NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

REVISED POST-REMEDIATION ENVIRONMENTAL AND MECHANICAL SYSTEM ASSESSMENTS
25 SIGOURNEY STREET
HARTFORD, CONNECTICUTT

Prepared For:

Jean Cox-Ganser, Ph.D.
Research Team Supervisor, Field Studies Branch
Centers for Disease Control (NIOSH)
1095 Willowdale Road
Mail Stop 2800
Morgantown, WV 26505

Prepared By:

Environmental Health & Engineering, Inc.
60 Wells Avenue
Newton, MA 02459-3210

EH&E Report #11767
February 2, 2005

P:\11767\Project Reports\EH&E August 2004 Comprehensive report 05Feb2Revisions.doc

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 1
2.0 ANALYSIS OF AIR SAMPLES COLLECTED 3
2.1 SUMMARY 3
2.2 SAMPLING LOCATIONS AND RATIONALE 3
2.3 BIOAEROSOLS 4
2.4 CHEMICAL POLLUTANTS 6
2.5 PARTICULATE MATTER 8
2.6 INDOOR ENVIRONMENTAL MEASUREMENTS 9
3.0 MECHANICAL SYSTEMS ASSESSMENT 13
3.1 SUMMARY 13
3.2 BUILDING HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS 13
3.3 BUILDING HISTORY 17
3.4 HEATING, VENTILATING, AND AIR-CONDITIONING ADJUSTMENTS 18
3.5 EH&E MEASUREMENTS 18
3.6 EH&E OBSERVATIONS 20

LIST OF TABLES

Table 2.1 Total Airborne Fungal Spores Collected at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.2 Total Airborne Culturable Fungi Collected in August 2004 at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.3 Total Airborne Culturable Bacteria Collected at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.4 Total Volatile Organic Compounds Levels Measured at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.5 Formaldehyde and Acetaldehyde Levels Measured at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.6 Airborne Particulate Matter Concentrations Measured at 25 Sigourney Street, Hartford, CT, March 10 – 14, 2003 and August 16 – 17, 2004
Table 2.7 Results of Carbon Dioxide Monitoring During Occupied Hours at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004
Table 2.8 Results of Carbon Monoxide Monitoring at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004
Table 2.9 Thermal Comfort Summary During Occupied Hours at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004
Table 3.1 Measured Outdoor and Exhaust Airflow Rates on Each of the Floors Studied by EH&E on August 17 and 18, 2004
Table 3.2 Measured Pressure Relationships between Various Floors of the Building and Outdoors Measured by EH&E on August 17, 2004

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 1
2.0 ANALYSIS OF AIR SAMPLES COLLECTED 3
2.1 SUMMARY 3
2.2 SAMPLING LOCATIONS AND RATIONALE 3
2.3 BIOAEROSOLS 4
2.4 CHEMICAL POLLUTANTS 6
2.5 PARTICULATE MATTER 8
2.6 INDOOR ENVIRONMENTAL MEASUREMENTS 9
3.0 MECHANICAL SYSTEMS ASSESSMENT 13
3.1 SUMMARY 13
3.2 BUILDING HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS .. 13
3.3 BUILDING HISTORY 17
3.4 HEATING, VENTILATING, AND AIR-CONDITIONING ADJUSTMENTS 18
3.5 EH&E MEASUREMENTS 18
3.6 EH&E OBSERVATIONS 20

LIST OF TABLES

Table 2.1 Total Airborne Fungal Spores Collected at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.2 Total Airborne Culturable Fungi Collected in August 2004 at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.3 Total Airborne Culturable Bacteria Collected at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.4 Total Volatile Organic Compounds Levels Measured at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.5 Formaldehyde and Acetaldehyde Levels Measured at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study
Table 2.6 Airborne Particulate Matter Concentrations Measured at 25 Sigourney Street, Hartford, CT, March 10 – 14, 2003 and August 16 17, 2004
Table 2.7 Results of Carbon Dioxide Monitoring During Occupied Hours at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004
Table 2.8 Results of Carbon Monoxide Monitoring at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004
Table 2.9 Thermal Comfort Summary During Occupied Hours at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004
Table 3.1 Measured Outdoor and Exhaust Airflow Rates on Each of the Floors Studied by EH&E on August 17 and 18, 2004
Table 3.2 Measured Pressure Relationships between Various Floors of the Building and Outdoors Measured by EH&E on August 17, 2004

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

Figure 3.1	Schematic Depiction of the HVAC System of the 25 Sigourney Street Building
Figure 3.2	Photo of Outdoor Air Damper and Control Station Installed in a Typical Mechanical Room
Figure 3.3	Photo of Typical Filter Installation in an Air Handling Unit
Figure 3.4	Photo Inside a Typical Air Handling Unit, Showing the Cleanliness of the Coils, Fan, and Bottom of the Drain Pan
Figure 3.5	Photo of Heat Coil and Freeze Thermostat in Typical Air Handling Unit

LIST OF ABBREVIATIONS AND ACRONYMS

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
BASE	Building Assessment Survey and Evaluation
cfm	cubic feet per minute
cfu/m^3	colony-forming units per cubic meter
CO	carbon monoxide
CO_2	carbon dioxide
EH&E	Environmental Health & Engineering, Inc.
EPA	U.S. Environmental Protection Agency
HVAC	heating, ventilating, and air-conditioning
IAQ	indoor air quality
IEQ	indoor environmental quality
in-H_2O	inches of water column
NIOSH	National Institute for Occupational Safety and Health
OA	outdoor air
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
ppb	parts per billion
ppm	parts per million
spores/m^3	spores per cubic meter
VAV	variable air volume
VOC	volatile organic compound
°F	degrees Fahrenheit
ΔP	difference in pressure
$\mu g/m^3$	micrograms per cubic meter
μm	microns

1.0 EXECUTIVE SUMMARY

Environmental Heath & Engineering, Inc. (EH&E) is pleased to provide a summary of the investigative work completed at 25 Sigourney Street, Hartford, Connecticut in August 2004, following the completion of remediation to address water incursion in the building. EH&E participated in a building investigation led by the National Institute for Occupational Safety and Health (NIOSH). The findings of the post-remediation assessment completed by EH&E are described in this report.

The post-remediation assessment of 25 Sigourney Street included: 1) collecting and analyzing air samples for bioaerosols, chemical pollutants, and particulate matter; 2) collecting indoor environmental measurements; and 3) evaluating the heating, ventilating, and air-conditioning (HVAC) systems. Each of these activities are summarized below.

The measured fungal spore levels and particulate matter levels were compared to levels from previous investigations in March 2003 and July 2002. In addition, the bioaerosol, chemical pollutant and particulate matter levels were compared to reference ranges reported for non-complaint buildings in the United States. Overall, the measures were similar to conditions found in the building previously by EH&E and in the range of levels reported for a randomized sample of non-complaint office buildings that constitute the Building Assessment Survey and Evaluation (BASE) study sponsored by the U.S. Environmental Protection Agency (EPA). The conclusion of this portion of the investigation is that concentrations of all of the pollutants measured in the building were not elevated above normal levels at the time of sampling.

As part of the mechanical systems assessment, EH&E reviewed the design, operation, and adjustment of selected HVAC systems. In this investigation, EH&E measured the flow of outdoor air into selected floors during occupied conditions, measured the differential pressure between indoors and outdoors, and measured exhaust flows. EH&E also inspected the various mechanical rooms and air handling equipment serving the floors studied.

Overall, EH&E observed that the HVAC systems were clean and well maintained. A review of air flows and building pressurization shows that the floors are operating at or slightly below design flows relative to outdoor air delivery, but that the floors are maintained at a positive pressure with respect to outdoors.

2.0 ANALYSIS OF AIR SAMPLES COLLECTED

2.1 SUMMARY

EH&E conducted a post-remediation assessment at 25 Sigourney Street from August 16 – 19, 2004. A primary goal of the post-remediation assessment was to determine if present indoor environmental conditions are within the range observed in buildings with no history of health complaints related to indoor environmental quality (IEQ). Another primary goal was to determine if current IEQ conditions are similar to those measured by EH&E in March 2002 when mold and dust levels, as well as ventilation conditions, were typical of non-complaint buildings. In addition to collecting airborne fungal spore samples and particulate matter, which were also collected in March 2003, EH&E expanded the current assessment to include volatile organic compounds, aldehydes, culturable fungi, and culturable bacteria. The protocols used to assess these pollutants closely mirror the protocols used in the EPA BASE study, a multi-year study that evaluated IEQ conditions in 100 non-complaint office buildings. EH&E employed BASE protocols in order to facilitate comparison of 25 Sigourney Street to the BASE population of non-complaint buildings.

2.2 SAMPLING LOCATIONS AND RATIONALE

Sampling was conducted on the sixth, eighth, and eighteenth floors, all of which were also evaluated in March 2003 by EH&E. The Department of Revenue Services occupies the sixth and eighteenth floors, while the eighth floor is occupied by the Department of Social Services. We chose the sixth floor because the airborne mold spore levels measured there in March 2003 differed from those of the other floors. However, it is important to note that the mold levels on all of the floors, including the sixth, were well within the range of the non-complaint buildings assessed by EH&E as part of the BASE study. We chose the eighth floor because although the March 2003 sample concentrations were normal with respect to non-complaint buildings, there were more samples above the detection limit when compared to other floors. We chose the eighteenth floor because it is among the upper floors that have a history of water incursion.

The sampling protocol was designed to address the following two questions regarding the building environment:

- Are the airborne fungal spore and particulate matter levels different for levels measured during the March 2003 sample period?
- How does the current indoor environment compare to non-complaint office buildings sampled as part of the EPA BASE study?

2.3 BIOAEROSOLS

The bioaerosol assessment included sampling for fungal spores, viable fungi, and viable bacteria samples. Similar to the BASE study, bioaerosol samples were collected in the morning and afternoon at two stations per floor. The locations of these stations were approximately the same as the locations used in the March 2003 sampling. Additionally, bioaerosol samples were collected from the roof and the mezzanine outside the cafeteria, the same locations used for the previous 25 Sigourney Street assessments.

Each fungal spore sample was collected for three minutes using a sampling pump controlled by a timer and attached to an Air-O-Cell® cassette. Sampling for viable airborne fungi and viable airborne bacteria was conducted with an Andersen N-6 single-stage bioaerosol sampler (Grasby Andersen, Smyrna, Georgia) for five minutes using a vacuum pump set at a flow rate of 28.3 liters per minute. Fungal samples were collected onto malt extract agar, while bacteria samples were collected onto tryptic soy agar. All bioaerosol samples were sent to Environmental Microbiology Laboratory (San Bruno, California) for analysis.

The airborne fungal spore concentrations were compared to results obtained from the March 2003 assessment of the building (see Table 2.1). Outdoor and indoor fungal spore concentrations were greater during the August 2004 sampling period compared to the March 2003 samples because of seasonal differences in fungal populations. This is particularly evident in the outdoor samples where the median concentration was approximately 50 times greater during the Summer 2004 samples compared to the Spring 2003 samples. The bioaerosol concentrations on all floors of the building were low and in the range observed in non-complaint buildings. For example, the measured indoor total spore concentrations were below levels measured by EH&E for the EPA in its BASE study of buildings located throughout the United States.

Table 2.1 Total Airborne Fungal Spores Collected at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study

	Total Indoor Fungal Spores		Total Outdoor Fungal Spores	
	Median (spores/m^3)	Range (spores/m^3)	Median (spores/m^3)	Range (spores/m^3)
25 Sigourney St.—August 2004	66	ND – 267	2,714	2,244 – 7,420
25 Sigourney St.-March 2003	13	ND – 653	53	ND – 746
BASE	124	ND – 16,958	14,210	3,408 – 66,463

spores/m^3 spores per cubic meter
ND non-detect
BASE Building Assessment Survey and Evaluation

Culturable fungi samples can provide information about the species of fungi present in a building. Culturable fungi sample results were compared to samples collected in the summer months in non-complaint buildings as part of the EPA BASE study. As evident from Table 2.2, culturable fungi concentrations were below those measured in the EPA BASE study.

Table 2.2 Total Airborne Culturable Fungi Collected in August 2004 at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study

	Total Indoor Culturable Fungi		Total Outdoor Culturable Fungi	
	Median (cfu/m^3)	Range (cfu/m^3)	Median (cfu/m^3)	Range (cfu/m^3)
25 Sigourney Street	7	ND – 28	410	162 – 787
BASE	1,539	ND – 188,748	15,624	ND – 352,868

cfu/m^3 colony-forming units per cubic meter
ND non-detect
BASE Building Assessment Survey and Evaluation

Culturable airborne bacteria are commonly found in indoor environments. In office settings, the majority of airborne bacteria are shed from the building occupant's skin and respiratory tracts. Culturable airborne bacteria results were compared to results collected in the summer months in non-complaint buildings as part of the EPA BASE study. Although the median culturable bacteria concentration was above the EPA BASE study median concentration, the 25 Sigourney Street samples were all within the range of the samples collected in the EPA BASE study.

Table 2.3 Total Airborne Culturable Bacteria Collected at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study

	Total Indoor Bacteria		Total Outdoor Bacteria	
	Median (cfu/m³)	Range (cfu/m³)	Median (cfu/m³)	Range (cfu/m³)
25 Sigourney Street	67	21 – 340	32	28 – 64
BASE	14	ND – 919	14	ND – 1,187

cfu/m³ colony-forming units per cubic meter
ND non-detect
BASE Building Assessment Survey and Evaluation

The conclusion of the August 2004 bioaerosol sampling is that bioaerosol concentrations in the sampled areas of the building were again well within the range for non-complaint buildings.

2.4 CHEMICAL POLLUTANTS

The assessment of chemical pollutants included sampling for volatile organic compounds (VOCs) and aldehydes. EH&E has not conducted previous sampling for chemical pollutants at 25 Sigourney Street, but these analyses were conduced as part of the EPA BASE study.

VOCs and aldehyde compounds are commonly found in indoor and outdoor environments. VOCs have many sources, such as solvents, spray product propellants, combustion byproducts, emissions from household furnishings, and some natural sources. The most common aldehydes are formaldehyde and acetaldehyde. Formaldehyde has many indoor sources, including textiles and building materials. Acetaldehyde in indoor environments typically results from automobile emissions and tobacco smoke.

Sampling and analysis was conducted for 66 common VOCs using the protocols specified in EPA Method TO-14. Both indoor and outdoor air samples were collected with SUMMA® polished stainless steel canisters. Formaldehyde and acetaldehyde samples were collected using Sep-Pak cartridges by protocols specified in EPA Method TO-11. Samples for both VOCs and aldehydes were collected from approximately 8:00 a.m. to 5:00 p.m. on August 17, 2004. Colombia Analytical Services, Inc. (Canoga Park, California) provided certified clean canisters for the VOC samples and analyzed the VOC and aldehyde samples.

Sample results for both VOCs and aldehydes were compared to results collected in the summer months in non-complaint buildings as part of the EPA BASE study. Not all VOCs that were reported in our analysis were reported for the EPA BASE study. Of the 66 compounds that were analyzed, 48 were not detected in any of the indoor samples. The compounds that were detected are summarized in Table 2.4 and compared to the results of the EPA BASE study. All of the detected compounds were within the range of those detected in non-complaint buildings, with the exception of ethanol.

Table 2.4 Total Volatile Organic Compounds Levels Measured at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study

Compound	25 Sigourney Street		EPA BASE	
	Median (µg/m³)	Maximum (µg/m³)	Median (µg/m³)	Maximum (µg/m³)
1,2,4-Trimethylbenzene	1.6	1.7	0.6	4.6
2-Butanone (MEK)	2.5	5.5	1.9	9.8
Acetone	21.0	140.0	19.1	92.1
Acetonitrile	6.8	180.0	NA	NA
Acrolein	2.8	4.6	NA	NA
Dichlorodifluoromethane (CFC 12)	3.3	2.8	1.4	360.1
d-Limonene	3.2	5.8	1.1	25.5
Ethanol	81.5	210.0	30.1	108.1
Isopropyl alcohol	18.5	31.0	NA	NA
m,p-Xylenes	1.6	1.6	1.5	16.6
Methylene chloride	2.0	2.0	0.8	391.6
n-Butyl acetate	2.0	2.3	0.2	6.9
n-Hexane	2.1	2.2	1.0	18.5
n-Nonane	1.8	2.2	0.3	8.5
Tetrachloroethene	1.3	1.3	0.4	7.5
Toluene	3.0	8.1	4.3	98.5
Trichlorofluoromethane	2.9	3.5	0.7	175.6
Vinyl acetate	3.7	6.0	NA	NA

EPA U.S. Environmental Protection Agency
BASE Building Assessment Survey and Evaluation
µg/m³ micrograms per cubic meter
NA not available

Formaldehyde and acetaldehyde results are summarized in Table 2.5. The concentrations of formaldehyde and acetaldehyde detected at 25 Sigourney Street were within the range found in samples collected in the EPA BASE study. Results of sampling for airborne concentrations of formaldehyde and acetaldehyde indicate that formaldehyde and acetaldehyde levels at all sampling locations were below Occupational Safety and Health Administration (OSHA) guidelines[1,2] and within levels detected in non-compliant buildings.

Table 2.5 Formaldehyde and Acetaldehyde Levels Measured at 25 Sigourney Street Compared to Samples Collected as Part of the EPA BASE Study

	Formaldehyde		Acetaldehyde	
	Median (ppb)	**Maximum (ppb)**	**Median (ppb)**	**Maximum (ppb)**
25 Sigourney Street	17	23	3	4
BASE	12	41	4	12

ppb parts per billion
BASE Building Assessment Survey and Evaluation

2.5 PARTICULATE MATTER

Real-time, data-logging particle monitors were used to collect and record data on airborne particulate matter concentrations continuously at each sampling location. One 24-hour period of sampling was conducted for particulate matter less than 10 microns (μm) in diameter (PM_{10}) and sampling for particulate matter less than 2.5 μm ($PM_{2.5}$) was conducted during the second 24-hour period. As part of the March 2003 building assessment, PM_{10} was sampled for four days at the same locations.

The monitoring instrument used was a DustTrak™, Model 8520, manufactured by TSI, Inc. (St. Paul, Minnesota). The DustTrak™ instrument measures airborne dust concentrations with an accuracy of 1% and a resolution of 1 microgram per cubic meter ($\mu g/m^3$), using a 90° light scattering laser diode. The monitoring range of the DustTrak™

1 OSHA 29 CFR 1910. Formaldehyde Time Weighted Average Limit of 750 parts per billion.

2 OSHA 29 CFR 1910. Acetaldehyde Time Weighted Average Limit of 100,000 parts per billion.

is 0.001 – 100.0 milligrams per cubic meter. The logging interval of the instrument was five minutes. The unit is factory-calibrated annually.

Table 2.6 presents the summary results of dust monitoring in August 2004 and the sampling conducted in 2003. PM_{10} concentrations measured in August 2004 were similar to or lower than concentrations measured in 2003, with the exception of location 18B. All PM_{10} and $PM_{2.5}$ concentrations measured in August 2004 were lower than levels measured outdoors.

Table 2.6 Airborne Particulate Matter Concentrations Measured at 25 Sigourney Street, Hartford, CT, March 10 – 14, 2003 and August 16 – 17, 2004

Location	PM_{10} Measurements March 2003			PM_{10} Measurements August 2004			$PM_{2.5}$ Measurements August 2004		
	Median (µg/m³)	75th (µg/m³)	95th (µg/m³)	Median (µg/m³)	75th (µg/m³)	95th (µg/m³)	Median (µg/m³)	75th (µg/m³)	95th (µg/m³)
6A	7	9	13	7	15	17	13	17	25
6B	8	11	18	6	13	16	11	13	27
8A	16	18	25	5	7	8	4	7	19
8B	7	10	16	3	4	6	4	6	10
18A	54	57	67	5	6	8	5	7	16
18B	6	8	12	25	31	32	26	29	38
Roof	26	45	76	62	68	75	82	157	305
Mezzanine	33	61	87	30	33	39	39	87	133

µg/m³ microgram per cubic meter
NA not applicable

All values are five-minute averages.
The monitoring instrument used was a DustTrak™, Model 8520, manufactured by TSI, Inc. (St. Paul, Minnesota).

2.6 INDOOR ENVIRONMENTAL MEASUREMENTS

EH&E's evaluation included continuous monitoring of several basic IEQ parameters, including carbon dioxide (CO_2), carbon monoxide (CO), temperature, and relative humidity at the selected monitoring location between August 16 and 18, 2004. CO_2 concentrations were measured in the 25 Sigourney Street space to assess the adequacy of the ventilation; CO measurements were obtained within the space to evaluate the potential impact of combustion sources on the occupied spaces. Temperature and relative humidity measurements were also obtained to assess thermal comfort within these spaces.

Continuous measurements for CO_2, CO, temperature, and relative humidity were made using Q-Trak with CO Model 8551 and Q-Trak Plus with CO Model 8554 Indoor Air Quality (IAQ) Monitors, manufactured by TSI, Inc. (St. Paul, Minnesota). The real-time monitoring instruments were calibrated prior to field use.

2.6.1 Carbon Dioxide Results

A summary of the continuous monitoring results for CO_2 during occupied hours, between 7:00 a.m. and 5:00 p.m., is presented in Table 2.7.

Table 2.7 Results of Carbon Dioxide Monitoring During Occupied Hours at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004

Location	CO_2 Concentration* (ppm)			
	Minimum	Mean	Maximum	90th Percentile
6A	406	512	634	539
6B	389	498	579	529
8A	399	539	617	592
8B	421	605	715	690
18A	411	592	685	657
18B	390	584	696	657
Outdoors, roof	351	394	436	417

CO_2 carbon dioxide
ppm parts per million

* Representation of data during occupied hours. Occupied hours assumed to be 7:00 am to 5:00 pm.

In the six indoor monitoring locations, the 90th percentile CO_2 concentrations ranged from 529 and 657 parts per million (ppm). These monitoring results indicate that the recommended amount of outdoor air per person was delivered to these areas throughout the occupied hours.

2.6.2 Carbon Monoxide Results

The results of continuous CO measurements from six indoor and one outdoor location are summarized in Table 2.8 below.

Table 2.8 Results of Carbon Monoxide Monitoring at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004

Location	CO Concentration (ppm)			
	Minimum	Mean	Maximum	90th Percentile
6A	<3	<3	<3	<3
6B	<3	<3	3	<3
8A	<3	<3	<3	<3
8B	<3	<3	<3	<3
18A	<3	<3	<3	<3
18B	<3	<3	<3	<3
Outdoors, roof	<3	<3	<3	<3

CO carbon monoxide
ppm parts per million

At all times, all measurements for CO were below the EPA and American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) recommended exposure limits. A CO concentration of 3 ppm was detected at Station 6B during the beginning of the monitoring period on the evening of August 16, 2004. Following this, the CO concentration at this location remained below the detection limit of the monitoring instrument for the remainder of the monitoring period. These results indicate that there were no CO sources affecting the building during the sampling period.

2.6.3 Thermal Comfort Results

Temperature and relative humidity were continuously monitored concurrently with CO_2 and CO at the same locations on August 17 and 18, 2004. Temperature, relative humidity, and calculated dew point temperature results are summarized below in Table 2.9.

Table 2.9 Thermal Comfort Summary During Occupied Hours at 25 Sigourney Street, Hartford, Connecticut, August 17 through 18, 2004

Location	Temperature* (°F)			Relative Humidity* (%)		
	Range	Average	90th Percentile	Range	Average	90th Percentile
6A	69.6 – 71.6	70.8	71.4	54.8 – 62.0	58.5	61.3
6B	70.9 – 73.4	72.3	72.9	52.6 – 62.1	56.6	60.7
8A	72.7 – 74.9	73.8	74.5	55.3 – 62.9	58.2	61.5
8B	70.5 – 74.7	73.2	74.3	52.4 – 66.7	57.6	63.5
18A	72.1 – 73.8	73.0	73.6	57.3 – 62.9	60.0	62.5
18B	71.9 – 73.4	72.8	73.3	53.1 – 63.3	57.4	62.3

°F degrees Fahrenheit

* Representation of data during occupied hours. Occupied hours were assumed to be 7:00 a.m. to 5:00 p.m.

During occupied periods, temperatures ranged from 69.6 degrees Fahrenheit (°F) to 74.9 °F at the monitoring locations. This is within the range of temperatures recommended by ASHRAE[3]. The relative humidity levels were generally within the recommended range of 30% to 60%. Elevated indoor relative humidity is common during the cooling season in the Northeast. According to the building manager, the set points on the Invensys control system had recently been changed, which may correct the elevated relative humidity.

3 ASHRAE Standard 55-1992. 1992. *Thermal Environmental Conditions for Human Occupancy*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

3.0 MECHANICAL SYSTEMS ASSESSMENT

3.1 SUMMARY

In August 2004, EH&E reviewed the design, operation, and adjustment of selected HVAC systems in the 25 Sigourney Street Building in Hartford, Connecticut, as part of a larger building investigation led by NIOSH. In this investigation, EH&E measured the flow of outdoor air into selected floors during occupied operation conditions, the differential pressure between indoors and outdoors, and exhaust flows. EH&E also inspected the various mechanical rooms and air handling equipment serving the floors studied.

Overall, EH&E observed that the HVAC systems were clean and well maintained. A review of air flows and building pressurization showed that the floors are operating at or slightly below design flows relative to outdoor air delivery but that the floors are maintained at a positive pressure with respect to outdoors.

3.2 BUILDING HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

The following sections detail the design, operation, and observed maintenance of the HVAC systems for the building at 25 Sigourney Street in Hartford, Connecticut. This information was gained by a review of the original design drawings, a review of the various reports made by other entities concerning these systems, and measurements and inspections performed by EH&E in the course of performing its building evaluation.

To heat, ventilate, and air-condition each of the floors of the building, chilled or heated water generated from an off-site plant is supplied to two air handling units on each of the building's floors. There is also a cooling tower at the 25 Sigourney Street site that is used to provide chilled water for the water-side economizer during non-summer conditions. Each air handling unit is located in a room that acts as a mixing plenum, mixing outdoor air with return air from the space. Outdoor air is provided using fans and outdoor air inlets from the penthouse level of the building. During occupied time periods, the amount of outdoor air provided to each floor varies depending on outdoor weather conditions and CO_2 levels measured in the return air ducts. The outdoor air volume can also be changed on a floor-by-floor basis in response to fire and smoke alarm conditions to purge and/or pressurize floors as needed. Exhaust air is removed from each floor through bathroom exhaust.

The HVAC systems serving 25 Sigourney Street are currently controlled by an Invensys building management system. Installation of the system began in December of 2003 and has recently been completed. The Invensys system controls the temperature and volume of the supply air, as well as the ratio of outdoor air supplied to the space.

The control system resets the supply air conditions based on multiple parameters such as outdoor air temperature, return air CO_2 levels, and the occupied condition of the building. The Invensys system calculates the minimum amount of outdoor air supplied to the space based on the return air CO_2 levels. As the CO_2 levels rise above 800 ppm, the minimum amount of outdoor air increases from its minimum position to its maximum. The outdoor weather conditions determine the maximum amount of outdoor air provided to the space. The system compares the supply air set point to the actual supply air conditions. If there is a need for cooling, the control system first tries to meet the cooling demand with outdoor air. If the outdoor air enthalpy does not meet the preset requirements, the control system will minimize the outdoor air damper positions and activate the cooling coil.

Each of the thermal control zones in the occupied areas of the building operates according to a variable air volume (VAV) control strategy. Using this strategy, each of the air handling units in the building will control the supply air discharge temperature to assure both adequate cooling and dehumidification to meet the cooling requirements of the space. The volume of this air is then varied based on the demands of the space, as sensed by local zone thermostats. For instance, in cooling mode, if the space temperature is getting lower than the zone thermostat's set point, this control strategy will lessen the amount of supply air discharged into the zone. By this strategy, the amount of supply air temperature to an individual zone will reduce to some predetermined minimum to assure adequate ventilation of the zone.

In the interior zones of the building, this strategy works in an occupied building and requires no heating even during the coldest weather, assuming that the space is occupied with normal lighting and office equipment usage. However, in the exterior zones, this strategy can be problematic during winter conditions if there is no local heat source to compensate for heat lost through the building skin and air leakage.

In this building, once the minimum flow value for an exterior zone is reached, a fan-powered reheat box will reheat supply air before introduction into the occupied space. The fan assures better distribution of heating air, which is always difficult to do from a ceiling mounted diffuser, and a hot water coil in the VAV box reheats the supply air to appropriate conditions to heat the zone.

There are no provisions to humidify indoor air in this building. There are also not any provisions to provide direct exhaust of the paper processing equipment in the print room on the eighth floor.

Figure 3.1 provides, in schematic fashion, a description of the HVAC strategy used in this building.

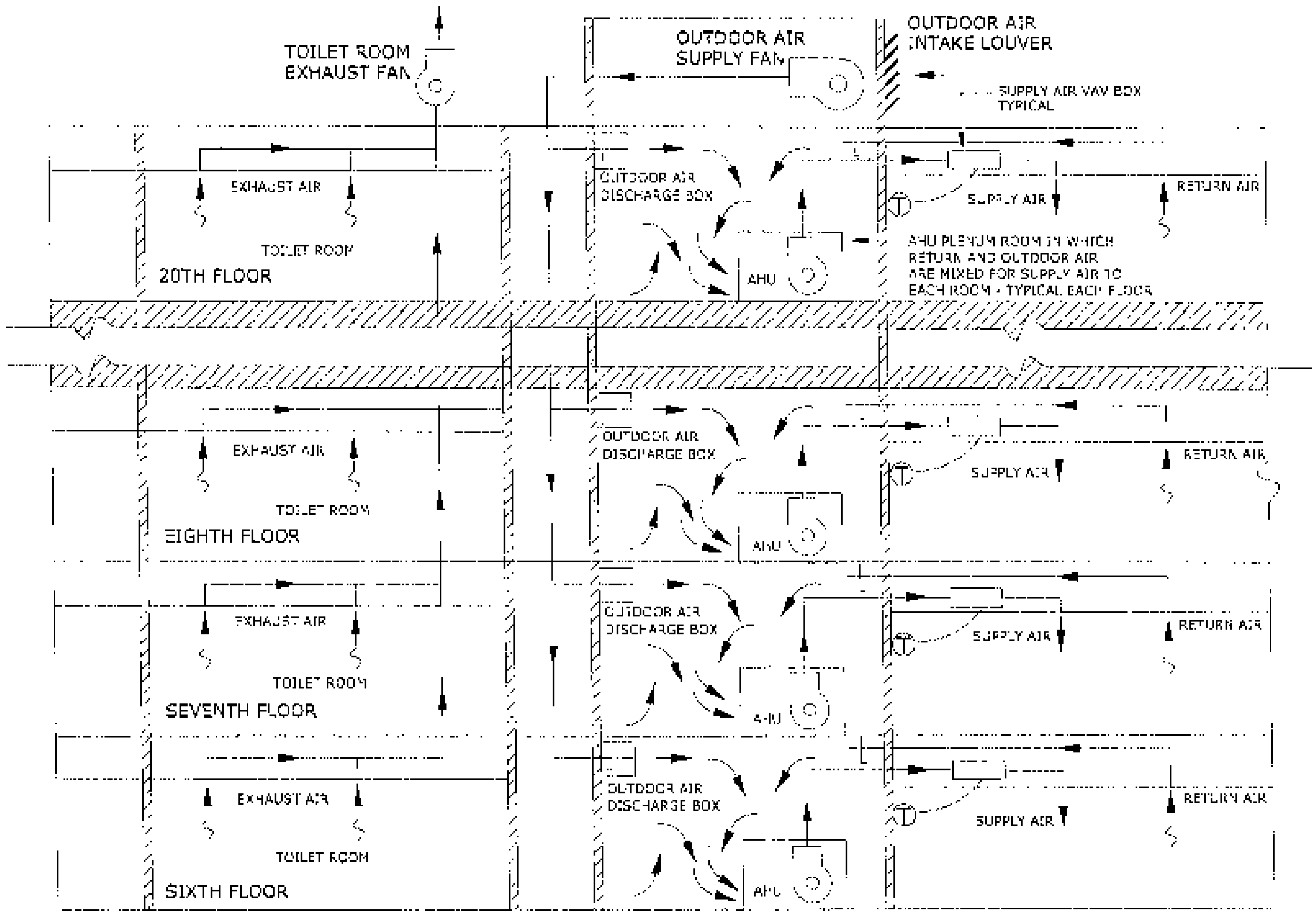

Figure 3.1 Schematic Depiction of the HVAC System of the 25 Sigourney Street Building

3.3 BUILDING HISTORY

The 25 Sigourney Street Building was built circa 1985 as an office building and referred to as the Xerox Centre. In the early 1990s, Xerox relinquished control of the building to the State of Connecticut. The State accepted the property and chose to use it as office space for their Social Services Department and Department of Revenue. It appears that the State performed some minor modifications to the building's HVAC systems in the form of a rezoning of floors six through twenty circa 1994.[4] However, from the original drawings to the current building, it appears that no radical changes were made to the design and operation of the building's HVAC systems.

In the late 1990s, mold was discovered on external walls of several floors. The source of water to enable this mold growth was thought to be water that was penetrating into the exterior of the walls. During the investigation of this problem, it was learned that, on some of the floors, the building was operating at a negative pressure with respect to outdoors. The fact that the building was operating at a negative pressure relative to outdoors was thought to exacerbate any leakage of water through the building envelope, as well as provide the transport mechanism for mold spores to move from their growth substrate into the occupied space.

Building pressurization issues, as well as various IAQ studies in which CO_2 was measured, called into question the relative performance of the building's outdoor air supply and exhaust systems. For a building of this type, it is common to mechanically supply more air to the building than is mechanically exhausted from each floor.

The rationale for this action is that it is better to have outdoor air enter the building in a controlled manner through the HVAC system. This assures that it is not contaminated by local pollutant source(s) and it can be appropriately filtered, thermally conditioned, and dehumidified prior to introduction into the occupied areas of the building.

4 As Built Drawings M-1 through M-6, prepared by Janazzo Heating & Air Conditioning, Inc., Contractors & Engineers, June 29, 1994.

3.4 HEATING, VENTILATING, AND AIR-CONDITIONING ADJUSTMENTS

Apparently, in response to reports and observations of building pressurization issues and high CO_2 measurements, the building management contracted with an engineering firm to assess the building.[5] The engineer, in cooperation with an air balancing and controls firm, developed a refined control strategy to deliver outdoor air to the various floors of the building. This involved upgrading the building controls and then adjusting them to achieve the amount of outdoor air ventilation in the original building design.

3.5 EH&E MEASUREMENTS

In August of 2004, EH&E performed measurements of the building's mechanical systems on floors six, eight, and eighteen as a component of a larger building investigation led by NIOSH. In this investigation, EH&E measured the amount of outdoor air supplied to the study floors, measured the building pressurization with respect to outdoors, and measured exhaust on the study floors. The following sections detail the results of these measurements.

3.5.1 Measured Outdoor Air Quantities

Outdoor air is supplied to each of the two mechanical rooms located on floors six through twenty at a varying rate based on indoor and outdoor conditions during normal building operation. Each mechanical room functions as a mixing plenum, mixing outdoor air with return air from the space for distribution by an air handling unit located in the mechanical room.

To measure the volume of outdoor air supplied to each mechanical room, EH&E took advantage of the outdoor airflow measurement stations that were installed. EH&E attached its own pressure measurement device in parallel with the measurement devices installed to measure duct velocity in the outdoor air delivery duct. EH&E then multiplied this value by the effective discharge area reported on the flow measurement station to determine the volume of outdoor air delivered to each mechanical room. Outdoor airflow rates were measured in each mechanical room twice each day over a

5 Air Flow Study for 25 Sigourney Street, Hartford, CT., prepared by Luchini, Milfort, Goodell & Associates, Inc., May 29, 2001.

two-day period. Table 3.1 reports the measurements performed for each of the floors studied.

According to the Invensys sequence of operation, for each floor, the target minimum outdoor air flow delivery was between 2,000 and 3,600 cubic feet per minute (cfm). The sixth and eighth floors are scheduled to receive between 2,200 and 3,600 cfm of outdoor air, while the eighteenth floor is scheduled to receive between 2,000 and 3,300 cfm of outdoor air during occupied hours. Based on EH&E's measurements, these targets were not achieved on all floors measured. The amount of outdoor air was generally lower than what was scheduled, according to the Invensys system. However, note that the amount of outdoor air supplied to each floor measured was significantly more than the amount of air exhausted from the floor. In addition, CO_2 concentrations indicate that the amount of outdoor air per person delivered to the space was consistent with ASHRAE guidelines.

The lowest outdoor air reading was collected in the eighth floor south mechanical room on August 18, 2004. At that time, the building maintenance staff was aware of the low outdoor air supply condition and was working to remedy the situation.

Table 3.1 Measured Outdoor and Exhaust Airflow Rates on Each of the Floors Studied by EH&E on August 17 and 18, 2004

Floor	Minimum OA (cfm)	Average OA (cfm)	Maximum OA (cfm)	Bath Exhaust Totals	OA Less Exhaust (cfm)
6	1,770	2,109	2,771	380	1,729
8	863	1,697	2,856	620	1,077
18	1,496	1,619	1,931	500	1,119

OA outdoor air
cfm cubic feet per minute

3.5.2 Building Pressure Measurements

During August of 2004, EH&E measured pressure relationships of the various floors relative to outdoor air over the course of two days.

Table 3.2 depicts the observed pressure relationship between the various floors and outdoors.

Table 3.2 Measured Pressure Relationships between Various Floors of the Building and Outdoors Measured by EH&E on August 17, 2004

Time	Floor	ΔP (in-H_2O)	Reference Point
10:55	20	0.100	20th floor outdoors
10:57	19	0.110	20th floor outdoors
11:00	18	0.127	20th floor outdoors
11:03	17	0.130	20th floor outdoors
11:25	10	0.148	20th floor outdoors
11:30	9	0.139	20th floor outdoors
11:45	8	0.118	20th floor outdoors
11:48	7	0.102	20th floor outdoors
11:50	6	0.119	20th floor outdoors
11:53	5	0.080	20th floor outdoors

ΔP difference in pressure
in-H_2O inches of water column

During the measurement period, winds were relatively calm, ranging between 0 and 6 miles per hour, as measured at Bradley International Airport. Therefore, the outdoor pressure reference was fairly constant. These measurements show that the building, as operated at the time of the measurements, was always positively pressurized with respect to outdoors. This is not surprising, given that the outdoor air flows significantly exceeded the exhaust air flows on all floors on which outdoor air and exhaust flows were measured.

3.6 EH&E OBSERVATIONS

During EH&E's August 2004 site investigation, EH&E inspected the building's mechanical systems with the exception of the cooling tower and the water-side economizer, which according to building maintenance staff is no longer used. Generally, EH&E observed that the mechanical systems on the floors observed were well maintained and in a good state of cleanliness. The mechanical room in which the air handling units are located is a part of the return air plenum and EH&E observed that these rooms were kept clean and not used for storage of cleaning supplies or other inappropriate materials.

The air handling units were inspected inside and observed to have clean coils, clean linings, etc. The units are fitted with filters in their racks in a manner that minimized the amount of air bypass that normally occurs in typical HVAC equipment.

Figures 3.2 through 3.5 show typical conditions observed in the building's mechanical rooms.

Figure 3.2 Photo of Outdoor Air Damper and Control Station Installed in a Typical Mechanical Room

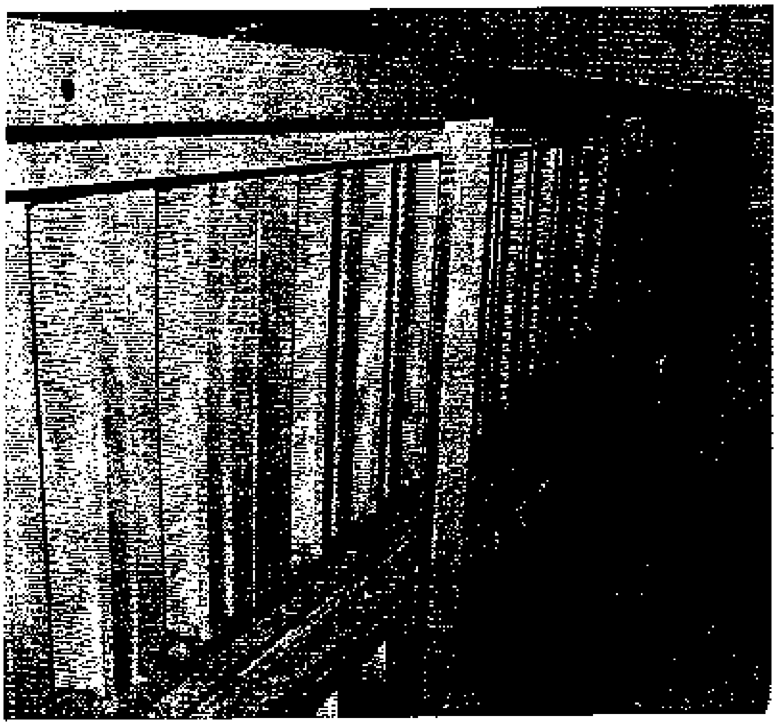

Figure 3.3 Photo of Typical Filter Installation in an Air Handling Unit

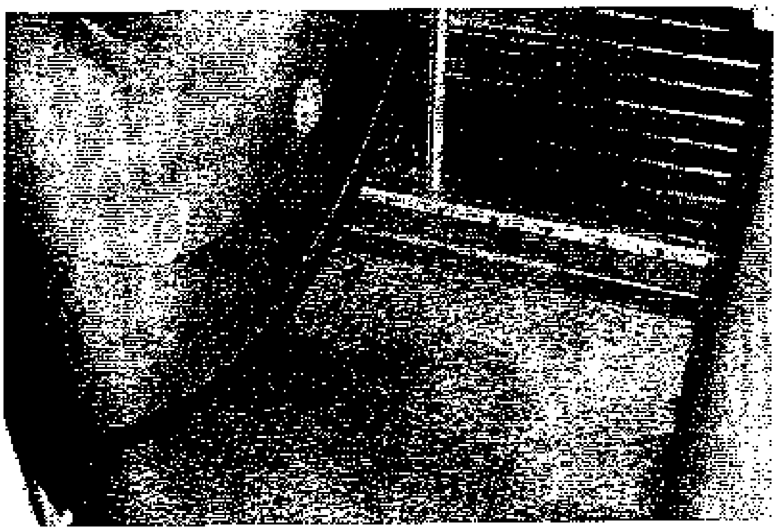

Figure 3.4 Photo Inside a Typical Air Handling Unit, Showing the Cleanliness of the Coils, Fan, and Bottom of the Drain Pan

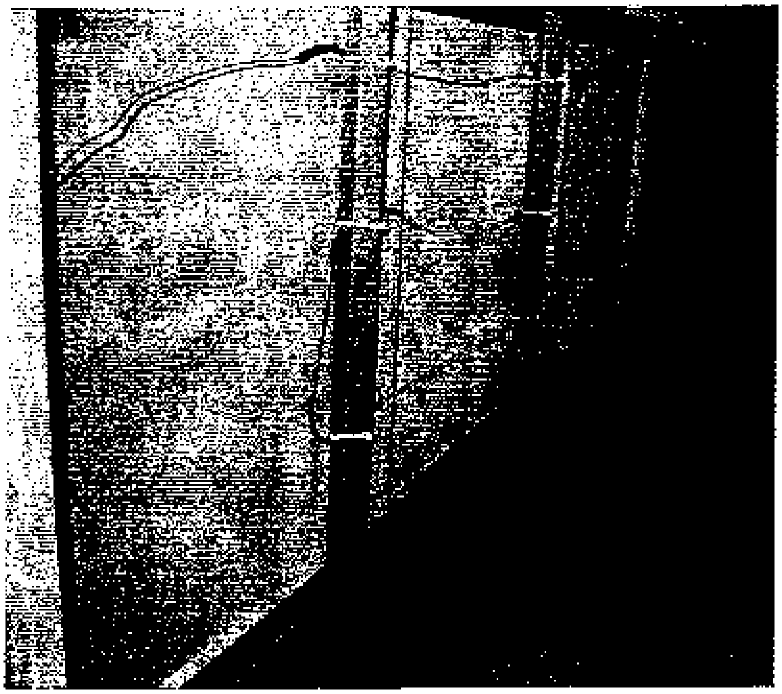

Figure 3.5 Photo of Heat Coil and Freeze Thermostat in Typical Air Handling Unit