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CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 93-0154-2527
Truman State Office Building
Jefferson City, Missouri

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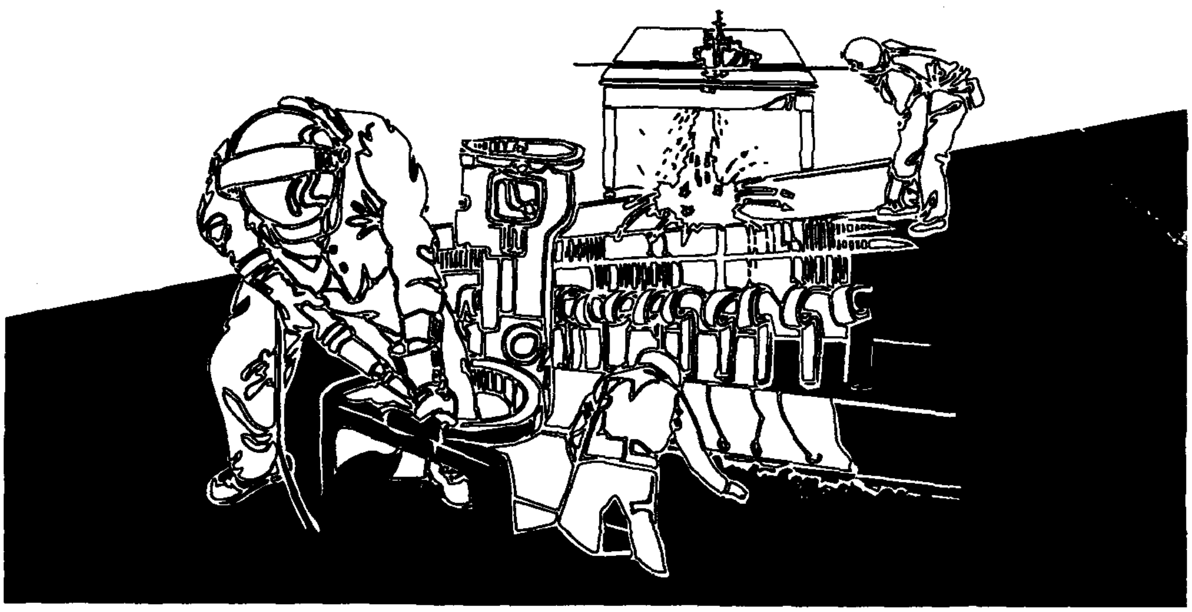

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PREFACE

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.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 93-0154-2527	**NIOSH INVESTIGATORS:**
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SUMMARY

On November 2, 1992, the National Institute for Occupational Safety and Health (**NIOSH**) received a request to conduct a health hazard evaluation from employees of the Division of Motor Vehicles, Department of Revenue at the Harry S. Truman State Office Building, Jefferson City, Missouri. Employees had experienced a variety of symptoms, including headaches, chronic cough, sinus problems, and sleepiness, which they related to the indoor environmental quality (**IEQ**).

An **initial survey** was conducted in May 1993. The evaluated area was occupied by five groups within the Division (Processing 1, Processing 2, Special Registrations, Receiving and Validations, and Quick Titles). These areas occupied approximately 6300 square foot (**ft^2**) of the total 39,000 ft^2 of the third floor south, and 72 employees worked in the evaluated area. Measured temperatures were within the comfort ranges currently recommended by the American Society of Heating, Refrigerating and Air-conditioning Engineers (**ASHRAE**) for the cooling season (73°F to 79°F); however, some relative humidity (**RH**) measurements were below the ASHRAE recommended guidelines (30% to 60%). Questionnaire survey results and concerns raised during small voluntary group meetings with workers showed that more than 50% of the workers reported experiencing symptoms during the four weeks preceding the survey that are commonly reported by occupants of "problem" buildings. Concerns regarding workplace conditions (e.g., too little air movement, air too dry, and odors in the restrooms), work organization (lack of opportunity for advancement, lack of support from supervisors, use of work quotas, and low pay scale) and health concerns (cancer and contagious illnesses) were raised during the initial visit.

A **follow-up survey** was scheduled in February 1994, during the cold weather (heating season). The evaluated area was expanded to include all areas of the third floor south occupied by employees within the Division of Motor Vehicles, with the exception of the Division's Administrative Offices. The evaluated areas occupied approximately 29,700 ft^2 of the total 39,000 ft^2 of the third floor south. At the time of the evaluation, a total of 323 employees worked on the third floor south, 249 in the evaluated areas. General-area air samples were collected on the third floor south, the second floor north, and outdoors on the rooftop of the building (the latter two locations were selected for environmental comparison purposes). General workroom area samples were collected for airborne formaldehyde and volatile organic compounds (**VOCs**). Additionally, direct reading instrumentation was used to measure airborne particulate concentrations, CO_2 concentrations, temperatures, and relative humidities. Finally, HVAC system outside-air and supply-air flowrates were also measured to assess the adequacy of outside-air exchange (ventilation effectiveness) on the third floor south.

Formaldehyde was detected at all sample locations (i.e., second floor north, third floor south, and outdoors); the highest concentration detected was 0.008 parts per million (**ppm**). Exposure to these levels is not associated with health or comfort effects. Other VOC concentrations were below the

analytical limit of quantitation. Measured indoor particulate concentrations were on average lower than outdoor (rooftop) particulate concentrations, as expected, suggesting an efficiently operating ventilation filtration system. All CO_2 readings collected during the two-day survey on the third floor south were 800 ppm or less. This is consistent with the evaluation of ventilation-system outside-air and supply-air flow rates, which suggested that adequate outside-air exchange is provided to the third floor south. Specifically, the minimum percentage of outside-air in the supply-air likely to occur in System 3A, which serves the third floor south, is an estimated 36%; by comparison, the *needed* percentage, based on occupancy and estimated supply-air flowrates determined, is unlikely to exceed an estimated 28% (except during relatively brief periods affecting small portions of the area served). The highest measured CO_2 concentration on the second floor was 1000 ppm, and all others were 875 ppm or lower. Temperature measurements ranged from 73°F to 77°F; 10 of 114 measurements collected on the third floor south were 77°F, and one of six measurements on the second floor north was 77°F. The ASHRAE comfort zone recommendation for the winter heating season is 68°F to 76°F. All 120 indoor relative humidity measurements were below the ASHRAE recommendation of 30% to 60%; this situation is common during the heating season in buildings that are not artificially humidified. Additionally, the thermostat locations for certain zones of HVAC System 3A appear to be non-representative (i.e., located near the edges of zones and/or too close to supply-air outlets of neighboring zones), and the spatial distribution of the supply-air-outlet luminaires in some zones appeared to be less than ideal (i.e., clustered together in some parts of zones, with few in other parts). Finally, measured individual supply-air-outlet flowrates in three selected VAV zones *qualitatively* suggest that the ventilation rates are possibly inadequate in two small offices in two zones (53 and 54), that a relatively large portion of the supply-air flow in another zone (66) is supplied to a room where few employees work, and that two supply-air outlets in this zone had no airflow.

Questionnaires were returned by 197 of the 202 employees at work that day, representing approximately 98% of workers. The follow-up survey questionnaire results indicate that 50-60% of the employees surveyed reported having frequently experienced one or more "building-related" symptoms during the four weeks preceding the administration of the questionnaire. The concerns regarding workplace conditions, work organization, and health identified during the initial survey were also raised during the follow-up survey.

The HHE did not identify environmental conditions likely to cause the high prevalence of symptoms reported by employees in the Division of Motor Vehicles, but, some environmental deficiencies, as well as work organization and communication problems were identified. Based on the results, and observations made during this evaluation, recommendations for improving HVAC-system performance, including recalibration of sensors and possible reconfiguration of hardware, and for improving work organization and communication among management and workers, were offered to optimize employee comfort and satisfaction.

KEYWORDS: SIC 9621 (Public Administration: Regulation and Administration of Transportation Programs); indoor environmental quality (IEQ); air temperature; relative humidity; ventilation rates; carbon dioxide concentrations; heating, ventilating, and air-conditioning (HVAC) system configurations.

INTRODUCTION

On November 2, 1992, the National Institute for Occupational Safety and Health (**NIOSH**) received a request for a health hazard evaluation from employees at the Harry S. Truman State Office Building, in the Division of Motor Vehicles of the Department of Revenue. These employees had experienced a variety of symptoms that they thought were related to the indoor environmental quality (**IEQ**). The health effects mentioned included headaches, chronic cough, sinus problems, and sleepiness.

In response to this request, an initial site visit was conducted in May 1993. A report of that evaluation was distributed in July 1993. A follow-up site visit was conducted in February 1994.

BACKGROUND

The Harry S. Truman Building is located across the street from the Missouri State Capital in Jefferson City, Missouri. The facility was opened for occupancy in 1983. It is an eight-story structure, with approximately 700,000 square feet (**ft^2**). A center atrium divides the second to eighth floor of the building into north and south sections. Approximately 2900 state government employees work in the building. Normal hours of occupancy are from 6:30 a.m. to 5:30 p.m., although a few areas are occupied 24 hours per day. The building is used primarily as office space; other usage includes a cafeteria on the fourth floor, a loading dock on the ground level, storage, and public assembly. Smoking is not permitted anywhere in the building.

Management and employees reported an event occurring in June 1986 in which workers were taken to the hospital ill; this incident was investigated by representatives of the Missouri Department of Health. No toxic substance or other direct cause for the illnesses was found. This incident was the subject of an article published in the American Journal of Epidemiology.[1] Investigators identified several factors that may have reduced air quality in the affected areas, including a low proportion of outside air, crowding, blocked vents, smoking, and use of office chemicals.

The building has 16 individual heating, ventilating, and air-conditioning (**HVAC**) systems. They are single-duct, "variable-air-volume" (**VAV**) systems (the conditioned. supply-air volumetric flowrate is variable to provide thermal control) with supplemental electric-resistance reheat coils serving specific zones. Each HVAC system is equipped with direct digital controls (**DDCs**) and devices which monitor, record, and display outside-, return-, mixed-, and supply-air temperatures and return-, relief- and supply-air flowrates at the systems' air-handling units (**AHUs**); outside-air-intake rate and outside-air percentage can be calculated from these parameters. The systems also monitor the supply-air flow at each VAV terminal, using a flow sensor. Each AHU is equipped with chilled-water cooling coils and two types of filters. The primary filter is a panel filter (40% efficiency, 93% arrestance); the secondary filter is a bag system with an efficiency rating of 85%. Both return-air and outside-air pass through the panel and bag filters before being circulated to the occupied spaces. Air supply and return in the office spaces is through slotted ceiling luminaires. Return air enters the above-ceiling plenums through the return luminaires and moves through this space to large return-air ducts, which enter the mechanical rooms and lead to the AHUs. Conditioned supply air from the AHUs travels through ducts to the VAV terminals and/or reheat coils, and onto the slotted supply-air luminaires.

The requesting employees worked in the Division of Motor Vehicles on the third floor south; therefore, this area was chosen for evaluation (see Figure 1). During the **initial survey** the **evaluated area** was defined as that occupied by five groups within the Division. The five groups (Processing 1, Processing 2, Special Registrations, Receiving and Validations, and Quick Titles) were separated by 5½-foot-high partitions or walls of approximately 4-foot-high filing cabinets. These areas occupied approximately 6300 ft^2 of the total 39,000 ft^2 of the third floor south. At the time of the initial evaluation, a total of 72 employees worked in the evaluated area.

During the **follow-up survey** the **evaluated area** was expanded to include most areas of the third floor south, with the exception of the areas occupied by the Taxation Bureau, the Division of Motor Vehicle's Administrative Offices, the Missouri Highway Patrol's Criminal Investigations Branch, and a small office occupied by the ISD. The evaluated areas occupy approximately 29,700 ft^2 of the total 39,000 ft^2 of the third floor south. At the time of the follow-up evaluation, a total of 323 employees worked on the third floor south. Of these, 249 worked in the evaluated areas; their normal hours of occupancy were from 7:45 a.m. to 4:45 p.m.

One HVAC system, "3A," exclusively serves the entire third floor south. System 3A includes a primary, VAV AHU, "3A1," with 35 VAV zones; a smaller, constant-volume-type AHU, "3A2," with three large perimeter reheat zones; a return-air parallel-flow dual-fan unit; and, relief-, return-, and outside-air-intake dampers. The outside air is ducted to AHU 3A1, which then provides outside-air exchange to all occupied spaces; AHU 3A2 does not provide outside-air exchange to the spaces. An area on the second floor north was chosen as an environmental **comparison area**. This area was occupied by the employees of the Taxation Bureau and had a similar number of workers doing similar work.

EVALUATION METHODS

An initial site visit was conducted in May 1993 during warm weather (air cooling season), and a report of that evaluation was distributed in July 1993. A return site visit was scheduled for winter to evaluate the building's indoor environmental status during the heating season.

ENVIRONMENTAL METHODS

In May 1993 an **initial environmental evaluation** was conducted during which information was collected using standardized checklists and inspection forms. These forms were grouped to address the whole building, the evaluation area, and the HVAC system. Descriptive information for the building (age, size, construction, location, etc.), the area to be evaluated (size, type of office space, cleaning policies, furnishings, pollutant sources, etc.), and the HVAC systems (type, specifications, maintenance schedules, etc.) were included. Inspections of the evaluated area and HVAC systems were conducted to determine current conditions. The purpose of the environmental investigation was to obtain information required to classify the building, determine the condition of building systems, and document its current indoor environmental status. Additionally, indicators of occupant comfort and ventilation effectiveness were measured. These indicators were CO_2, temperature, and relative humidity.

During the **follow-up environmental evaluation** of February 14-17, 1994, air samples were collected on the third floor south, the second floor north, and outdoor on the rooftop of the building. General workroom area samples were collected for airborne formaldehyde and volatile organic chemicals (**VOCs**). Additionally, direct reading instrumentation was used to measure airborne particulate concentrations, carbon dioxide (**CO_2**) concentrations, temperatures, and relative humidities. Finally, HVAC-system outside-air (**OA**) and supply-air (**SA**) flowrates were also measured to assess the adequacy of OA exchange (ventilation effectiveness) on the third floor south.

Airborne contaminant concentrations in the general workroom air were evaluated by placing three sampling pumps along with the appropriate sampling media at four locations within the building (three on the third floor south, one on the second floor north) and one outdoor on the rooftop for comparison. Each sample group included the following: qualitative "screening" samples for VOCs, quantitative samples for VOCs and formaldehyde. All area sample pumps were started and stopped at the same time so that relative comparisons from area to area could be made.

Qualitative samples for VOCs were collected on thermal desorption tubes connected via Tygon® tubing to battery-powered sampling pumps calibrated to provide a volumetric airflow rate of 0.02 liters per minute (**Lpm**). Samples were screened via gas chromatography/mass spectrometry (**GC/MS**).

Quantitative samples for VOCs were collected on solid sorbent charcoal tubes connected via Tygon® tubing to battery-powered sampling pumps calibrated to provide a volumetric airflow rate of 0.1 Lpm. Samples were analyzed for specific compounds as indicated by the results of the qualitative analyses.

Formaldehyde samples were collected using impingers (containing an aqueous 1% sodium bisulfite solution) connected via Tygon® tubing to battery-powered sampling pumps calibrated to provide a volumetric airflow rate of 1 Lpm. Sodium bisulfite solutions were analyzed for formaldehyde by reaction with chromotropic acid and subsequent visible absorption spectrophotometry in accordance with NIOSH Method No. 3500.[2]

Particulate concentrations (dust particles) were measured at 19 locations on the third floor south. For comparison purposes, particulate measurements were also collected at one location on the second floor north, and one outdoor location on the rooftop of the building. Particulate measurements were collected on two successive days at all 21 locations three times per day using two Met One Model 227 hand-held laser particle counters. Both particle counters were programmed to measure particulates in two size ranges. The first particle counter was programmed to measure relative particulate concentration greater than or equal to ($\geq$) 0.3 micrometers (**μm**) and $\geq$ 1.0μm, while the second particle counter was programmed to measure relative particulate concentrations $\geq$ 1.0μm and $\geq$ 5.0μm.

Indicators of occupant comfort -- air temperatures and relative humidities -- were measured in "real time" using a Vaisala Model HM 34 battery-powered, direct-reading meter. This meter is capable of providing direct readings for dry-bulb temperature and relative humidity (**RH**), ranging from -4°F to 140°F and 0% to 100%, respectively. Instrument calibrations are performed monthly using primary standards. These parameters were measured at the same 21 locations, and at the same times on the same days, as the particulate concentrations.

Ventilation effectiveness (or adequacy of outside-air [**OA**] exchange) was evaluated by measuring the concentration of CO_2 in the air, which is a secondary indicator of this parameter, and by measuring actual HVAC system airflows. "Real-time" CO_2 concentrations were measured using a Gastech Model RI-411A portable CO_2 indicator. This battery-powered instrument uses a non-dispersive infrared-absorption detector to measure CO_2 in the range of 0-4975 parts per million (**ppm**), with a sensitivity of ±25 ppm. Instrument zeroing and calibration were performed prior to use with, respectively, "zero air" and a known-concentration (800 ppm) of CO_2 "span gas." The CO_2 concentrations were measured at the same 21 locations, and times as the particulate concentrations.

Volumetric airflow rates were measured, using several techniques, at numerous locations in HVAC system 3A, including supply-air (**SA**) flowrates at the AHUs and certain VAV terminals and SA diffusers, and return-air (**RA**) and relief-air flowrates at the AHUs. The AHU and VAV-terminal flowrates are constantly monitored and recorded by the Honeywell control system, and OA flowrates (and thus the percentage of OA in the SA) can be calculated from this data (specifically, from the SA, RA, and relief-air flowrates). The flowrates are monitored with pressure transducers (which have direct-transducing, electric-resistance-modulating diaphragms) connected to pressure-differential monitoring ports (similar to "pitot tubes"), installed in several locations in the AHU and at each VAV terminal. The percentage of OA in the SA also can be estimated using the OA, RA, and "mixed-air" temperatures, and these also are continuously monitored (with thermoelectric sensors) and recorded by the control system. In addition, certain VAV-terminal SA flowrates were estimated, for comparison to those recorded by the system, by directly measuring the pressure differentials at the Tempmaster Flow Sensor monitoring ports and using manufacturer-supplied calibration curves. These pressure differentials were measured with an inclined manometer, an Alnor Compuflow electronic air pressure, velocity, and flow meter, and a Shortridge Instruments, Inc., Airdata™ Multimeter ADM-860 electronic micromanometer. Finally, SA flowrates at certain slotted ceiling-luminaire diffusers were measured with a Shortridge Instruments Flowhood® Series 8400 Backpressure-Compensated Air Balance System balometer, which incorporates the Shortridge Airdata™ Multimeter micromanometer. This electronic micromanometer is local-density corrected and barometric-pressure and temperature compensated.

MEDICAL METHODS

During the initial survey on May 19-20, 1993, interviews were held with six randomly selected employees and with two employees chosen because they reportedly had experienced symptoms while in the building. In addition, on May 19, questionnaires were distributed to the 70 employees working in the Division of Motor Vehicles during small group meetings with the NIOSH epidemiologist. The questionnaire asked if the employee had experienced, while at work on the day of the survey, any of the symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of "problem buildings." The questionnaire also asked about the frequency of occurrence of these symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The final section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks preceding the questionnaire administration.

During the follow-up survey on February 14, 1994, questionnaires were distributed to all available employees, excluding management, working in the Division of Motor Vehicles (n=202), after a brief introduction/explanation given by two epidemiologists to groups of employees in each section.

EVALUATION CRITERIA

Indoor environmental quality (**IEQ**) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are:

- sources of odors or contaminants,
- problems with the design or operation of the HVAC system,
- pathways between contaminant sources and the location of complaints,
- and the activities of building occupants.

A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats and other respiratory irritations. Usually, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported high prevalence of symptoms among occupants of office buildings.(3-7) Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.(8,9) Among these factors are imprecisely defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.(10-15) Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related than any measured indoor contaminant or condition to the occurrence of symptoms.(16-18) Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.(18-21)

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems NIOSH investigators have found in the non-industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[22-24] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society for Heating, Refrigerating, and Air-Conditioning Engineers (**ASHRAE**) has published recommended building ventilation design criteria and thermal comfort guidelines.[25,26] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[27]

Measurement of indoor environmental contaminants has rarely been helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature and relative humidity, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are listed below.

VENTILATION RATES AND CARBON DIOXIDE

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether fresh air is being introduced into an occupied space at an adequate rate. ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends effective outdoor air delivery rates of 20 cubic feet per minute per person (**cfm/person**) for office spaces and conference rooms, and 15 cfm/person for reception areas, and provides estimated maximum occupancy figures for each area.[25]

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). NIOSH has recently stated that a level of 800 ppm should trigger an inspection of ventilation system operation.[28] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

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. ANSI/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[26]

FORMALDEHYDE (Non-Industrial Environments)

Sources

Formaldehyde and other aldehydes may be released from foam plastics, carbonless copy paper, particle board, and plywood. Formaldehyde is a constituent of tobacco smoke and of combustion gases from heating stoves and gas appliances. This chemical has also been used in the fabric and clothing industry to impart permanent press characteristics, in the manufacturer of some cosmetics, and in disinfectants and fumigants. Formaldehyde levels in ambient air can result from diverse sources such as automobile exhaust, combustion processes, and certain industrial activities such as the production of resins.

Non-Industrial Exposure Guidelines for Formaldehyde

The fact that formaldehyde is found in so many home products, appliances, furnishings, and construction materials has prompted several agencies to set standards or guidelines for residential formaldehyde exposure. ASHRAE has recommended, based on personal comfort, that exposure to formaldehyde be limited to 0.1 ppm. This guideline has also been adopted by the National Aeronautics and Space administration (NASA) and the governments of Canada, Germany, and the United Kingdom.[29] An indoor air formaldehyde concentration of less than 0.05 ppm is of limited or no concern according to the World Health Organization (WHO).[30] NIOSH considers formaldehyde to be a suspected human carcinogen and, as such, recommends that exposures be reduced to their lowest feasible level.

PARTICULATES (Non-Industrial Environments)

Currently there are no regulatory standards for particulate concentrations in non-industrial indoor environments.

RESULTS AND DISCUSSION

ENVIRONMENTAL

Initial Survey Results Summary

Several employees working in the evaluated area mentioned that the thermal conditions in the area were either too hot or too cold, and several mentioned odors in the restroom. The building management indicated that the air supply and return ceiling luminaires are frequently rearranged (by the building engineers) to accommodate employees. The carpet, painted wall board, and suspended ceiling panels were clean and in good condition, but some dust accumulation was evident.

The mechanical room housing AHU 3A1 was clean and orderly. Additionally, the mechanical room housing the AHU serving the eighth floor north was also clean and orderly. The interior of AHU 3A1 mixed-air plenum was inspected. The cooling coils were free of dirt and dust, and the condensate drain pans were clean and dry. The outside-air intake dampers were open.

The results of CO_2, temperature, and RH measurements on Thursday, May 20, 1993, are presented in the accompanying table. These data show that all 16 temperature measurements during the morning, noon time, and afternoon measurement periods were within the ASHRAE recommended range for the cooling season (73°F to 79°F). RH measurements during the morning were within the ASHRAE recommended range (30%-60%), but fell slightly below the lower end of this range during the noon time and afternoon measurement period. All CO_2 concentrations were 775 ppm or below; ASHRAE recommends that CO_2 concentrations not exceed 1000 ppm, while NIOSH recommends that 800 ppm be used as a guideline to trigger a ventilation system inspection. The outdoor temperature ranged from 70°F to 73°F and the RH dropped from 40% to 27%. All three outdoor CO_2 concentration measurements were 350 ppm.

Carbon Dioxide (CO_2) Temperature, and Relative Humidity Measurements†
May 18, 1993

Time Period	CO_2	Temperature	Relative Humidity
8:12 a.m. - 8:45 a.m.	575 - 700	74°F - 76°F	34% - 37%
12:48 p.m. - 1:18 p.m.	500 - 675	74°F - 76°F	28% - 30%
3:37 p.m. - 3:57 p.m.	575 - 775	74°F - 76°F	27% - 30%
outside*	350	70°F - 73°F	27% - 40%

† Measurements collected at 16 locations.
* Outside measurements collected at the end of the three time periods.

VOCs (Including Formaldehyde)

The results of air sampling for VOCs, including formaldehyde, are provided in Tables 1 and 2. All samples submitted for qualitative analysis for VOCs by GC/MS identified similiar compounds in all areas. The major contaminants identified were a naphtha mixture consisting of mainly C_{10} -C_{12} branched alkanes, a mixture similiar to liquid copier solution often found in many IEQ samples. Based on the qualitative analyses, charcoal tubes were analyzed and quantitated for **total hydrocarbons**, and are reported in the tables as VOCs. Outdoor VOC concentrations were nondetectable (**ND**) on both days, while indoor concentrations ranged from ND to trace concentrations (i.e., between the analytical limit of detection and the analytical limit of quantitation).

As shown in Tables 1 and 2, trace **formaldehyde** concentrations were detected in the ambient environment (outdoors) on both sample days. Formaldehyde concentrations detected indoors ranged from "trace" to 0.008 ppm. NIOSH recommends that exposures to airborne formaldehyde be kept below the lowest feasible concentration. The formaldehyde levels measured in the Truman Building are very low and are considered background concentrations, and are unlikely to cause adverse health or comfort effects.

Particulates

Results of air sampling for particulates are shown graphically in Figures 2 and 3. Measured indoor particulate concentrations were on average, and in the cases of most individual measurements, lower than outdoor (rooftop) particulate concentrations, as expected, and indicative of an efficiently operating ventilation filtration system. In a few instances, and almost always among the largest particle-size range reported (5.0μm), indoor concentrations were higher than outdoors; this is likely due to the high volume of paper processed in the Division of Motor Vehicles, within those locations. The high concentration at any of the six measurement times varied widely by location. When comparing the high and low concentrations at the 20 indoor locations where particulate concentrations were measured there did not seem to be a regular pattern (i.e., no particular area had consistently higher concentrations).

Temperature and Relative Humidity

A summary of the measurements for air temperature, relative humidity, and CO_2 concentration are provided in Table 3. All temperature measurements collected during the follow-up survey ranged from 73°F to 77°F. The ASHRAE comfort-zone recommendation for the winter heating season is 68°F to 76°F. The highest temperatures recorded were 77°F, 10 of 114 measurements collected on the third floor south were 77°F, and one of six measurements on the second floor north was 77°F. Relative humidity measurements on both floors, which ranged from 13% to 21%, were consistently below the ASHRAE-recommended range of 30% to 60%.

Ventilation Rates and Carbon Dioxide Concentrations

All 114 **CO_2 readings** collected on the third floor during the follow-up survey were 800 ppm or less (see Table 3); ASHRAE recommends that CO_2 concentrations not exceed 1000 ppm, while NIOSH recommends 800 ppm, in non-industrial indoor spaces when the only source of CO_2 is exhaled breath. One CO_2 reading collected on the second floor was 1000 ppm, and all others were 875 ppm or lower. The measured outdoor concentrations were all 375 or 400 ppm, fairly typical for outdoors in an urban area.

To estimate the **effective outside-air delivery rates** to the occupied spaces, the percentages of OA (**OA%**) in the SA from VAV-AHU 3A -- at several selected reporting times during the occupied hours on the days of the follow-up visit -- were determined from DDC-report "printouts." Each reporting time was selected to represent system operating conditions subjectively determined to be either "typical" or in some way particularly "unique" for the days of the survey. The OA% for each reporting time was calculated using both the airflow-data and temperature-data methods; the results are provided in Table 4. Poor agreement was observed between these methods, with the temperature-data method always providing a much lower result.

Truman Building HVAC-system operating and maintenance personnel reported that the precision of the airflow sensors may be somewhat variable, at about ± 10% for the SA traverses, about ± 25% for the RA, and inconsistent at lower flows for the relief-air traverse. However, the temperature-data method is ***flawed in theory*** because the relationship between air temperature and total enthalpy (which must balance when airstreams are mixed) is only approximate. Furthermore, in some cases, the temperature-data method provided results that were not plausible, including a calculated "negative" OA% (see Table 4) that mathematically resulted when the mixed air (**MA**) was reported to be higher in temperature than either airstream (OA or RA) of which it is composed; this suggests that one of the temperature sensors -- perhaps the MA-temperature sensor -- was not accurate. Additionally, the OA% in the SA calculated from the recorded airflows appears more plausible compared to the reported OA-damper positions ("% open;" see Table 4). Because of the latter three findings, the airflow-data method was selected for use in subsequent determinations.

Several measured and calculated operating parameters for System 3A at the selected reporting times are provided in Table 4. As these data indicate, during these hours the OA-damper position for System 3A ranged from 30% open to 100% open, the OA% in the SA from VAV AHU 3A1 ranged from 36% to 78%, and OA-intake flowrates ranged from 8800 cfm to 24700 cfm.

To estimate the effective outside-air delivery rates to the occupied spaces, it was necessary to evaluate **VAV-zone SA flowrate data**, for use in conjunction with the above evaluation of System 3A OA-intake and VAV SA flowrates. As mentioned previously, VAV-terminal flowrates are constantly monitored and recorded by the control system. In addition, two other methods were used to estimate these flowrates for selected terminals, for comparison to those recorded by the system: direct, manual measuring of the pressure differentials at the flow sensor monitoring ports followed by the use of manufacurer-supplied calibration curves; and, measuring with a balometer the SA flowrates at all slotted ceiling-luminaire diffusers connected to selected VAV terminals, calculating the sum for each selected terminal. For five selected VAV terminals (53, 54, 66, 67, and 68), the SA flowrates determined with the pressure differential/calibration curve method averaged only 0.839 times the flowrates recorded by the system at the same point in time (range 0.729 to 0.960). For three selected terminals (53, 54, 66), the SA flowrate totals determined from the sums of balometer measurements averaged only 0.47 times the flowrates recorded by the system (range 0.44 to 0.50). Due to physical difficulties making the measurements, inconsistent individual readings, and difficulties locating every SA outlet slot, the balometer measurements are likely the least reliable. The pressure differential/calibration curve method is likely the most reliable because it relies on a primary standard and a calibration curve created based on unchanging physical characteristics of the flow-sensor monitoring ports and their immediate vicinities, whereas the system-recorded data depend upon the calibration of the pressure transducers. The pressure differential/calibration curve method also provides more conservative flowrates than the system-recorded data, affording an extra margin of error. Therefore, the pressure differential/calibration curve method was selected for use in subsequent determinations.

A hypothetical "effective OA% *needed* in the SA" for each zone was calculated based on 20 cfm/person in accordance with ASHRAE Standard 62-1989, using estimated numbers of occupants in each zone, along with system-recorded VAV-zone SA flowrates adjusted by a correction factor of 0.839 (ratio derived above) to reflect the pressure differential/calibration curve method. Zone 52, with an estimated 40 occupants and for which the SA flowrate was consistently an estimated 2100 cfm on the days of the follow-up survey, had the highest *consistent* "effective OA% needed in the SA" calculated, at 38%. The highest "uncorrected (minimum) system-wide OA% needed in the SA," based on 330 occupants and the lowest VAV-system SA flowrate recorded during the follow-up survey, is 31%. Using the Multiple Spaces procedure of ASHRAE Standard 62-1989 with these two uncorrected figures (38% and 31%), the resulting "corrected," *actual OA% needed* in the VAV-system SA is 33%. As the data in Table 4 indicate, the lowest OA% *actually estimated to have occurred* during the follow-up visit was 36%, and the estimated values for this parameter were usually much higher, up to 78%. *Both of these values exceed the estimated "needed" OA% of 33%.* Zone 65, with an estimated 17 occupants and for which the SA flowrate was only an estimated 630 cfm for much of the mornings on the days of the follow-up survey, had the only calculated "effective OA% needed in the SA" that exceeded that of Zone 52; this was 54% during those mornings. This results in a "corrected," *actual OA% needed* in the VAV-system SA of 40% based on the Multiple Spaces procedure, which is exceeded by the lowest OA% *actually estimated to have occurred* during the time periods in question of 42% (see Table 4). The above two estimates suggest that, during the follow-up survey, outside-air exchange was adequate for all spaces at all times.

The OA temperature during the afternoon of February 16, 1994, rose to 65°F, which is unfavorable for an HVAC-system "economizer" operating mode to use to assist with the system's thermal load. The OA damper modulated downward to the 40%-open position by 3:00 p.m. and to the 30%-open position by 3:30 p.m., where it remained even as the OA temperature rose to its peak. This performance record suggests that the minimum position is 30% open, which very likely results in an OA% in the VAV SA of at least 36%. However, other minimum OA criteria were reported by system operating and maintenance personnel, such as a minimum of about 6600 cfm or of 20% outside air, so it is not clear what the true minimum is. It is plausible that VAV-terminal SA flowrates are usually similar to those determined during the follow-up survey, regardless of season, considering that the VAV system serves the "building-core" areas of the third floor south where the thermal load is principally from internal sources, and that the flowrates recorded for most zones were quite constant during the occupied periods of the days of the survey. If this is true, and if the minimum OA% likely to occur in the VAV SA is actually 36%, then it is plausible that outside-air exchange is almost always adequate for almost all spaces.

The **individual SA-outlet flowrates** measured with the balometers for VAV zones 53, 54, and 66 were evaluated to *qualitatively* assess the relative distribution of the SA flow within these zones. (Despite the apparent limitations in these measurements, they are believed to be adequate to assess the *relative* distribution.) The data suggest possibly insufficient ventilation rates in two of the small, individual offices connecting to the common space in the F.S.B. area, in zones

53 and 54. The data also suggest that a relatively large portion of the SA flow in zone 66 is supplied to the file room, where few employees work, compared with the Telephone Information System and Repossesion areas in this zone, where larger numbers of employees work. Also, the SA outlet in this zone that was located just east of structural column D.12, as well as the one located just west of column B.12, were determined to have no airflow. Due to the apparent limitations in the balometer measurements, no other VAV zones were evaluated.

Two additional observations were made about the **configuration of HVAC system** 3A. Based upon observed SA-outlet luminaire locations for various VAV zones, the thermostat locations for certain zones appear to be non-representative (i.e., located near the edges of zones and/or too close to supply-air outlets of neighboring zones). These are zones 57, 58, 59, 66, 67, 69, 70, and 71. Also, the spatial distribution of the SA-outlet luminaires in some zones appeared to be less than ideal (i.e., clustered together in some parts of zones, with few in other parts), and many of these have reportedly been moved around over time due to occupant complaints.

MEDICAL

The May 1994 **initial survey** questionnaire was completed by 67 (96%) of the 70 workers in the area evaluated. Results showed that many employees had frequently experienced symptoms (e.g., unusual fatigue, eye irritation or strain, headache, and pain or stiffness in back, shoulders or neck) while in the building. A substantial proportion of the symptomatic employees reported that their symptoms tended to get better when they were away from the building. Seventy percent of the employees surveyed reported having frequently experienced one or more such "building-related" symptoms during the four weeks preceding the administration of the questionnaire. Thermal comfort was also a significant concern among the employees. During the interviews, many employees reported that the temperature in the work areas changed erratically from too cold to too hot. On the questionnaires, 36% reported frequently being too hot while at work during the four weeks preceding the survey, and 37% reported frequently being too cold while at work during the same period. Six percent of the workers perceived frequent chemical odors in the workplace, and 43% frequently sensed other unpleasant odors.

During the February 1994 **follow-up** survey, questionnaires were distributed to the 202 employees of the Division of Motor Vehicles who worked on the third floor south and were present on the first day of the survey. One-hundred and ninety-seven employees (97% response rate) returned questionnaires, representing 79% of the 249 employees. The median age of respondents lay in the range 40-49 years of age. Fifty-three (27%) workers currently smoked cigarettes, 30 (15%) were former smokers, and 113 (58%) had never smoked. Sixty-nine percent of the workers were high school graduates and 20% had some college. They used a computer for an average of 5.1 hours/day.

Workstation

Forty-four percent of the workers reported that the workplace was somewhat dusty or dirty, 23 percent reported that it was very dusty or dirty, and 32 percent reported that it was reasonably clean. Fifty-three percent of the workers reported that the lighting was just right, 34 percent reported that it was a little too dim, 3-percent reported the lighting as much too dim, and 9-percent thought that it was too bright. Fifty-five percent of the workers reported occasionally or sometimes experiencing glare in their field of vision at their workstation; 27 percent reported rarely experiencing glare; and 17 percent reported experiencing glare fairly often or very often. Eight percent of the workers reported the set-up of their desk or workstation as very comfortable; 61 percent reported that the current set-up was reasonably comfortable; 22 percent rated it as somewhat uncomfortable; and 7 percent rated it as very uncomfortable.

Diagnosed Health Problems

Table 5 shows the percent of workers who indicated that they had been told by a doctor that they had the conditions listed in the table. The most common conditions were sinus infection, migraines, and allergies.

Symptoms

Symptom prevalances are shown in Table 6. The first two columns of data show the number and percentage of the 197 respondents who reported the occurrence of symptoms while at work on the days of the survey. Stuffy nose or sinus congestion; unusual fatigue or drowsiness, tired or strained eyes; dry, itchy or irritated eyes; headache; and pain or stiffness in back, shoulders or neck were the most commonly reported symptoms.

The last two columns of data in Table 6 show the number and percent of workers who indicated that they experienced the symptom either "fairly often" or "very often" during the last four weeks while at work. The percentages are similar to those reporting that they experienced the symptoms on the days of the survey, although for half of the symptoms listed they were higher, and the other half lower.

In addition, approximately 46 percent of the workers indicated that generally they felt especially sensitive to the presence of tobacco smoke, and almost 51 percent reported being sensitive to the presence of chemicals in the air.

Environmental Comfort at Workstations

Table 7 shows employee reports regarding environmental conditions at their workstations on the day of the survey, and during the four weeks preceding the survey. The first two columns of data show that on the day of the survey 27% reported too much air movement; 38% of respondents perceived insufficient air movement; 24% were too hot; 30% were too cold; 61% felt the air was too dry; 5% perceived chemical odors in the workplace; and 30% sensed other unpleasant odors.

The last two columns of data show the responses to the questions about environmental comfort conditions experienced in the facility during the four weeks preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered "frequent" if workers reported that they occurred "fairly often" or "very often." The results differ somewhat from those experienced during the day of the survey. The table shows that 45% of the respondents perceived that the ventilation system frequently did not provide sufficient air movement; 63% thought it was often too dry; 38% thought it was often too hot; 35% felt that it was often too cold; and 29% frequently perceived experiencing unpleasant odors (e.g., body odor, food odor, perfume) during at least part of their work day.

Other workstation aspects, not included in the table, are conversational privacy and freedom from distracting noise. Sixty percent of the workers reported that they were not satisfied with the amount of conversational privacy; 72% were not satisfied with the freedom from distracting noise.

Employee Perceptions of their Jobs

The largest group of workers completing the questionnaire (greater than 70%) were examiners or clerks, and the next largest group were telephone assistants (13%). Eighty-three percent were either somewhat satisfied, or very satisfied with their jobs. Workers perceived the workload to be high, with 64% of the workers reporting that their job frequently requires them to work very fast, and 83% reporting that there was a great deal to be done. Several questionnaire items addressed the degree of social support received from various people. When asked whether other people at work go out of their way to make work life easier, 12% reported very much, 39% reported somewhat, and 48% indicated either a little, or not at all. Eighteen percent of the workers reported that their immediate supervisor goes out of their way "very much" to make their work life easier; 36% reported that their immediate supervisor "somewhat" makes their work life easier; and 32% responded "a little." Relationships between workload and social support with the reporting of respiratory (e.g. shortness of breath, chest tightness, wheezing etc.) and neurologic symptoms (e.g. difficulty remember or concentrating, fatigue, dizziness or headaches etc.) were examined through logistic regression analyses. This analysis indicated that perceived workload was associated with the reporting of respiratory symptoms (OR= 1.15, 95% CI=1.00-1.32), after controlling for a number of potentially confounding variables such as age and gender. Workload (OR=1.20; 95% CI=1.06-1.36) and lack of social support from other people (OR=1.52; 95% CI=1.13-2.04) were also associated with the reporting of neurologic symptoms. Social support specifically from supervisors was found to be unrelated to these symptoms.

Interviews with Management and Staff

A number of changes in management had taken place between the first and second NIOSH surveys. At the nonsupervisory level turnover was about 5-percent, with approximately two to four positions open in a year. Ordinarily there was little turnover among supervisors, according to management. Training (e.g., computer software) had been curtailed, but management reported that they were starting this up again. Workers were offered the opportunity for a number of awards. These included Employee Quality Service Award, Employee of the Month, and other service and attendance awards. Employees were able to use the State Employees Assistance Systems, had access to an exercise facility, and brown bag lunches on various health topics (e.g., choleserol, stress). A newsletter had last been sent in November 1993, and management was going to try to produce one at least quarterly.

Workers are given a 15-minute break in the morning and afternoon. Lunch is scheduled for 12:00 p.m. to 1:00 p.m. Smoking was allowed outside the building only. Excessive perfume was dealt with on a one-on-one basis with the assistant supervisor. There was a suggestion box available to workers. Workers were expected to follow the chain of command if there were any problems. In addition, workers were required to attend a sexual harrassment seminar. Flex-time was tried for several months, however, it was taken away without further discussion with workers.

There appeared to be a general sense of suspicion and mistrust of management. Employees believed that management had worked on the ventilation system and had changed the environmental conditions in preparation for our visit. This was mentioned both at our initial survey in May 1993 and our follow-up survey in February 1994.

There were multiple rumors regarding health risks from exposure to what employees referred to as "this sick building." The issue of cancer risk was raised during both NIOSH evaluations. This concern was discussed with management and employees. The NIOSH investigator explained the difficulties in determining whether cancer deaths in a workplace were associated with occupational exposures, especially in the absence of identified exposure. Most cancers have a long latency period (typically 10-20 years) and that cancer at a single body site would be more suggestive of a common cause than multiple types of cancer.

During both evaluations there appeared to be consensus among the employees regarding problems with odors in the restrooms. When this was discussed with a member of the building maintenance staff, the odor was explained as too many employees using the restroom at the same time (e.g., during scheduled breaks). Employees were reluctant to use restrooms on other floors. On the third floor, a former men's restroom had been converted to a women's restroom to accommodate the number of female employees.

During both surveys employees reported that their co-workers often came to work with contagious illnesses (e.g., colds and flu) and stated that this should not be permitted. In addition there were a number of complaints during both visits concerning lack of cleanliness of the office. For example, employees reported that certain areas in need of additonal cleaning were: corners of the room, trash cans (before placing a new bag), file cabinets, partitions, etc. In addition, many employees complained of the crowding, dust, and noise. Excess boxes and equipment in the office was identified as contributing to dust and a feeling of crowding. The majority of the workers spoken with, and those who provided comments on the questionnaires felt that there was not enough fresh air, and this coupled with the dust and dryness irritated their sinuses and made them sleepy.

Concerns were also voiced during both NIOSH surveys regarding the routine nature of the work, lack of opportunity for advancement, use of work quotas, and trouble with difficult employees that management refused to deal with. Supervisors were perceived to be "watch dogs." Employees felt that communication between management (including supervisors) and employees was poor. Employees also believed that they were required to work hard and fast to meet their quotas, yet were not appreciated. Some employees did mention the existence of an Employee Assistance Program, but, no mention was made of any health promotion activities, although management reported that these were available.

CONCLUSIONS

During the **initial environmental survey** measured temperatures were within the comfort ranges currently recommended by ASHRAE for the cooling season, however some RH measurements were below the ASHRAE recommended guidelines, and 48% of the respondents indicated that they felt the air was too dry. The measured CO_2 concentrations were below the 1000-ppm ASHRAE criteria, and the NIOSH recommendation of 800 ppm.

During the **follow-up environmental survey of February 1994**, very low formaldehyde concentrations were detected at all sample locations (i.e., second floor north and third floor south). The highest concentration detected was 0.008 ppm. The levels found are below the IEQ criteria recommended by the WHO and ASHRAE, and are unlikely to cause adverse health or comfort effects. Other VOC concentrations were below the analytical limit of quantification.

Measured indoor particulate concentrations were on average lower than outdoor (rooftop) particulate concentrations, as expected, and indicative of a efficiently operating ventilation filtration system -- despite reported perceptions of some employees that the air was excessively dusty. In some widely scattered instances, the measured indoor concentrations exceeded the outdoor concentrations; this is likely due to the high volume of paper processed in some locations within the Division of Motor Vehicles.

All 114 CO_2 measurements made over the two-day survey, on the third floor south, were 800 ppm or less. One CO_2 measurement made on the second floor north was 1000 ppm, while all others were 875 ppm or lower. The measured CO_2 concentrations suggest adequate outside-air exchange during the follow-up survey period throughout the evaluated area. Temperature measurements ranged from 73°F to 77°F. The ASHRAE comfort zone recommendation for the winter heating season is 68°F to 76°F. The highest temperatures recorded were 77°F, 10 of 114 measurements collected on the third floor south were 77°F, and one of six measurements made on the second floor north was 77°F. Questionnaire-reported complaints of temperatures being “too hot” or “too cold” are not consistent with these data. All 120 relative humidity measurements collected indoors were consistently below the ASHRAE recommendation of 30% to 60%, which is consistent with employee complaints of dry air reported in the questionnaire survey. This situation is common during the winter heating season in buildings that are not artificially humidified.

The estimated **ventilation rates** suggest that, during the **follow-up survey**, outside-air exchange was adequate for virtually all spaces on the third floor-north, at virtually all times. This is consistent with measured CO_2 concentrations. It is also consistent with the fact that the recorded control system parameters indicate that the System 3A OA dampers were widely opened (75% to 100%), and most System 3A VAV zones' SA flowrates were fairly constant, during most of the occupied hours during the survey. Any widespread complaints received about IEQ on the third floor north during the follow-up survey period have no apparent basis in lack of adequate OA exchange during that time. Relatively high OA-intake rates during the survey period reflect the "economizer" mode of system operation, in which the system uses increased intake of "cool" (approximately 30°F to 60°F) outside air to assist with the thermal (heat) load generated in the occupied spaces.

Beyond the above conclusion that estimated OA exchange was adequate *during the follow-up survey period*, the findings of the ventilation evaluation suggest the possibility that OA exchange is *almost always* adequate for almost all spaces on the third floor south. This is consistent with the measured CO_2 concentrations during both the initial and follow-up surveys. As with any VAV system, however, it is always possible that some zone may occasionally experience inadequate OA exchange under some operating conditions. However, there is little evidence to suggest widespread inadequate ventilation rates on a continuing basis that could support any continuing, widespread complaints received about IEQ on the third floor south.

The conclusions of the above two paragraphs are based partly upon the estimated OA-exchange rates developed from the data collected. Therefore, the potential limitations of these data (which were fully described in the discussion of the results), and thus of the estimated OA-exchange rates, must be considered because they may affect the strength of those conclusions.

The **individual SA-outlet flowrates** measured with the balometers for VAV zones 53, 54, and 66 *qualitatively* suggest that the ventilation rates are possibly inadequate in two offices in the F.S.B. area, in zones 53 and 54, that a relatively large portion of the SA flow in zone 66 is supplied to the file room, where few employees work, compared with the Telephone Information System and Repossesion areas in this zone, where larger numbers of employees work, and that two SA outlets in this zone (66) had no airflow.

Two additional observations made about the **configuration of HVAC System 3A** *potentially* could affect thermal control or ventilation effectiveness: thermostat locations for certain zones that apparently are non-representative (i.e., located near the edges of zones and/or too close to supply-air outlets of neighboring zones); and, a spatial distribution of the SA-outlet luminaires in some zones that appeared to be less than ideal (i.e., clustered together in some parts of zones with few in other parts). On the other hand, despite questionnaire-reported complaints of insufficient air movement, the SA flowrates recorded for most zones were quite constant during the occupied periods of the days of the survey, suggesting that periods of air stagnation were not widespread during the follow-up survey period.

The results of the **initial and follow-up medical investigations** suggest that more than half of the employees experienced symptoms temporally associated with being in the building. Concerns about job and work organizational issues were common among employees. Neither the initial or follow-up surveys identified conditions likely to cause the high prevalence of symptoms reported by the Division of Motor Vehicles employees, despite the identification of some environmental deficiencies at the Truman State Office Building. One complaint about environmental conditions reported by the employees, that the air in the work areas is "too dry," is consistent with the low relative humidities measured; this situation is common during the winter heating season in buildings that are not artificially humidified. Reports of building related health complaints have become increasingly common in recent years; unfortunately the causes of these symptoms have not been clearly identified. As discussed in the criteria section of this report, many factors are suspected (e.g., volatile organic compounds, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air, etc.). While it has been difficult to identify concentrations of specific contaminants that are associated with the occurrence of symptoms, it is felt by many researchers in the field that the occurrence of symptoms among building occupants can be lessened by providing a properly maintained interior environment. Adequate control of the temperature and relative humidity is a particularly important aspect of employee comfort.

RECOMMENDATIONS

These recommendations are intended to correct environmental deficiencies, optimize employee comfort and address additional employee concerns.

1. Employee concerns about thermal comfort and air movement and supply should be promptly forwarded by supervisors to the HVAC-system operations and maintenance staff. The responses made by the system operations and maintenance staff should be communicated to the affected employees through their supervisors.

2. Because of the high volume of work, and large amounts of paper, employees should be given time, at least weekly, to clean their desks and work area. Janitorial staff should also be supervised more closely to ensure that the offices are cleaned properly.

3. The concern regarding contagious diseases and other health problems should be addressed directly through education.

4. Possible modifications to the work area to decrease the sense of crowding and noise should be explored (e.g., increased use of partitions, provided that the possible effects on air distribution is carefully considered).

5. To help alleviate concerns regarding cleanliness of the restrooms, building maintenance should inform employees that the restrooms are being cleaned and disinfected with odorless products.

6. Supervisor training should be provided to improve communication, and to increase feelings of supervisor support among workers.

7. Regular staff meetings should be held to facilitate communication, inform workers of future changes, and address any concerns/questions that workers may have.

8. Consideration should be given to job redesign so that workers have more control or decision-making authority over their jobs, and opportunity to advance in positions that may be other than supervisory. In any redesign effort the high level of workload reported by employees should also be considered.

9. Opportunity for increasing workers' skills and knowledge should be provided to boost morale and create a more productive and satisfying work environment.

10. The following recommendations pertain to the heating, ventilating, and air conditioning system serving the third floor south, System 3A. Any extensive system modifications needed should be undertaken by a qualified mechanical contractor with engineering capability.

    a. The calibration of the pitot-type air-flow rate sensors and the air-temperature sensors throughout HVAC-System 3A's AHUs and return- and relief-air ducting should be checked and adjusted as necessary (especially the mixed-air temperature sensor). In addition, the air-flow-sensor locations and physical configurations should be re-evaluated in terms of the ability to provide representative "velocity pressures." The addition of supplemental pitot grids designed for low velocities might be considered (especially for the relief-air flowrate measuring location); the DDC system could continuously decide which measured flow rate to record and use based on pre-selected pressure-differential ranges.

    b. If reasonable accuracy for the air-flow rate sensors at the AHUs can be assured, then the flow rate measurements alone should be used to make OA calculations. If not, perhaps total-enthalpy sensors (or relative-humidity sensors, to allow the system to use this parameter and temperature to calculate total enthalpy) could be installed, but, in any case, the calculation of the OA% in the VAV SA based on temperatures alone should be eliminated.

c. The system manufacturer should be consulted to assess the systematic disagreement between the recorded pressure-transducer results for VAV-terminal air-flow rates and those obtained from manual pressure-differential measurements and the use of the manufacturer's calibration curve, and, likely, the VAV-terminal flow-rate sensors should be re-calibrated. In addition, the balometer manufacturer should be consulted about the apparently low air-flow rates provided by the instrument, in this case, with the instrument hood used and slot-type SA outlets encountered. Also, the actual locations of all SA-outlet luminaires should be documented to assure that balometer surveys can be accurately conducted.

d. The individual SA-outlet flowrates for VAV zones 53, 54, and 66 should be checked and re-balanced if necessary.

e. Two observations made about the configuration of HVAC system 3A that *potentially* could affect thermal control or ventilation effectiveness should be corrected as necessary: thermostat locations for certain zones (57, 58, 59, 66, 67, 69, 70, and 71) that apparently are non-representative (i.e., located near the edges of zones and/or too close to supply-air outlets of neighboring zones); and, the spatial distribution of the SA-outlet luminaires in some zones that appeared to be less than ideal ideal (i.e., clustered together in some parts of zones, with few in other parts). An accurate documentation of SA-outlet locations will be needed to help determine those that possibly should be moved.

f. A copy of the ASHRAE thermal-comfort standard (ASHRAE Standard 55-1992) should be obtained. Maintenance personnel should monitor *all* of the building's thermal comfort parameters (not just "dry-bulb" temperature, but other parameters such as turbulence intensity, temperature change, etc., as delineated in the standard).

g. The restroom exhaust systems on the third floor south should be evaluated to determine whether they are exhausting air at a sufficient rate. If necessary, higher exhaust-air flowrates should be provided, but the restrooms should continue to be maintained at a negative static air pressure in relation to the hallway static air pressure.

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Copies of this report have been sent to:
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2. Manager, State of Missouri Department of Revenue Motor Vehicle Division, Jefferson City, Missouri.
3. Building Operations Manager, State of Missouri, Office of Administration, Division of Design and Construction
4. Confidential Requestors

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1

Air Sampling Results

Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

February 15, 1994

Tuesday Morning 10:08 a.m. to 12:08 p.m.		
Location	**Formaldehyde (ppm)**	**Volatile Organic Chemicals (mg/m^3)**
2 north (taxation)	0.007	trace*
3 south (microfilm)	0.007	ND
3 south (proc/receiving)	0.007	trace*
3 south (records maint.)	trace*†	trace*
Roof	trace*	ND

* - airborne concentration was between the minimal detectable concentration (MDC) and the minimal quantifiable concentration (MQC).

† - pump faulted after 20-25 minutes.

ppm - parts of formaldehyde per million parts of air.

mg/m^3 -milligrams of total hydrocarbons per cubic meter of air.

ND - non-detectable

NIOSH recommends that exposures to airborne formaldehyde be kept below the lowest feasible concentration.

TABLE 2

Air Sampling Results

Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

February 16, 1994

Wednesday Afternoon 1:08 p.m. to 3:08 p.m.		
Location	**Formaldehyde (ppm)**	**Volatile Organic Chemicals (mg/m³)**
2 north (taxation)	0.008	trace*
3 south (microfilm)	0.007	ND
3 south (proc/receiving)	0.008	trace*
3 south (records maint.)	†	trace*
roof	trace*	ND

† - pump failure, no sample result for this location

* - airborne concentration was between the MDC and MQC.

ppm - parts of formaldehyde per million parts of air.

mg/m^3 - milligrams of total hydrocarbons per cubic meter of air.

ND - non-detectable

NIOSH recommends that exposures to airborne formaldehyde be kept below the lowest feasible concentration.

TABLE 3
Indoor IEQ Measurements
Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

TUESDAY FEBRUARY 15, 1994

Location		Carbon Dioxide (ppm)	Temperature (°F)	Relative Humidity (%)
Morning -	3rd Floor	625 - 800	74 - 77	13 - 16
	2nd Floor	750	77	13
	Outdoors	375	49	30
Mid-day -	3rd Floor	475 - 675	73 - 77	13 - 16
	2nd Floor	650	75	15
	Outdoors	375	57	26
Afternoon -	3rd Floor	525 -750	74 - 77	13 - 15
	2nd Floor	725	76	15
	Outdoors	375	58	19
ASHRAE Recommendation		< 1000	68 - 76	30 - 60

WEDNESDAY FEBRUARY 16, 1994

Location		Carbon Dioxide (ppm)	Temperature (°F)	Relative Humidity (%)
Morning -	3rd Floor	575 - 800	73 - 74	15 - 18
	2nd Floor	875	74	18
	Outdoors	400	44	25
Mid-day -	3rd Floor	500 - 750	73 - 76	18 - 20
	2nd Floor	750	76	21
	Outdoors	400	61	23
Afternoon -	3rd Floor	500 - 800	73 - 77	13 - 17
	2nd Floor	1000	75	19
	Outdoors	375	68	12
ASHRAE Recommendation		< 1000	68 - 76	30 - 60

TABLE 4
Outside-Air and Supply-Air Measurements and Calculations, HVAC System 3A, Occupied Hours during Follow-up Survey

Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

Date (1994)	Time	Description of System Operating Conditions	Recorded OA Temp.	Recorded OA-Damper Position (% Open)	Measured SA Flowrate from VAV-AHU 3A1 (cfm)	Calculated OA-Intake Flowrate (cfm)	Calculated OA% in the SA of VAV-AHU 3A1: Based on Recorded Airflow	Calculated OA% in the SA of VAV-AHU 3A1: Based on Recorded Temps
Feb. 14	4:00p	Typical of days of follow-up survey	NR	NR	27500	20000	73%	(NR)
Feb. 15	8:00a	NR	39°F	NR	NR	NR	NR	(46%)
	10:00a	Lowest recorded relief-air flowrate of the day	42°F	74	31000	20600	67%	(50%)
	12:30p	Typical for this day	48°F	100	31100	23800	76%	(46%)
	4:00p	Lowest recorded RA and SA (for VAV-AHU 3A1)	54°F	100	28100	20900	74%	(31%)
Feb. 16	7:30a	Lowest relief-air flowrate of the day	29°F	57	21000	8800	42%	(29%)
	9:00a	Average relief-air flow for this morning	34°F	62	29300	14700	50%	(35%)
	2:30p	Typical flowrates for mid-afternoon on this day with OA damper 100% open	61 °F	100	31900	24700	78%	(29%)
	4:00p	OA damper position and OA % in the VAV SA: Lowest observed during	65°F	30	32100	11700	36%	(-19%)

NR -- Not Reported (or, data required to calculate this parameter was not reported).

TABLE 5

Percent of Workers Having Reported Diagnosis of Health Conditions

Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

February 15, 1994

Conditions Workers Were Told They Have/Had	Number of Workers	Number Positive Repsonses	Yes (%)
Sinus Infection	191	126	66.0
Asthma	155	17	11.0
Migraine	161	41	25.5
Eczema	150	14	9.3
Hayfever	159	39	24.5
Allergy to Dust	166	45	27.1
Allergy to Mold	163	37	22.7
Allergy to Cats	156	20	12.8

TABLE 6
Symptoms at Work
Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

February 15, 1994

Symptoms of 197 Workers	Experienced on Days of Survey While at Work		Frequently Experienced Lasts Four Weeks	
Stuffy Nose or Sinus Congestion	102	63%	111	57%
Tired or Strained Eyes	82	53%	97	52%
Unusual Fatigue or Drowsiness	90	56%	119	53%
Dry, Itchy or Irritated Eyes	84	52%	76	40%
Headache	70	42%	98	52%
Pain/Stiffness in Back, Shoulders or Neck	96	42%	102	54%
Dry or Itchy Skin	92	37%	103	54%
Tension, Irritability or Nervousness	53	34%	78	42%

TABLE 7
Description of Workplace Environmental Conditions
Truman State Office Building
Jefferson City, Missouri
HETA 93-0154

February 15, 1994

Conditions	Experienced at Work During Days of Survey		Frequently Experience at Work During Previous Four Weeks	
Too Much Air Movement	43	27%	21	11%
Too Little Air Movement	61	38%	86	45%
Temperature Too Hot	38	24%	71	38%
Temperature Too Cold	49	30%	67	35%
Air Too Humid	12	8%	18	10%
Air Too Dry	96	61%	118	63%
Tobacco Smoke Odors	5	3%	3	2%
Chemical Odors (e.g., paint, cleaning fluids, etc.)	8	5%	13	7%
Other Unpleasant Odors (e.g., body odor, food odor, perfume)	47	30%	55	29%

Figure 1.
Truman State Office Building
3rd Floor South
Jefferson City, Missouri
HETA 93-0154

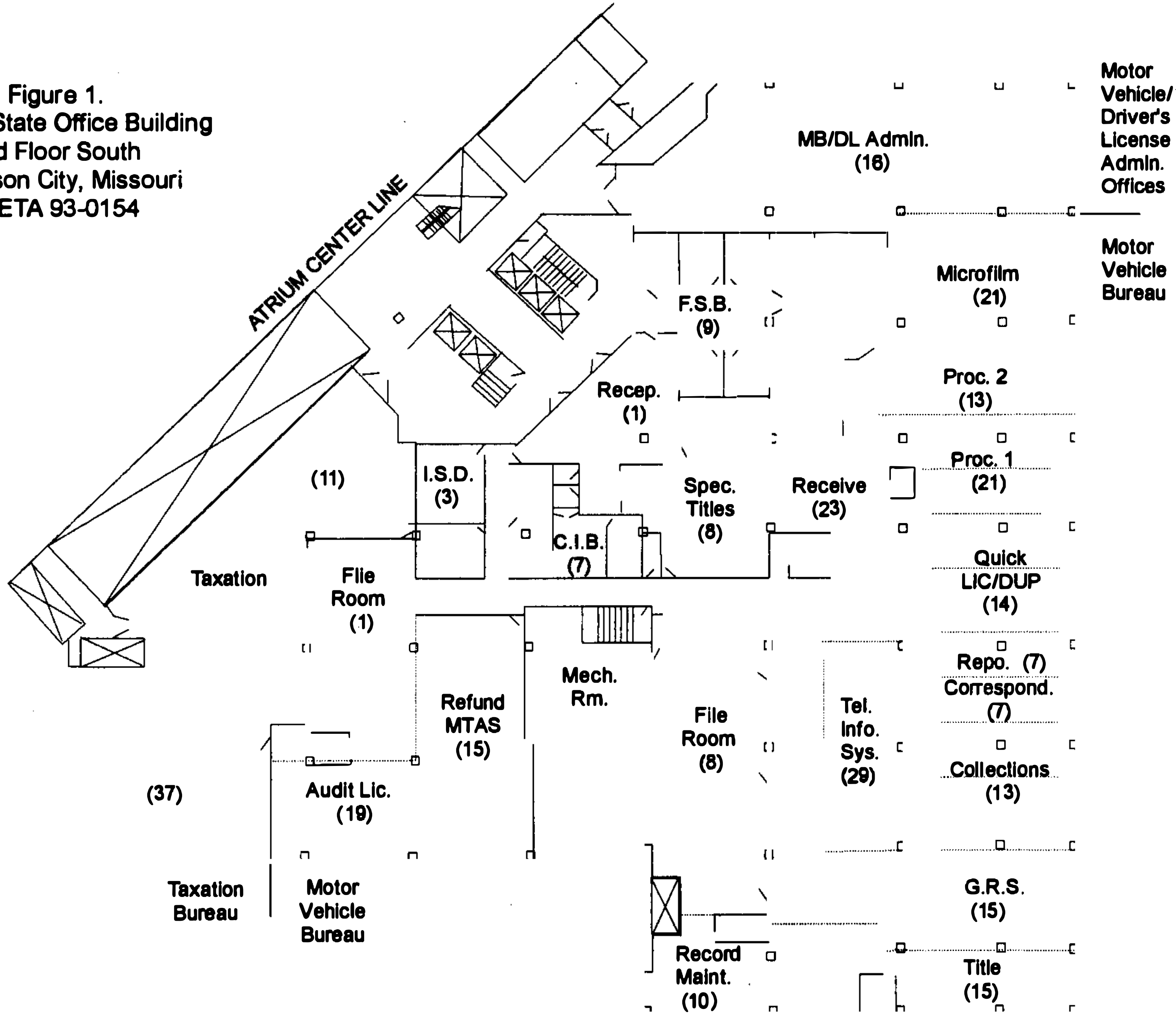

Figure 2

Particulate Sampling Results
Truman State Office Building
Jefferson City, Missouri
February 15, 1994
HETA 93-0154

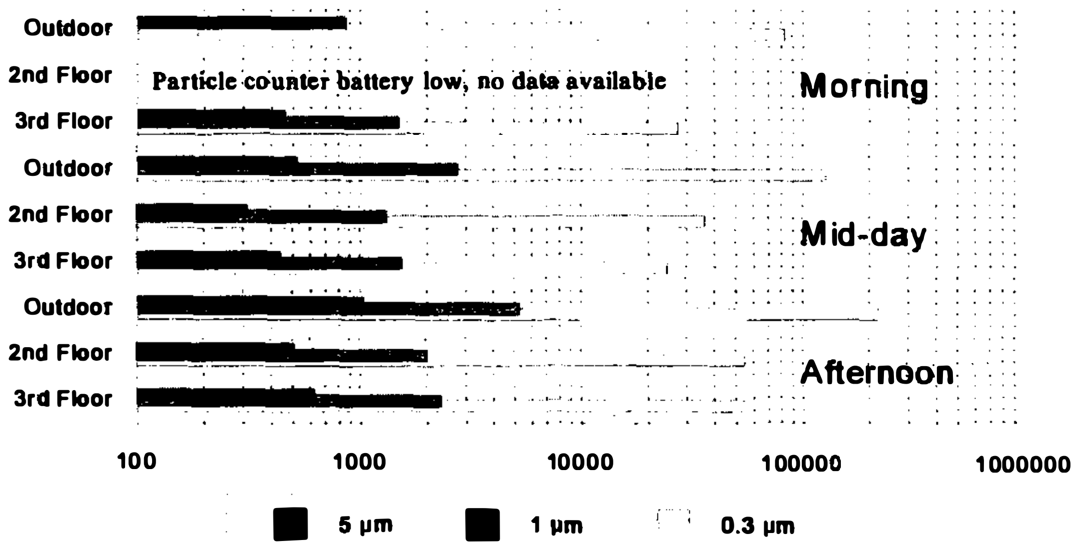

Figure 3

Particulate Sampling Results
Truman State Office Building
Jefferson City, Missouri
February 16, 1994
HETA 93-0154