.9	1.2	0.9	nc	0.9	-
Minimum	-	0.7	0.7	0.8	0.8	0.7	nc	0.7	-
Number of trace values	3	3	8	5	0	1	2	0	5

Table D.3. Descriptive statistics for Tetrachloroethylene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	5	55
Sample mean	3.9	31.0
Standard error of the mean	0.6	2.5
Median	4.0	24.3
Maximum	5.9	118.4
Minimum	2.4	12.7
Number of trace values	0	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	31.9	30.3	33.7	18.1	22.0	46.1	70.2	21.9	27.3
Standard error of the mean	9.6	4.5	3.4	2.1	3.7	13.9	25.6	0.9	0.9
Median	41.3	24.8	34.9	17.7	18.9	55.1	61.0	21.9	28.0
Maximum	41.8	56.0	53.2	27.6	47.5	64.4	118.4	22.8	29.0
Minimum	12.7	16.7	15.5	12.7	17.1	18.8	31.2	21.1	23.8
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.4. Descriptive statistics for 111-trichloroethane ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	5	55
Sample mean	1.7	23.0
Standard error of the mean	0.2	3.6
Median	1.5	16.4
Maximum	2.3	191.2
Minimum	1.3	7.2
Number of trace values	0	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	24.9	16.9	12.4	22.1	44.2	54.2	14.9	21.7	15.8
Standard error of the mean	12.1	2.7	1.8	3.6	21.2	18.7	2.1	0.7	3.1
Median	13.7	15.1	10.0	20.0	19.5	71.6	13.5	21.7	19.0
Maximum	49.0	37.6	31.7	39.5	191.2	74.0	19.1	22.4	23.2
Minimum	11.9	9.7	7.2	12.1	17.0	16.9	12.1	21.1	7.3
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.5. Descriptive statistics for P-dichlorobenzene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	0	0
Sample mean	-	-
Standard error of the mean	-	-
Median	-	-
Maximum	-	-
Minimum	-	-
Number of trace values	0	6

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	0	0	0	0	0	0	0	0	0
Sample mean	-	-	-	-	-	-	-	-	-
Standard error of the mean	-	-	-	-	-	-	-	-	-
Median	-	-	-	-	-	-	-	-	-
Maximum	-	-	-	-	-	-	-	-	-
Minimum	-	-	-	-	-	-	-	-	-
Number of trace values	0	2	2	1	0	0	0	0	1

Table D.6. Descriptive statistics for Benzene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	3	31
Sample mean	6.0	6.8
Standard error of the mean	1.3	0.5
Median	4.7	6.2
Maximum	8.6	13.0
Minimum	4.6	3.9
Number of trace values	2	24

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	7	2	2	8	2	3	2	3
Sample mean	5.9	5.2	5.5	5.0	8.2	10.2	9.3	6.4	5.3
Standard error of the mean	1.3	0.6	1.4	1.1	0.9	1.0	2.4	0.4	0.8
Median	5.1	4.5	5.5	5.0	7.9	10.2	10.2	6.4	4.8
Maximum	8.5	7.8	6.8	6.1	12.3	11.2	13.0	6.8	6.8
Minimum	4.2	3.9	4.1	3.9	5.0	9.2	4.8	6.1	4.1
Number of trace values	0	4	12	5	0	1	0	0	2

Table D.7. Descriptive statistics for Toluene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	2	55
Sample mean	8.0	15.9
Standard error of the mean	0.8	1.1
Median	8.0	14.4
Maximum	8.8	55.5
Minimum	7.1	7.6
Number of trace values	3	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	9.1	13.4	15.3	10.6	18.5	13.2	33.7	32.0	13.1
Standard error of the mean	0.4	0.3	0.8	0.8	0.6	0.3	11.6	14.2	1.9
Median	8.7	13.4	15.4	10.1	17.9	13.0	29.7	32.0	11.7
Maximum	10.0	14.5	22.5	13.5	22.0	13.7	55.5	46.2	18.9
Minimum	8.7	11.9	8.2	7.6	16.6	12.8	15.9	17.7	8.2
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.8. Descriptive statistics for Ethylbenzene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	2	55
Sample mean	1.1	2.2
Standard error of the mean	0.1	0.1
Median	1.1	2.2
Maximum	1.2	8.0
Minimum	1.0	1.2
Number of trace values	3	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	1.7	1.9	2.2	1.7	2.7	2.0	4.3	2.5	1.9
Standard error of the mean	0.1	0.0	0.1	0.2	0.1	0.1	1.9	0.1	0.1
Median	1.6	1.9	2.2	1.6	2.7	2.1	2.7	2.5	1.8
Maximum	1.9	2.2	2.5	2.5	3.0	2.1	8.0	2.7	2.2
Minimum	1.6	1.7	1.5	1.2	2.4	1.9	2.2	2.4	1.5
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.9. Descriptive statistics for O-xylene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	4	55
Sample mean	1.2	3.2
Standard error of the mean	0.1	0.2
Median	1.2	3.0
Maximum	1.6	13.0
Minimum	1.0	1.9
Number of trace values	1	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	2.2	2.7	3.1	2.4	3.9	2.8	6.5	3.7	2.5
Standard error of the mean	0.1	0.1	0.1	0.2	0.2	0.2	3.2	0.2	0.2
Median	2.1	2.7	3.1	2.3	3.8	3.0	3.8	3.7	2.5
Maximum	2.4	3.0	3.4	3.5	4.8	3.0	13.0	3.8	3.0
Minimum	2.0	2.5	1.9	1.9	3.3	2.5	2.9	3.5	1.9
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.10. Descriptive statistics for P-xylene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	4	55
Sample mean	3.2	7.2
Standard error of the mean	0.3	0.4
Median	3.1	6.9
Maximum	4.0	26.9
Minimum	2.6	4.0
Number of trace values	1	0

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	5.8	6.1	7.1	5.8	8.7	6.5	14.2	8.2	5.9
Standard error of the mean	0.4	0.1	0.2	0.8	0.2	0.3	6.4	0.4	0.4
Median	5.6	6.0	7.1	5.0	8.6	6.5	8.6	8.2	5.5
Maximum	6.5	7.1	7.9	9.0	10.0	7.0	26.9	8.6	6.9
Minimum	5.3	5.6	4.8	4.0	8.1	6.1	6.9	7.8	4.8
Number of trace values	0	0	0	0	0	0	0	0	0

Table D.11. Descriptive statistics for Styrene ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	0	0
Sample mean	-	-
Standard error of the mean	-	-
Median	-	-
Maximum	-	-
Minimum	-	-
Number of trace values	0	26

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	0	0	0	0	0	0	0	0	0
Sample mean	-	-	-	-	-	-	-	-	-
Standard error of the mean	-	-	-	-	-	-	-	-	-
Median	-	-	-	-	-	-	-	-	-
Maximum	-	-	-	-	-	-	-	-	-
Minimum	-	-	-	-	-	-	-	-	-
Number of trace values	1	3	5	1	5	2	3	2	5

Table D.12. Descriptive statistics for N-decane ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	0	21
Sample mean	-	8.5
Standard error of the mean	-	0.9
Median	-	9.2
Maximum	-	17.2
Minimum	-	3.1
Number of trace values	0	9

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	0	2	5	1	6	1	2	2	2
Sample mean	-	3.3	8.9	3.8	9.5	10.5	10.8	8.2	8.5
Standard error of the mean	-	0.2	2.8	nc	1.1	nc	4.1	2.1	0.7
Median	-	3.3	6.6	nc	10.3	nc	10.8	8.2	8.5
Maximum	-	3.5	17.2	nc	11.7	nc	14.8	10.3	9.2
Minimum	-	3.2	3.1	nc	4.3	nc	6.7	6.1	7.9
Number of trace values	0	3	1	5	0	0	0	0	0

Table D.13. Descriptive statistics for N-dodecane ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	0	0
Sample mean	-	-
Standard error of the mean	-	-
Median	-	-
Maximum	-	-
Minimum	-	-
Number of trace values	0	14

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	0	0	0	0	0	0	0	0	0
Sample mean	-	-	-	-	-	-	-	-	-
Standard error of the mean	-	-	-	-	-	-	-	-	-
Median	-	-	-	-	-	-	-	-	-
Maximum	-	-	-	-	-	-	-	-	-
Minimum	-	-	-	-	-	-	-	-	-
Number of trace values	1	0	4	1	5	1	0	0	3

Table D.14. Descriptive statistics for N-octane ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	0	50
Sample mean	-	1.4
Standard error of the mean	-	0.1
Median	-	1.1
Maximum	-	5.8
Minimum	-	0.6
Number of trace values	4	5

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	0	11	13	6	8	3	3	2	4
Sample mean	-	1.4	1.0	0.8	2.6	1.1	1.7	1.9	1.0
Standard error of the mean	-	0.2	0.1	0.1	0.5	0.2	0.5	0.2	0.1
Median	-	1.2	0.8	0.7	2.3	1.0	1.5	1.9	1.0
Maximum	-	2.6	2.5	1.2	5.8	1.5	2.6	2.1	1.3
Minimum	-	0.8	0.6	0.6	1.3	0.8	1.0	1.7	0.8
Number of trace values	3	0	1	1	0	0	0	0	1

Table D.15. Descriptive statistics for Sum of VOCs ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	5	55
Sample mean	16.7	95.8
Standard error of the mean	3.6	5.6
Median	17.7	86.5
Maximum	25.7	267.0
Minimum	7.5	47.7

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	83.4	82.2	86.4	66.2	122.2	139.5	164.7	111.6	78.3
Standard error of the mean	2.6	5.2	5.0	4.9	20.8	32.4	51.4	19.8	4.3
Median	81.1	76.5	85.6	61.8	101.1	163.1	121.9	111.6	78.1
Maximum	88.7	114.3	116.0	81.8	264.6	180.0	267.0	131.4	88.1
Minimum	80.5	61.7	60.0	47.7	85.1	75.5	105.1	91.8	64.1

Table D.16. Descriptive statistics for Total VOCs (ppm carbon) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outside	Total Inside
Total number of samples	5	55
Number of samples above LOQ	5	55
Sample mean	0.3	1.1
Standard error of the mean	0.1	0.1
Median	0.3	1.0
Maximum	0.5	3.5
Minimum	0.2	0.4

	Floor								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	3	11	14	7	8	3	3	2	5
Number of samples above LOQ	3	11	14	7	8	3	3	2	5
Sample mean	1.0	1.0	1.0	1.1	1.3	1.8	0.8	0.8	0.9
Standard error of the mean	0.1	0.1	0.1	0.2	0.3	0.1	0.3	0.3	0.2
Median	1.0	1.0	1.0	0.8	1.1	1.8	0.6	0.8	1.1
Maximum	1.2	1.3	1.6	1.9	3.5	2.1	1.3	1.1	1.3
Minimum	0.9	0.8	0.4	0.7	0.4	1.6	0.5	0.5	0.5

APPENDIX E

Summary Statistics for Nicotine

Table E.1. Descriptive statistics for nicotine ($\mu g/m^3$) measured at the LOC Madison building Primary sites. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Inside
Total number of samples	64
Number of samples above LOQ	13
Sample mean	4.8
Standard error of the mean	1.6
Median	1.8
Maximum	18.5
Minimum	0.4

	Floor							
Statistic	6	5	4	3	2	1	Grd	SubGrd
Total number of samples	3	15	20	9	9	1	5	2
Number of samples above LOQ	1	2	3	3	3	0	1	0
Sample mean	0.7	11.7	4.8	1.3	0.6	-	18.5	-
Standard error of the mean	nc	0.1	0.5	0.5	0.0	-	nc	-
Median	nc	11.7	4.6	1.7	0.6	-	nc	-
Maximum	nc	11.7	5.7	1.8	0.6	-	nc	-
Minimum	nc	11.6	4.2	0.4	0.6	-	nc	-

APPENDIX F

Summary Statistics for Fixed Indoor and Fixed Outdoor Monitoring Locations

Table F.1. Descriptive statistics for Turner-10 particle concentration ($\mu g/m^3$) measured at the LOC Madison building Fixed Indoor site. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Indoor Site
Total number of samples	5
Number of samples above LOQ	5
Sample mean	11.7
Standard error of the mean	1.1
Median	11.8
Maximum	15.3
Minimum	8.2

Table F.2. Descriptive statistics for Turner-2.5 particle concentration ($\mu g/m^3$) measured at the LOC Madison building Fixed Indoor site. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Indoor Site
Total number of samples	5
Number of samples above LOQ	5
Sample mean	5.9
Standard error of the mean	0.9
Median	6.4
Maximum	7.7
Minimum	2.5

Table F.3. Descriptive statistics for coarse dichotomous particle concentration ($\mu g/m^3$) measured at the LOC Madison building Fixed Outdoor site. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outdoor
Total number of samples	5
Number of samples above LOQ	5
Sample mean	10.5
Standard error of the mean	1.7
Median	9.8
Maximum	15.8
Minimum	5.3

Table F.4. Descriptive statistics for fine dichotomous particle concentration ($\mu g/m^3$) measured at the LOC Madison building Fixed Outdoor site. Statistics are computed only for values greater than the limit of quantification (LOQ).

Statistic	Total Outdoor
Total number of samples	5
Number of samples above LOQ	5
Sample mean	21.1
Standard error of the mean	3.3
Median	17.4
Maximum	29.7
Minimum	14.1

APPENDIX G

Summary Statistics for Microbiological Contaminants

Table G.1. Descriptive statistics for fungi measured at the LOC Madison building

Statistic	Outside	Total Inside
Total number of samples	1	92
Number of samples	1	91
Sample mean	102.5	34.7
Standard error of the mean	nc	18.2
Median	nc	7
Maximum	nc	1637
Minimum	nc	0

	Sector								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	4	16	18	11	13	9	13	7	1
Number of samples	4	16	18	11	12	9	13	7	1
Sample mean	12.8	15.0	109.6	46.7	8.6	2.7	9.9	3.0	10.6
Standard error of the mean	5.4	3.7	90.0	25.8	2.7	1.5	3.7	1.9	nc
Median	12	11	12	7	5	0	4	0	nc
Maximum	26	53	1637	254	30	14	39	14	nc
Minimum	0	0	0	0	0	0	0	0	nc

Table G.2. Descriptive statistics for bacteria measured at the LOC Madison building

Statistic	Outside	Total Inside
Total number of samples	1	92
Number of samples	1	90
Sample mean	79.5	44.3
Standard error of the mean	nc	6.4
Median	nc	26
Maximum	nc	370
Minimum	nc	0

	Sector								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	4	16	18	11	13	9	13	7	1
Number of samples	4	15	18	11	12	9	13	7	1
Sample mean	114.9	30.9	18.1	51.7	76.4	10.5	69.2	26.2	0.0
Standard error of the mean	42.3	11.2	4.6	16.8	14.2	6.0	30.7	3.5	nc
Median	88	21	14	32	74	4	26	28	nc
Maximum	236	173	67	202	182	56	370	35	nc
Minimum	48	0	0	7	0	0	0	11	nc

Table G.3. Descriptive statistics for thermophilic bacteria measured at the LOC Madison building

Statistic	Outside	Total Inside
Total number of samples	1	92
Number of samples	1	91
Sample mean	7.1	13.3
Standard error of the mean	nc	3.8
Median	nc	2
Maximum	nc	224
Minimum	nc	0

	Sector								
Statistic	6	5	4	3	2	1	Grd	SubGrd	Fixed Site
Total number of samples	4	16	18	11	13	9	13	7	1
Number of samples	4	16	18	11	12	9	13	7	1
Sample mean	110.5	2.2	0.9	13.9	38.6	0.8	3.7	5.0	0.0
Standard error of the mean	35.1	0.9	0.4	4.6	18.8	0.5	1.1	1.7	nc
Median	103	0	0	7	14	0	4	4	nc
Maximum	194	11	5	45	224	4	11	11	nc
Minimum	42	0	0	0	0	0	0	0	nc

Table G.4. Descriptive statistics for number of colony-forming units (water) measured at the LOC Madison building

Steam units

	Type			
Statistic	HSB	HB	T	F
Number of samples	11	10	1	1
Sample mean	0.0	75.0	0.0	0.0
Standard error of the mean	0.0	75.0	nc	nc
Median	0	0	nc	nc
Maximum	0	750	nc	nc
Minimum	0	0	nc	nc

Water spray units

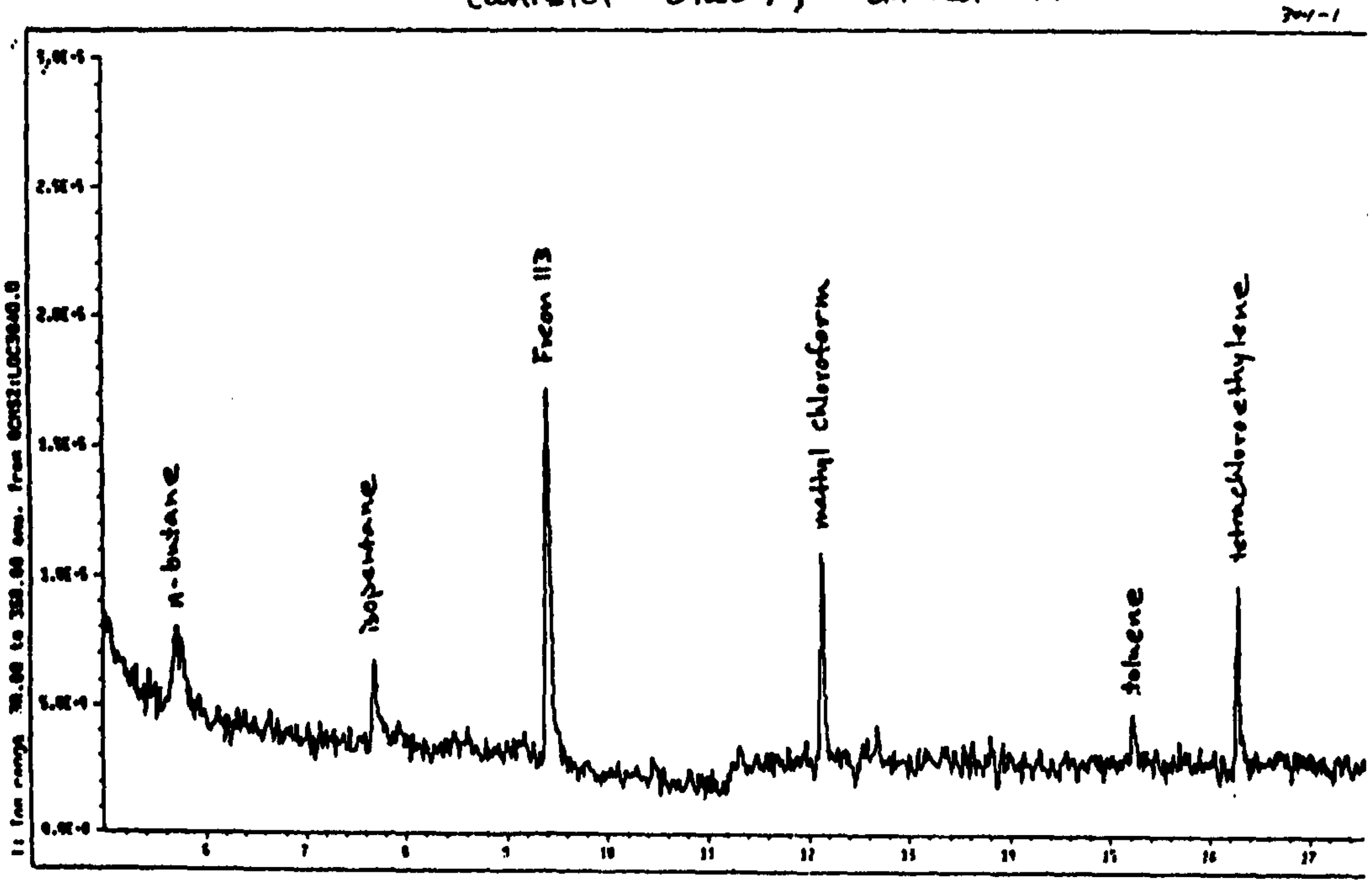
	Type			
Statistic	HSB	HB	T	F
Number of samples	27	27	6	6
Sample mean	2895.9	444178.9	0.5	352.5
Standard error of the mean	883.1	144732.3	0.5	157.4
Median	1100	78000	0	328
Maximum	18000	2720000	3	740
Minimum	0	0	0	0

APPENDIX H

Full Scan VOC Analysis on Selected VOC Canisters

GC/MS Chromatogram for Library of Congress Site 1 - Before Monitoring

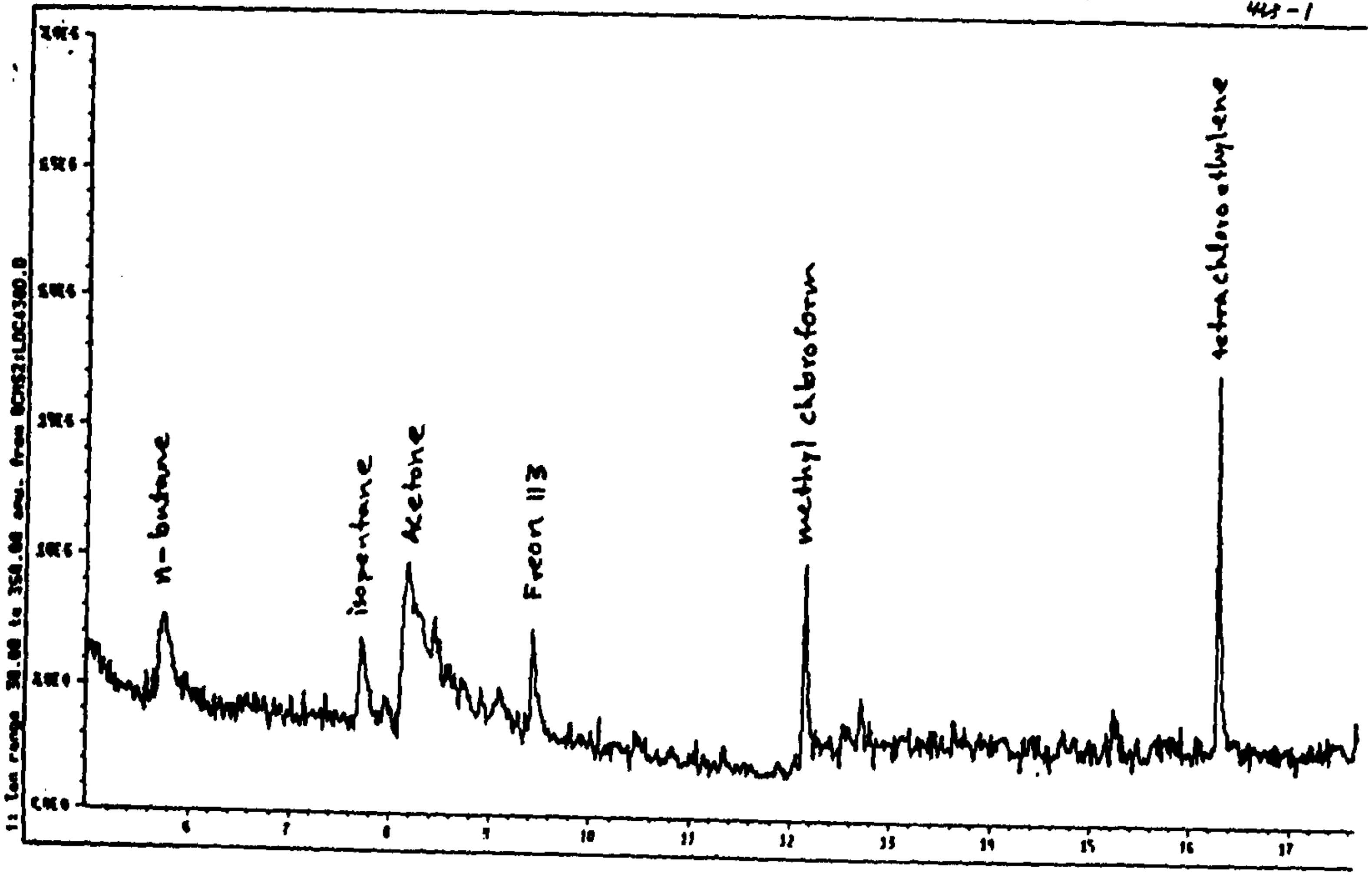
canister 01257, diluted 2/1



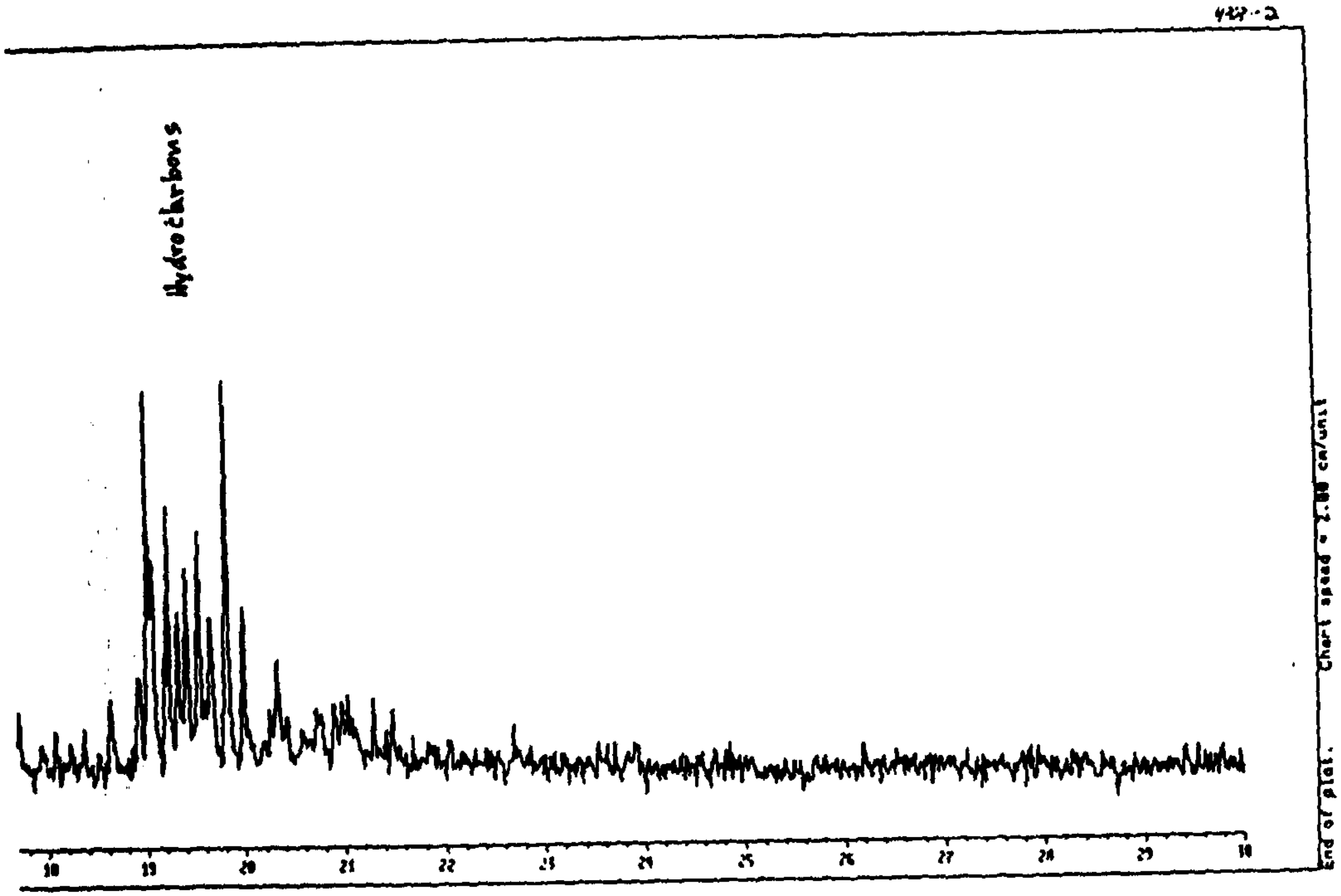
GC/MS Chromatogram for Library of Congress Site 2 - Before Monitoring

Canister 01274, diluted 2/1

43-1



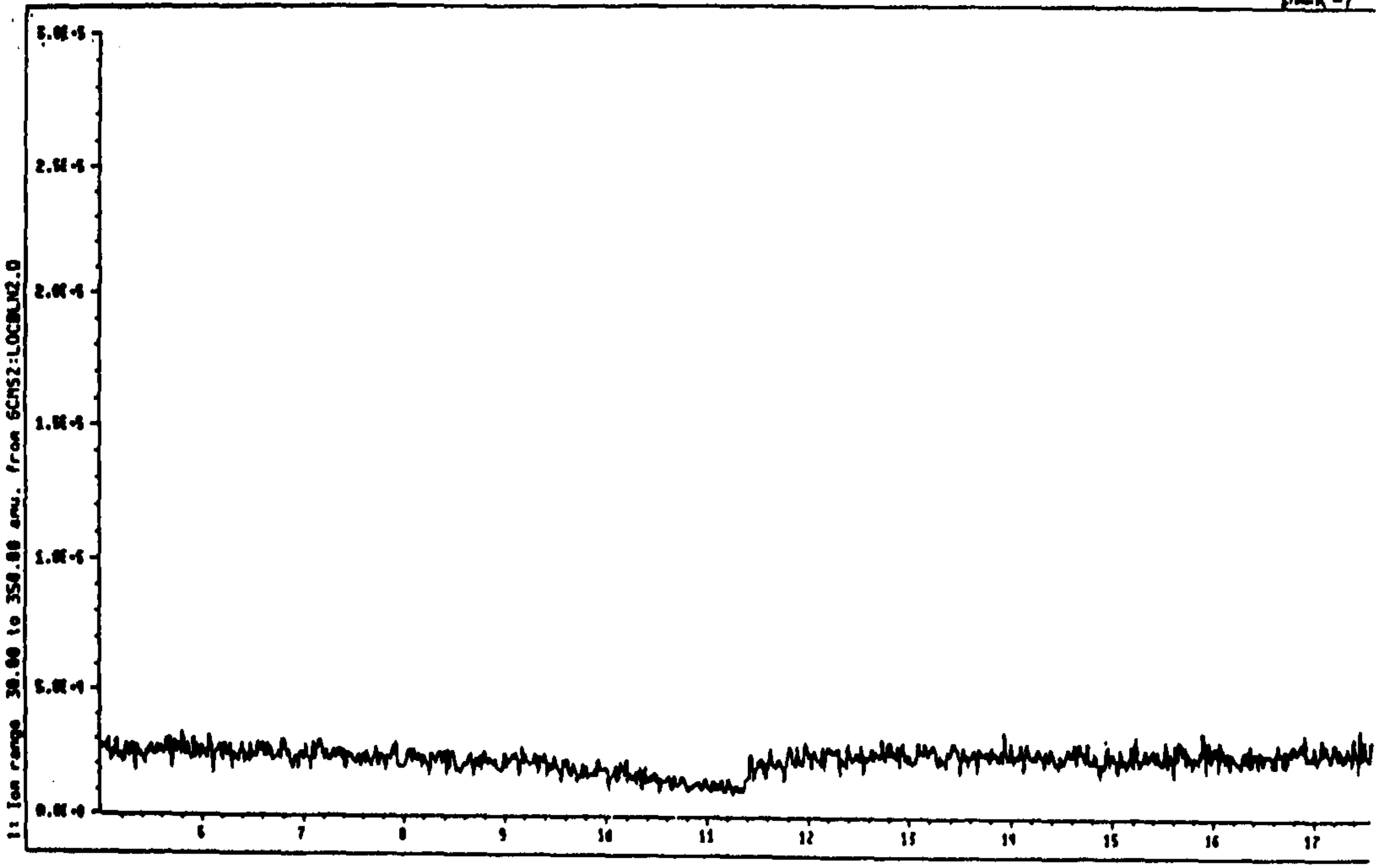
GC/MS Chromatogram for Library of Congress Site 2 - Before Monitoring
Continued



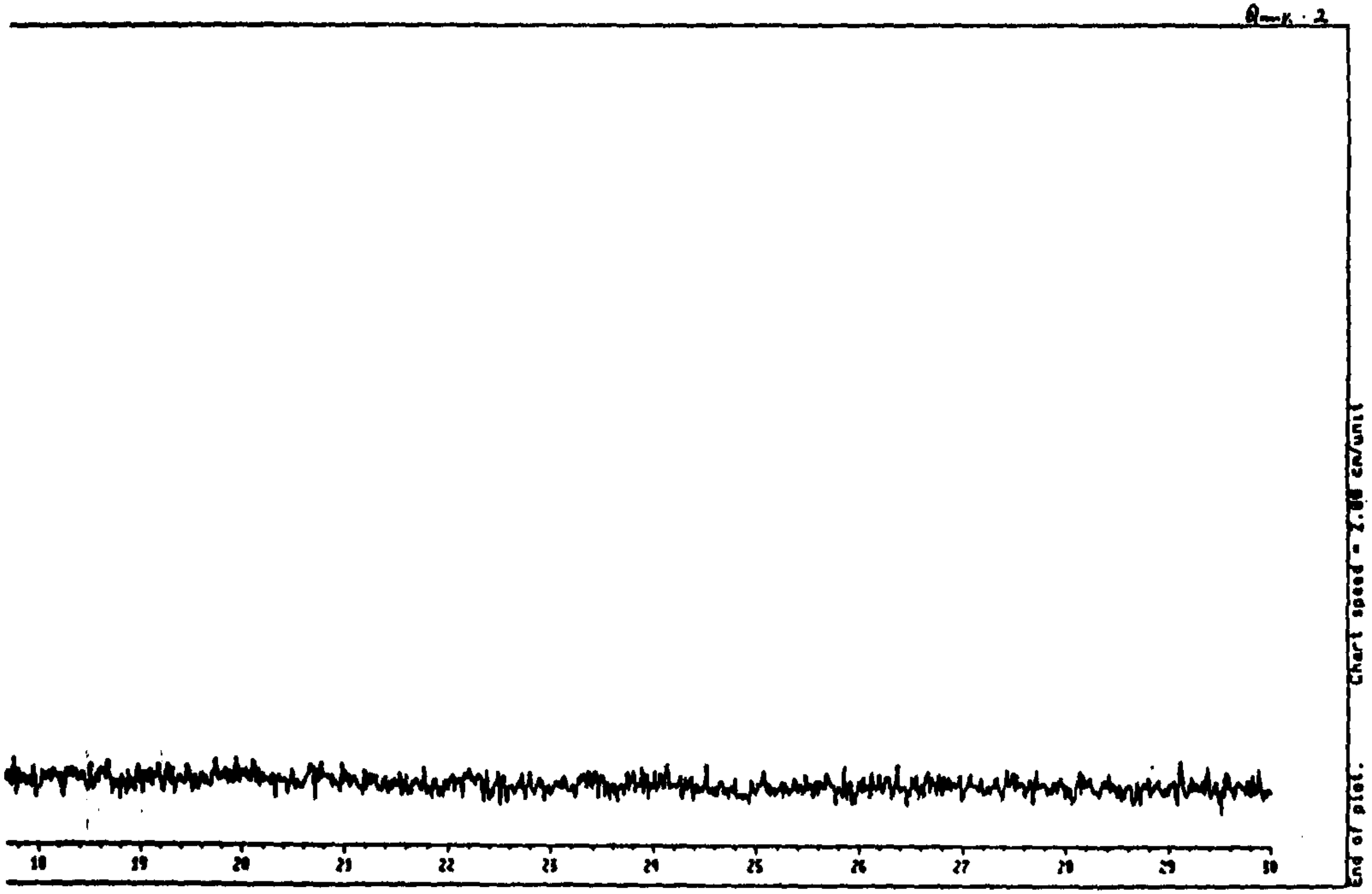
GC/MS Chromatogram for Library of Congress Blank Canister - Before Monitoring

"Field Blank", Canister 01273

Blank-1

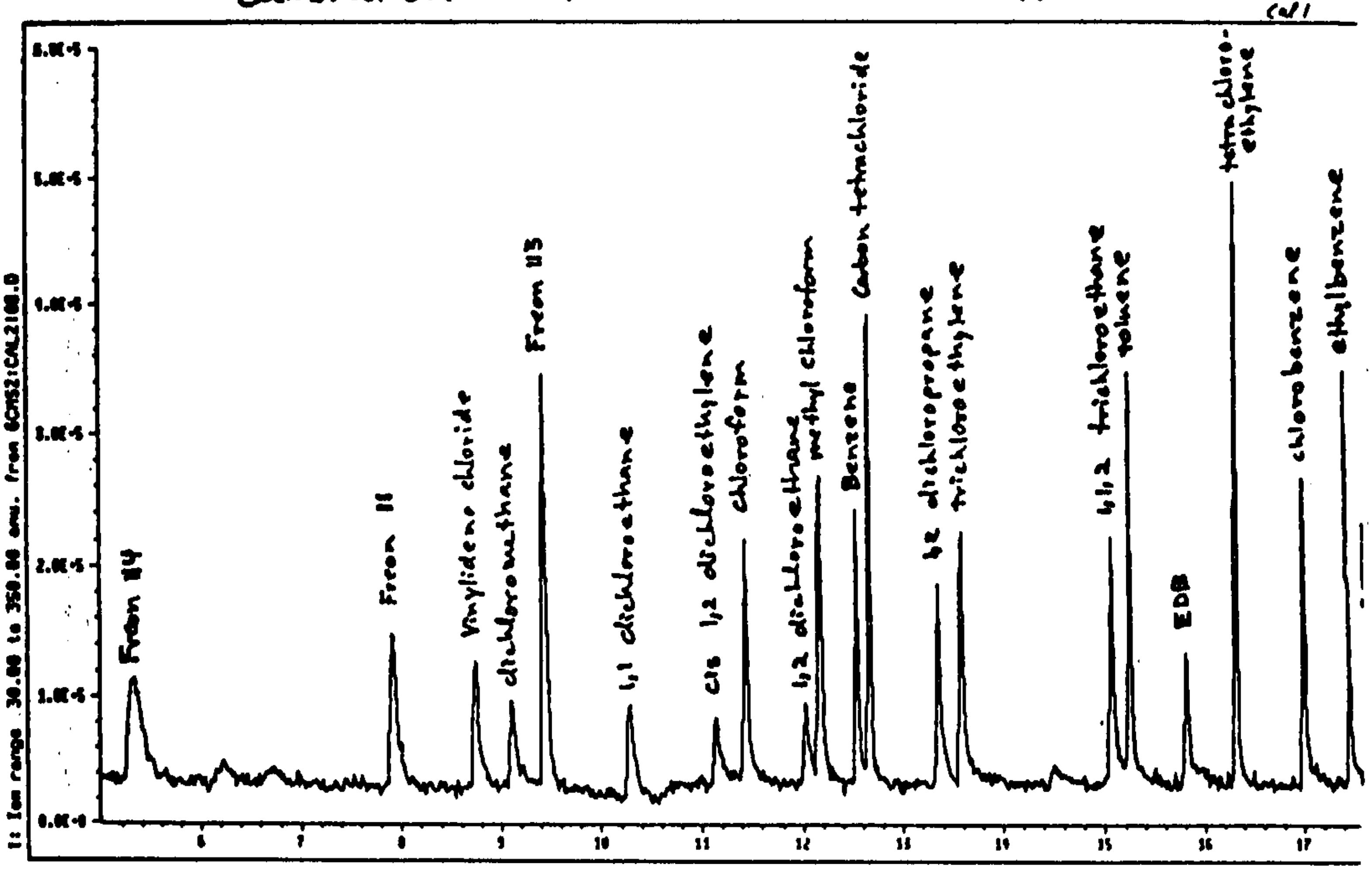


GC/MS Chromatogram for Library of Congress Blank Canister - Before Monitoring
Continued

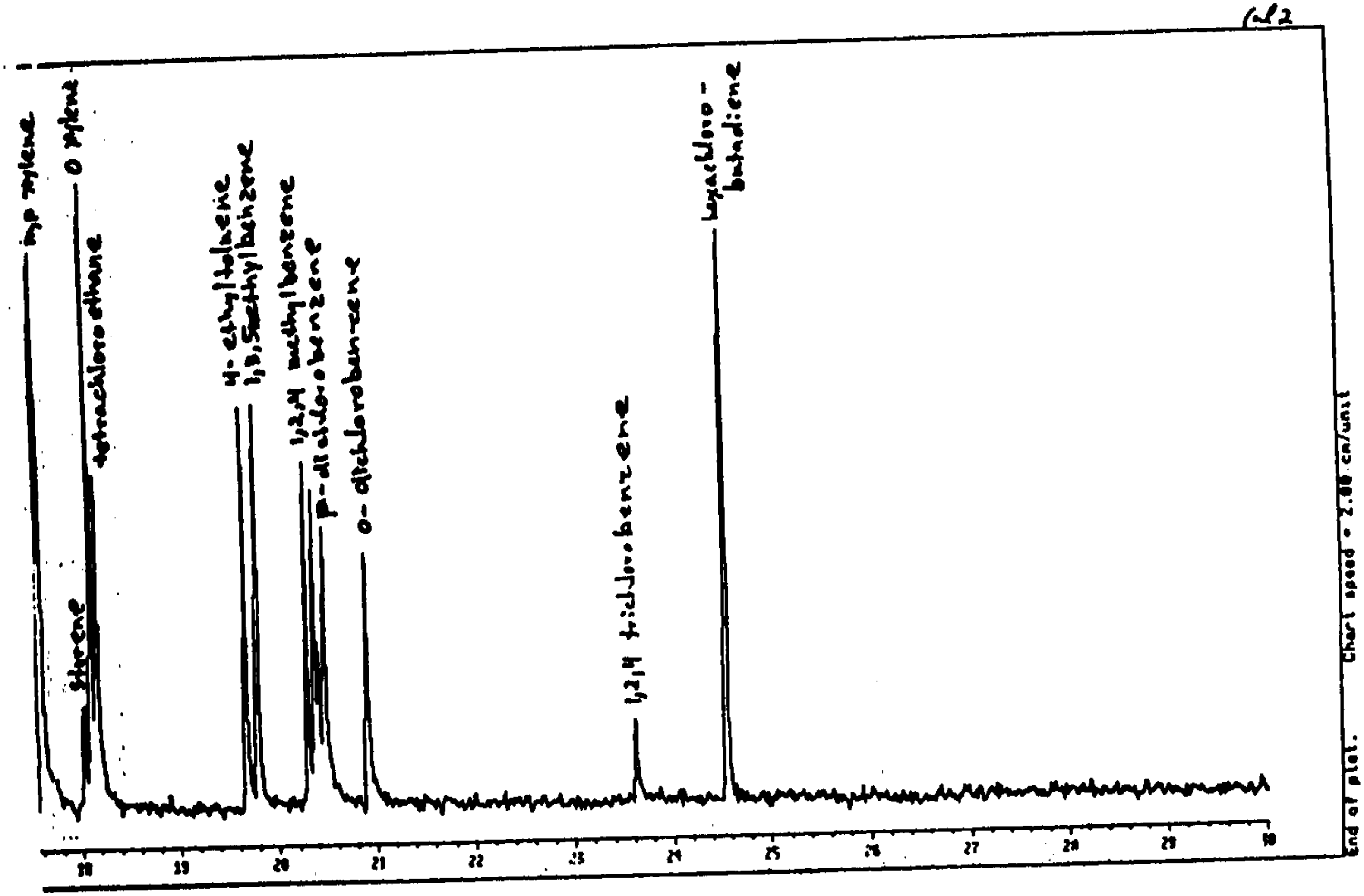


GC/MS Chromatogram for Library of Congress Calibration Canister - Before Monitoring

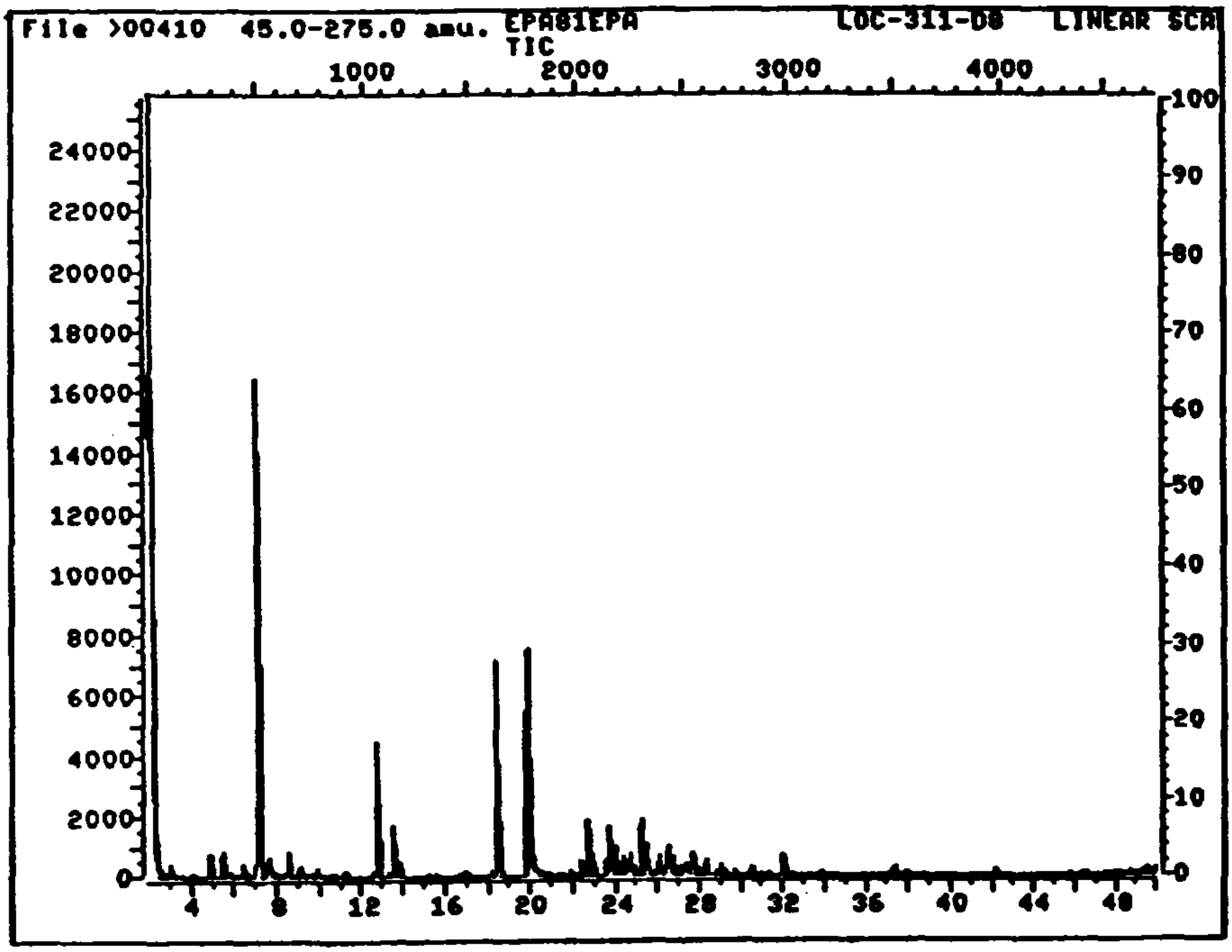
Calibration Sample – VOCs at ~10ppbv



GC/MS Chromatogram for Library of Congress Calibration Canister - Before Monitoring
Continued



GC/MS Chromatogram for Library of Congress Site 3 - After Monitoring



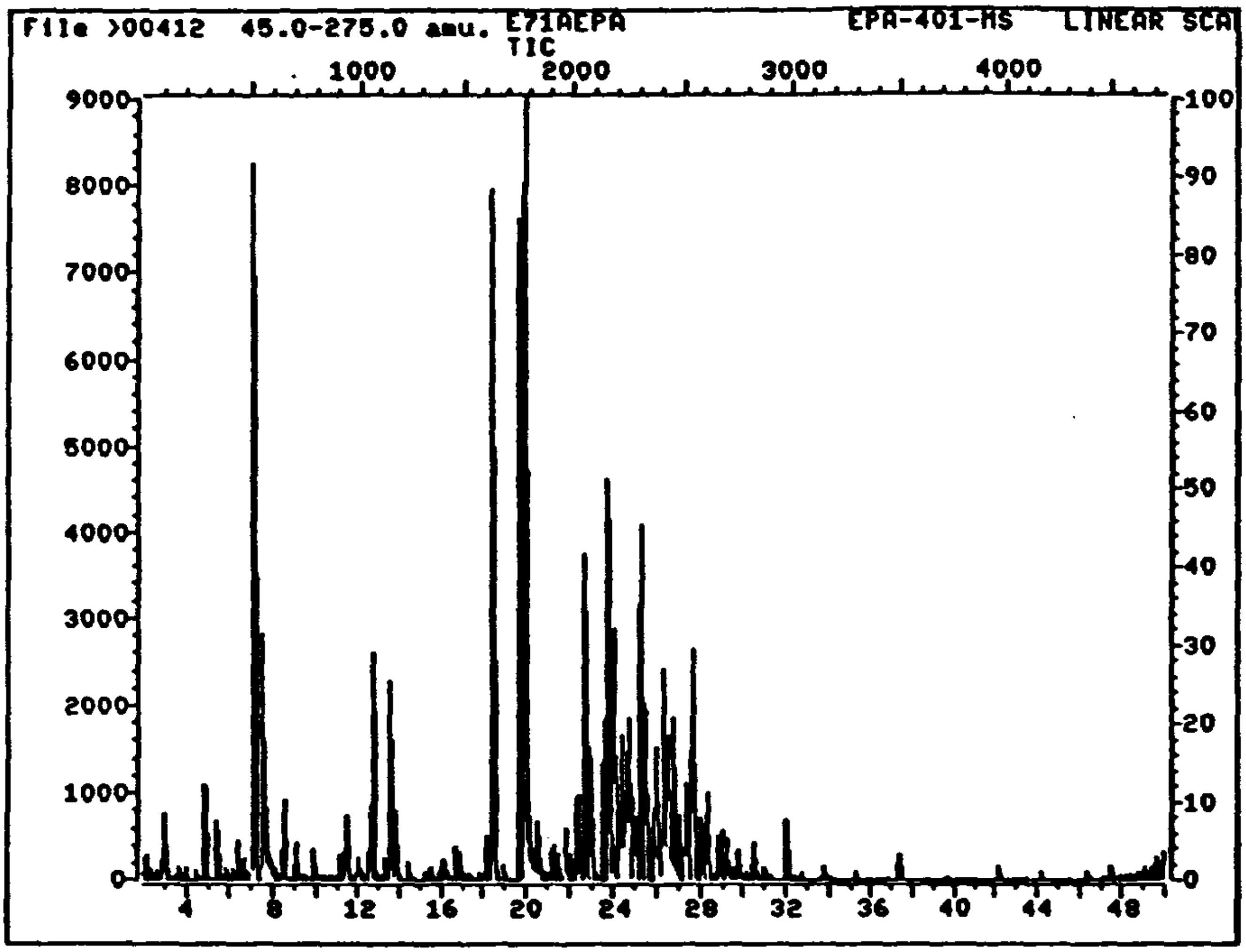
List of VOC Compounds Observed in Site 3 Canister

Peak No.	Retention Time (min)	Identification
1	2.30	chlorodifluoromethane
2	2.97	unknown (tent. butane)
3	4.78	unknown (tent. C_5H_{12})
4	5.35	unknown (tent. trichlorofluoromethane)
5	6.41	unknown (tent. C_5H_8)
6	7.12	trichlorotrifluoroethane
7	7.59	unknown (tent. acetone)
8	8.50	unknown (tent. dichloromethane)
9	9.03	unknown
10	9.84	unknown (tent. C_6H_4)
11	11.13	unknown
12	12.47	unknown
13	12.66	1,1,1-trichloroethane
14	13.57	benzene
15	13.83	unknown (tent. C_7H_{16})
16	18.33	toluene
17	19.67	tetrachloroethylene
18	19.93	hexamethylcyclotrisiloxane
19	21.87	unknown (tent. C_nH_{2n+2})
20	22.36	unknown (tent. ethylbenzene)
21	22.40	unknown (tent. C_nH_{2n+2})
22	22.69	unknown (tent. p-xylene)
23	22.94	unknown (tent. C_nH_{2n+2})
24	23.49	unknown (tent. C_nH_{2n+2})
25	23.69	unknown (tent. C_nH_{2n+2})
26	23.82	unknown (tent. o-xylene)
27	23.98	unknown (tent. C_nH_{2n+2})
28	24.24	unknown
29	24.32	unknown (tent. C_nH_{2n+2})
30	24.43	unknown (tent. C_nH_{2n+2})
31	24.54	unknown

List of VOC Compounds Observed in Site 3 Canister
Continued

Peak No.	Retention Time (min)	Identification
32	24.69	unknown
33	24.81	unknown
34	25.16	unknown
35	25.42	unknown
36	25.87	unknown (tent. C_nH_{2n+2})
37	26.12	unknown
38	26.31	unknown (tent. C_3-alkyl benzene)
39	26.48	unknown
40	26.58	unknown (tent. C_3-alkyl benzene)
41	26.80	unknown (tent. C_nH_{2n+2})
42	27.10	unknown (tent. C_3-alkyl benzene)
43	27.31	unknown
44	27.63	unknown (tent. C_3-alkyl benzene)
45	27.71	unknown (tent. C_3-alkyl benzene)
46	28.02	unknown (tent. $C_{10}H_{16}$)
47	28.27	unknown (tent. C_nH_{2n+2})
48	29.01	unknown
49	29.22	unknown
50	30.48	unknown
51	31.94	unknown (tent. misc. siloxane)
52	37.31	unknown (tent. misc. siloxane)

GC/MS Chromatogram for Library of Congress Site 4 - After Monitoring



List of VOC Compounds Observed in Site 4 Canister

Peak No.	Retention Time (min)	Identification
1	2.92	unknown (tent. C_4H_{10})
2	2.95	unknown (tent. C_4H_{10})
3	4.76	unknown (tent. C_5H_{12})
4	5.34	unknown (tent. trichlorofluoromethane)
5	6.41	C_5H_8
6	6.70	unknown (tent. C_5H_{10})
7	7.12	trichlorotrifluoroethane
8	7.52	unknown
9	7.70	unknown (tent. acetone)
10	8.42	unknown (tent. C_6H_{14})
11	8.50	unknown (tent. dichloromethane)
12	9.04	unknown (tent. C_nH_{2n+2})
13	9.83	unknown (tent. C_6H_{14})
14	11.13	unknown
15	11.38	unknown (tent. C_6H_{14})
16	11.94	unknown (tent. C_6H_{14})
17	12.49	unknown (tent. formaldehyde dimethylacetal)
18	12.68	1,1,1-trichloroethane
19	13.56	benzene
20	13.82	unknown (tent. C_7H_{16})
21	16.14	unknown
22	18.09	unknown (tent. C_nH_{2n+2})
23	18.35	toluene
24	19.68	tetrachloroethylene
25	19.94	hexamethylcyclotrisiloxane
26	20.39	unknown (C_nH_{2n+2})
27	20.57	unknown (tent. n-hexanal)
28	20.63	unknown
29	21.28	unknown (tent. C_nH_{2n+2})
30	21.87	unknown (tent. C_nH_{2n+2})
31	22.11	unknown

List of VOC Compounds Observed in Site 4 Canister
Continued

Peak No.	Retention Time (min)	Identification
32	22.38	ethylbenzene
33	22.42	C_nH_{2n+2}
34	22.70	p-xylene
35	22.99	C_nH_{2n+2}
36	23.50	C_nH_{2n+2}
37	23.69	C_nH_{2n+2})
38	23.98	C_nH_{2n+2})
39	24.13	unknown
40	24.24	unknown (tent. C_nH_{2n+2})
41	24.33	C_nH_{2n+2}
42	24.46	unknown (tent. C_nH_{2n+2})
43	24.56	unknown (tent. C_8H_{18})
44	24.69	C_nH_{2n+2}
45	24.85	C_3-alkyl benzene
46	24.92	unknown (tent. C_nH_{2n+2})
47	25.01	unknown (tent. C_nH_{2n+2})
48	25.17	C_nH_{2n+2}
49	25.43	C_nH_{2n+2}
50	25.53	unknown (tent. C_nH_{2n+2})
51	25.77	unknown
52	25.86	unknown
53	25.91	C_nH_{2n+2}
54	25.97	C_nH_{2n+2}
55	26.04	n-propylbenzene
56	25.16	C_nH_{2n+2}
57	26.33	C_3-alkyl benzene
58	26.52	unknown
59	26.59	C_3-alkyl benzene
60	26.81	C_nH_{2n+2}
61	26.94	unknown (tent. C_nH_{2n+2})
62	27.10	C_3-alkyl benzene
63	27.31	unknown

List of VOC Compounds Observed in Site 4 Canister
Continued

Peak No.	Retention Time (min)	Identification
64	27.35	C_nH_{2n+2}
65	27.52	unknown (tent. C_nH_{2n+2})
66	27.63	trimethylbenzene isomer
67	27.72	C_nH_{2n+2}
68	28.02	$C_{10}H_{16}$
69	28.29	C_nH_{2n+2}
70	28.82	unknown (tent. C_3-alkyl benzene)
71	28.90	C_nH_{2n+2}
72	29.00	unknown
73	29.02	unknown (tent. C_nH_{2n+2})
74	29.70	unknown (tent. C_nH_{2n+2})
75	29.72	unknown
76	30.42	unknown
77	30.47	unknown (tent. C_nH_{2n+2})
78	31.94	unknown
79	37.32	unknown

APPENDIX I

VOC and Pesticide Quality Assurance Procedures

TABLE I-1. BACKGROUND LEVEL EVALUATION OF CLEANED VOC CANISTERS (µg/m3)

		Canister Code						
	LOD (ng/L)	RTI 01483	RTI 01477	RTI 01446	RTI 01454	RTI 01478	Mean BKGD	Range
Vinyl chloride	2.02	0.0	0.0	0.0	0.0	0.0	0.0	
Vinylidene chloride	0.73	0.0	0.0	0.0	0.0	0.0	0.0	
Methylene chloride	0.32	1.2	0.8	0.6	0.8	0.6	0.2	0.6-1.2
trans-1,2-Dichloroethene	0.15	0.1	0.0	0.0	0.0	0.0	0.1	0.0-0.1
1,1-Dichloroethane	0.20	0.0	0.0	0.0	0.0	0.0	0.0	
cis-1,2-Dichloroethene	0.25	0.0	0.0	0.0	0.2	0.0	0.1	0.0-0.2
Chloroform	0.25	0.1	0.1	0.0	0.1	0.1	0.1	0.0-0.1
1,1,1-Trichloroethane	0.14	0.0	0.0	0.0	0.0	0.0	0.0	
Carbon tetrachloride	1.71	0.0	0.0	0.0	0.0	0.0	0.0	
Benzene	0.96	1.6	1.8	1.8	1.3	1.5	0.2	1.3-1.8
Trichloroethylene	0.18	0.0	0.0	0.0	0.0	0.0	0.0	
Toluene	1.72	0.3	0.3	0.2	0.2	0.2	0.0	0.2-0.3
n-Octane	0.15	0.0	0.0	0.0	0.0	0.0	0.0	
Tetrachloroethylene	0.24	0.3	0.2	0.3	0.2	0.0	0.1	0.0-0.3
1,2-Dibromoethane	0.38	0.0	0.0	0.0	0.0	0.0	0.0	
Chlorobenzene	0.09	0.0	0.0	0.0	0.0	0.0	0.0	
Ethylbenzene	0.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0-0.0
m-Xylene	0.59	0.1	0.1	0.1	0.1	0.1	0.0	0.1-0.1
o-Xylene	0.25	0.1	0.1	0.0	0.0	0.1	0.0	0.0-0.1
Styrene	0.37	0.1	0.0	0.0	0.0	0.0	0.0	0.0-0.1
1,1,2,2-Tetrachloroethane	0.64	0.0	0.0	0.0	0.0	0.0	0.0	
n-Decane	0.70	0.0	0.0	0.0	0.0	0.0	0.0	
m-Dichlorobenzene	0.44	0.0	0.0	0.0	0.0	0.0	0.0	
p-Dichlorobenzene	0.43	0.0	0.0	0.0	0.0	0.0	0.0	
o-Dichlorobenzene	0.54	0.0	0.0	0.0	0.0	0.0	0.0	
n-Dodecane	1.11	0.2	0.0	0.0	0.0	0.4	0.2	0.0-0.4
4-Phenylcyclohexene	1.23	0.0	0.0	0.0	0.0	0.1	0.0	0.0-0.1
Total Target Level	16.03	4.0	3.4	2.9	2.9	3.0	0.4	2.9-4.0

TABLE I-1. BACKGROUND LEVEL EVALUATION OF CLEANED VOC CANISTERS (μg/m³)
CONTINUED

		Canister Code									
	LOD (ng/L)	EPA 50	EPA 43	EPA 10	EPA 50	EPA 57	EPA 83	EPA 77	EPA 33A	EPA 43	EPA 1276
Vinyl chloride	2.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vinylidene chloride	0.73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Methylene chloride	0.32	0.5	0.7	0.6	1.7	0.5	0.6	0.6	0.7	0.7	1.5
trans-1,2-Dichloroethene	0.15	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
1,1-Dichloroethane	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
cis-1,2-Dichloroethene	0.25	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Chloroform	0.25	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.6
1,1,1-Trichloroethane	0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon tetrachloride	1.71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene	0.96	1.9	1.4	1.5	2.1	2.0	1.8	1.5	1.7	1.4	1.8
Trichloroethylene	0.18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Toluene	1.72	0.1	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.5
n-Octane	0.15	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Tetrachloroethylene	0.24	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.1
1,2-Dibromoethane	0.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorobenzene	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Ethylbenzene	0.24	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p-Xylene	0.59	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
o-Xylene	0.25	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Styrene	0.37	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
1,1,2,2-Tetrachloroethane	0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
n-Decane	0.70	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
m-Dichlorobenzene	0.44	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p-Dichlorobenzene	0.43	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
o-Dichlorobenzene	0.54	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0
n-Dodecane	1.11	1.3	1.3	0.0	0.0	0.0	0.0	0.2	1.9	1.3	0.0
4-Phenylcyclohexene	1.23	0.4	0.8	0.1	0.0	0.1	0.0	0.0	1.2	0.8	0.0
Total Target Level	16.03	6.5	5.5	2.9	4.4	3.0	2.9	2.8	6.0	5.5	4.6

TABLE I-1. BACKGROUND LEVEL EVALUATION OF CLEANED VOC CANISTERS ($\mu g/m^3$) CONTINUED

	LOD (ng/L)	Canister Code EPA 1265	EPA 37	EPA 1265	EPA 19	EPA 8917	EPA 1478	EPA 8917	EPA 8A	EPA 8710
Vinyl chloride	2.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vinylidene chloride	0.73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Methylene chloride	0.32	0.7	0.6	0.5	0.6	0.5	0.7	0.6	0.8	0.6
trans-1,2-Dichloroethane	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,1-Dichloroethane	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
cis-1,2-Dichloroethane	0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chloroform	0.25	0.2	0.1	0.1	0.2	0.0	0.5	0.0	0.5	0.1
1,1,1-Trichloroethane	0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon tetrachloride	1.71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene	0.96	1.7	1.6	1.7	1.6	1.7	1.8	1.6	1.8	1.7
Trichloroethylene	0.18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Toluene	1.72	0.3	0.2	0.2	0.2	0.4	0.2	0.3	0.2	0.3
n-Octane	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetrachloroethylene	0.24	0.1	0.2	0.1	0.3	0.3	0.0	0.2	0.0	0.0
1,2-Dibromoethane	0.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorobenzene	0.09	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Ethylbenzene	0.24	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
m-Xylene	0.59	0.1	0.0	0.0	0.2	0.2	0.1	0.2	0.1	0.2
o-Xylene	0.25	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.1
Styrene	0.37	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1
1,1,2,2-Tetrachloroethane	0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
n-Decane	0.70	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
m-Dichlorobenzene	0.44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p-Dichlorobenzene	0.43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
o-Dichlorobenzene	0.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
n-Dodecane	1.11	0.0	0.0	0.0	0.2	0.4	0.0	0.3	0.0	0.0
4-Phenylcyclohexene	1.23	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Total Target Level	16.03	3.8	3.0	2.6	3.4	3.8	3.4	3.4	3.6	3.3

TABLE I-1. BACKGROUND LEVEL EVALUATION OF CLEANED VOC CANISTERS ($\mu g/m^3$)
CONTINUED

	LOD (ng/L)	EPA 0754	EPA 2073	EPA 0719	Mean BKGD	Range
Vinyl chloride	2.02	0.0	0.0	0.0	0.0	
Vinylidene chloride	0.73	0.0	0.0	0.0	0.0	
Methylene chloride	0.32	1.0	0.0	0.4	0.3	0.0 - 1.7
trans-1.2-Dichloroethene	0.15	0.0	0.0	0.0	0.0	
1.1-Dichloroethane	0.20	0.0	0.0	0.0	0.0	
cis-1.2-Dichloroethene	0.25	0.0	0.0	0.0	0.0	
Chlorofprm	0.25	0.0	0.1	0.1	0.2	0.0 - 0.6
1.1.1-Trichloroethane	0.14	0.0	0.0	0.0	0.0	
Carbon tetrachloride	1.71	0.0	0.0	0.0	0.0	
Benzene	0.96	2.1	35.0	0.9	13.4	0.9 - 35.
Trichloroethylene	0.18	0.0	0.0	0.0	0.0	
Toluene	1.72	0.2	0.5	0.1	0.1	0.1 - 0.5
n-Octane	0.15	0.0	0.3	0.0	0.1	0.0 - 0.3
Tetrachloroethylene	0.24	0.0	0.2	0.0	0.1	0.0 - 0.3
1.2-Dibromoethane	0.38	0.0	0.0	0.0	0.0	
Chlorobenzene	0.09	0.0	0.0	0.0	0.0	0.0 - 0.1
Ethylbenzene	0.24	0.0	0.0	0.0	0.0	0.0 - 0.1
m-Xylene	0.59	0.1	0.0	0.1	0.1	0.0 - 0.2
o-Xylene	0.25	0.0	0.0	0.0	0.0	0.0 - 0.1
Styrene	0.37	0.0	0.0	0.0	0.0	0.0 - 0.1
1.1.2.2-Tetrachloroethane	0.64	0.0	0.0	0.0	0.0	
n-Decane	0.70	0.0	0.0	0.0	0.0	
m-Dichlorobenzene	0.44	0.0	0.0	0.0	0.0	
p-Dichlorobenzene	0.43	0.0	0.0	0.0	0.0	
o-Dichlorobenzene	0.54	0.0	0.0	0.0	0.0	
n-Dodecane	1.11	0.0	0.0	0.0	0.0	
4-Phenylcyclohexene	1.23	0.1	0.0	0.0	0.1	0.0 - 1.2
Total Target Level	16.03	3.6	36.1	1.5	13.3	1.5 - 36.

TABLE I-2. RESULTS OF ANALYSIS OF CANISTER FIELD BLANKS ($\mu g/m^3$)

Target Compound	FB1	FB2	FB3	FB4	FB5	FB6	FB7	Mean Blank
Vinyl chloride	0.00[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vinylidene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methylene chloride	0.55	0.36	0.63	0.74	0.32	0.26	0.46	0.47
trans-1,2-Dichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,1-Dichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-1,2-Dichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloroform	0.18	0.19	0.10	0.43	0.10	0.00	0.21	0.17
1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon tetrachloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzene	2.49	0.64	0.74	1.02	1.91	1.19	3.70	1.67
Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Toluene	0.38	0.24	0.22	0.30	0.48	0.69	0.87	0.45
n-Octane	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01
Tetrachloroethylene	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.04
1,2-Dibromoethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorobenzene	0.02	0.00	0.03	0.06	0.12	0.07	0.25	0.08
Ethylbenzene	0.03	0.00	0.04	0.04	0.12	0.10	0.25	0.08
m-Xylene	0.04	0.00	0.07	0.04	0.07	0.26	0.21	0.10
o-Xylene	0.03	0.00	0.05	0.03	0.05	0.09	0.12	0.05
Styrene	0.00	0.00	0.00	0.00	0.10	0.00	0.04	0.02
1,1,2,2-Tetrachloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
n-Decane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m-Dichlorobenzene	0.21	0.17	0.00	0.00	0.00	0.00	0.00	0.05
p-Dichlorobenzene	0.23	0.12	0.00	0.00	0.00	0.00	0.00	0.05
o-Dichlorobenzene	0.37	0.36	0.00	0.00	0.00	0.00	0.00	0.10
n-Dodecane	3.45	3.05	0.75	0.49	0.09	0.25	0.26	1.19
4-Phenylcyclohexene	0.98	0.95	0.37	0.28	0.20	0.17	0.19	0.45

[a] 0.00 = No measurable peak area.

TABLE I-3. RECOVERY OF TARGET COMPOUNDS FROM FIELD CONTROL CANISTERS ($\mu g/m^3$)

	Percent Recovery, Corrected for Background								
Target Compound	FC1	FC2	FC3	FC4	FC5	FC6	FC7	Mean	%RSD
Vinyl chloride	72	74	70	55	73	74	67	69	8.8
Vinylidene chloride	102	103	106	110	108	115	99	106	4.7
Methylene chloride	92	89	95	106	92	100	97	96	5.6
trans-1,2-Dichloroethylene	100	106	108	115	109	114	97	107	5.9
1,1-Dichloroethane	102	102	102	102	102	106	94	102	3.3
cis-1,2-Dichloroethylene	104	108	103	105	107	113	99	106	4.0
Chloroform	92	98	96	101	98	102	92	97	4.0
1,1,1-Trichloroethane	96	102	100	100	99	109	94	100	4.5
Carbon tetrachloride	105	71	108	103	0	0	110	71	65.6
Benzene	105	93	98	91	95	100	89	96	5.5
Trichloroethylene	102	106	101	104	106	113	93	104	5.2
Toluene	97	98	106	100	99	103	93	99	3.7
n-Octane	104	100	104	104	104	107	96	103	3.3
Tetrachloroethylene	100	115	104	102	100	112	100	105	5.6
1,2-Dibromoethane	107	114	114	117	110	118	115	113	3.2
Chlorobenzene	103	109	107	108	103	109	99	105	3.2
Ethylbenzene	111	109	108	111	108	110	102	108	2.7
p-Xylene	108	105	105	108	107	110	99	106	3.2
o-Xylene	117	113	109	109	107	110	102	110	4.1
Styrene	107	95	57	107	115	118	102	100	19.1
1,1,2,2-Tetrachloroethane	111	111	106	103	100	108	101	106	4.0
n-Decane	208	170	97	115	111	106	97	129	30.7
m-Dichlorobenzene	182	157	124	138	114	117	107	134	18.7
p-Dichlorobenzene	176	150	126	128	117	119	117	133	15.2
o-Dichlorobenzene	190	161	115	122	109	113	109	131	22.3
n-Dodecane	171	145	6	70	92	69	50	86	60.3
4-Phenylcyclohexene	28	25	-1	29	64	28	16	27	66.7

TABLE I-4. PERCENT RELATIVE STANDARD DEVIATION FOR DUPLICATE CANISTER ANALYSIS

	Samples		Field Controls		Field Blanks	
	N[a]	Mean %RSD	N[a]	Mean %RSD	N[b]	Mean %RSD
Vinyl chloride	-[c]	-	3	6.6	-	-
Vinylidene chloride	-	-	3	3.1	-	-
Methylene chloride	8	9.3	3	6.9	3	61.5
trans-1,2-Dichloroethane	-	-	3	4.9	-	-
1,1-Dichloroethane	-	-	3	5.7	-	-
cis-1,2-Dichloroethene	-	-	3	1.9	-	-
Chloroform	-	-	3	3.6	3	12.7
1,1,1-Trichloroethane	11	2.4	3	3.5	-	-
Carbon tetrachloride	-	-	2	5.8	-	-
Benzene	1	8.2	3	7.7	2	60.0
Trichloroethylene	1	5.4	3	2.0	-	-
Toluene	9	2.2	2	10.2	2	51.6
n-Octane	4	2.1	3	2.4	-	-
Tetrachloroethylene	11	4.5	3	11.1	-	-
1,2-Dibromoethane	-	-	3	7.9	-	-
Chlorobenzene	-	-	3	6.4	1	15.7
Ethylbenzene	10	3.2	3	2.9	1	0
p-Xylene	11	3.4	3	2.7	2	28.2
o-Xylene	11	3.1	3	2.6	2	29.5
Styrene	-	-	3	8.4	1	7.4
1,1,2,2-Tetrachloroethane	-	-	3	4.7	-	-
n-Decane	2	4.3	3	4.5	-	-
m-Dichlorobenzene	-	-	3	12.4	1	28.3
p-Dichlorobenzene	-	-	3	14.0	-	-

TABLE I-4. PERCENT RELATIVE STANDARD DEVIATION FOR DUPLICATE CANISTER ANALYSIS CONTINUED

	Samples		Field Controls		Field Blanks	
	N[a]	Mean %RSD	N[a]	Mean %RSD	N[b]	Mean %RSD
o-Dichlorobenzene	-	-	3	13.5	2	12.6
n-Dodecane	-	-	3	13.5	3	41.4
4-Phenylcyclohexene	-	-	3	63.6	3	46.8

[a] N = Number of pairs where both have measurable data.

[b] N = Number of pairs where both values are greater than 0.00

[c] – = One or both values of pair below quantifiable limit (samples, controls); one or both values 0.00 (blanks).

TABLE I-5. RESULTS OF ANALYSIS OF EXTERNAL PERFORMANCE EVALUATION VOC SAMPLES

Target Compound	Amount Spiked, ppb			
	1000 8788	8800 8711	8740 8763	8734
Vinyl chloride	4.2	3.1	1.7	2.5
Chloroform	4.0	3.0	1.6	2.4
Carbon tetrachloride	3.9	3.0	1.6	2.4
Methylene chloride	3.5	2.6	1.4	2.1
1,2-Dichloroethane	4.2	3.2	1.7	2.5
Trichloroethylene	4.4	3.3	1.8	2.6
Benzene	4.3	3.2	1.7	2.6
Tetrachloroethylene	4.5	3.4	1.8	2.7
Bromomethane	3.7	2.8	1.5	2.2
Trichlorofluoromethane	3.8	2.9	1.5	2.3
1,1,1-Trichloroethane	4.2	3.2	1.7	2.5
1,2-Dichloropropane	4.2	3.2	1.7	2.5
1,2-Dibromoethane	4.1	3.1	1.6	2.4
Toluene	4.4	3.3	1.7	2.6
Chlorobenzene	4.4	3.3	1.8	2.6
Ethylbenzene	4.0	3.0	1.6	2.4
o-Xylene	4.0	3.0	1.6	2.4

TABLE I-5. RESULTS OF ANALYSIS OF EXTERNAL PERFORMANCE EVALUATION VOC SAMPLES CONTINUED

	Results, Expressed as % Bias[a]						
Target Compound	1000	8788	8800	8711	8740	8763	8734
Vinyl chloride	-76	-55	-58	-45	-53	-29	-48
Chloroform	-15	-18	-17	-13	-12	-12	-12
Carbon tetrachloride	2.6	2.6	0.0	6.7	12	6.2	0.0
Methylene chloride	-5.7	-5.7	0.0	7.7	14	7.1	9.5
Trichloroethylene	-20	-23	-24	-18	-22	-22	-23
Benzene	-26	-19	-16	-16	-29	-18	-15
Tetrachloroethylene	-20	-24	-35	-21	-5.6	-17	-30
1,1,1-Trichloroethane	-21	-19	-22	-19	-12	-18	-16
1,2-Dibromoethane	-24	-24	-32	-26	-19	-25	-25
Toluene	-18	-23	-24	-21	-18	-18	-19
Chlorobenzene	-25	-25	-33	-27	-28	-28	-31
Ethylbenzene	-22	-25	-30	-20	-19	-25	-17
o-Xylene	-18	-20	-23	-20	-19	-19	-21

[a] $\%\text{Bias} = \frac{\text{Amount Spiked} - \text{Amount Found}}{\text{Amount Spiked}} \times 100$

TABLE I-6. PESTICIDE MATRIX SPIKE RECOVERY DATA

EXTRACTION DATE (MS-1): 03/08/89
(MS-2): 03/14/89

OCN RECOVERIES (MS-1): 98 %
(MS-2): 107%

COMPOUND	SPIKE LEVEL (ng/plug)	CONC. MS-1	% RECOVERY	CONC. MS-2	% RECOVERY	Rel. % Diff.
ALPHA-BHC	100	76.3	76	70.3	70	8
HEXACHLOROBENZENE	150	152.7	102	148.6	99	3
HEPTACHLOR	200	189.6	95	175.9	88	7
CHLORPYRIFOS	1000	838.3	84	795.7	80	5
DIELDRIN	200	190	95	181.4	91	5
PROPOXUR *	2500	2300	92	2000	80	14
DIAZINON *	2500	2500	100	1600	64	44

APPENDIX J

Ventilation Evaluation Data

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	A-1	A-1	A-2	A-2	A-3
Date	27-Feb	3-Mar	28-Feb	1-Mar	2-Mar
Time	1:40	8:59	10:06	8:56	9:08
OA Damper Position	100% Open	100% Open	100% Open	100% Open	90% Open
Filter Pressure Drop	0.61	0.61	0.50	0.51	0.85
Humidification Method	Spray	Spray	Spray	Spray	Steam (not on)
Control Panel Gage Readings:					
Preheat Discharge Temp. (TH-1)	59	58	72	72	55
Dehum. Coil Discharge Temp. (TH-2)	51	52	55	55	45
Supply Air Temp. (TH-3)	62	63	60	59	63
Supply Air Dew Point Temp. (TH-4)	33	33	43	43	37
Outside Air Dew Point Temp. (TH-5)	3.5	4	18	17	14
Supply Air Static Pressure (TH-6)	3.1	3.1	2.5	2.5	3.2
Supply Air Humidity	No Gage	No Gage	No Gage	No Gage	44
AMD Gages Readings:					
Main Pressure	20.6	20.6	21.5	21.5	20.3
Damper Branch Line Pressure	11	10.9	10.8	10.2	9.7
Transmitter Reading	73	68	77	77	64
Corresponding Outside Air Flow			9558	9558	6232
Design Setting	59	59	75	75	68
Corresponding Outside Air Flow			9450	9450	6384

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	A-4	A-4	A-4	B-1	B-1	B-2	B-2	B-2
Date	27-Feb	1-Mar	3-Mar	2-Mar	3-Mar	27-Feb	28-Feb	1-Mar
Time	1:46	8:51	9:01	9:52			10:39	9:18
OA Damper Position	98% Open	98% Open	98% Open	90% Open	90% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.70	0.70	0.70	0.49	0.50	0.65	0.65	0.65
Humidification Method	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Spray
Control Panel Gage Readings:								
Preheat Discharge Temp. (TH-1)	62	65	65	59	59	57	57	57
Dehum. Coil Discharge Temp. (TH-2)	50	50	49	45	48	50	50	50
Supply Air Temp. (TH-3)	60	60	60	63	64	59	59	58
Supply Air Dew Point Temp. (TH-4)	48	48	48	31	33	28	28	28
Outside Air Dew Point Temp. (TH-5)	off scale	off scale	off scale	2	7	7	7	16
Supply Air Static Pressure (TH-6)	4.1	4.1	4.1	3.0	3.0	3.1	3.1	3.1
Supply Air Humidity	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage
AMD Gages Readings:								
Main Pressure	20.5	20.5	20.5	20.2	20.6	19.5	19.5	19.5
Damper Branch Line Pressure	9.6	9.6	9.6	9.9	9.9	10.5	10.5	10.6
Transmitter Reading	45	36	34	55	54	70	70	64
Corresponding Outside Air Flow	9640	9042	8908	9300	9240	10200	10200	9840
Design Setting	59	59	59	72	72	70	70	70
Corresponding Outside Air Flow	10573	10573	10573	9720	9720	10200	10200	10200

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	B-3	B-4	B-4	B-4	C-1	C-1	C-1
Date	2-Mar	28-Feb	1-Mar	2-Mar	27-Feb	1-Mar	2-Mar
Time	9:47	10:40	9:15	9:43		9:09	9:38
OA Damper Position		100% Open	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.55	0.70	0.70	0.70	0.58	0.58	0.58
Humidification Method	Steam	Spray	Spray	Spray	Spray	Spray	Spray
Control Panel Gage Readings:							
Preheat Discharge Temp. (TH-1)	60	50	52	52	59	59	58
Dehum. Coil Discharge Temp. (TH-2)	55	49.5	49.5	46	50	50	48
Supply Air Temp. (TH-3)	59	49	48	49	61	61	60
Supply Air Dew Point Temp. (TH-4)	23	21	21	20	36	37	37
Outside Air Dew Point Temp. (TH-5)	10	off scale	off scale	off scale	7	7	8
Supply Air Static Pressure (TH-6)	2.6	2.8	2.7	2.8	2.3	2.3	2.3
Supply Air Humidity	61	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage
AMD Gages Readings:							
Main Pressure	20	19.5	19.5	19.5	20	20.5	20.2
Damper Branch Line Pressure	13.2	10	9.9	9.9	11.5	12.2	12.2
Transmitter Reading	46	51	56	59	43	29	27
Corresponding Outside Air Flow	9706	8050	8300	8450	11011	9933	9779
Design Setting	74	56			69	69	69
Corresponding Outside Air Flow	11568				13013	13013	13013

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	C-2	C-2	C-2	C-3	C-3	C-3	C-3
Date	27-Feb	2-Mar	3-Mar	27-Feb	1-Mar	2-Mar	3-Mar
Time	11:00	9:35	10:33	1:09	9:06	9:25	10:30
OA Damper Position	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.40	0.40	0.40	0.65	0.69	0.69	0.70
Humidification Method	Steam	Steam	Steam	Spray	Spray	Spray	Spray
Control Panel Gage Readings:							
Preheat Discharge Temp. (TH-1)	61	61	61	52	53	53	57
Dehum. Coil Discharge Temp. (TH-2)	47	45	47	49	49	48	49
Supply Air Temp. (TH-3)	63	63	60	61	62	62	63
Supply Air Dew Point Temp. (TH-4)	20	20	19	47	45	44	44
Outside Air Dew Point Temp. (TH-5)	14	15	15	14	13	14	14
Supply Air Static Pressure (TH-6)	3.2	3.1	3.1	2.6	2.5	2.0	2.1
Supply Air Humidity	49.5	49.5	53	No Gage	No Gage	No Gage	No Gage
AMD Gages Readings:							
Main Pressure	20	20.2	20	20.5	20.5	20.5	20.7
Damper Branch Line Pressure	13.3	13.3	13.3	9.5	10.1	10	10.1
Transmitter Reading	55	49	50	45	66	68	68
Corresponding Outside Air Flow	11160	10728	10800	8265	9462	9576	9576
Design Setting	72	72	72	68	68	68	68
Corresponding Outside Air Flow	12384	12384	12384	9576	9576	9576	9576

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	C-4	C-4	C-4	D-1	D-2
Date	28-Feb	1-Mar	2-Mar	27-Feb	2-Mar
Time	10:28	9:03	9:17	1:28	8:40
OA Damper Position	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.70	0.55	0.55	0.70	0.71
Humidification Method	Spray	Spray	Spray	Spray	Steam (not on)
Control Panel Gage Readings:					
Preheat Discharge Temp. (TH-1)	57	57	57	60	68
Dehum. Coil Discharge Temp. (TH-2)	50	50	48	47	39
Supply Air Temp. (TH-3)	64	64	63	60	54
Supply Air Dew Point Temp. (TH-4)	23	25	22	27	34
Outside Air Dew Point Temp. (TH-5)	off scale	off scale	off scale	3	11
Supply Air Static Pressure (TH-6)	2.7	2.7	2.7	3.9	1.6
Supply Air Humidity	No Gage	No Gage	No Gage	No Gage	58
AMD Gages Readings:					
Main Pressure	20	20	20	20.5	20.5
Damper Branch Line Pressure	9.1	9.1	9.2	12.7	10.8
Transmitter Reading	52	55	51	55	85
Corresponding Outside Air Flow	7752	7905	7701	6975	8325
Design Setting	71	71	71	58	70
Corresponding Outside Air Flow	9747	9747	9747	7110	8100

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	D-3	D-3	D-3	D-3	D-4	D-4	D-4
Date	27-Feb	28-Feb	1-Mar	3-Mar	27-Feb	1-Mar	3-Mar
Time	1:20	10:00	8:38	9:10	1:24	8:36	9:14
OA Damper Position	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.75	0.75	0.75	0.78	0.67	0.67	0.62
Humidification Method	Spray	Spray	Spray	Spray	Spray	Spray	Spray
Control Panel Gage Readings:							
Preheat Discharge Temp. (TH-1)	62	61	70	61	51	51	searching
Dehum. Coil Discharge Temp. (TH-2)	51	51	51	53	52	53	53
Supply Air Temp. (TH-3)	61	60.5	60.5	60.5	60	60	60
Supply Air Dew Point Temp. (TH-4)	38	38	38	33	33	33	33
Outside Air Dew Point Temp. (TH-5)	48	46	46	-5	-4	off scale	-5
Supply Air Static Pressure (TH-6)	2.7	2.7	2.7	2.7	2.6	2.7	2.7
Supply Air Humidity	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage
AMD Gages Readings:							
Main Pressure	20.5	21	21	20	20	20	20
Damper Branch Line Pressure	11.5	11.5	11.5	10.8	10.8	10.9	10.8
Transmitter Reading	57	57	58	65	71	63	66
Corresponding Outside Air Flow	10990	10990	11060	11650	7695	7335	7470
Design Setting	73	73	73	73	71	71	71
Corresponding Outside Air Flow	12110	12110	12110	12110	7695	7695	7695

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	E-1-E	E-1-E	E-3-E	E-1-W	E-1-W	E-1-W	E-2-W	E-2-W
Date	28-Feb	1-Mar	3-Mar	27-Feb	28-Feb	1-Mar	2-Mar	3-Mar
Time	10:15	9:22	10:07	2:00	9:55	8:46	8:58	9:34
OA Damper Position	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.50	0.51	0.45	0.55	0.55	0.61	searching	searching
Humidification Method	Spray	Spray	Spray	Spray	Spray	Spray	Steam (light)	Steam (light)
Control Panel Gage Readings:								
Preheat Discharge Temp. (TH-1)	59	60	50	49	49	49	searching	searching
Dehum. Coil Discharge Temp. (TH-2)	59	58	51	57	57	58	42	42
Supply Air Temp. (TH-3)	62	65	60	59	59	57	56	58
Supply Air Dew Point Temp. (TH-4)	41	41	16	31	31	32	31	31
Outside Air Dew Point Temp. (TH-5)	9	8	off scale	9	9	9	2	7
Supply Air Static Pressure (TH-6)	2.9	2.9	2.8	3.5	3.5	0.2	searching	searching
Supply Air Humidity	No Gage	No Gage	No Gage	No Gage	No Gage	No Gage	60	62
AMD Gages Readings:								
Main Pressure	20	20.2	19.9	20.7	20.7	20.4	20.5	20.3
Damper Branch Line Pressure	9.9	10	10.8	12.2	12.2	12.2	searching	searching
Transmitter Reading	35	46	55	56	56	56	searching	searching
Corresponding Outside Air Flow	7695	8322	7650	7020	7020	7020		
Design Setting	71	71		67	67	67	75	75
Corresponding Outside Air Flow	9747	9747		7515	7515	7515	4550	4550

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	E-3-W	E-3-W	F-1-E	F-2-E	F-2-E	F-3-E
Date	2-Mar	3-Mar	3-Mar	28-Feb	1-Mar	3-Mar
Time	8:55	9:31	10:25	10:21	9:27	10:21
OA Damper Position	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.45	0.40	0.50	0.55	0.55	0.40
Humidification Method	Spray	Spray	Spray	Spray	Spray	Steam
Control Panel Gage Readings:						
Preheat Discharge Temp. (TH-1)	60	58	53	56	59	61
Dehum. Coil Discharge Temp. (TH-2)	54	50	51	49	48	38
Supply Air Temp. (TH-3)	62	60	56	62	64	53
Supply Air Dew Point Temp. (TH-4)	41	39	38	48	48	23
Outside Air Dew Point Temp. (TH-5)	13	13	41	14	14	18
Supply Air Static Pressure (TH-6)	2.4	2.5	2.6	2.6	2.6	1.9
Supply Air Humidity	No Gage	No Gage	No Gage	No Gage	No Gage	30
AMD Gages Readings:						
Main Pressure	20.7	20.4	19.6	19.5	19.5	19.7
Damper Branch Line Pressure	14.2	14.2	10.9	10.2	10.5	10
Transmitter Reading	21	10	93	44	34	55
Corresponding Outside Air Flow	6897	6270	16984	10800	10050	11160
Design Setting	68	68	39	41	41	47
Corresponding Outside Air Flow	9576	9576	12232	10575	10575	10584

Table J.1. AHU Data for LOC During Sampling Days

Air Handling Unit	F-1-W	F-1-W	F-1-W	F-2-W	F-2-W	F-3-W	F-3-W
Date	27-Feb	2-Mar	3-Mar	2-Mar	3-Mar	28-Feb	1-Mar
Time	2:05	8:46	9:25	8:49	9:28	9:46	8:43
OA Damper Position	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open	100% Open
Filter Pressure Drop	0.60	0.60	0.61	0.50	0.50	0.38	0.38
Humidification Method	Spray	Spray	Spray	Steam	Steam	None	None
Control Panel Gage Readings:							
Preheat Discharge Temp. (TH-1)	57	55	56	60	58	60	60
Dehum. Coil Discharge Temp. (TH-2)	52	52	53	48	48	46	46
Supply Air Temp. (TH-3)	62	62	62	66	66	66	67
Supply Air Dew Point Temp. (TH-4)	32	31	32	31	33	23	26
Outside Air Dew Point Temp. (TH-5)	53	53	53	11	10	12	12
Supply Air Static Pressure (TH-6)	3.6	3.8	3.6	2.4	2.4	2.3	2.3
Supply Air Humidity	No Gage	No Gage	No Gage	57	60	No Gage	No Gage
AMD Gages Readings:							
Main Pressure	20.5	20.3	20.3	20.2	21.2	21.2	21.2
Damper Branch Line Pressure	8.5	8.7	8.5	10.3	10.6	9.9	10.3
Transmitter Reading	23	30	31	53	44	58	62
Corresponding Outside Air Flow	9840	10400	10480	9180	8640	11584	11876
Design Setting	37	37	37	45	45	35	35
Corresponding Outside Air Flow	10960	10960	10960	8700	8700	9895	9895

Table J.2. Outside Air Flow (cfm).

AHU	2/27/89		2/28/89		3/1/89		3/3/89		Overall	
	Mean[1]	SD	Mean[2]	SD	Mean[3]	SD	Mean[4]	SD	Mean[5]	SD
A-1	11545	67	11675	190	11605	194	11605	194	11611	173
A-2	7886	794	8284	739	8325	820	8325	820	8243	766
A-3	6072	32	6023	55	6057	110	6057	110	6037	75
A-4	9018	88	8896	334	9116	357	9116	357	8941	794
B-1	9275	13	9226	45	9220	60	9220	60	9233	56
B-2	10048	34	9983	118	9841	104	9841	104	9905	132
B-3	10161	90	10133	70	10067	106	10067	106	10092	89
B-4	7122	22	7285	54	7431	72	7431	72	7396	151
C-1	9833	38	9833	55	9842	66	9842	66	9818	58
C-2	11104	57	11054	145	11131	204	11131	204	10940	261
C-3	9585	38	9616	92	9626	132	9626	132	9627	114
C-4	8110	36	8047	77	8121	94	8121	94	8121	101
D-1	10837	48	10830	235	10931	676	10931	676	10048	1259
D-2	7761	50	7822	84	7806	85	7806	85	7827	82
D-3	11231	56	11236	258	11197	179	11197	179	11139	267
D-4	7496	16	7471	101	7472	84	7472	84	7485	81
E-1-E	8467	143	8343	335	8517	288	8517	288	8423	275
E-2-E	9323	155	9337	166	9240	166	9240	166	9307	269
E-3-E	7330	93	7343	103	7360	97	7360	97	7361	114
E-4-E	5403	32	5423	55	5388	41	5388	41	5411	47
E-1-W	7342	53	7337	108	7264	51	7264	51	7302	83
E-2-W	4265	261	3916	415	4056	300	4056	300	4056	357
E-3-W	8613	669	9423	939	9346	924	9346	924	8591	1268
E-4-W	8972	63	8938	124	8894	99	8894	99	8854	138
F-1-E	15743	50	15583	267	15769	143	15769	143	15630	201
F-2-E	10497	124	10496	101	10537	127	10537	127	10528	119
F-3-E	11256	30	11253	43	11269	31	11269	31	11269	46
F-1-W	10726	55	10711	105	10717	66	10717	66	10730	76
F-2-W	8707	127	8886	255	8748	319	8748	319	8824	262
F-3-W	11550	312	11459	342	11136	44	11136	44	11257	280
Total	275275	709	275863	2191	276027	2492	276027	2492	274204	3010

Notes: AHU stands for air handling unit.

1. N = 6.
2. N = 20.
3. N = 19.
4. N = 20.
6. N = 65.

Table J.3. Supply Air Dry Bulb Temperatures at the Air Handling Unit Discharges.

AHU	2/27/89		2/28/89		3/1/89		3/3/89		Overall	
	Mean[1]	SD	Mean[2]	SD	Mean[3]	SD	Mean[5]	SD	Mean[6]	SD
A-1	65.4	0.6	64.7	1.7	61.8	0.5	61.9	0.4	63.1	1.8
A-2	60.2	0.0	60.6	0.3	60.5	0.4	60.5	0.0	60.5	0.3
A-3	64.8	0.0	65.2	0.3	64.9	0.5	64.8	0.3	65.0	0.4
A-4	59.3	0.0	59.1	0.4	58.7	1.0	59.1	0.4	59.0	0.7
B-1	63.8	0.0	63.9	0.3	63.9	0.2	64.0	0.0	63.9	0.2
B-2	57.9	0.5	57.5	0.4	57.8	0.4	58.1	0.0	58.0	0.7
B-3	59.9	0.0	59.8	0.2	59.6	0.2	59.5	0.3	59.6	0.3
B-4	61.8	0.0	61.6	0.2	61.4[4]	0.3	61.6	0.4	61.6	0.3
C-1	61.0	0.0	60.9	0.4	60.3	0.6	60.6	0.2	60.6	0.5
C-2	63.3	0.0	63.3	0.1	62.1	0.1	57.2	0.4	61.1	2.7
C-3	63.1	1.4	63.2	1.2	63.0	1.2	63.6	1.2	63.2	1.2
C-4	62.4	0.0	62.3	0.4	62.3	0.1	62.1	0.5	62.2	0.4
D-1	57.6	0.0	58.1	0.1	58.1	0.3	57.8	0.0	57.9	0.2
D-2	61.2	0.0	61.3	0.2	61.0	0.5	60.9	0.1	61.1	0.3
D-3	65.5	0.0	66.0	0.2	65.6	0.4	65.5	0.1	65.7	0.3
D-4	57.9	0.0	57.9	0.9	57.8	0.4	57.6	0.7	57.8	0.6
E-1-E	61.0	0.0	61.2	0.2	61.3	0.3	60.9	0.0	61.1	0.3
E-2-E	58.5	0.0	58.8	0.2	59.0	0.2	58.6	0.3	58.8	0.3
E-3-E	60.6	0.0	60.2	0.3	60.0	0.2	60.1	0.0	60.1	0.3
E-4-E	67.2	0.0	67.2	0.0	67.3	0.1	67.3	0.2	67.2	0.2
E-1-W	57.2	0.0	56.8	0.2	56.5	0.2	57.4	0.3	56.9	0.5
E-2-W	56.7	0.6	56.1	0.8	55.7	0.8	56.0	0.9	56.0	0.8
E-3-W	63.1	0.5	63.6	0.4	63.0	0.2	60.9	0.5	62.5	1.2
E-4-W	61.7	0.0	61.7	0.4	61.2	0.3	61.7	0.5	61.5	0.5
F-1-E	53.7	0.0	53.8	0.6	53.2	0.3	53.8	0.5	53.6	0.5
F-2-E	59.4	0.0	59.6	0.6	59.4	0.4	59.7	0.6	59.6	0.5
F-3-E	59.6	0.0	59.7	0.1	59.4	0.5	59.0	0.0	59.4	0.4
F-1-W	62.0	0.0	62.3	0.3	62.1	0.5	61.9	0.0	62.1	0.3
F-2-W	65.0	0.8	64.8	1.0	64.2	1.1	63.1	0.0	64.1	1.1
F-3-W	65.7	0.6	65.7	0.9	64.7	1.0	64.8	0.9	65.1	1.0
NE-1	63.3	0.5	63.2	0.4	62.5	0.1	63.1	0.5	63.0	0.5
NE-2	51.5	0.2	51.6	0.9	50.2	0.6	51.3	0.7	51.1	0.9
NE-3	63.8	0.0	64.9	0.8	64.4	0.5	63.9	0.0	64.3	0.6
NW-1	55.8	0.0	55.5	0.5	55.3	0.5	55.4	0.5	55.4	0.5
NW-2	63.8	0.0	64.2	0.5	63.4	0.9	62.7	0.0	63.5	0.8
NW-3	49.7	0.0	50.1	1.0	49.3	0.5	50.2	0.6	49.8	0.8
E-1	61.2	0.0	61.3	0.1	61.3	0.1	61.3	0.0	61.3	0.1
E-2	64.2	0.5	64.3	0.3	64.1	0.0	64.3	0.1	64.3	0.2
W-1	51.0	0.0	51.2	0.8	50.4	0.6	51.1	0.8	50.9	0.8
W-2	62.7	0.0	62.0	0.5	61.9	0.4	62.4	0.5	62.2	0.5

Notes: AHU stands for air handling unit.

1. N = 6.
2. N = 20.
3. N = 19.
4. N = 14; Sensor problem.
5. N = 20.
6. N = 65 for all units except C-1; for C-1, N = 60.

Table J.4. Main Supply Air Duct Static Pressure (inches water gage).

AHU	2/27/89		2/28/89		3/1/89		3/3/89		Overall	
	Mean[1]	SD	Mean[2]	SD	Mean[3]	SD	Mean[4]	SD	Mean[5]	SD
A-1	2.7	0.5	2.7	0.1	2.8	0.1	2.8	0.1	2.7	0.1
A-2	2.3	0.0	2.3	0.1	2.3	0.1	2.1	0.1	2.2	0.1
A-3	3.0	0.0	3.0	0.1	3.0	0.1	2.9	0.0	3.0	0.1
A-4	3.7	0.1	3.6	0.2	3.7	0.1	3.6	0.2	3.6	0.2
B-1	2.8	0.1	2.7	0.1	2.8	0.1	2.7	0.1	2.7	0.1
B-2	2.9	0.0	2.9	0.0	2.5	0.3	2.3	0.1	2.6	0.3
B-3	2.2	0.0	2.2	0.1	2.3	0.1	2.2	0.1	2.2	0.1
B-4	2.8	0.1	2.8	0.1	2.7	0.1	2.7	0.1	2.7	0.1
C-1	1.9	0.0	1.9	0.1	1.9	0.1	1.9	0.1	1.9	0.1
C-2	3.0	0.0	3.0	0.1	3.0	0.0	3.0	0.1	3.0	0.1
C-3	2.0	0.1	1.8	0.3	1.7	0.3	1.5	0.4	1.7	0.3
C-4	2.4	0.0	2.4	0.0	2.4	0.0	2.4	0.0	2.4	0.0
D-1	3.6	0.0	3.6	0.1	3.6	0.1	3.7	0.1	3.6	0.1
D-2	1.4	0.0	1.4	0.1	1.4	0.1	1.3	0.0	1.3	0.1
D-3	2.3	0.0	2.3	0.0	2.3	0.0	2.3	0.1	2.3	0.0
D-4	2.4	0.0	2.4	0.1	2.4	0.1	2.4	0.1	2.4	0.1
E-1-E	2.4	0.0	2.4	0.1	2.4	0.1	2.4	0.1	2.4	0.1
E-2-E	2.8	0.0	2.8	0.1	2.8	0.1	2.8	0.0	2.8	0.1
E-3-E	2.6	0.0	2.6	0.1	2.6	0.1	2.5	0.1	2.6	0.1
E-4-E	2.1	0.0	2.2	0.1	2.2	0.1	2.2	0.1	2.2	0.1
E-1-W	3.2	0.1	3.1	0.1	3.1	0.0	3.0	0.0	3.1	0.1
E-2-W	2.4	0.4	1.8	0.7	2.0	0.6	2.2	0.6	2.0	0.6
E-3-W	2.3	0.1	2.2	0.1	2.2	0.1	2.2	0.1	2.2	0.1
E-4-W	2.5	0.0	2.5	0.1	2.5	0.1	2.5	0.1	2.5	0.1
F-1-E	2.4	0.0	2.4	0.1	2.4	0.1	2.2	0.1	2.3	0.1
F-2-E	2.3	0.1	2.3	0.1	2.3	0.1	2.3	0.1	2.3	0.1
F-3-E	1.8	0.0	1.8	0.1	1.8	0.0	1.7	0.1	1.8	0.1
F-1-W	3.4	0.1	3.4	0.1	3.3	0.1	3.2	0.1	3.3	0.1
F-2-W	2.2	0.0	2.2	0.0	2.2	0.1	2.2	0.1	2.2	0.1
F-3-W	1.9	0.1	1.9	0.1	1.8	0.1	1.7	0.1	1.8	0.1
NE-1	1.5	0.0	1.5	0.0	1.5	0.0	1.5	0.0	1.5	0.0
NE-2	2.6	0.0	2.6	0.0	2.6	0.0	2.6	0.0	2.6	0.0
NE-3	2.2	0.0	2.2	0.1	2.2	0.1	2.2	0.0	2.2	0.0
NW-1	4.7	0.1	4.9	0.1	4.8	0.1	4.8	0.1	4.8	0.1
NW-2	2.0	0.0	2.0	0.1	2.0	0.1	2.0	0.1	2.0	0.1
NW-3	3.1	0.0	3.1	0.0	3.1	0.0	3.1	0.0	3.1	0.0
E-1	2.3	0.1	2.4	0.1	2.4	0.1	2.3	0.1	2.4	0.1
E-2	1.9	0.0	1.8	0.1	1.9	0.1	1.8	0.1	1.8	0.1
W-1	2.9	0.0	2.9	0.0	2.9	0.0	2.9	0.0	2.9	0.0
W-2	2.5	0.0	2.5	0.1	2.4	0.0	2.4	0.0	2.4	0.1

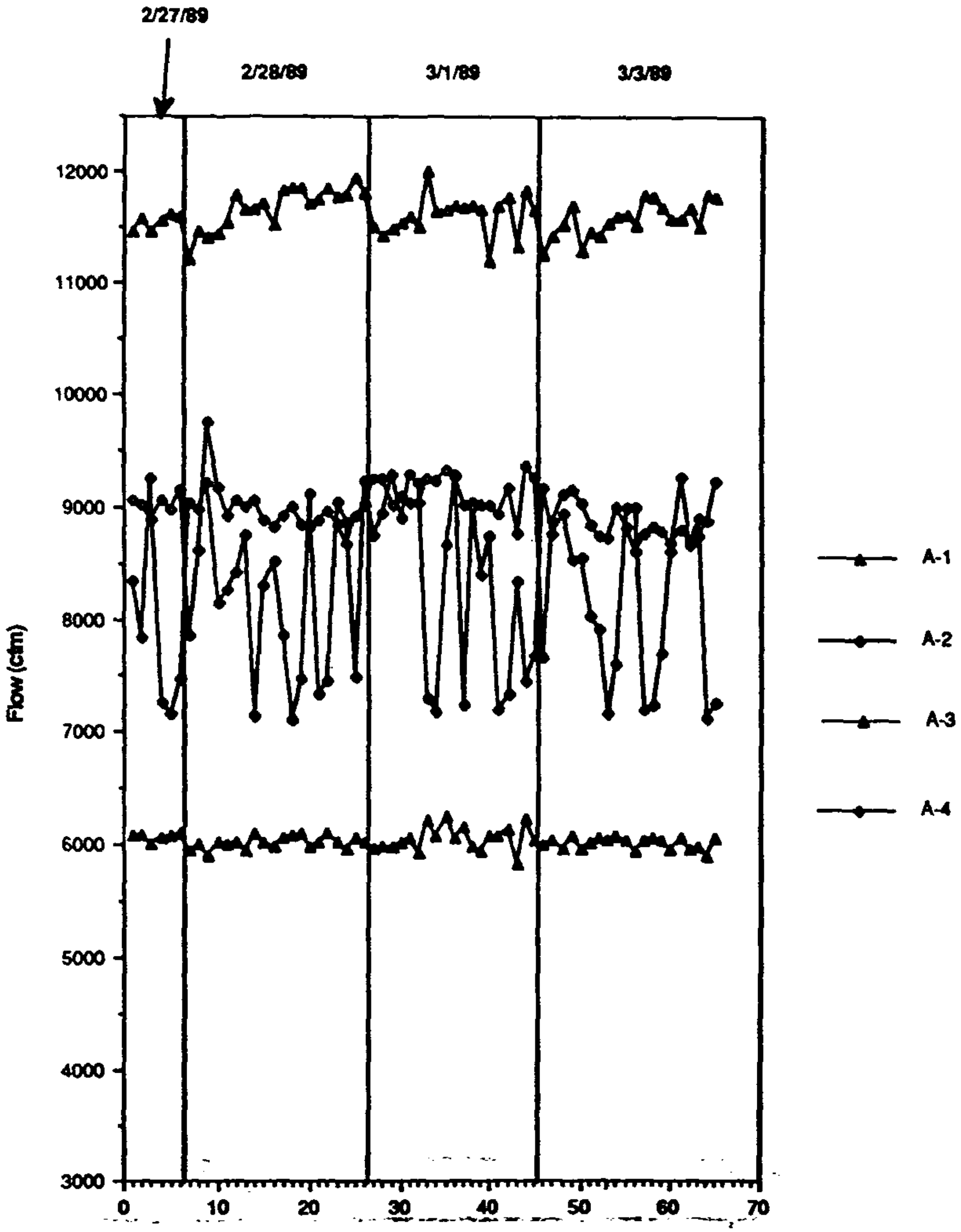
Notes: AHU stands for air handling unit.
1. N = 6.
2. N = 20.
3. N = 19.
4. N = 20.
6. N = 65.

Table J.5. Thermostat Data.

Floor	n[1]	Mean[2] Temperature at Stat	Mean Setpoint on Stat	Mean[3] As-Found BLP	Mean BLP[4] When SP=RT	Mean VAV[5] Box Opening Temperature	Local Supply Air Temperature
1st	3	72	74	17.8	16.7	75.2	73
1st	1	71	72	12.5	11.7	71.2	
2nd	3	73	71	12.8	15.7	72.4	63
2nd	3	75	71	7.7	16.0	73.1	
2nd	3	75	69	3.7	17.3	71.1	71
2nd	4	75	73	12.1	18.9	76.1	68
2nd	3	72	67	3.5	14.8	65.5	61
3rd	1	74	70	3.0	14.5	70.9	
3rd	1	73	64	0.0	18.0	66.5	
3rd	3	74	55	0.0	10.0	53.7	71
4th	4	75	71	7.6	15.3	72.0	64
4th	3	74	72	9.5	13.3	72.2	66
4th	4	74	71	6.0	13.8	70.9	67
4th	3	75	72	7.0	13.9	72.4	65
4th	1	77	65	0.0	15.6	66.2	64
4th	2	72	75	18.5	13.9	75.7	62
5th	4	74	73	13.1	14.1	73.9	66
5th	3	74	73	9.5	14.2	74.0	69
5th	3	75	68	0.0	10.1	66.5	68
5th	4	74	71	8.3	15.9	72.4	59
5th	3	74	73	8.8	14.4	73.4	66
5th	3	75	72	6.7	13.4	72.2	65

Notes:
1. "n" is the number of sets of data used to calculate the means listed in the table.
2. "stat" is a shortened form of thermostat.
3. "BLP" stands for branch line pressure or the pressure in the line going from the thermostat to the VAV box damper motor.
4. "SP" stands for setpoint and "RT" stands for room temperature. These values were calculated from the throttling range data.
5. These temperatures are the temperatures at at the thermostat at which the damper motor would start opening up the VAV damper. These values were calculated based on the setpoint and branch line pressure.

Figure J.1. Outside Air Flow at the LOC During the Survey.



Data Points

Figure J.1. Outside Air Flow at the LOC During the Survey.

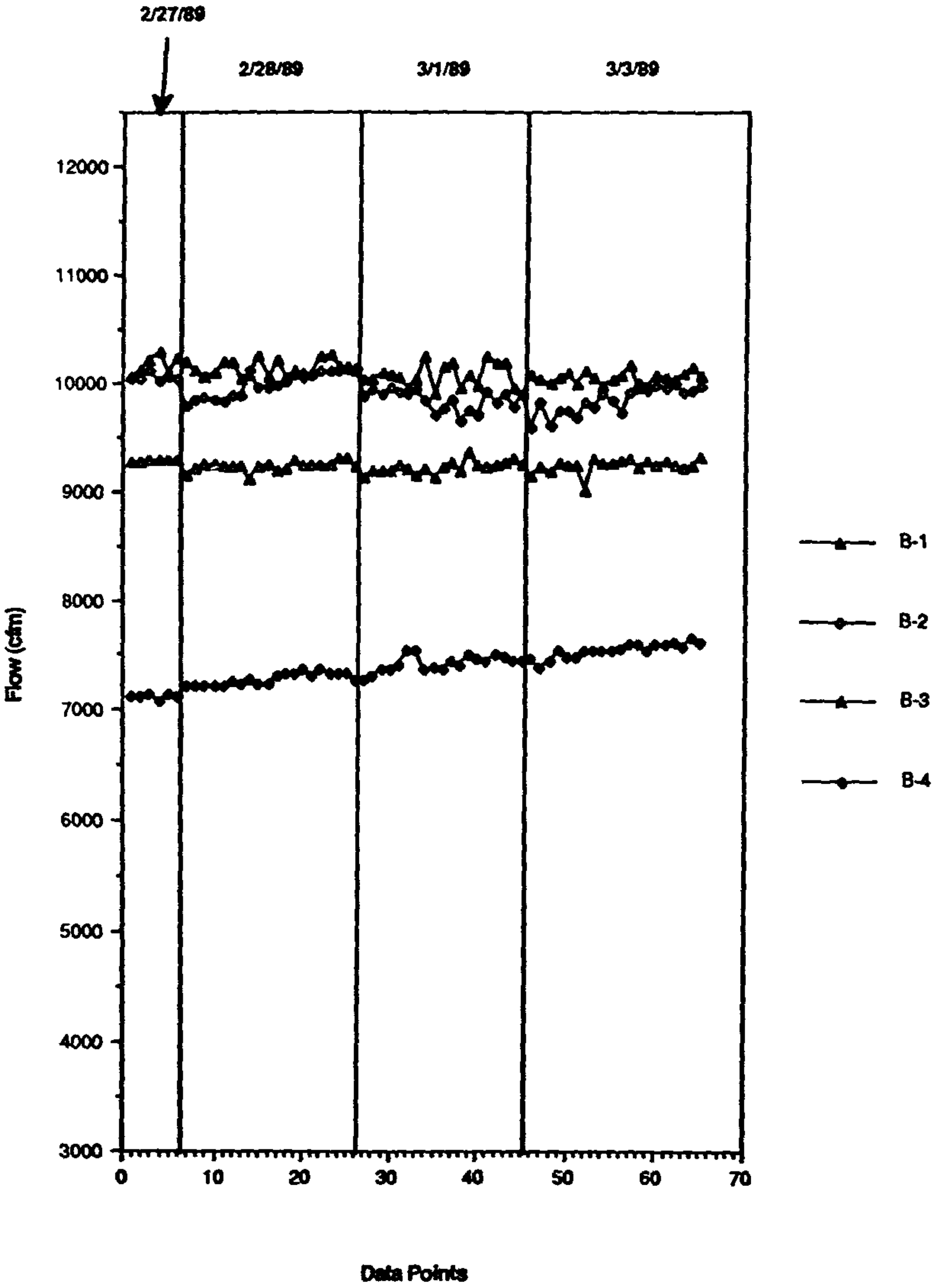


Figure J.1. Outside Air Flow at the LOC During the Survey.

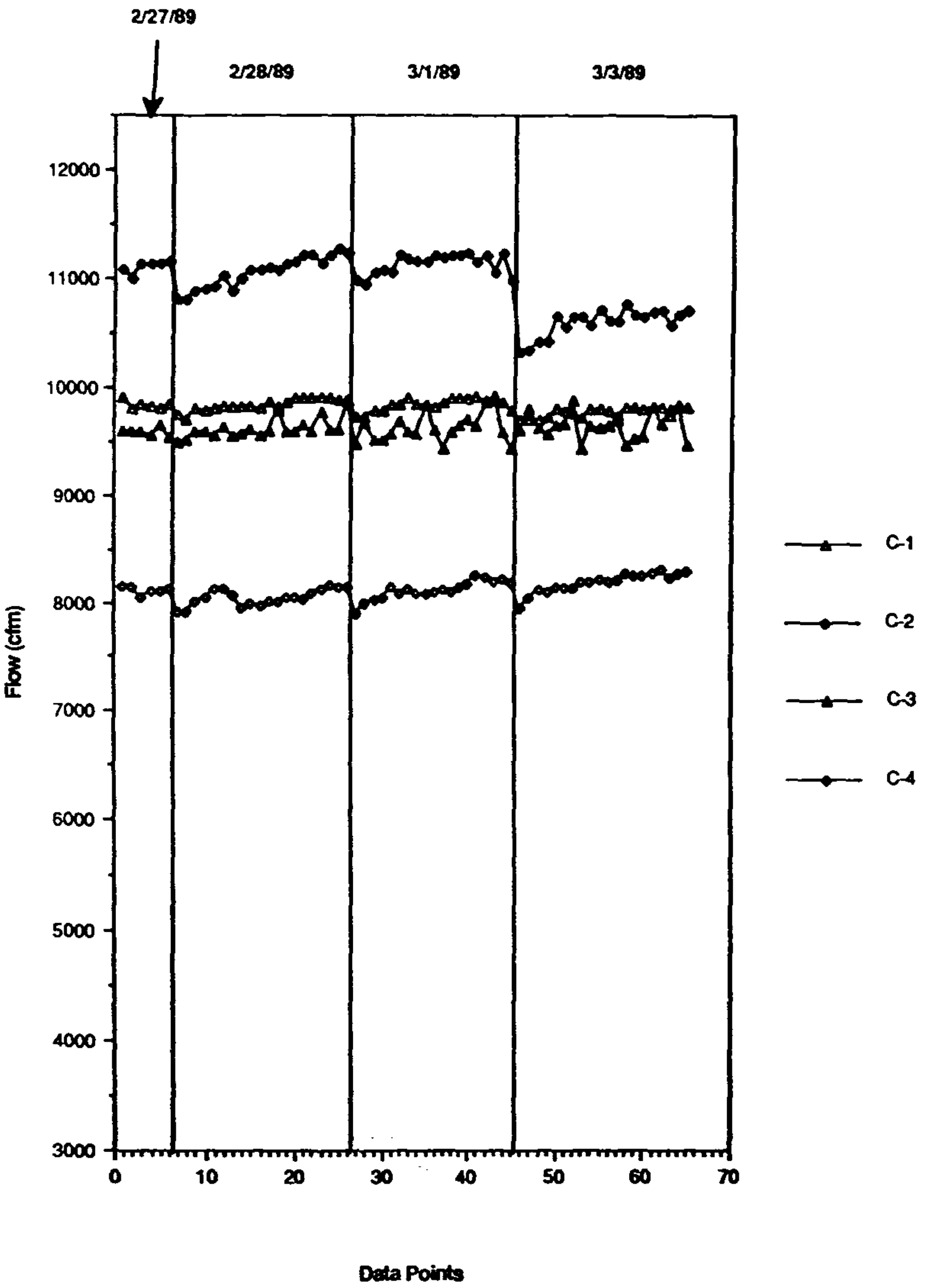


Figure J.1. Outside Air Flow at the LOC During the Survey.

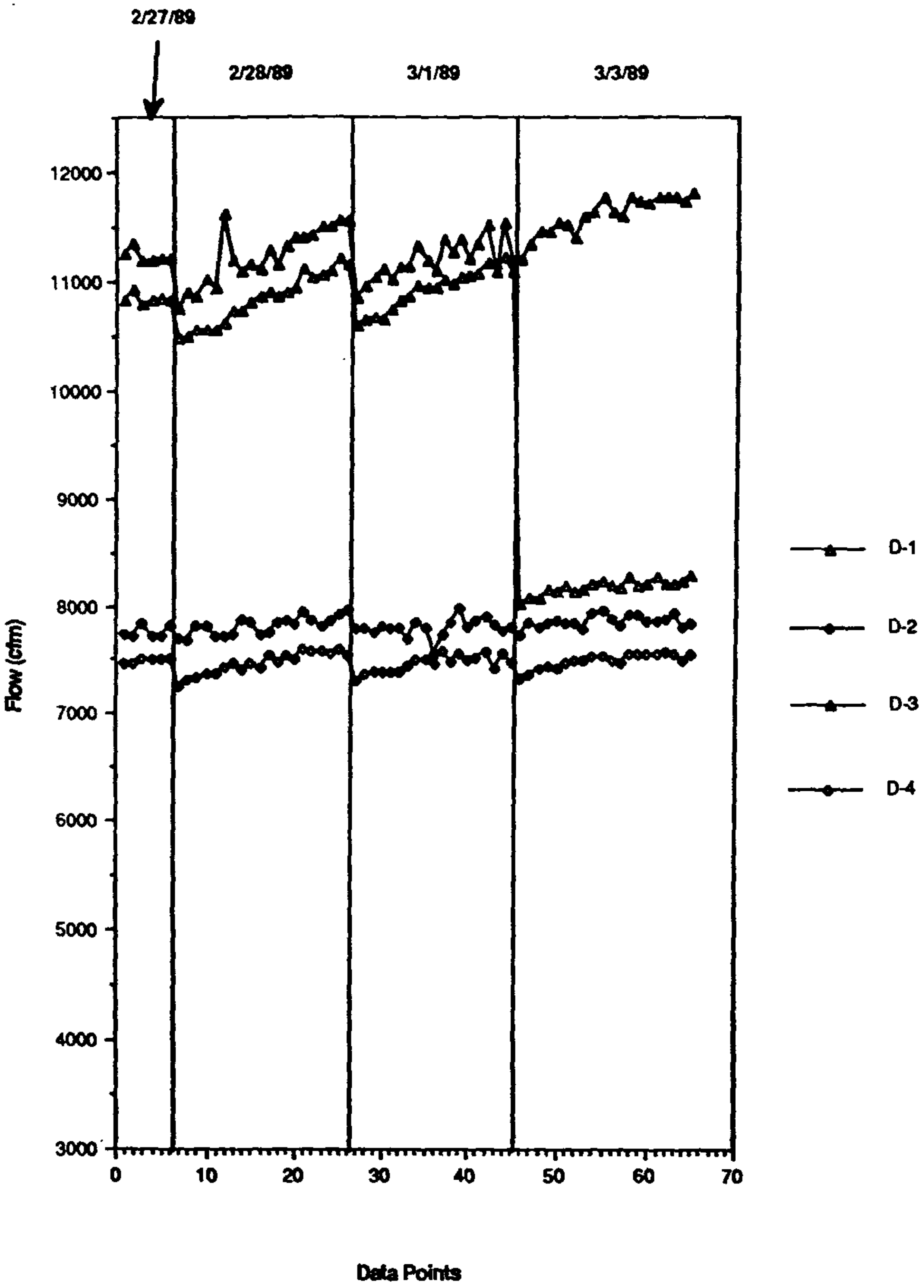


Figure J.1. Outside Air Flow at the LOC During the Survey.

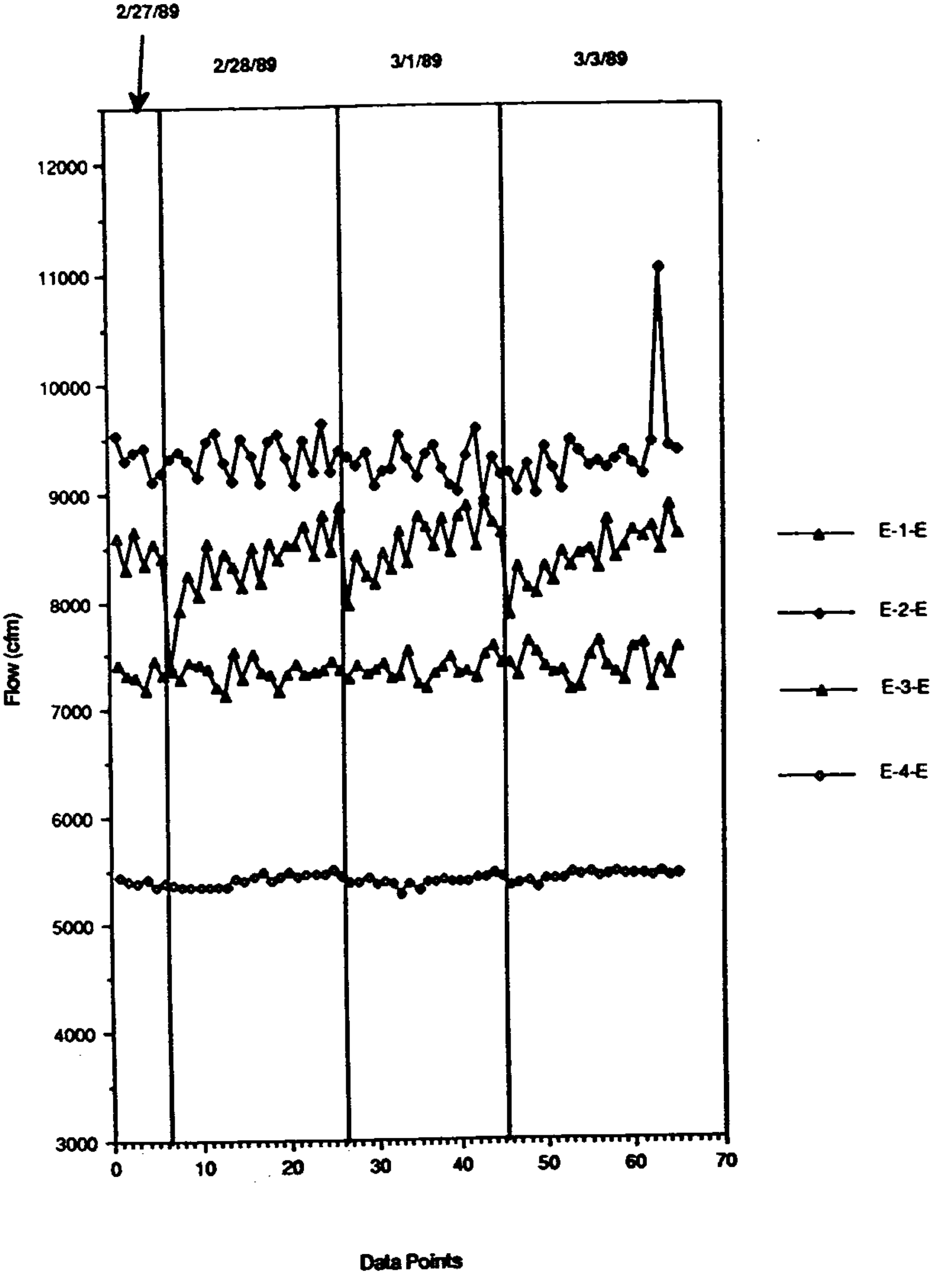


Figure J.1. Outside Air Flow at the LOC During the Survey.

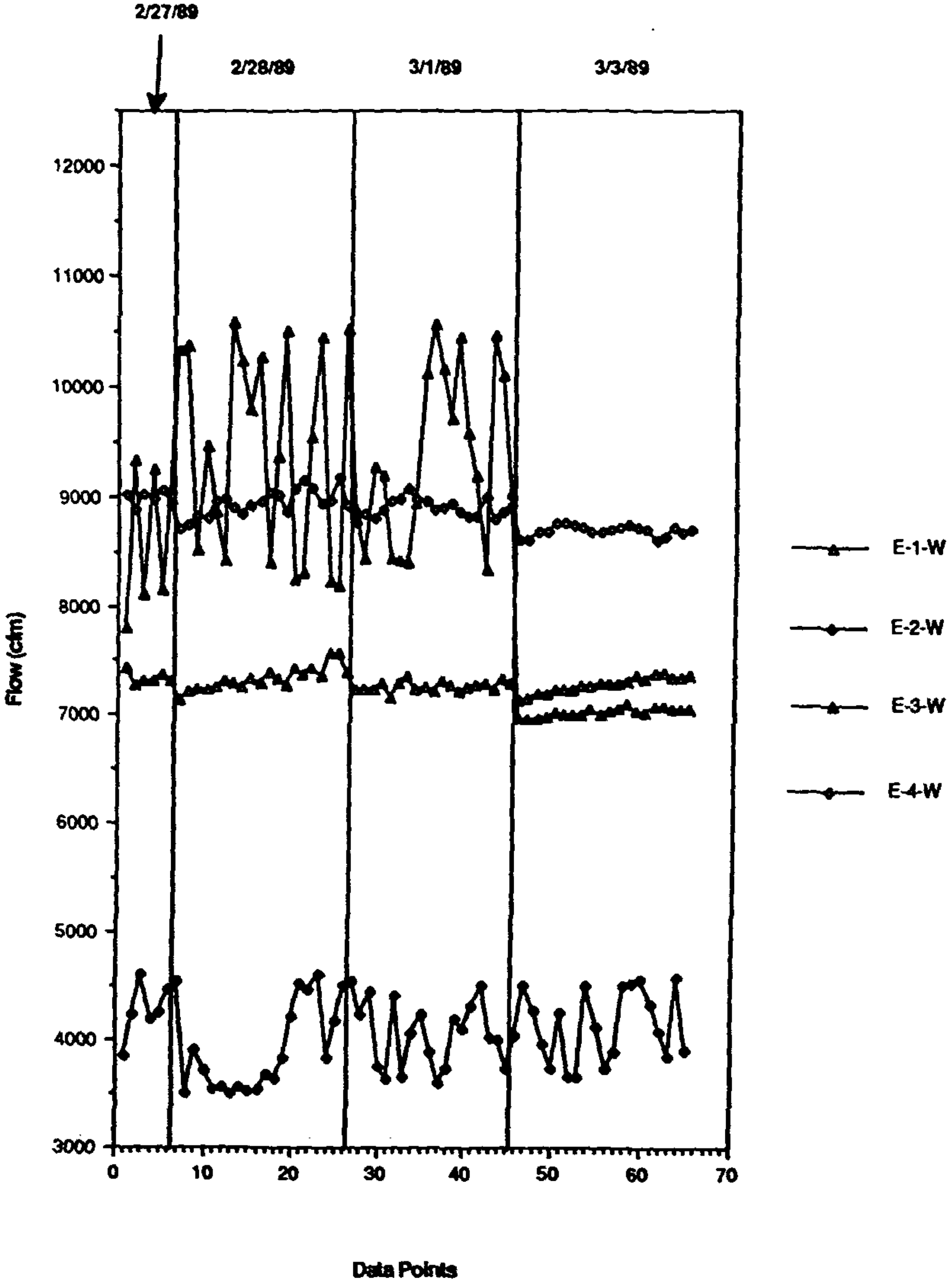


Figure J.1. Outside Air Flow at the LOC During the Survey.

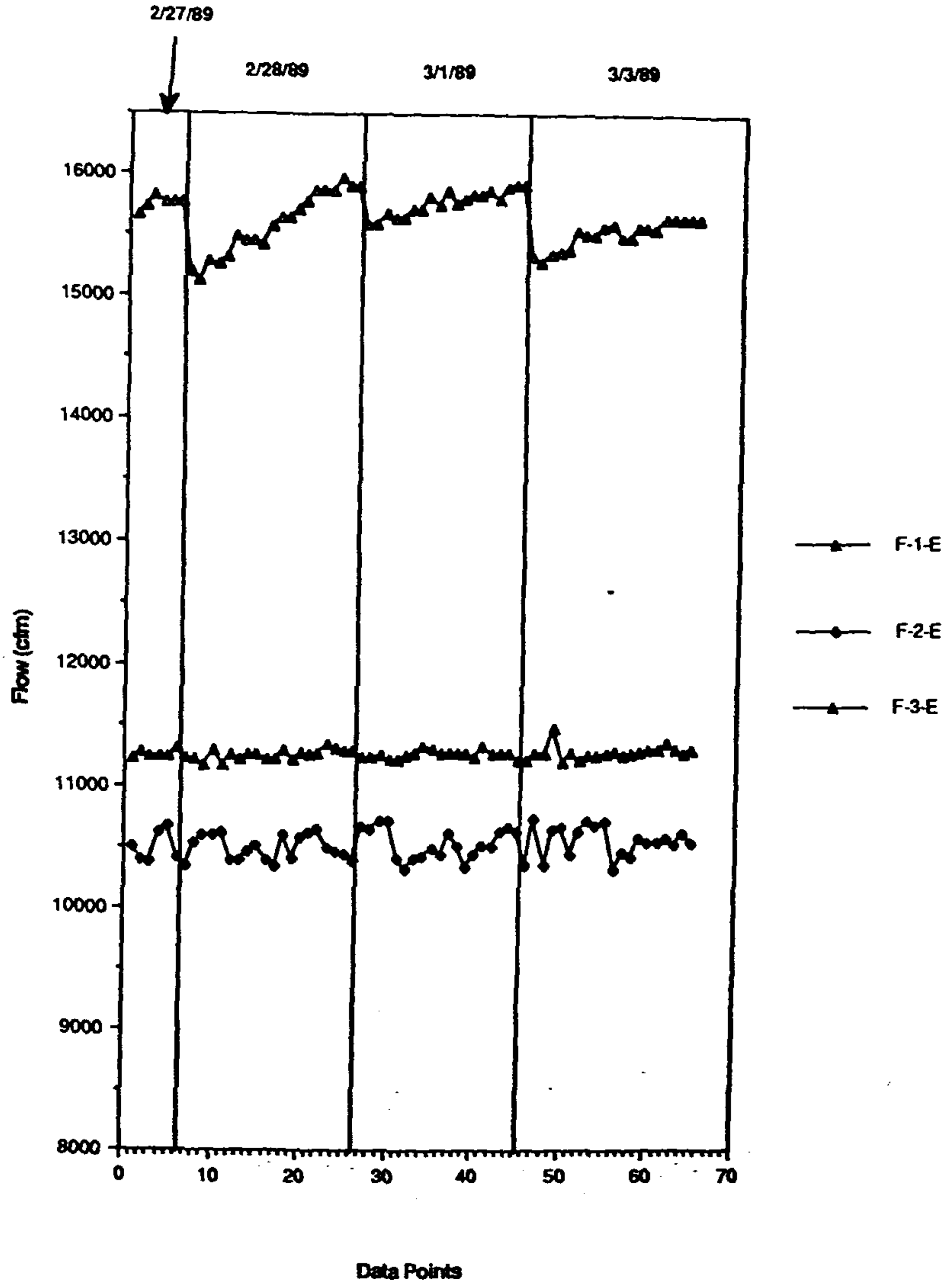


Figure J.1. Outside Air Flow at the LOC at During the Survey.

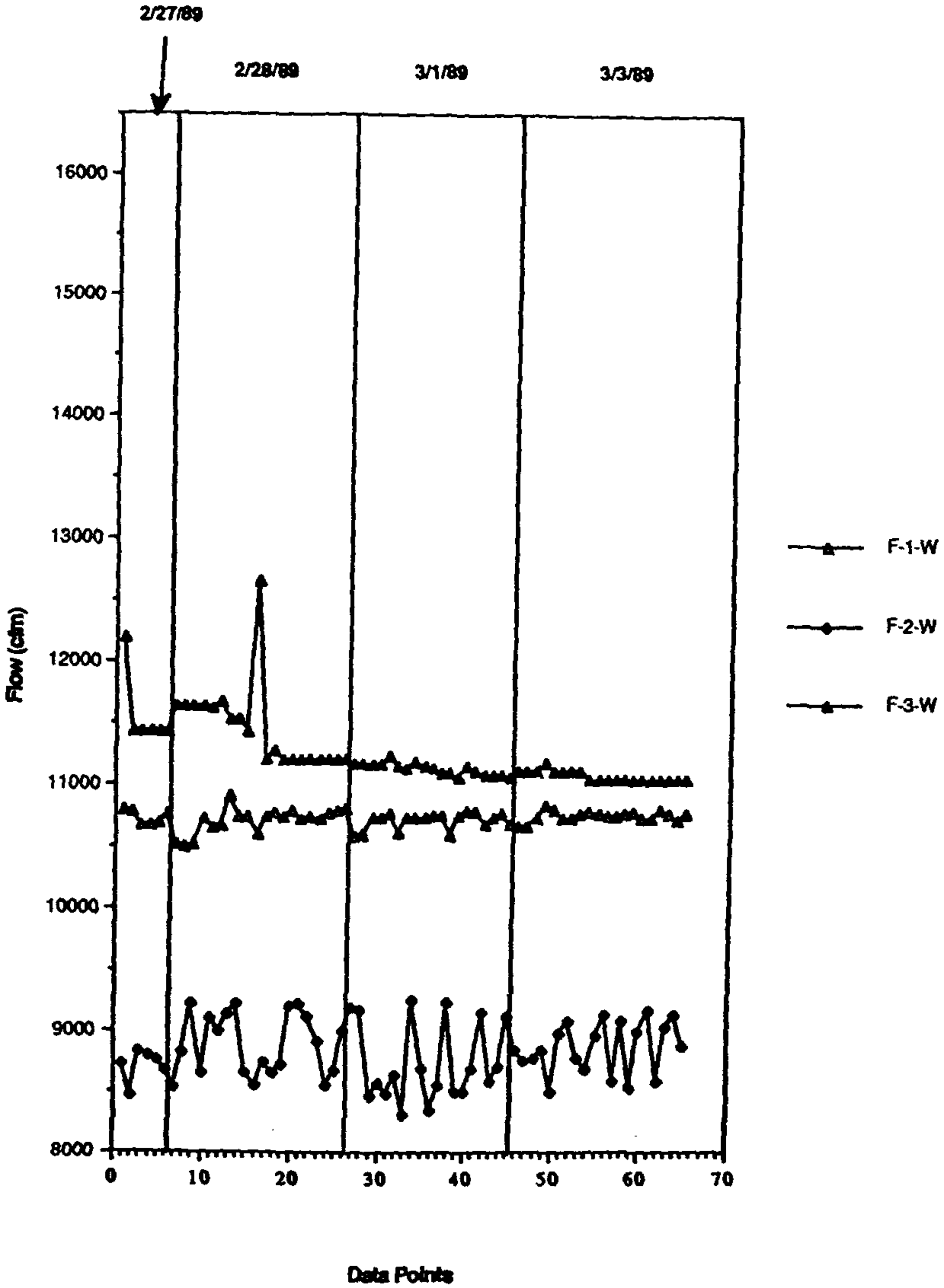


Figure J.1. Total Outside Air Flow for the Units on Pages J-14 Through J-21.

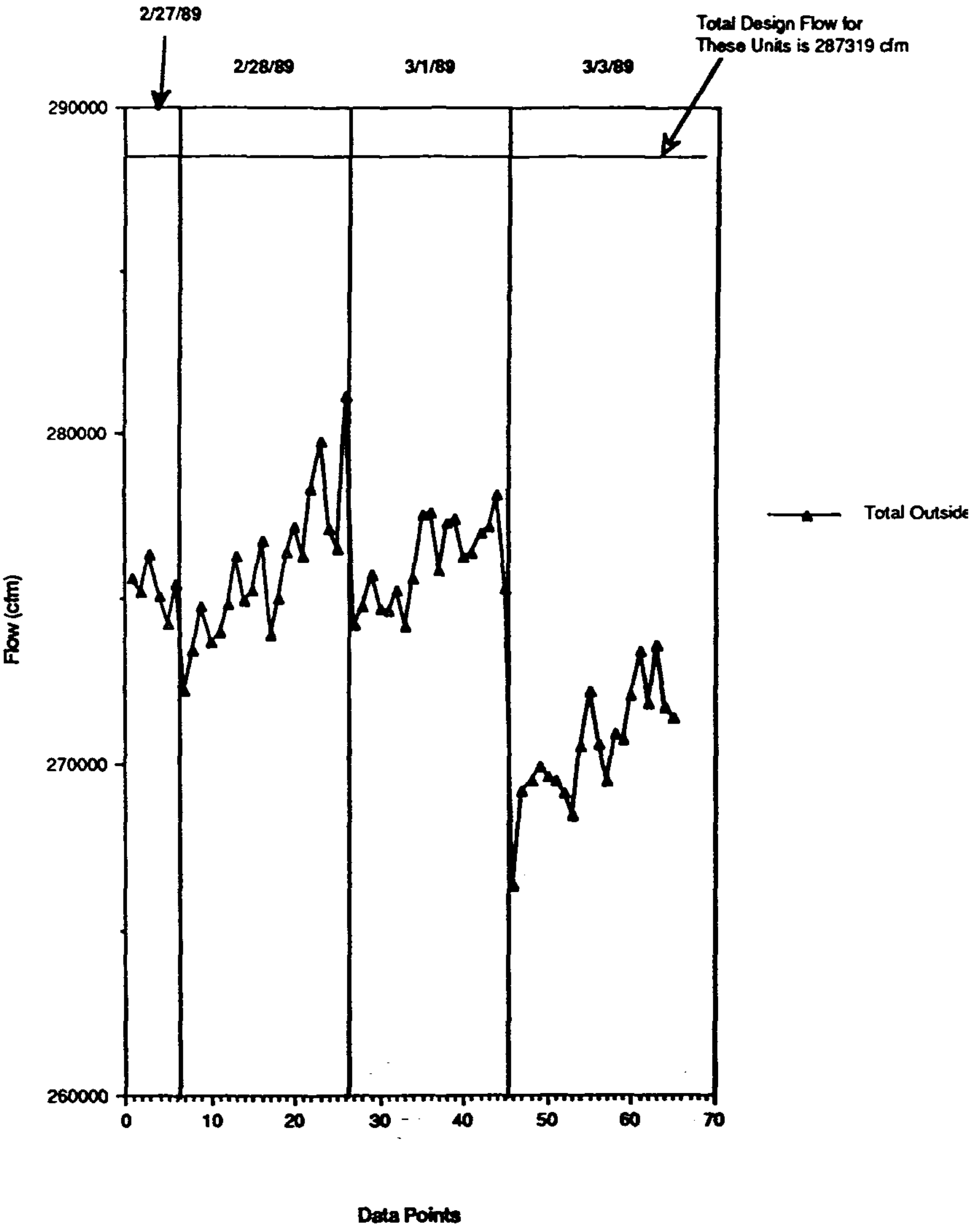


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

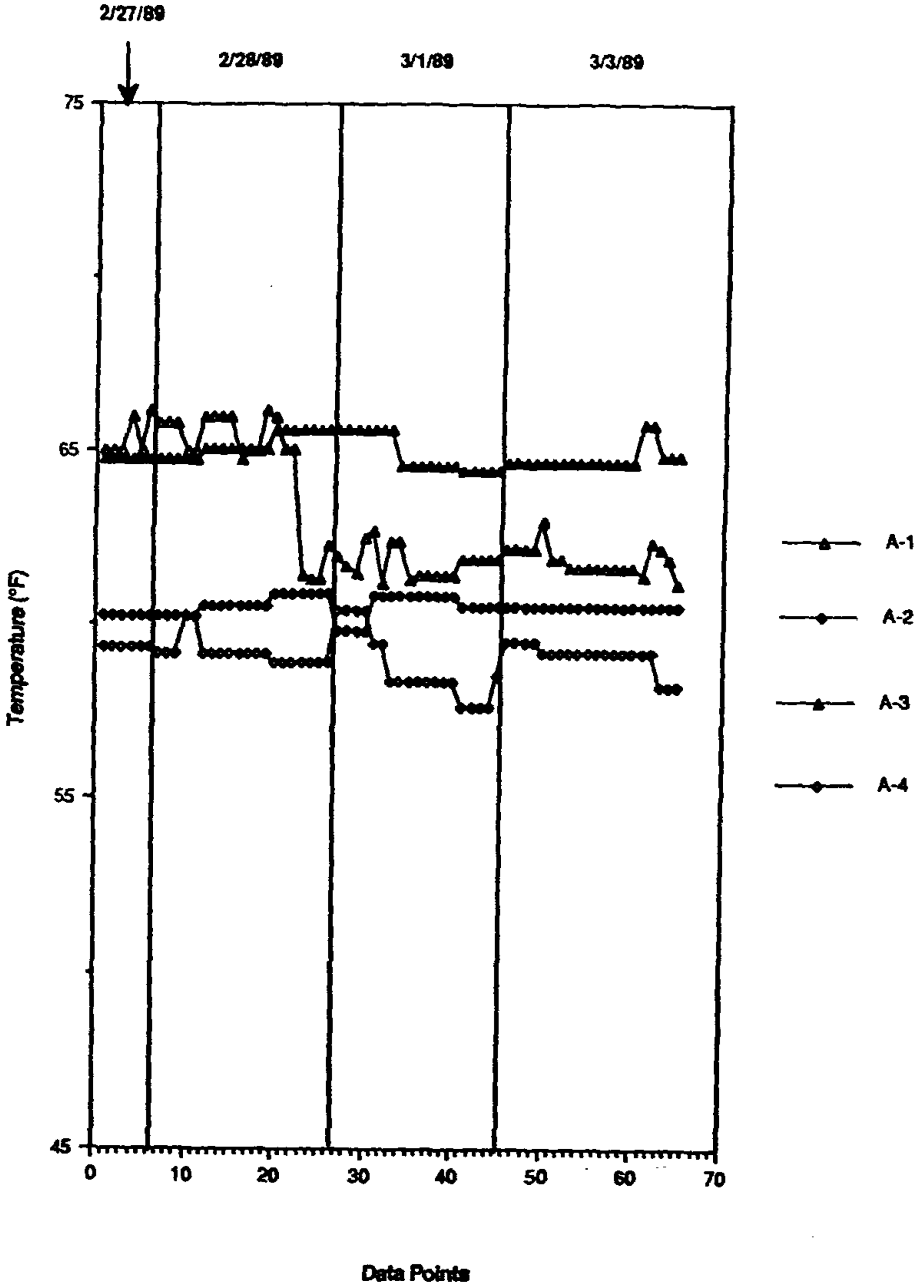


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

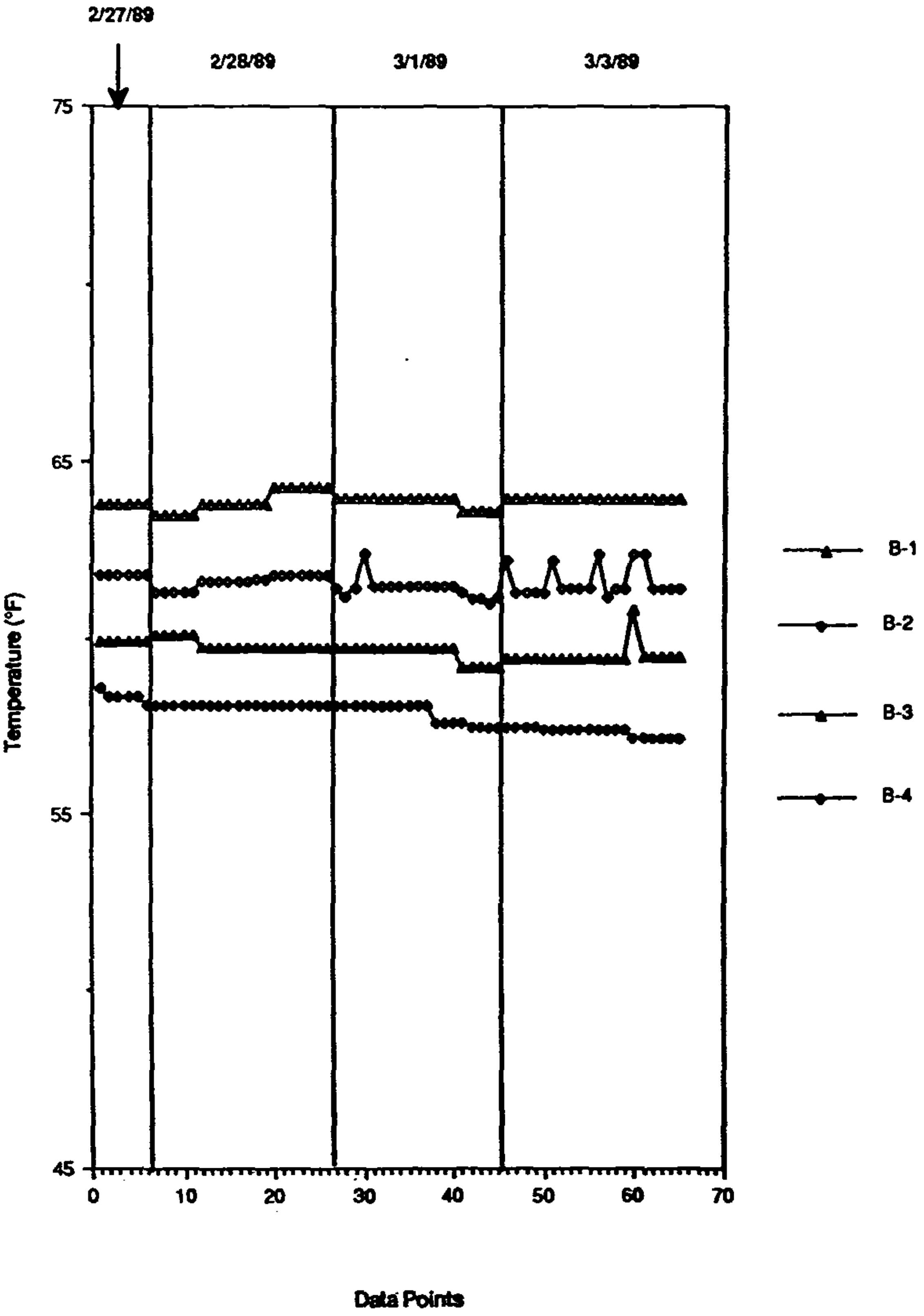


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

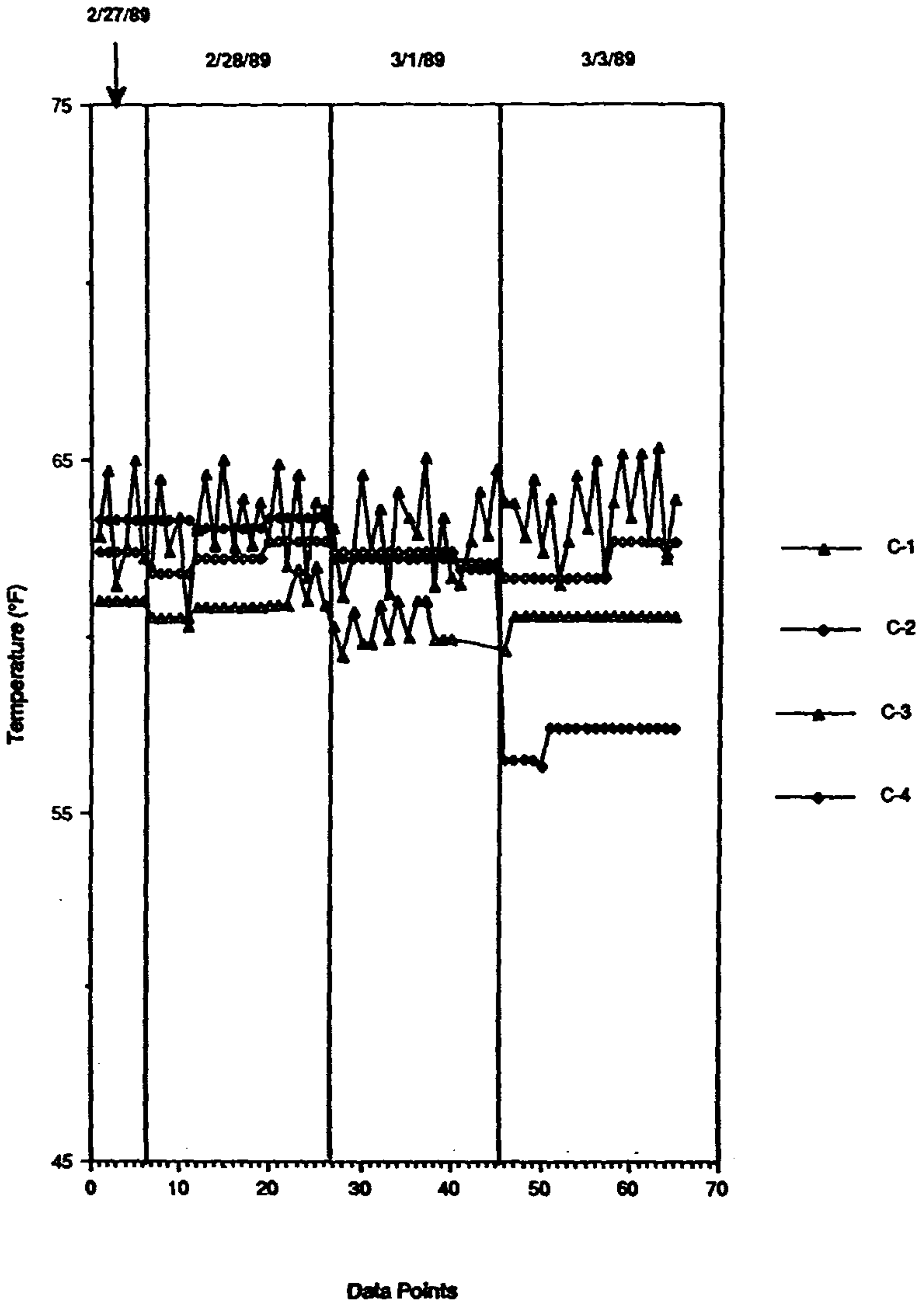


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

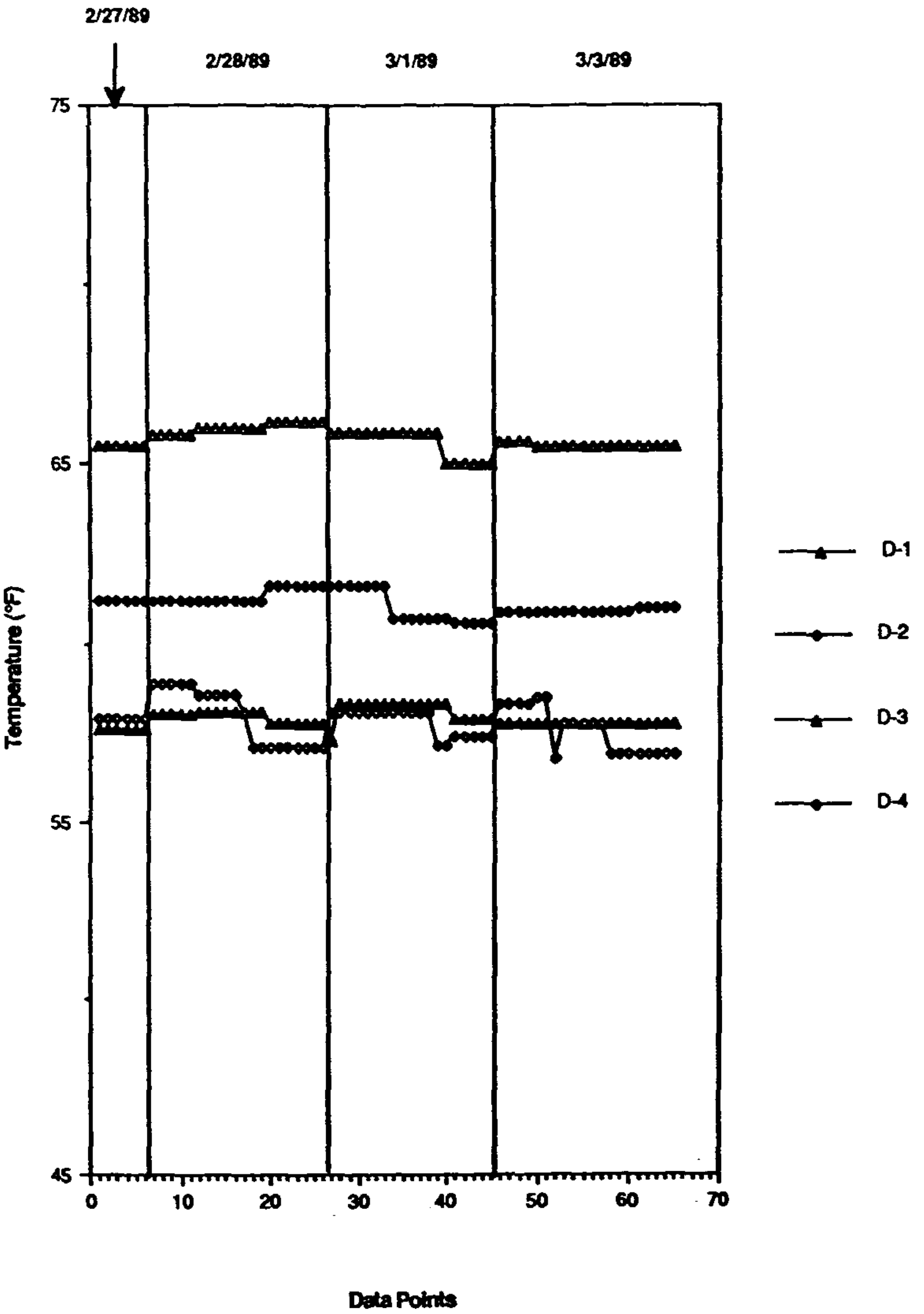


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

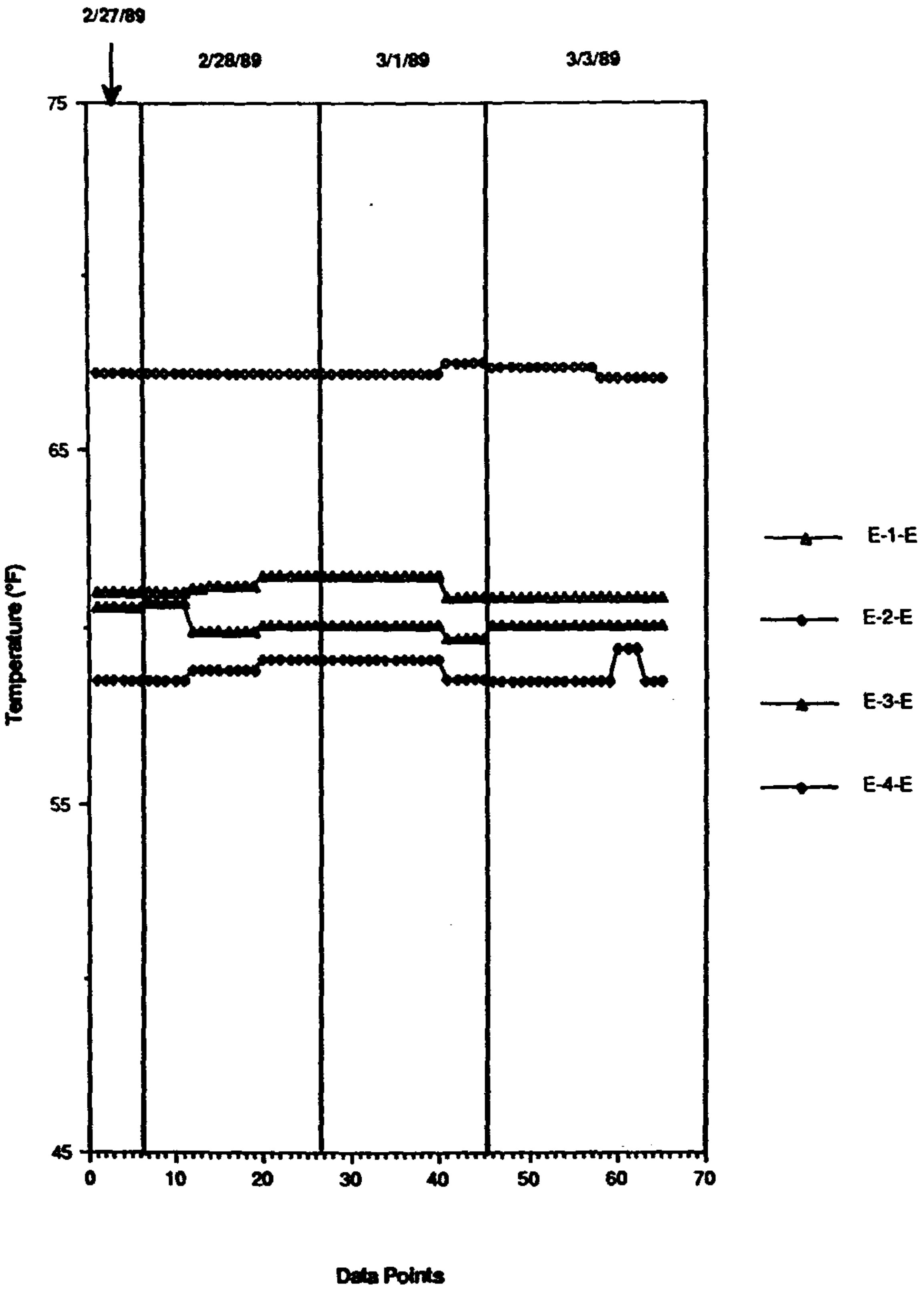


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

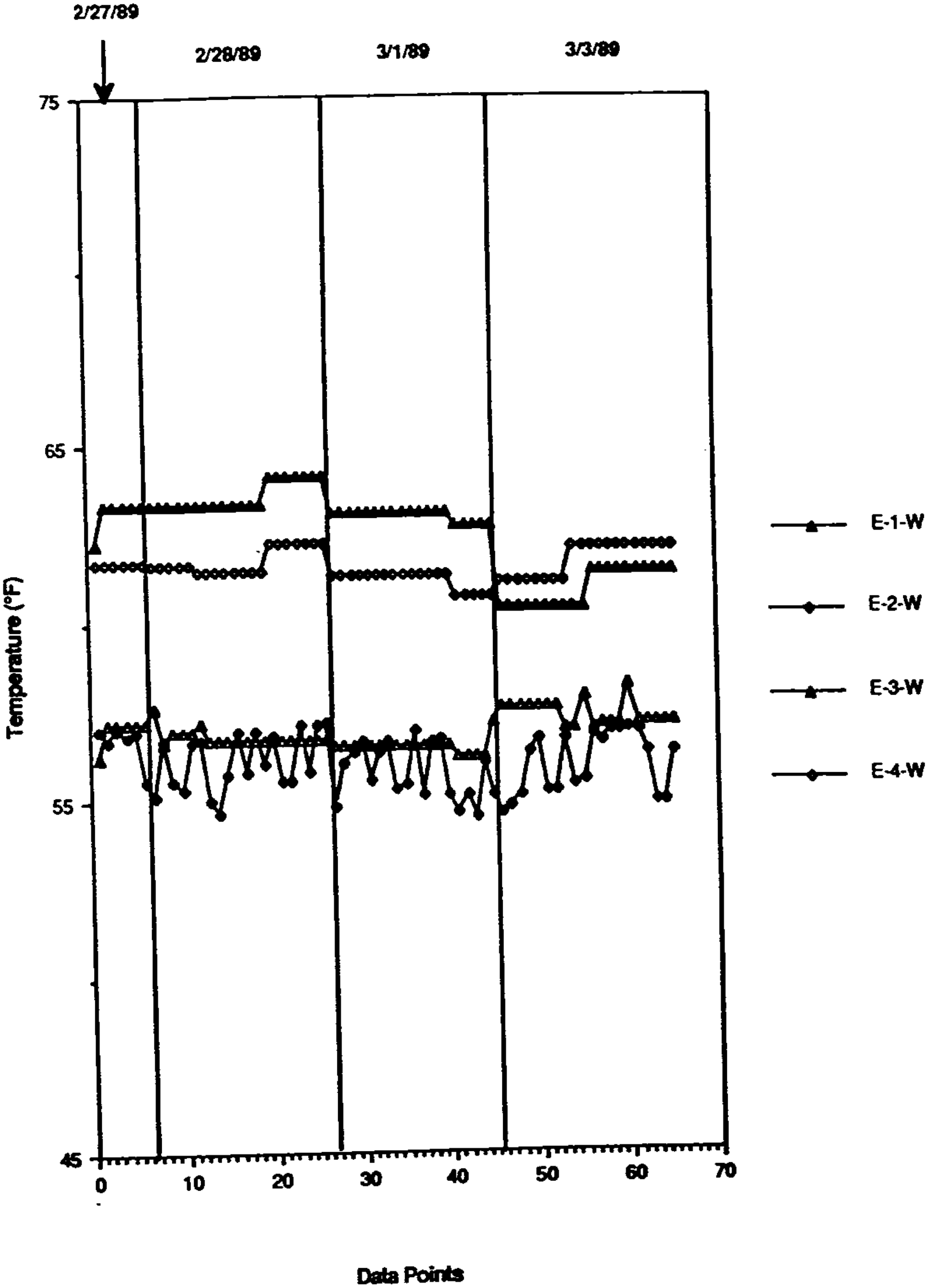


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

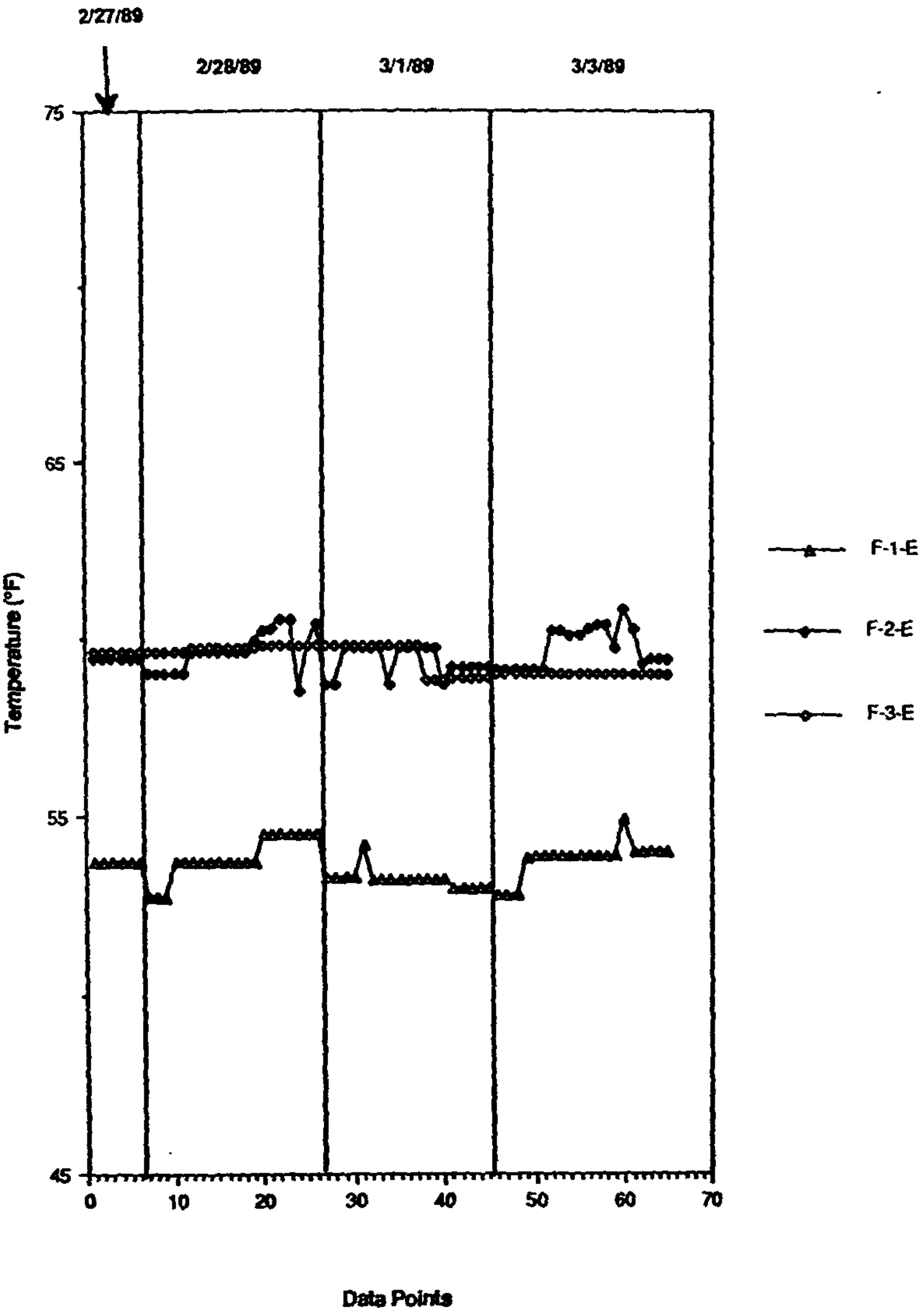


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

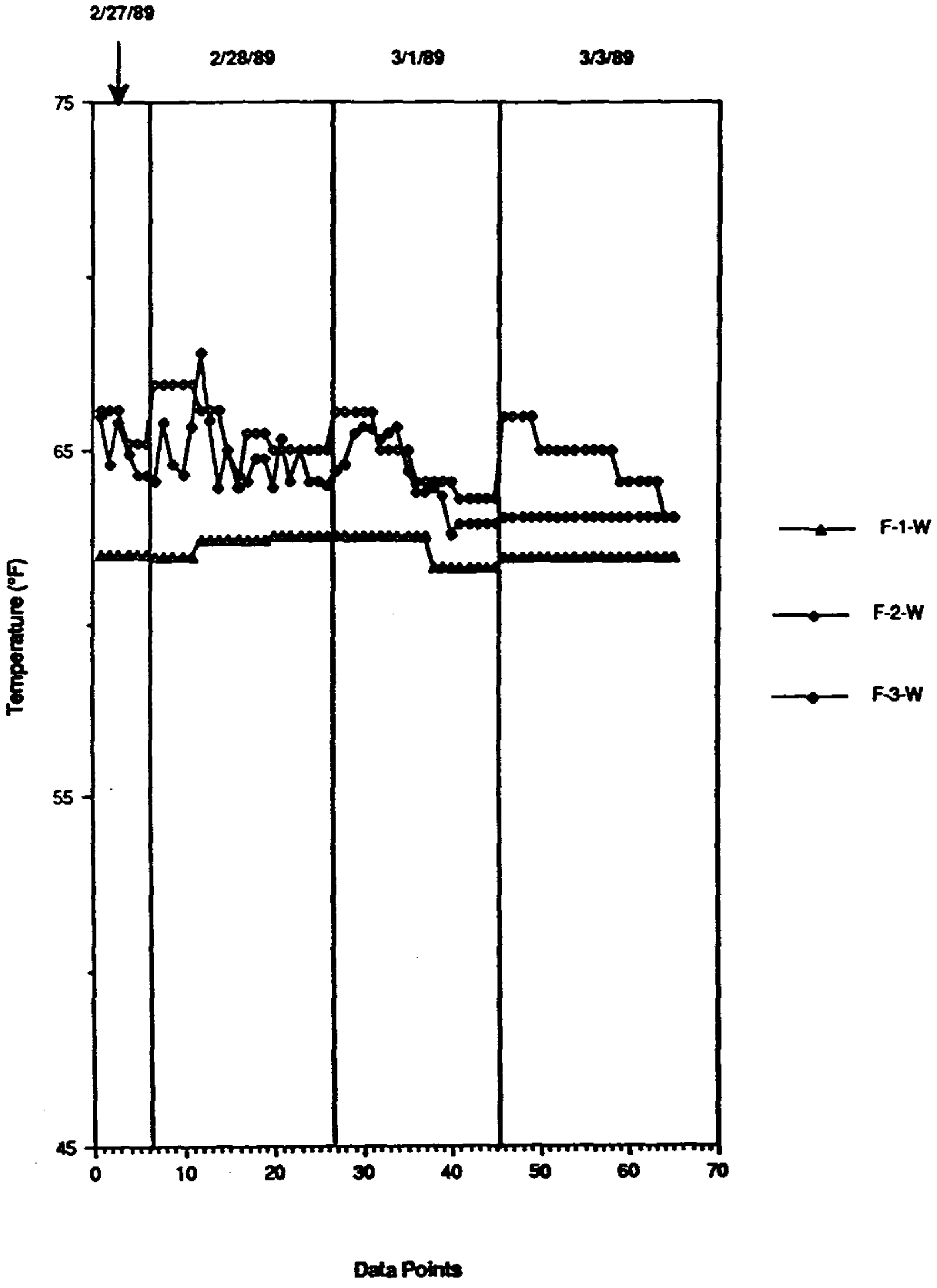


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

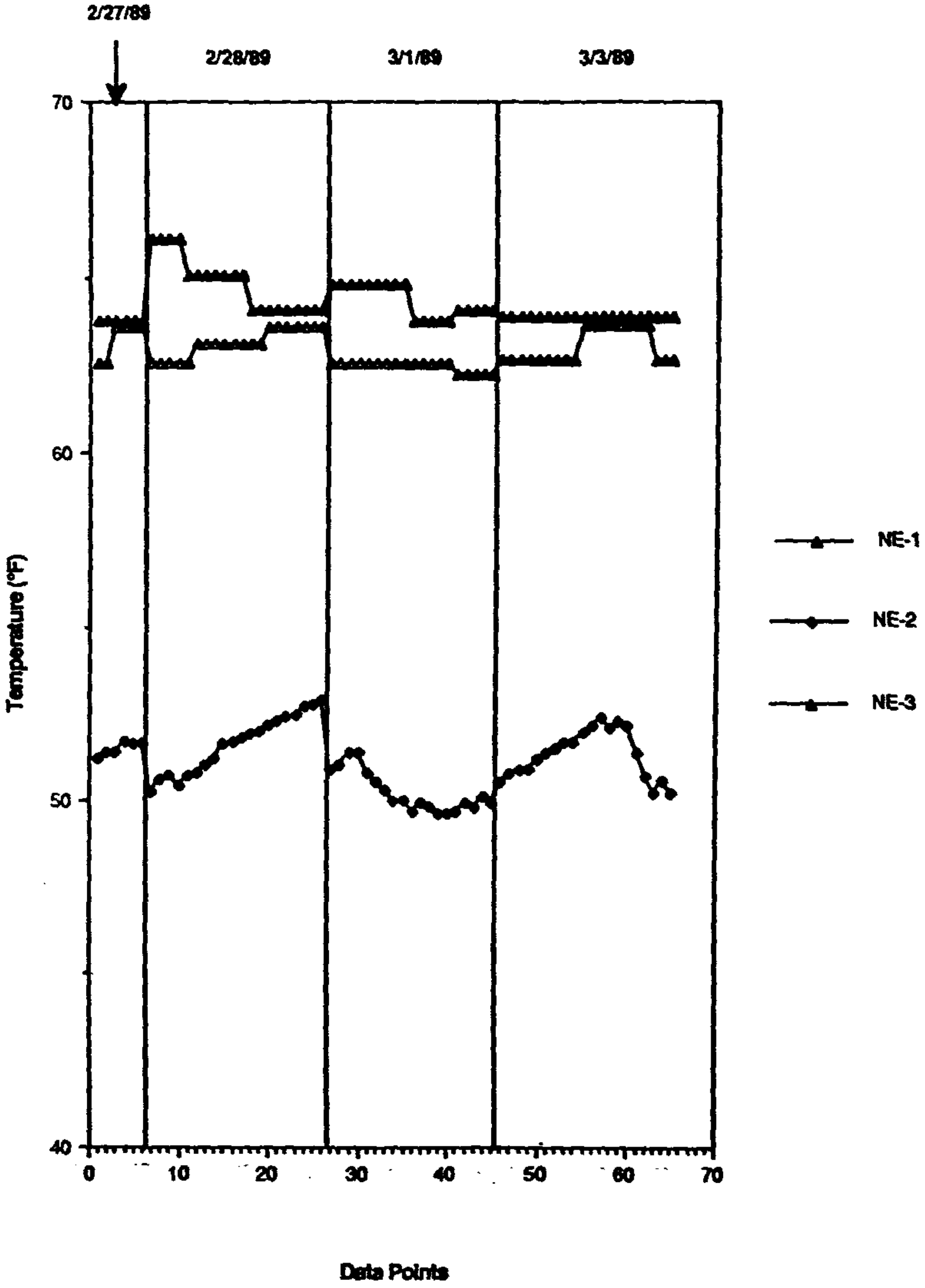


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

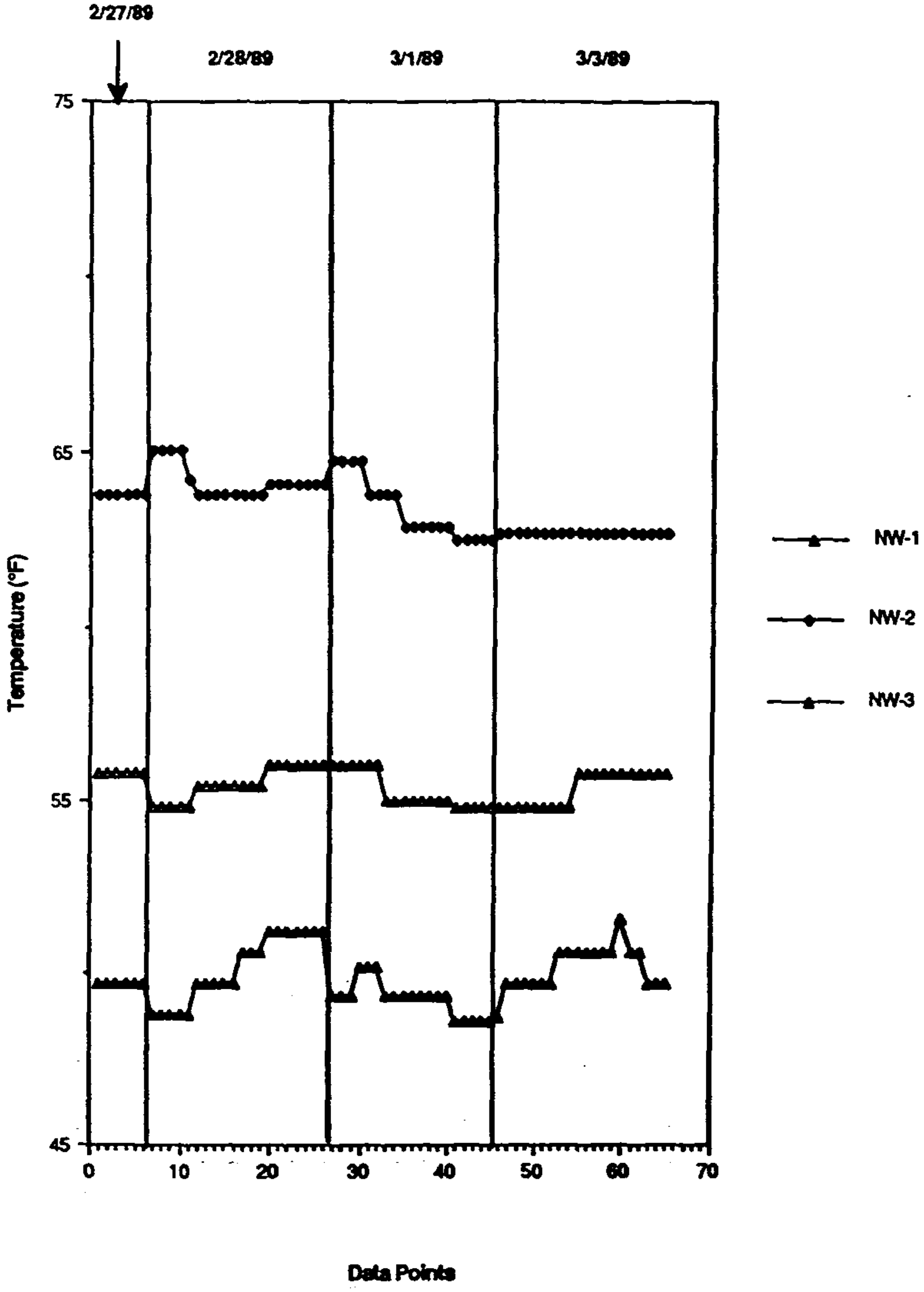


Figure J.2. Dry Bulb Temperatures of the Air Leaving the AHU During the Survey

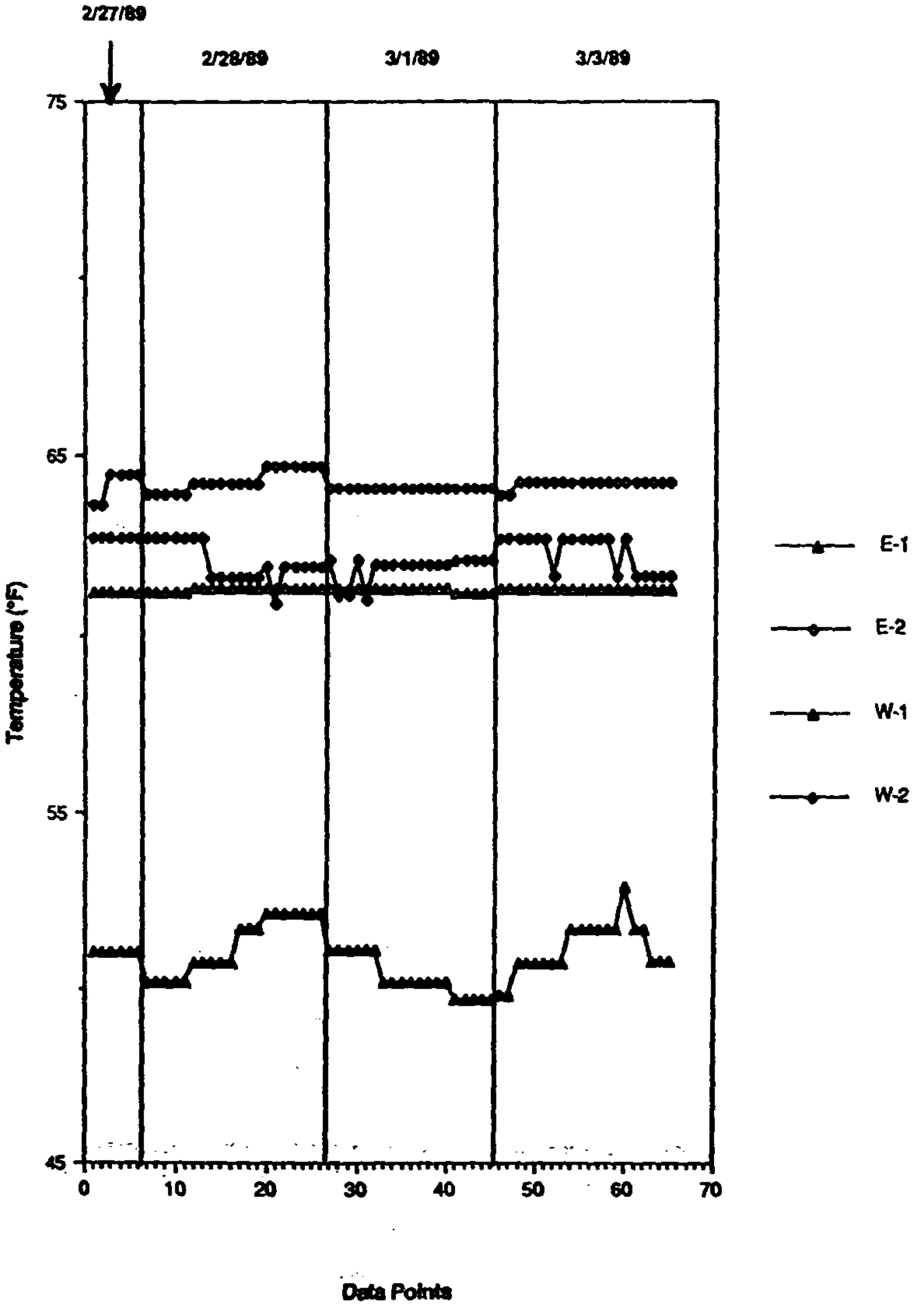


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

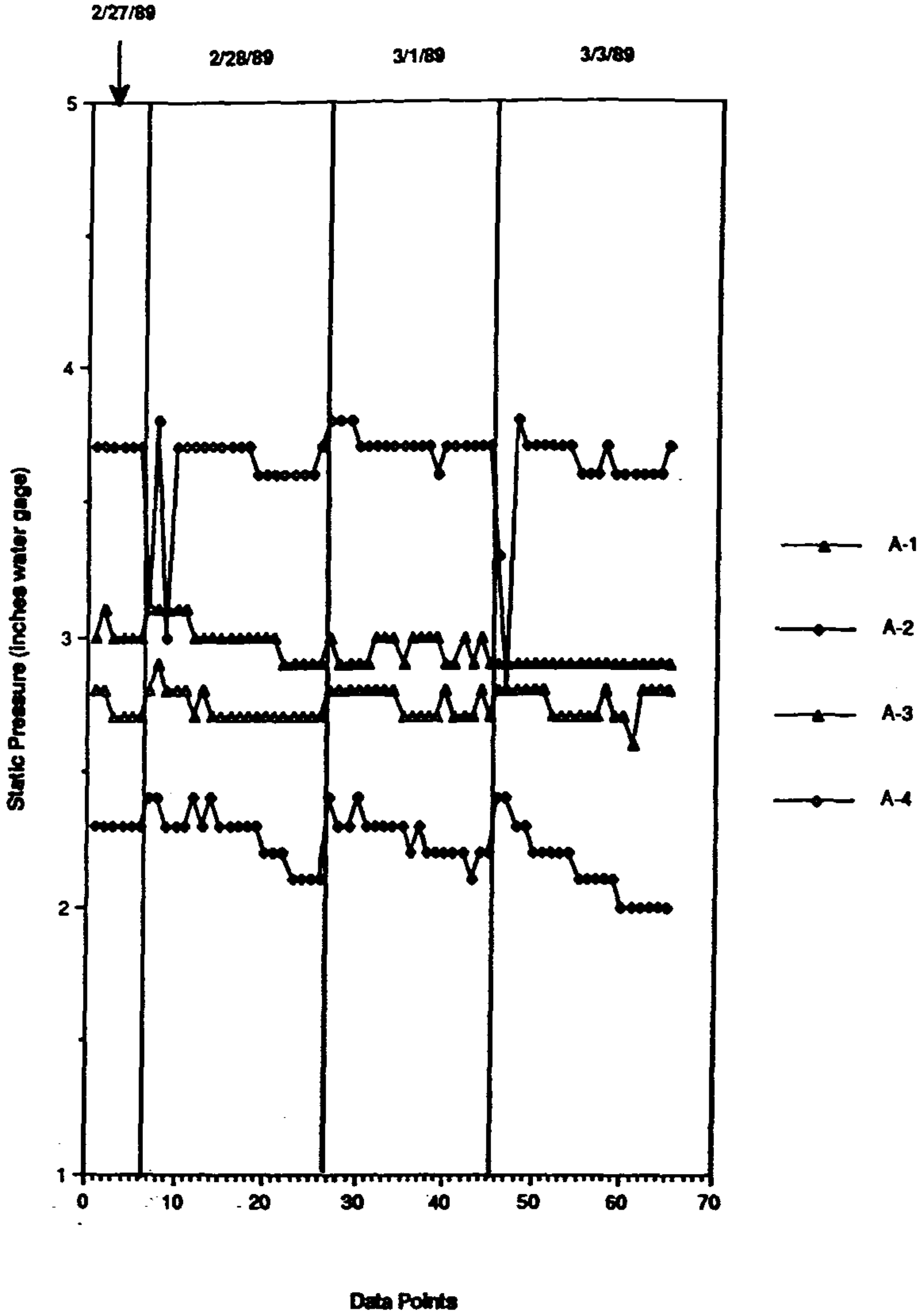


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

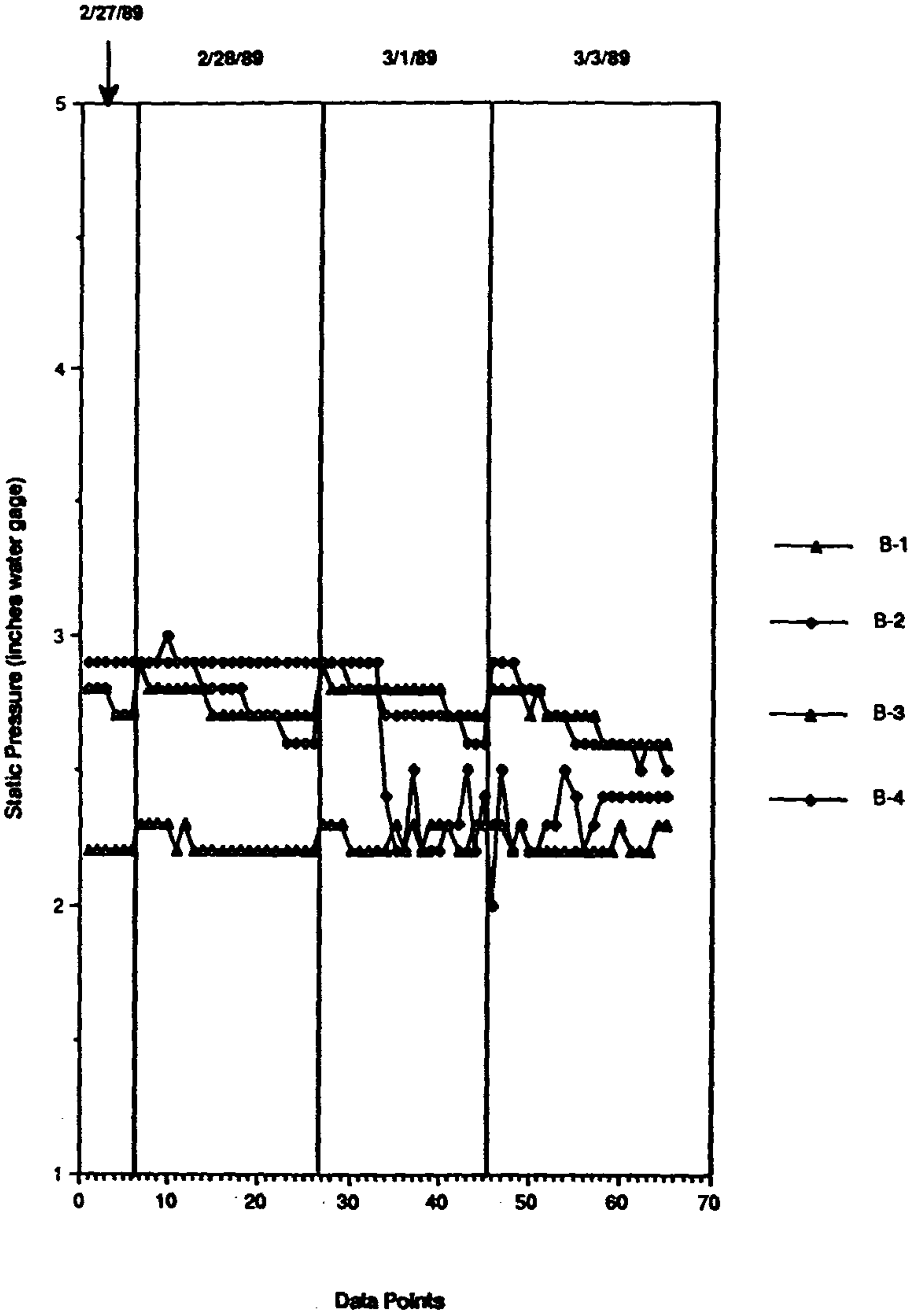


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

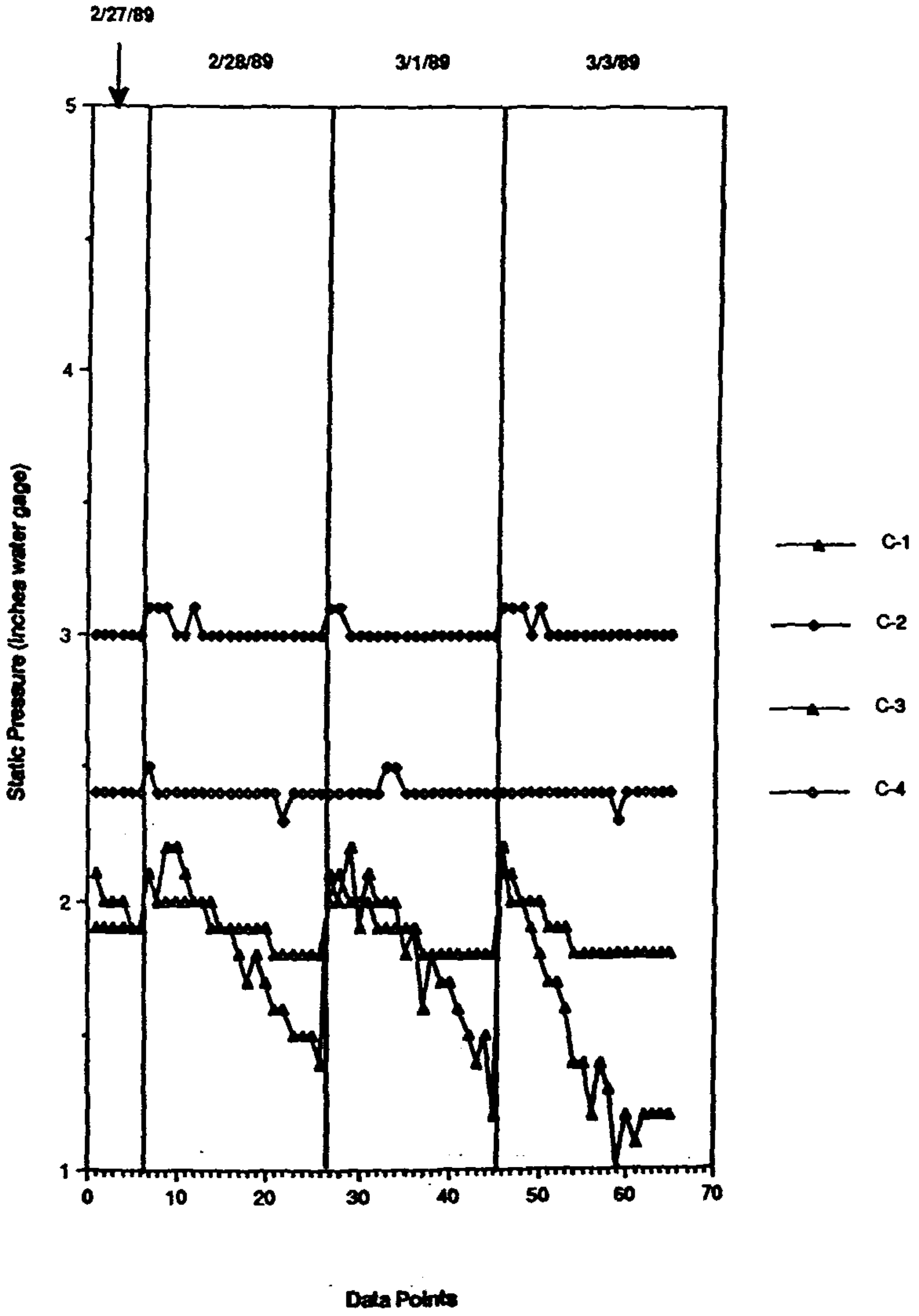


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

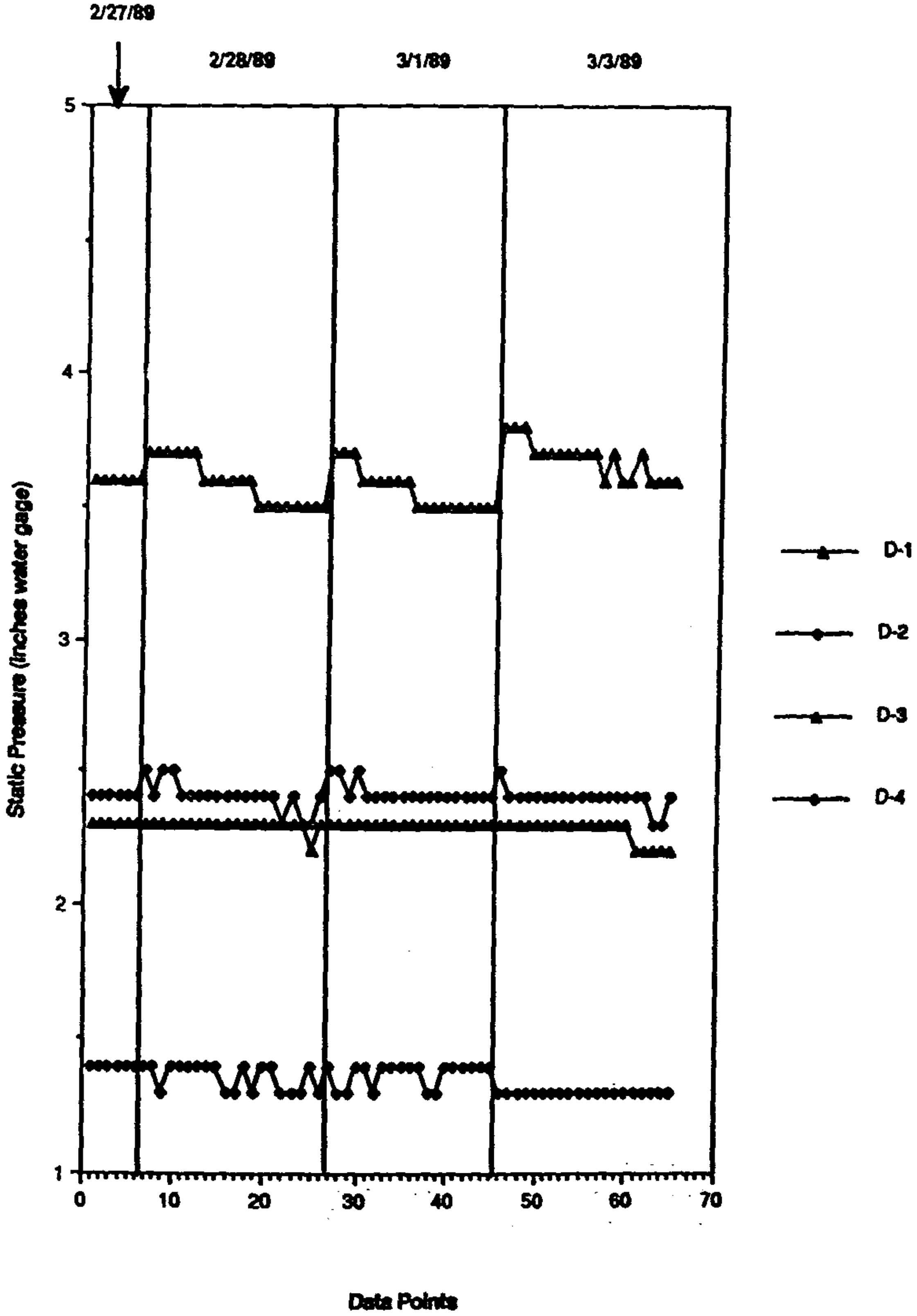


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

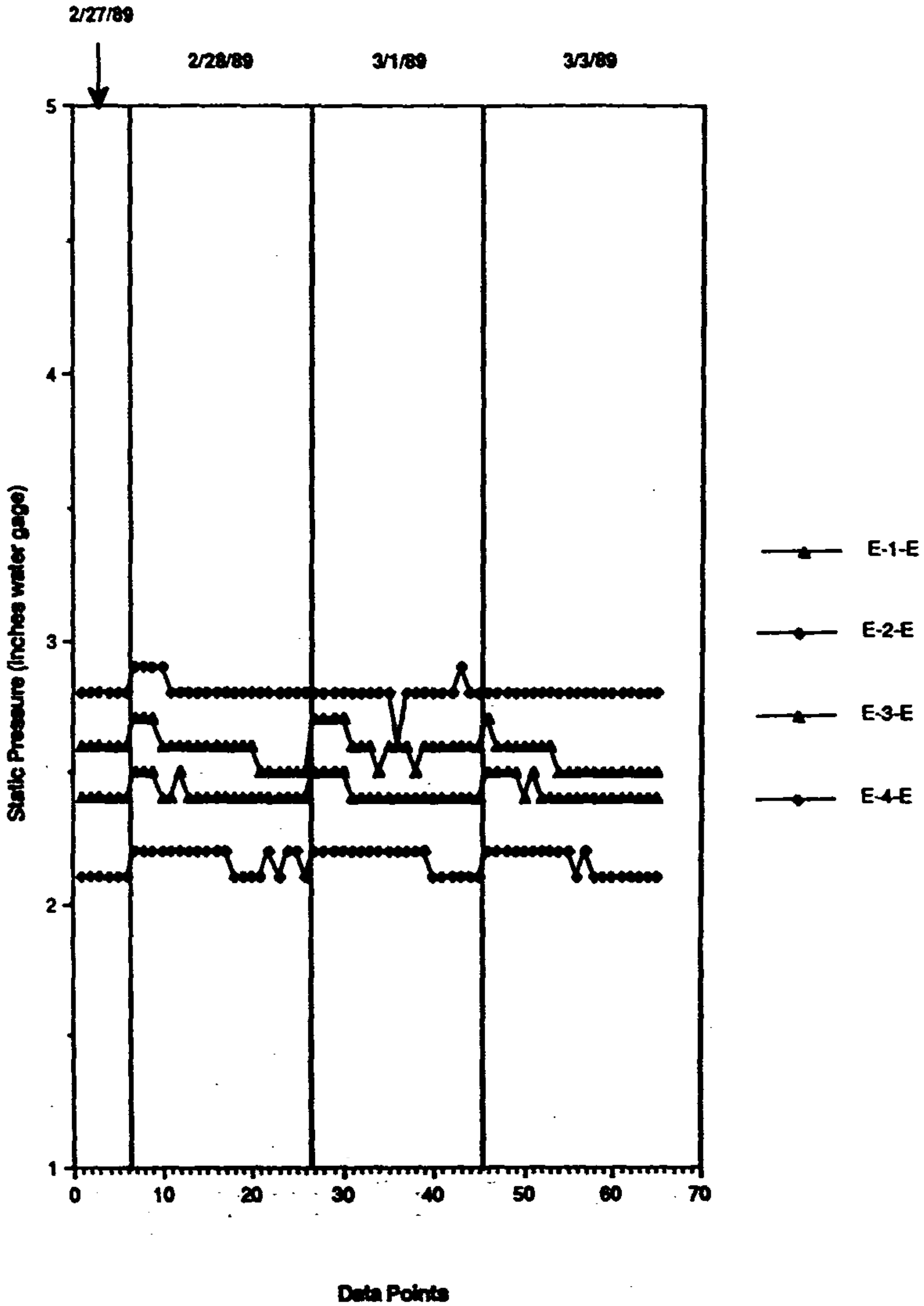


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

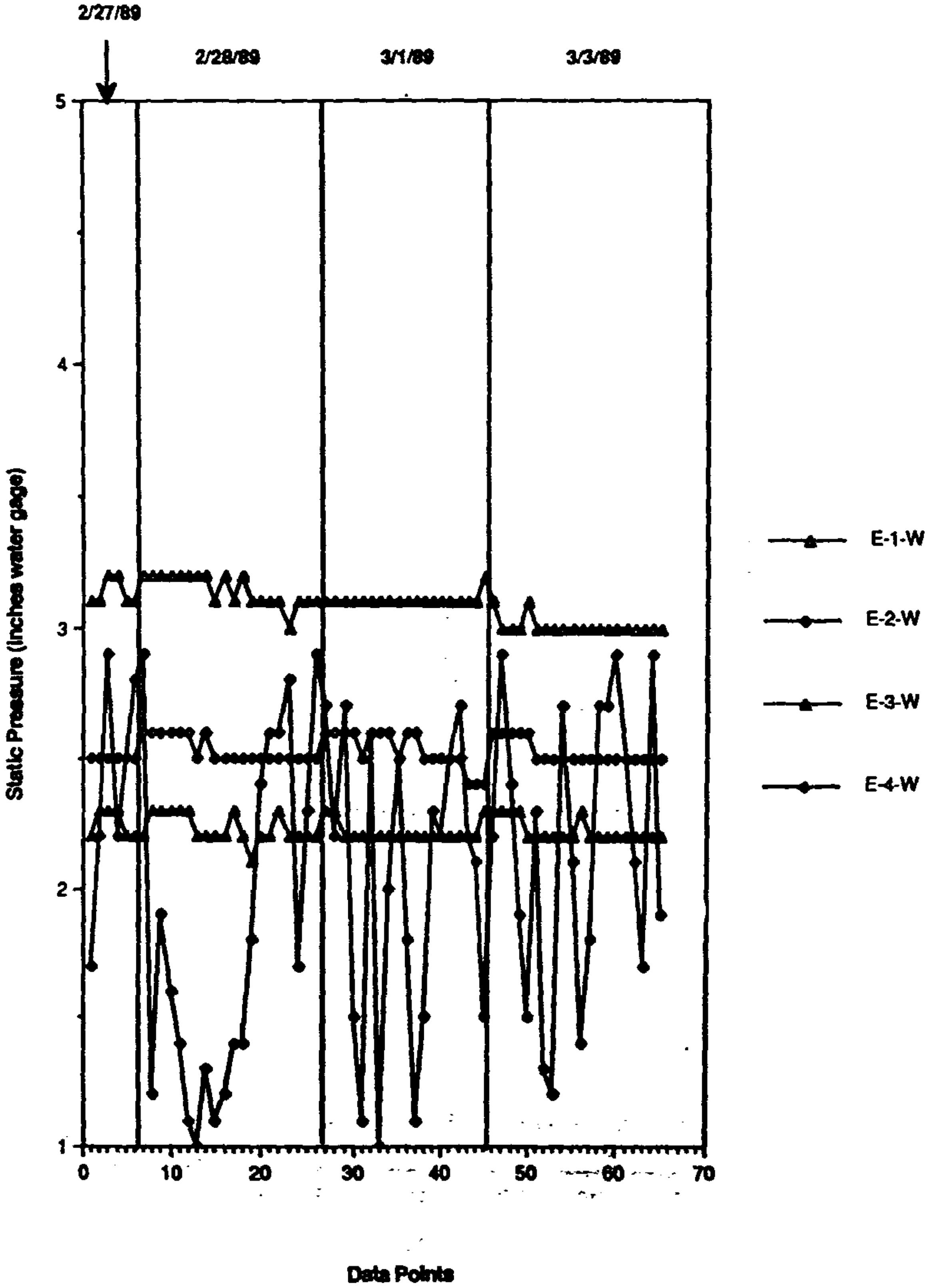


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

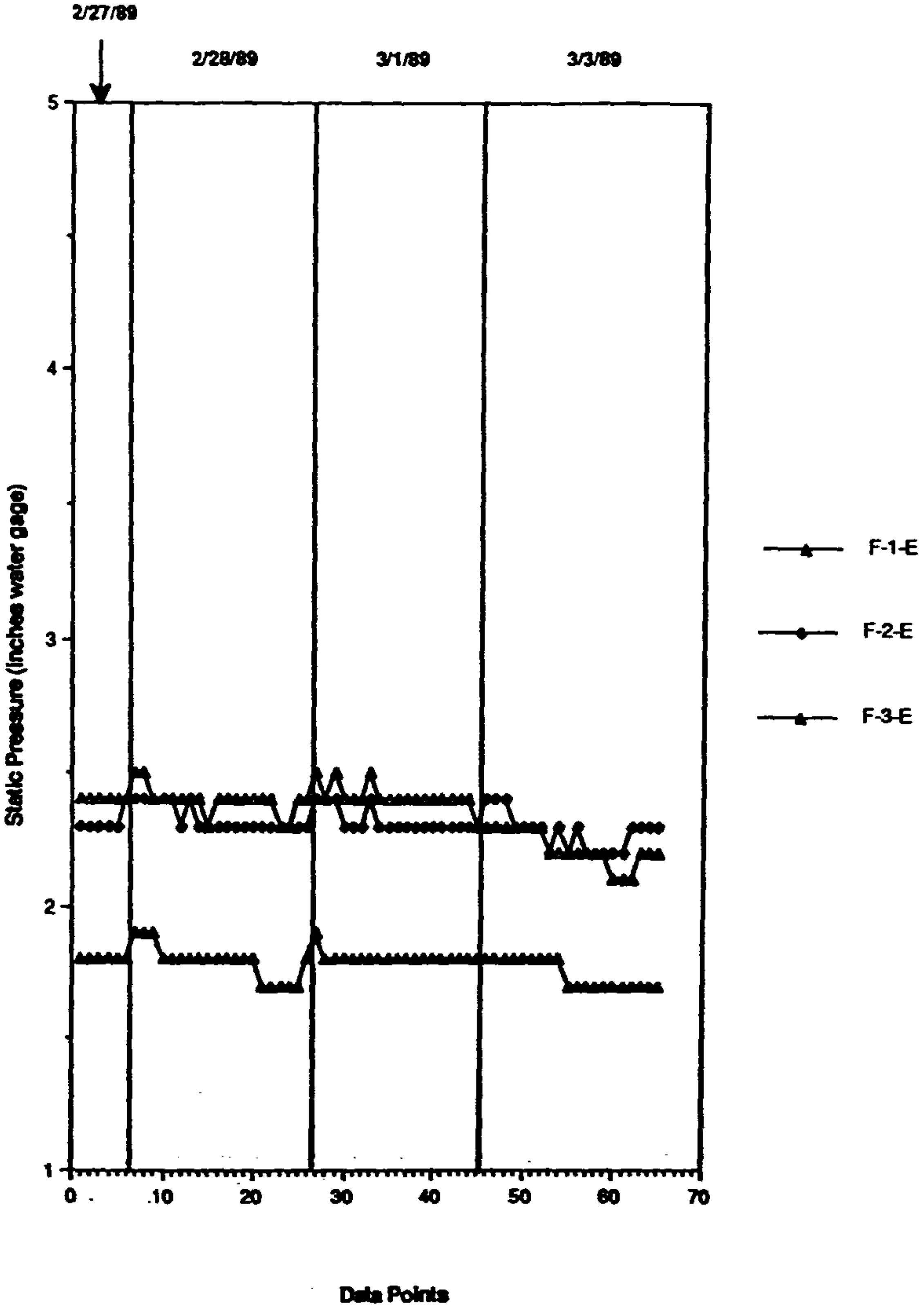


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

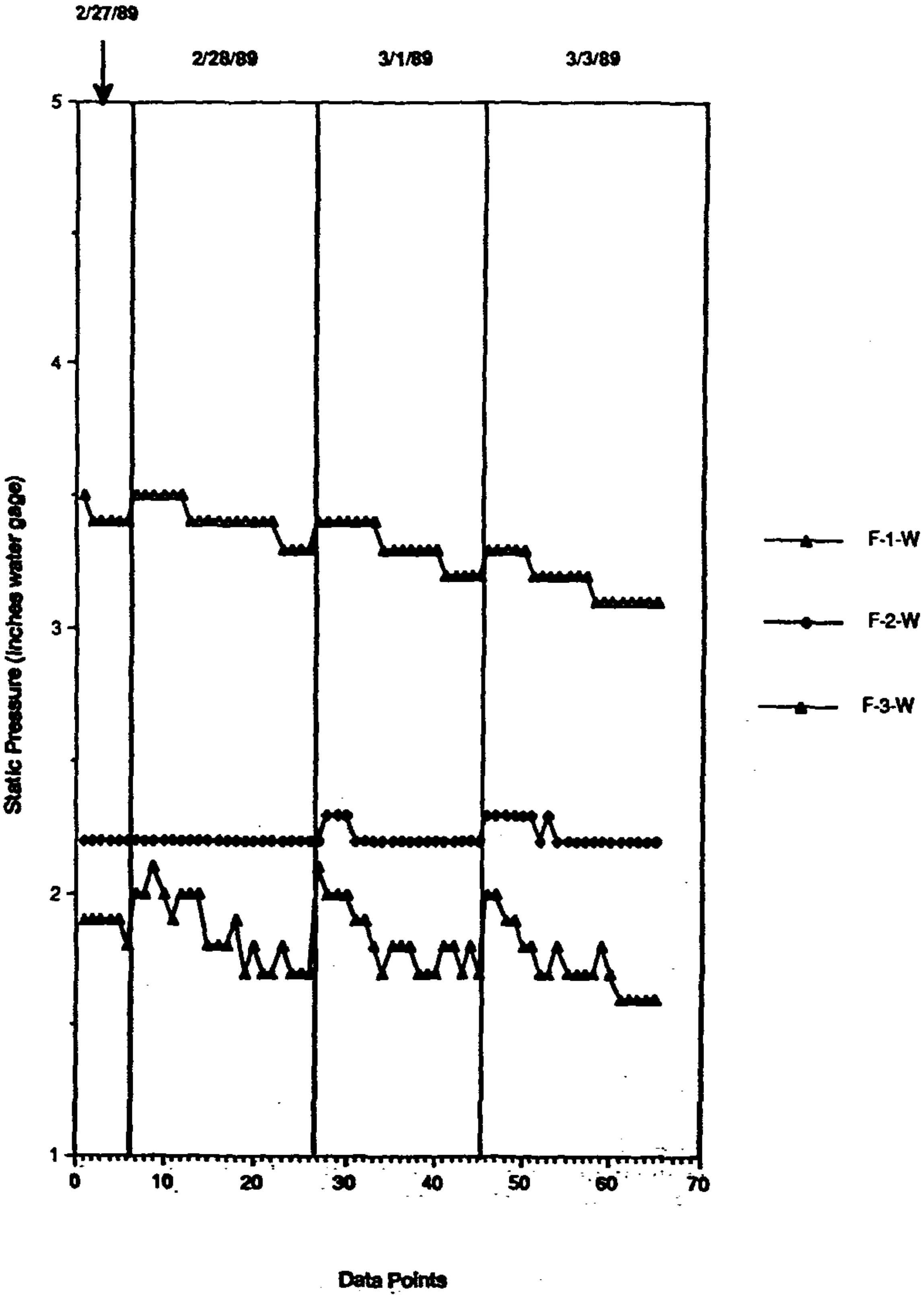


Figure J.3. Static Pressure Sepoint in the AHU Main Duct During the Survey

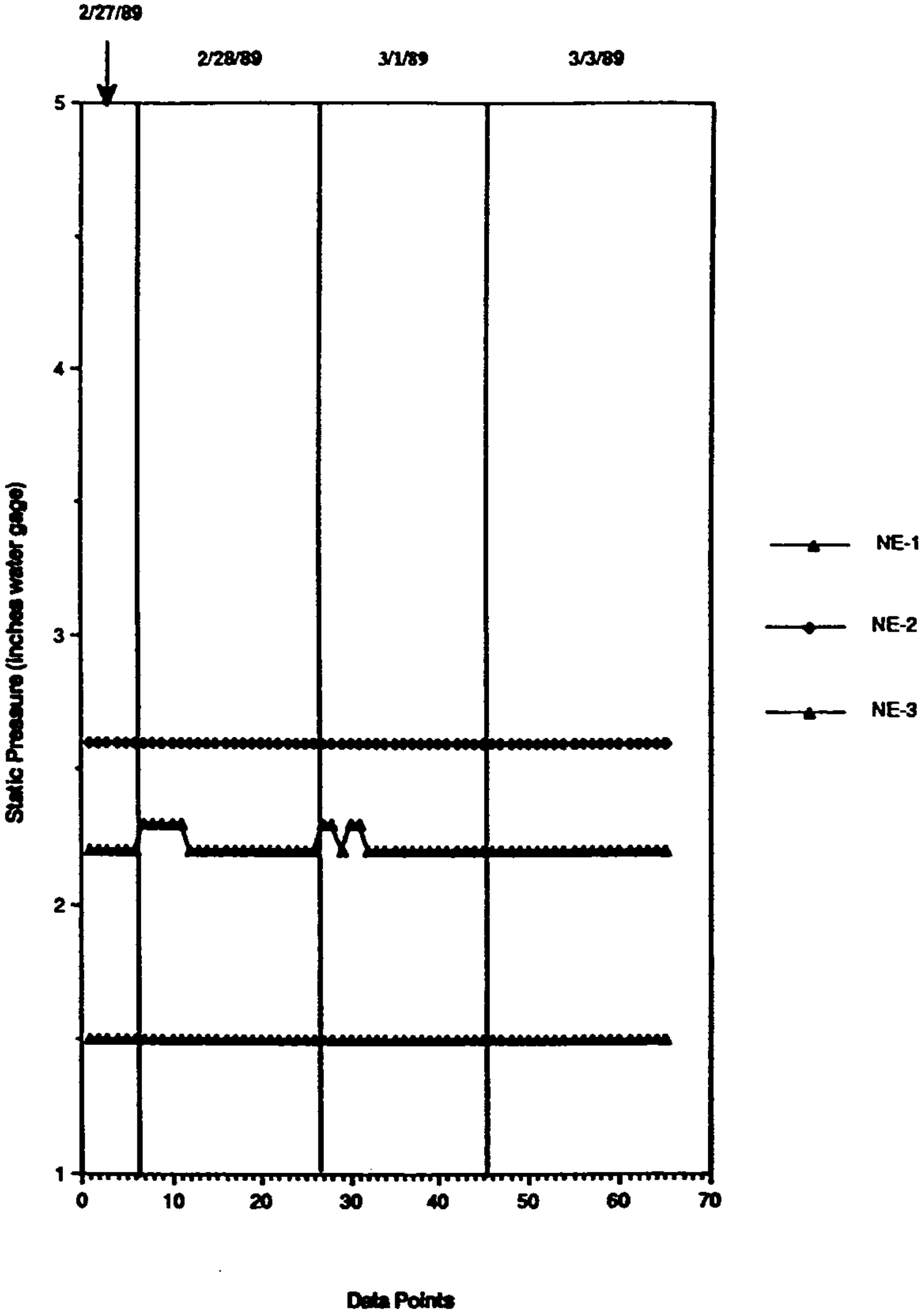


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey

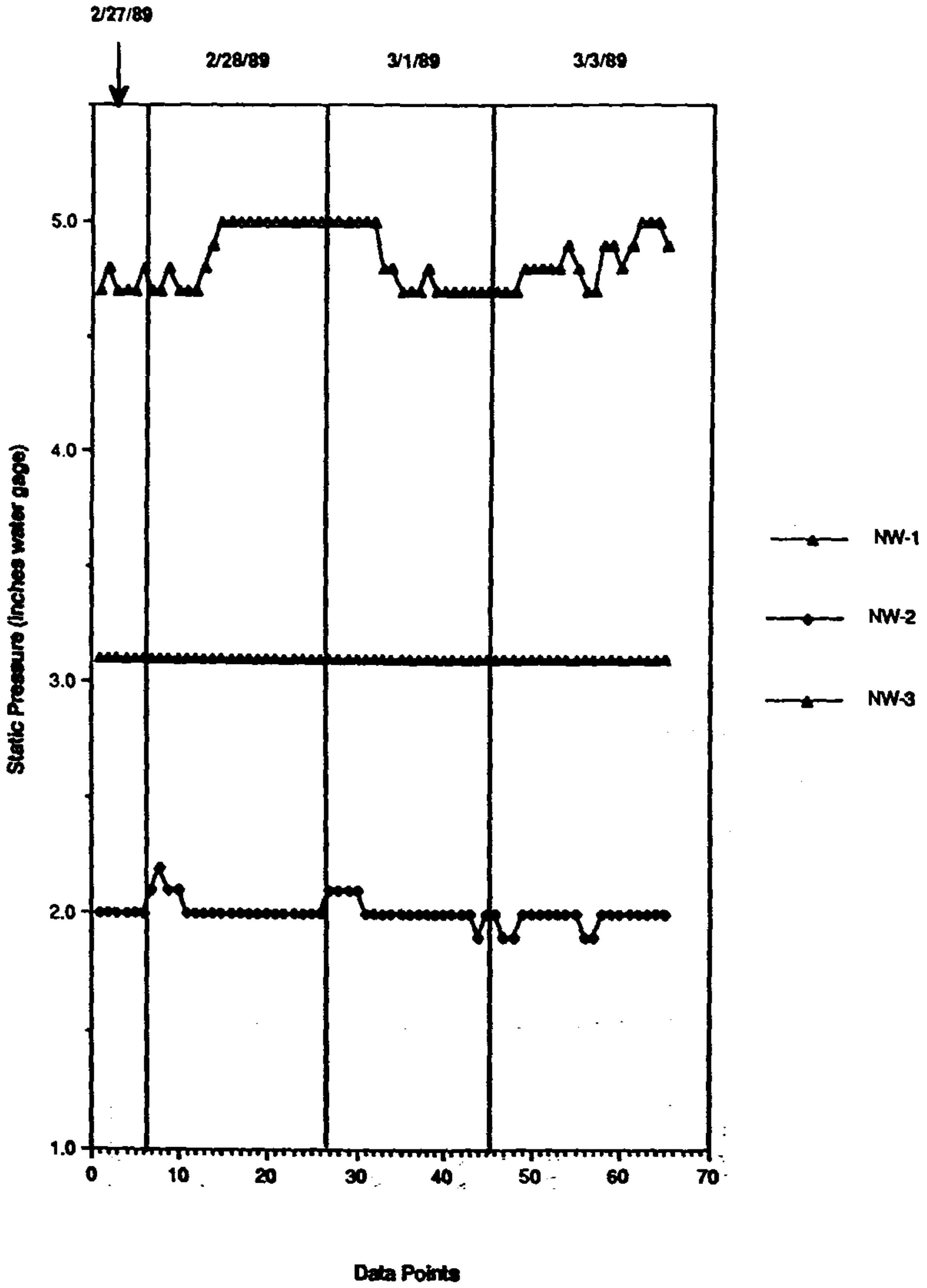
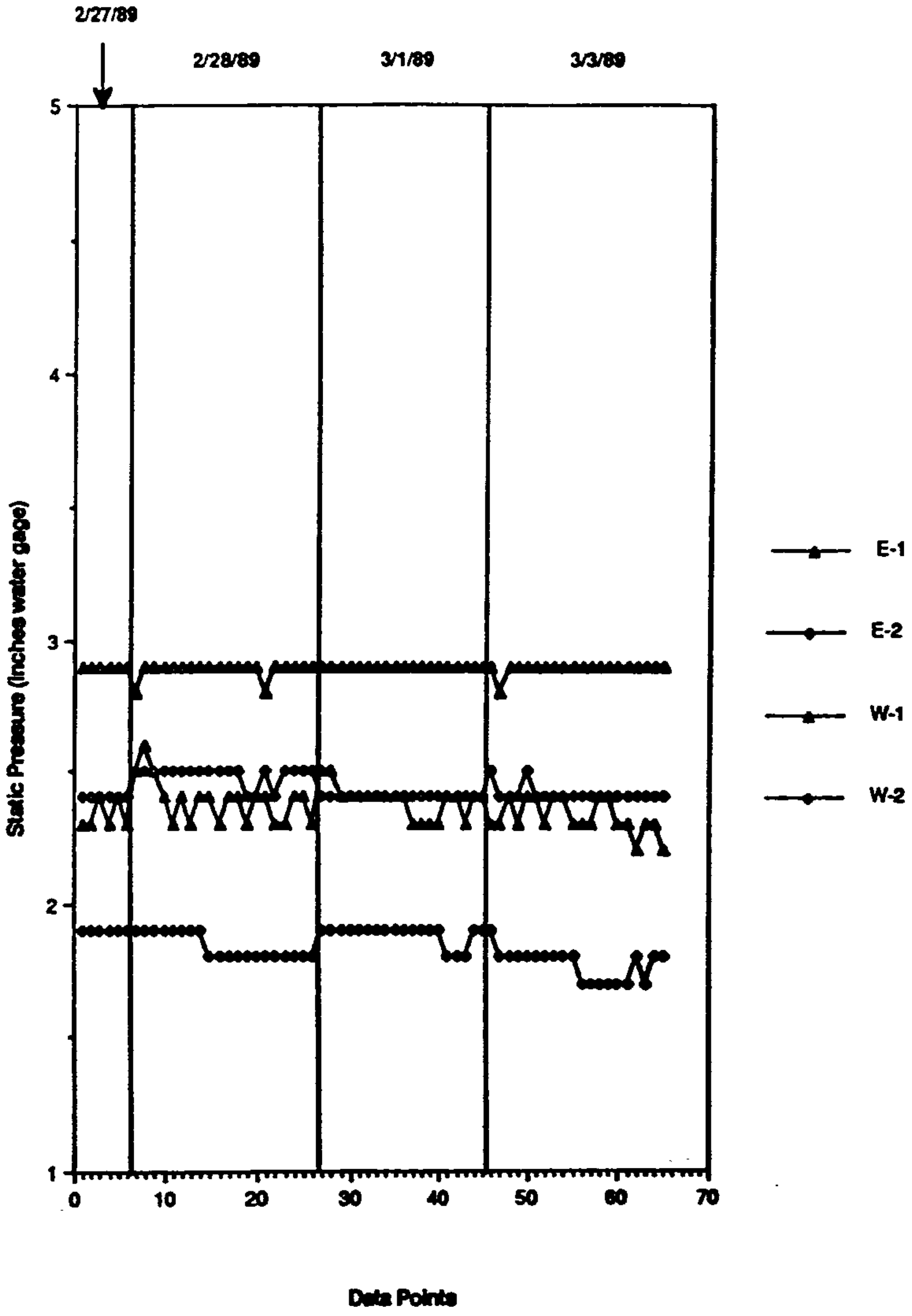


Figure J.3. Static Pressure Setpoint in the AHU Main Duct During the Survey



★U.S. GOVERNMENT PRINTING OFFICE:1993 -[illegible]