HETA 92-024-2285 **NIOSH**
INVESTIGATOR:
FEBRUARY 1993
LEGI-SLATE®
WASHINGTON, D.C.

I. SUMMARY

On October 16, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential written request to evaluate indoor environmental quality (IEQ) at the Legi-Slate® offices in Washington, D.C. The request concerned thermal comfort, lack of sufficient ventilation in the office areas, and associated symptoms, including irritation and nausea.

On October 26, 1992, NIOSH industrial hygienists conducted a building investigation at the Legi-Slate® offices, which occupy most of one floor in a ten-story office building. An inspection of the heating, ventilating, and air conditioning (HVAC) system was performed and environmental monitoring was conducted at 18 locations in the offices during four intervals to evaluate temperature, relative humidity (RH), and carbon dioxide (CO_2).

Average temperatures in the office ranged from 74.2°F (7:30 - 8:00) to 76.5°F (16:00 - 16:30); average RH levels for these periods were 27.2% and 25.5%, respectively. Average CO_2 concentrations ranged from 425 parts per million (ppm) to 575 ppm; no trend was seen during the day.

On the day of the survey, average temperatures exceeded the American National Standards Institute/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ANSI/ASHRAE) guidelines for thermal environmental conditions for human occupancy (Standard 55-1981) during three of four time periods sampled. Average relative humidity, which was nearly the same as the outdoor level, was less than the ANSI/ASHRAE recommended range during the day of the survey. CO_2 concentrations were well below the recommended maximum of 1000 ppm, indicating that there was adequate dilution ventilation in the occupied space, on the day of the survey.

Inspection of the HVAC system revealed the presence of visible microbial growth on the cooling coils and in the condensate drip pans below the coils. Scheduled cleaning and maintenance procedures appeared to be inadequate to control such growth on the coils.

No health hazard was identified at this facility, however, observations and measurements indicated that conditions did not meet thermal comfort recommendations on the day of the survey. The presence of microbial growth within the HVAC system presents the possibility of aerosolization and distribution of this material into the occupied portions of the building. Recommendations for reducing microbial growth and for cleaning cooling coil condensate pans and drains are included in this report.

KEYWORDS: SIC 8999 (Services, Not Elsewhere Classified), Indoor Environmental Quality (IEQ), Indoor Air Quality (IAQ), office areas.

II. INTRODUCTION

On October 16, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from employees of Legi-Slate® to conduct a health hazard evaluation (HHE) in their office building in Washington, D.C. In the request, some of the staff at Legi-Slate® reported thermal comfort problems and lack of sufficient air flow in their work environment. The requestors associated illness symptoms, including headaches, fatigue, eye irritation, and nausea, with poor indoor environmental quality (IEQ) in the office space. The symptoms reportedly cleared up within an hour after leaving work.

III. BACKGROUND

Legi-Slate® tracks and analyzes federal legislation to compile an indexed database of legislative action. The company, with about 80 employees, occupies most of one floor (about 18,000 square feet) in a ten-story office building located at 777 North Capitol Street, Washington, D.C. The work area consists of separate offices and open areas with portable dividers separating the work spaces. Individual work spaces usually consist of a chair, desk, file cabinets, and a computer.

The heating, ventilating, and air conditioning (HVAC) system serving Legi-Slate® offices draws in outside air from the roof and sends it down a central shaft to the variable air volume (VAV) boxes located throughout the building. Each VAV box is connected to a thermostat in the area to which the box supplies air. The pneumatically operated VAV boxes regulate the amount of air supplied to the area depending upon the temperature at the thermostat. The minimum setting for the VAV boxes is about 25%, meaning that air supply to the occupied space is always at least 25% of maximum. Supply air enters the office spaces through ceiling troffer units, which are electric lighting fixtures equipped for HVAC systems, with a diffuser to warm the room with the heat dissipated by the lights.

During the heating season, outside air is humidified using a compressed air sprayer at the point of intake to the HVAC system. The humidification system is designed to operate when relative humidity (RH) drops below 45%. Air then passes through a fiberglass pre-filter and then a bag filter. After filtration, air passes through the cooling coils, then to the main supply shaft. The HVAC system can be run in economizer mode, which controls the amount of recirculated air and outside air intake depending on air temperature.

IV. EVALUATION DESIGN AND METHODS

To characterize ventilation and thermal comfort, measurements for temperature, RH, and airborne CO_2 concentration were collected with direct-reading instruments at eighteen locations throughout the office space (Figure 1) and one location on the rooftop near the air intake unit on the day of the survey. Measurements were collected during four intervals: 7:30 - 8:00, 11:00 - 11:30, 14:00 - 14:30, and

16:00 - 16:30. Temperature and RH measurements were made with a TSI model 8360 Velocicalc® Plus air velocity meter. CO_2 concentrations were measured using a Gastech RI-411 infrared CO_2 indicator. This instrument is capable of measuring CO_2 concentrations from 50 to 9950 parts per million (ppm). The CO_2 meter was calibrated prior to and after use with span gas containing 800 ppm CO_2.

A building operations engineer accompanied the NIOSH investigators during an evaluation of the HVAC system, located in the penthouse. This assessment began at the air intake unit and proceeded through the spray humidifier, mixing plenum, filtration system, cooling coil units, and main supply shaft. Bulk samples of what appeared to be microbiological growth were collected from the drip pans below the cooling coils in the HVAC system.

V. EVALUATION CRITERIA

NIOSH investigators have completed over 1100 investigations of the occupational indoor environment in a wide variety of non-industrial settings. The majority of these investigations have been conducted since 1979.

The symptoms and health complaints reported to NIOSH by 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. Typically, 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 prevalences of symptoms among occupants of office buildings.[1-5] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] 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.[8-13] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than any measured indoor contaminant or condition.[14-16] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[16-19]

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.[20-22] 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 of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[23,24] 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.[25]

Measurement of indoor environmental contaminants has rarely proved to be 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 variable 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 RH has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[26] This manual suggests that IEQ is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: 1) a source of odors or contaminants; 2) a problem with the design or operation of the HVAC system; 3) a pathway between the contaminant source and the location of the complaint; 4) and the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The basis for measurements made during this evaluation are listed below.

CARBON DIOXIDE (CO_2)

CO_2 is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, 15 cfm/person for reception areas, and 60 cfm/person for smoking lounges, and provides estimated maximum occupancy figures for each area.[23]

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

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. The thermal comfort range, as specified by this standard, is 68°F to 74°F in winter months and 73°F to 79°F in summer months. The acceptable RH range for comfort and control of microbial growth is 30% to 60%, according to ASHRAE.[24] The ASHRAE acceptable ranges for temperature and RH are defined in the psychrometric chart presented in Figure 2.

MICROBIOLOGICAL CONTAMINANTS

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganisms can then be disseminated as individual cells or in association with soil/dust or water particles. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In a "normal" indoor environment, the level of microorganisms may vary somewhat as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency) with consistently similar ranking among the microbial species.[27,28]

Acceptable levels of airborne microorganisms have not been established, primarily due to the lack of research addressing the dose-response relationship of allergen exposure; the varying immunogenic susceptibilities of individuals are difficult to resolve. As such, causal relationships of microbial origin must be determined through the combined contributions of medical, epidemiologic, and on-site evaluation.[29] The current strategy for on-site evaluation involves a comprehensive walk-through of the problem building to identify sources of microbial contamination and routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes).

VI. RESULTS AND DISCUSSION

INSPECTION OF THE HVAC SYSTEM

On the day of the survey, the HVAC system was running in economizer mode, which means that outside air dampers were fully open. There was no air recirculation within the building, nor was the air heated or cooled prior to entering interior spaces during our investigation; these conditions probably represented a "best case" scenario for IEQ. Outside temperatures were such that the HVAC system could supply 100% outside air and still maintain a desired temperature range within the building. The air intake humidifier was operating on the day of the survey because of the low RH of the outside air (< 25%).

Table 1
Microbial Analysis of HVAC Bulk Samples
Legi-Slate®, Washington, D.C.
HETA 92-024
October 26, 1992

Sample number	Fungi (CFU/g)	Bacteria (CFU/g)	Identifications
1	n.d.	71,000,000	Xan>Pseud
2	n.d.	5,000,000	Pseud
3	n.d.	700,000	Pseud

CFU/g = colony forming units per gram
n.d. = none detected
Xan = *Xanthomonas campestris*
Pseud = *Pseudomonas paucimobilis*

The fiberglass pre-filters, which are changed monthly, were clean and properly installed. The bag filters, which are changed every three months, showed moderate dust accumulation. These filters were due for scheduled replacement shortly after our investigation.

Condensate pans, located below the cooling coils, contained a thick, desiccated layer of residue from microbial growth. Along the bottom of the coils, residue of microbial growth was visible up to a high water mark from fluid previously in the drip pan. During our investigation, the cooling coils were not in use so there was no condensation in the drip pans or on the coils. Bulk samples of microbial matter from the drip pans were collected and analyzed for the presence of fungi, bacteria, and thermoactinomycetes. The results of microbial analysis are presented in Table 1. Fungi were not detected in these samples, but two types of bacteria were present at levels high enough to indicate that proper cleaning and maintenance of the drip pans had not been undertaken. The bacteria detected, part of the normal flora, thrive in cool, damp environments. Water-filled drip pans present an opportunity for microbes to proliferate and potentially be disseminated into the building.

During summer months, the cooling coils are used to remove water vapor from humid outside air. Condensate which collects in the drip pans should be immediately drained, as accumulated water in the drip pans may foster microbiological growth. During the survey, there was no condensation on the coils or in the drip pans (due to low RH) so it was unclear whether the drains work properly.

According to the building operations engineer, the condensate pans and drains were scheduled to be cleaned monthly from March to September. Water conditioning tablets or "pill packs" were used in the condensate pans of all the coil units. The pill packs were used to help keep the condensate pans clean by preventing the buildup of slime, corrosion, and mineral deposits. However, it appeared that the maintenance performed was not adequate to prevent microbial growth in the HVAC system. This could potentially amplify microbial contamination throughout the building.

The building maintenance engineers reportedly used an aerosol coil cleaner (State ACC®) to clean dirt and debris from the coil units, as a substitute for high pressure water cleaning of these coils.

<u>TEMPERATURE AND RELATIVE HUMIDITY</u>

Results of temperature and RH measurements (at 18 locations) are presented in Table 2 and Figure 3. Temperature in the office ranged from 72.5°F to 78.2°F throughout the day, while RH ranged from 24.0% to 30.0%. Average temperatures in the office (at the 18 locations) appeared to increase slightly from the first sampling period to the last (74.2°F to 76.5°F), while RH appeared to decrease during the same period (27.2% to 25.5%).

Average temperatures measured in the office during the day exceeded the thermal comfort range for winter months during three of four sampling periods, but were within the comfort range for summer months. It is most appropriate to use the winter range, because clothing worn by the occupants was most similar to the ASHRAE typical clothing for winter. The RH within the offices was below the ASHRAE recommended range.

In general, the range of humidity levels recommended in the guidelines are 30% to 60%. Relative humidities below 30% may produce discomfort from dryness but low humidities also help restrict microbial growth. Therefore, the concerns over discomfort should be balanced against the risk of increased microbial growth associated with humidification. In general, if temperatures are maintained between 68°F to 70°F during the heating seasons, the RH will be approximately 30%.[26]

Figure 2 shows the acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light activity. This investigation was conducted during the seasonal transition between summer and winter. During colder months, people tend to wear heavier clothing and are thus able to adjust to slightly lower office temperatures. During warm months, people wear lighter clothing and can therefore be comfortable at slightly higher temperatures. During seasonal transitions, the appropriate thermal comfort range should be determined by typical clothing worn by building occupants.

OBSERVATIONS

Although neither questionnaires nor employee interviews were used to determine occupant perceptions of building thermal comfort, observations on the day of the survey indicated that comfort problems may exist. Several employees used small fans or space heaters, or both, at their work station to improve their environmental conditions. There were at least two locations where employees had attempted to block air flow from the ceiling supply slots by taping paper over the slots. Both of these measures, which are indicative of employee thermal discomfort, may also be detrimental to the overall operation of the HVAC system. Using a space heater near a thermostat may cause comfort for the person(s) in that immediate area, but it could cause the VAV boxes to increase air flow and overcool the rest of that zone. Blocking supply slots could adversely affect the overall air distribution and the effectiveness of the HVAC system in removing indoor contaminants.

CARBON DIOXIDE

Average CO_2 concentrations at the 18 sampling locations are presented in Table 2 and Figure 4. Indoor CO_2 concentrations ranged from 425 ppm to 575 ppm; the averages (at the 18 locations) for the four consecutive sampling periods were 447, 500, 474, and 481 ppm, respectively.

On the day of the survey, indoor CO_2 concentrations were well below 1000 ppm because the HVAC system was using 100% outside air throughout the day. Outdoor CO_2 concentrations ranged from 375 ppm to 425 ppm. Indoor levels were slightly higher because of CO_2 generation by building occupants.

VII. RECOMMENDATIONS

The following recommendations are offered as prudent practices to provide acceptable indoor air quality in the office space. These recommendations are based on the environmental sampling results and observations made during the evaluation.

1. The HVAC cooling coils and condensate drip pans below the coils should be kept free of visible microbial growth to the extent possible. Throughout the year, coils, condensate pans, and drains should be inspected monthly and, if necessary, cleaned. During the peak months for heat, humidity, and airborne microbes (March through September), the coils, drip pans, and drains should be inspected at least twice per month and, if necessary, cleaned. Water should not accumulate in the drip pans.

2. The cooling coils in the HVAC system should not be cleaned with the currently used aerosol coil cleaner (State ACC®). According to the manufacturer, this product is intended only for outdoor use; the vapor or aerosolized particles of the solution are not to be transmitted into occupied spaces of the building. Visible microbial growth on the coils should be cleaned using a high-pressure water sprayer, and a dilute aqueous household bleach solution (10%). The cleaning should be done when the

building is not occupied and the HVAC system is off. After cleaning, the HVAC system should run with the maximum amount of outside air and the building unoccupied for several days to enable any contaminants introduced to the office area to be removed from the building.

3. The pill packs should not be relied upon to keep the drip pans and drains free of debris or biological growth. These tablets are not effective unless a sufficient pool of water in the pan enables the tablet to dissolve evenly throughout the pan. They should not be considered an adequate substitute for routine cleaning of the pans and drains, which should be done in conjunction with coil cleaning.

4. Temperature and RH measurements should be collected periodically to determine the effectiveness of the HVAC system in providing thermal comfort to the occupants, particularly during seasonal transition months. The HVAC system should be adjusted as needed to provide temperature and RH within the ASHRAE/ANSI guidelines (Figure 1), recognizing that excessive humidity levels (>60%) create conditions which promote microbial growth.

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Copies of this report have been sent to:

1. Legi-Slate®, Washington, D.C.
2. QDC Property Management, Washington, D.C.
3. Confidential Requestors
4. OSHA, Region III

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.

Figure 1
Indoor Sampling Locations
Legi-Slate®, Washington, D.C.
HETA 92-024
October 26, 1992

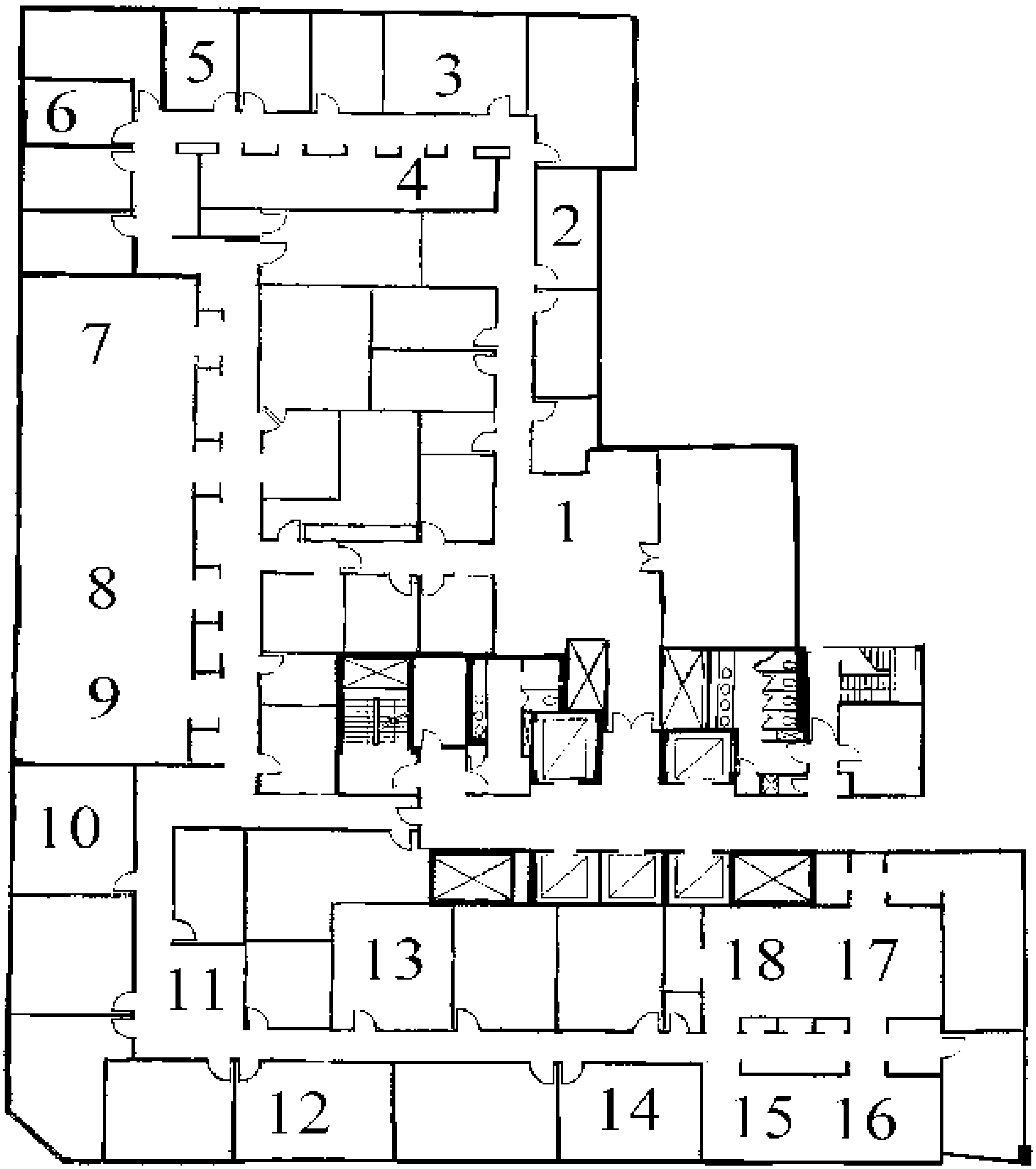


Table 2
Average Environmental Sampling Results for 18 Locations
Legi-Slate®, Washington, D.C.
HETA 92-024
October 26, 1992

Sampling Period	Average Temperature (°F)	Average Relative Humidity (%)	Average CO_2 concentration (ppm)
INSIDE:			
7:30 - 8:00	74.2 (72.5 - 76.0)	27.2 (24.0 - 30.0)	447 (425 - 475)
11:00 - 11:30	75.3 (73.7 - 78.2)	25.9 (25.3 - 27.6)	500 (425 - 575)
14:00 - 14:30	75.9 (74.7 - 76.9)	25.1 (24.5 - 26.1)	474 (425 - 550)
16:00 - 16:30	76.5 (75.3 - 77.8)	25.5 (24.8 - 26.3)	481 (425 - 575)
OUTSIDE*:			
7:30 - 8:00	55.7	44.3	400
11:00 - 11:30	65.9	25.0	425
14:00 - 14:30	66.2	26.5	425
16:00 - 16:30	67.7	27.6	375

ırement locati( )ns

* single sample location near building air intake unit

ppm: parts per million

Figure 2

Acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light, mainly sedentary activity (≤1.2 met).[24]

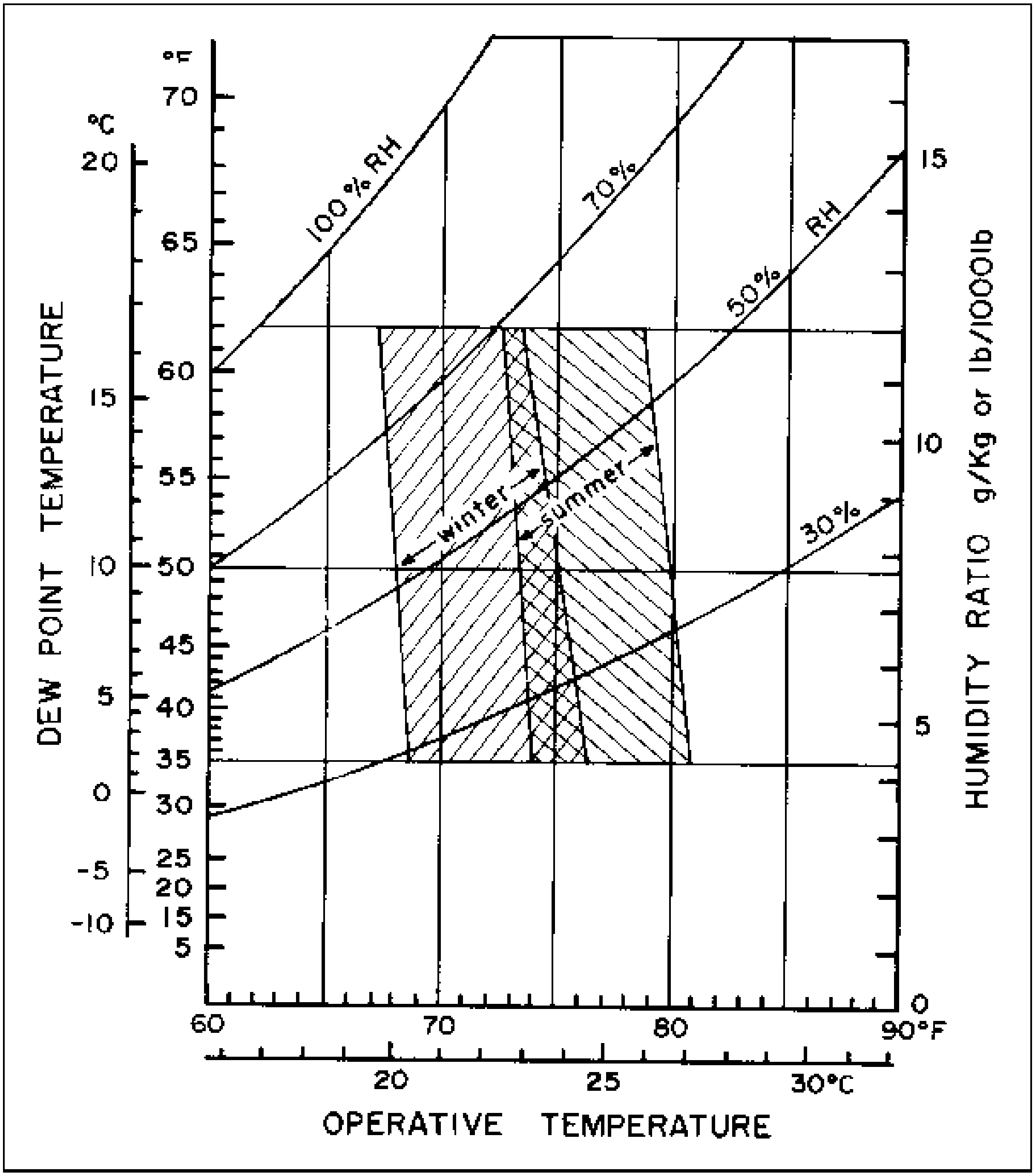


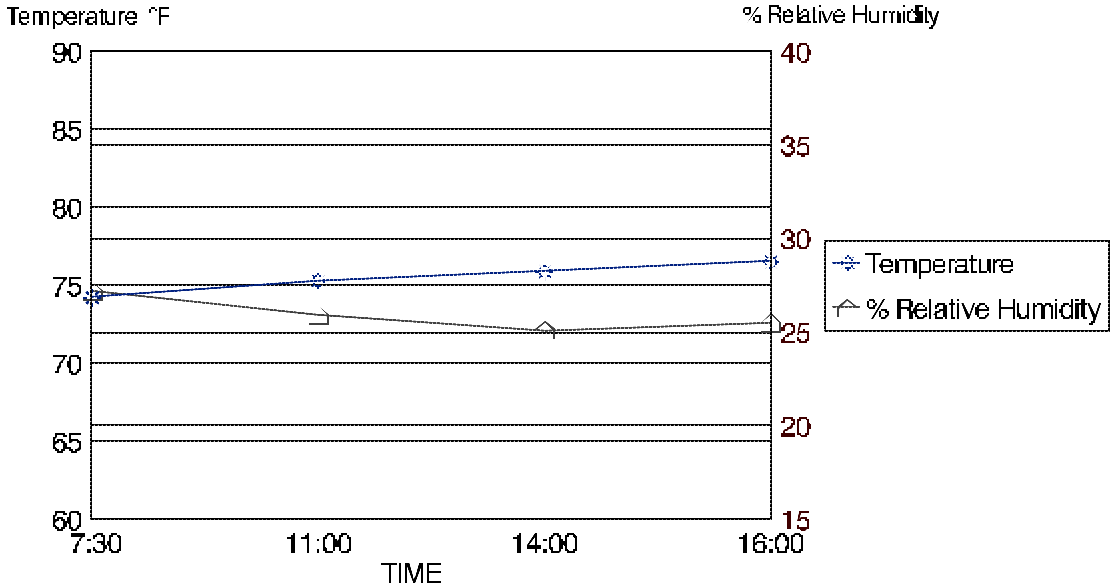
FIGURE 3

Average Temperature and Relative Humidity Trends

Legi-Slate®, Washington, D.C.

HETA 92-024

October 26, 1992



Average indoor measurements
(18 sampling locations)

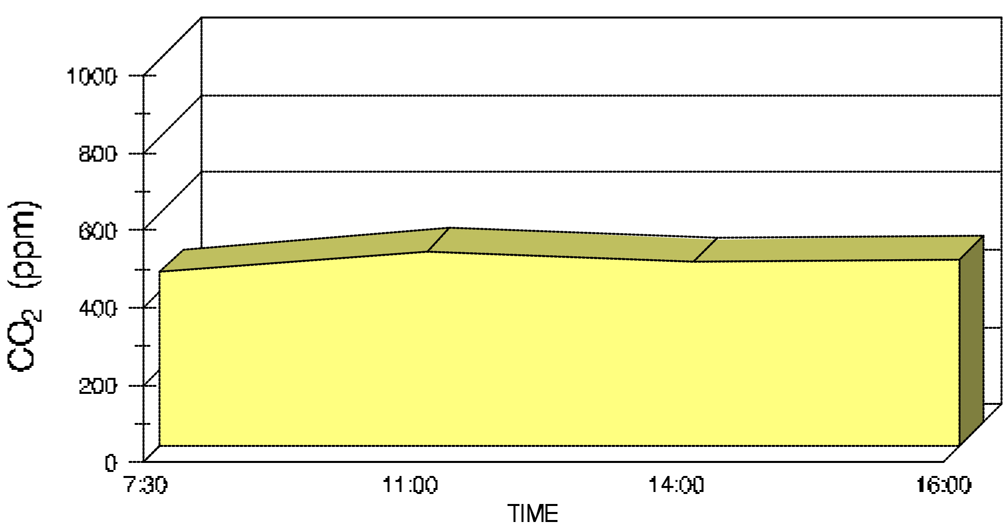
FIGURE 4

Average Carbon Dioxide Concentrations

Legi-Slate®, Washington, D.C.

HETA 92-024

October 26, 1992



Average indoor concentrations
(18 sampling locations)