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BERRY BUILDING
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I. SUMMARY

On February 19 and 20, 1991, an indoor air quality evaluation was performed at the Berry Building, an office building in Birmingham, Alabama. The evaluation was requested by the Department of Labor's health and safety committee for Region IV, as a result of recurring respiratory illnesses and eye irritation reported by employees. Environmental measurements for temperature, relative humidity (RH), carbon dioxide (CO_2), and airborne particulates were made on the second and third floors. Self-administered questionnaires were distributed to each employee present as part of this evaluation. A total of 26 out of 29 (89.7%) questionnaires were completed and returned for analysis.

The CO_2 concentrations measured during this survey were below 1,000 parts per million (ppm), a guideline which NIOSH uses to determine the adequacy of the ventilation in an office area. However, CO_2 may not be an effective indicator for this building since the occupant density was relatively low.

All areas surveyed, except one, were within the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) guidelines for both temperature and RH. The ASHRAE "comfort chart," a comfort range considered to be comfortable by at least 80% of the population, lies between 68 and 74°F (in winter) and 20 to 60% RH.

The concentrations of respirable particulate matter, measured with a direct reading aerosol monitor, ranged from 3 to 48 micrograms per cubic meter (ug/m^3). Although there are no established criteria for exposure to airborne particulates in office buildings, the Environmental Protection Agency's (EPA) Ambient Air Quality Standard for respirable particulate matter (PM_{10} standard, 150 ug/m^3 for 24 hours) was used as a guideline.

Leaking or standing water was not apparent, nor was there any visible evidence of microbial contamination. Monitoring for airborne bioaerosols was not performed.

Although no health hazards were specifically identified, questionnaires completed by employees revealed that the majority have experienced symptoms, at least sometimes, consistent with those commonly referred to as "sick building syndrome." Symptoms reported include headache, runny or stuffy nose, dry, itching, or tearing eyes, irritated throat, and drowsiness. Proper balancing of the ventilation system, and changes in the smoking policy are among the recommendations provided in Section VIII of this report.

Keywords: SIC 9199 (General Government), indoor air quality, carbon dioxide, ventilation, temperature, relative humidity, particulates, bioaerosols.

II. INTRODUCTION

On November 6, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the U.S. Department of Labor (DOL) for a Health Hazard Evaluation of the Berry Building, located at 2015 Second Avenue N., Birmingham, Alabama. The request was submitted jointly by the union and management through the Department of Labor's health and safety committee for Region IV. An indoor air quality investigation was requested as a result of recurring respiratory illnesses and eye irritation reported by employees in the Office of Federal Contract Compliance Programs (OFCCP).

On February 19 and 20, 1991, NIOSH investigators conducted an indoor air quality evaluation at the Berry Building in Birmingham, Alabama. During this investigation environmental monitoring was performed, the heating, ventilation, and air conditioning (HVAC) systems were evaluated, and employee questionnaires were administered. The environmental monitoring consisted of carbon dioxide (CO_2), respirable particulates, temperature, and relative humidity (RH) measurements utilizing direct reading instrumentation.

III. BACKGROUND

The Berry Building is a four story brick building built in the early 1900s and is located in downtown Birmingham. In the past, a furniture store and warehouse were located in this building. In 1985, following a period of vacancy, the building was renovated into offices.

The Department of Labor has leased space in this building coordinated through the General Services Administration (GSA) since 1985. This space is primarily located on the second and third floors, with the exception of a small area on the first floor. The U.S. Department of Commerce also leases some space on the third floor. The other tenants in this building include an accounting firm on the first floor, a law firm located on the mezzanine level, and the city of Birmingham on the fourth floor. The investigation predominantly focused on the second and third floors. The offices that were included in the investigation are reported below:

Agency	Location
Bureau of Apprenticeship and Training (BAT)	First floor
Office of the Solicitor (SOL)	Second floor
Office of Federal Contract Compliance Programs (OFCCP)	Second floor
Wage and Hour Division (WAH)	Third floor
Department of Commerce (DOC)	Third floor

The Berry Building is rectangular, with the circumference measuring 48 feet wide and 100 feet long. The floor area provided for each agency is 2688, 2112, 2688, and 2112 square feet, for SOL, OFCCP, WAH, and DOC, respectively. Windows, which may be opened, exist only in the front wall which borders Second Avenue. Behind the building is an alley containing a number of garbage dumpsters serving this building and the surrounding community.

Each floor is serviced by a separate HVAC system. The systems are between 20 and 30 years old, however, the ducting was replaced in 1985 during the renovation. These systems are constant volume HVAC systems with a capacity of 8,000-10,000 cubic feet per minute (cfm). Approximately 10-20 percent outside air is reportedly introduced during the operation of the units, which now occurs 24 hours per day. The outside air intakes for these HVAC units are located in the rear wall of the building adjacent to the alley. Two main air supply ducts are provided with each HVAC system. Flexible ducting is used to distribute the air from the main ducts to the diffusers mounted in the ceilings. Grilles are located in some of the walls to allow return air to flow from the office areas into the hallways and back to the mechanical rooms housing the HVAC units. Only one thermostat (and one HVAC unit) controls the temperature for the entire floor. Engineering diagrams and specifications are no longer available. The above information was provided by the air conditioning maintenance and service contractor, hired by the realtor managing this property.

The HHE request was initiated by employees of OFCCP. These employees have reported eye irritation and frequent upper respiratory illnesses. A number of these employees have visited a physician and were prescribed medication, such as but not limited to Seldane®, and Entex®. This problem was first reported in early 1989 and has continued since then. GSA hired a consulting firm to perform an air quality evaluation of the OFCCP area on the second floor. Initial screening samples for oxygen, carbon monoxide, formaldehyde, and air density were collected by this consultant. Based on these samples, the consultant concluded that the air quality was acceptable. The OFCCP employees and the regional health and safety committee did not believe that this survey satisfactorily addressed the problem.

Although DOL policy prohibits smoking in their offices, the areas designated for smoking by the building management (and GSA) are located in the hallways. (These smoking lounges are in the path of the HVAC return air.)

IV. METHODS

A. Environmental

A sampling and analysis protocol was developed and implemented for the Berry Building. Temperature, RH, CO_2, and respirable particulate monitoring was performed on February 20, 1991. A total of 26 sample locations were selected throughout the second and third floors, including an outside location. The monitoring and analytical procedures used in this survey included:

1. Temperature and Relative Humidity (RH)

Real-time temperature and relative humidity measurements were conducted using a Vaisala, Model HM 34, battery-operated meter. This meter is capable of providing direct readings for dry bulb temperature and relative humidity ranging from -4 to 140°F, and 0 to 100%, respectively.

2. Carbon Dioxide (CO_2)

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

3. Respirable Particulates (RSP)

Real-time RSP concentrations were measured using GCA Environmental Instruments Model RAM-1 monitor. This portable, battery-operated instrument assesses changes in particle concentrations via an infrared detector, centered on a wavelength of 940 nanometers. Indoor air is sampled (2 liters per minute) through a cyclone preselector which restricts the penetration of particles greater than 9 micrometers. The air sample then passes through the detection cell. Operating on the 0-2 milligram per cubic meter (mg/m3) range with a 32-second time constant yields a resolution of 0.001 mg/m3.

B. Questionnaire

A survey of all present employees working on the second and third floor of the Berry building was conducted on February 20, 1991, using a self-administered questionnaire. The survey collected information about employees' health symptoms and comfort concerns, along with a number of possible risk factors and confounding factors. This questionnaire was designed to yield a detailed data base concerning employee reactions to their workplace environment. The specific topics covered by the questionnaire included:

1. Location of workstation;

2. Health symptoms experienced while in the building, both in the previous week and the previous year;

3. Other health effects and confounding/risk factors, including contact lens, smoking, VDT use, etc.;

4. Comfort issues such as temperature, humidity, air movement, noise, dust, light and odors;

V. EVALUATION CRITERIA

A. Environmental

Standards for indoor air quality in office buildings do not exist. The Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards and recommended limits for occupational exposures (1,2). With few exceptions, pollutant concentrations observed in the office work environment fall well below these published standards or recommended exposure limits. Scientists suspect that work-related complaints may be attributable not to individual environmental species, but to the cumulative effect resulting from exposures to low concentrations of multiple pollutants. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building design criteria, regarding ventilation of indoor spaces, which can be used for evaluating HVAC system design and performance (3).

The basis for monitoring individual or classes of environmental parameters are presented below:

1. Temperature and Relative Humidity (RH)

   The perception of thermal 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 acceptable (4). The temperatures range from 68-74^{o}F in the winter, and from 73-79^{o}F in the summer. The difference between the two is largely due to seasonal clothing selection. In a separate document (ASHRAE standard 62-1989), ASHRAE also recommends that relative humidity be maintained between 30 and 60% (3). Excessive humidities can support the growth of pathogenic and allergenic microorganisms (3).

2. Carbon Dioxide (CO_2)

   CO_2 is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. ASHRAE's most recently published Ventilation Standard, ASHRAE 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 15 cfm/person for reception areas, classrooms, libraries, auditoriums, and corridors (3). This document also provides estimated maximum occupancy figures for each area.

   Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and there are no indoor emission sources, should provide for acceptable indoor air quality.

3. Respirable Suspended Particles (RSP) and Inhalable Particles (PM_{10})

   Respirable suspended particles (smaller than 2.5 micrometers) are associated with combustion source emissions. The greatest contributor to indoor RSP is environmental tobacco smoke. In buildings where smoking is not allowed, RSP levels are influenced by outdoor particle concentrations with minor contributions from other indoor sources. In buildings with oil, gas, or kerosene heating systems, increased RSP concentrations associated with the heating source may dominate. PM_{10} concentrations (particles smaller than 10 micrometers in diameter) combine combustion, soil, dust, and mechanical source particle contributions. The larger particles are associated with outdoor particle concentrations, mechanical processes, and human activity. When indoor combustion sources are not present, indoor particle concentrations generally fall well below the EPA ambient PM_{10} standard (150 ug/m3 for 24 hours).

VI. RESULTS AND DISCUSSION

A. Environmental Monitoring

On February 20, 1991, environmental monitoring for temperature, RH, CO_2, and respirable particulates was conducted at twenty-five sample locations throughout the second and third floors, and one outside location. The specific sample locations are identified on the floor diagrams for the second and third floors (Figures 1 and 2). Each sample site was sequentially monitored three times throughout the course of the day (early morning, late morning, and mid-afternoon). The results of this monitoring are presented below:

1. Temperature and Relative Humidity

Figure 3 lists the temperature and RH ranges observed on the second and third floors, as well as outside the building. The temperatures on the second and third floor ranged between 71 and 75°F. However, all but two of these measurements were either 72, 73, or 74°F. Overall, the temperatures recorded on the second and third floors of this building were within the thermal comfort guidelines for winter (68 to 74°F) as published by ASHRAE. One location (which was not one of the selected sample locations) was discovered to exceed the upper value of the ASHRAE thermal comfort criteria. The temperature in the BAT area on the first floor was measured to be 80-81°F, despite the thermostat setting of 72°F. Approximately 45 minutes later, repeated monitoring revealed the temperature in this area returning to 70-72°F.

2. Carbon Dioxide

Carbon dioxide (CO_2) measurements for the second and third floor sample locations are tabulated in Figure 4. The CO_2 levels ranged from 500-675 ppm on the second floor, and from 450-725 ppm on the third floor. On both floors, the CO_2 concentrations increased through the morning hours, and stabilized as the day progressed. The highest concentrations observed were well below 1000 ppm, which suggests the outside air supplied to this area was adequate. Carbon dioxide is not an etiological agent of indoor air quality symptoms. It is merely an indicator of the adequacy of outside air supplied to occupied areas. Carbon dioxide is not an effective indicator if the ventilated area is vacated. On the day of this investigation, the work areas were not densely populated. This was especially true for the third floor. Hence, CO_2 may not be an effective indicator for this building. Should the staffing levels increase substantially, a reevaluation of the outside air supply may be warranted.

3. Respirable Particulates

The concentrations of respirable particulate matter, measured with a direct reading aerosol monitor, ranged from 3 to 48 micrograms per cubic meter (ug/m^3). There are no established criteria for exposure to airborne respirable particulate in office buildings. However, the Environmental Protection Agency's (EPA) Ambient Air Quality Standard for respirable particulate matter (PM_{10} standard, 150 ug/m3 for 24 hours) is often used as a guideline. The respirable particulate concentrations measured on the second and third floors were well below this criteria.

4. Airborne Bioaerosols

Monitoring for airborne microbial contamination was not performed since visible evidence of microbial contamination, standing, or leaking water was not apparent. Concern, however, was expressed by the union (and management) that bioaerosols may be the cause of the problem.

Issues regarding airborne biological contamination are difficult to address. Contamination is typically characterized as colony forming units (CFUs) per cubic meter of air, or square inch of surface area. Unfortunately, this type of data is extremely difficult to interpret because of the large variety of methods used to collect, incubate, and cultivate the samples. One of the major problems is that there is not an established scientific data base concerning the "normal" range of microbial concentrations (and species) in indoor environments. A dose-response relationship in humans has not been established, and a criteria for acceptable exposure levels is not available. Furthermore, microbes are ubiquitous in nature; samples collected outdoors may reveal substantial bioaerosol concentrations. Hence, NIOSH generally does not routinely recommend this type of sampling. If there is visible microbial growth on interior building surfaces, that should serve as clear evidence that there is a potential biological problem. It is not typically necessary, or helpful to try to quantify the contamination.

The guidelines published by the American Conference of Governmental Industrial Hygienists' Committee on Bioaerosols shares this interpretation (5). "One should use air sampling as a last resort...Air sampling rarely provides proof of inappropriate exposure to bioaerosols."

B. Questionnaire Results

Twenty-nine (29) questionnaires were distributed to all employees working in the agencies included in this evaluation. Twenty-six (26) of these questionnaires were returned for analysis, yielding a 89.7% participation rate. The following is the specific agency and the number of participants included in the questionnaire survey - BAT (1), OFCCP (10), SOL (5), WAH (4), and DOC (6). Due to the small sample size, one must exercise caution when evaluating response percentages since they may be easily influenced.

Figure 5 presents the health symptom and the frequency of occurrence, as reported by all survey participants, and OFCCP participants. Different symptoms that occurred in the same bodily location were grouped together for tabulation purposes, (i.e. runny nose and stuffy nose were grouped under "nasal" symptoms). Negative responses (never and rarely) were not presented in this bar graph. Hence, the tabulated responses may not equal 100 percent. As it can be inferred from this graph, the majority of the participants have experienced symptoms (at least sometimes) consistent with those commonly described as "sick building syndrome." Interestingly, the total responses and the OFCCP responses correlate reasonably well.

Symptoms temporally related to the participant's presence in the building are provided in Figure 6. In order to be tabulated in this graph, symptoms must have been reported to occur either often or always, AND to get better when not at work. Using this analysis, temporal symptoms were reported by more than 25% of the participants for the following symptom categories - headache, nasal, sneeze/cough, eyes, and throat. Nasal and eye symptoms were reported in this manner by approximately 50% of the participants. OFCCP responses and the total responses were reasonably correlated, with the exception of eye symptom category, where the OFCCP rate was approximately twice that of the total rate.

Thermal comfort as perceived by the second and third floor participants is reported in Figure 7. It is interesting to note that half of the responses were "both too hot and too cold." This may be explained by the fact that the entire floor is serviced by only one HVAC system, with a single controlling thermostat.

C. Ventilation System Evaluation

A qualitative evaluation of the ventilation systems was performed during this investigation. This evaluation consisted of a review of the technical specifications, an indirect performance evaluation via CO_2 levels, and a visual inspection.

Using the minimum design specifications provided by the HVAC contractor (8,000 cfm; 10% outside air), these systems should be capable of providing 800 cfm of outside air. Theoretically, this quantity is sufficient to satisfy the minimum outside air volume per person, as recommended by ASHRAE, for forty people. Considering less than twenty people worked on each floor, the volume of outside air supplied should be more than satisfactory. Unfortunately, confirmation of the design specifications could not be accomplished since the engineering diagrams are no longer available. However, the CO_2 measurements did suggest that the ventilation rate of outside air was acceptable.

The HVAC units were inspected during this evaluation. The coil condensate drains were dry, and the filters were recently changed. The outside air dampers for the second and third floors were located in the rear wall of the building. The handles for these dampers suggested that they were in the fully-opened position. However, the actual position of these dampers could not be confirmed due to their location.

A number of deficiencies were noted during the visual inspection of the HVAC units and ductwork. Although the ventilation volume may be acceptable, the distribution of air supply may be ineffective. The system did not appear to be properly balanced to provide an adequate supply of air to satisfy the relative demand. Air flow through some diffusers was negligible as demonstrated by smoke tubes. A few of the flexible ducts supplying the diffusers had very sharp turns which restricted air flow; other ducts were of considerable length. Furthermore, one area in OFCCP contained four office cubicles without a supply diffuser in the immediate vicinity. The intended use of a space is very important in regards to effective HVAC balancing. For instance, a conference room which may be occupied by many individuals should not receive the same air flow as an equivalently sized office serving one employee.

Both the second and third floors had separate HVAC systems. However, there was only one HVAC unit and one controlling thermostat per floor to regulate the temperature. When a signal is received, the HVAC unit will supply tempered air (either hot or cold) to the offices throughout the entire floor regardless of their temperature. A system with this design will inevitably result in temperature zones. Installation of additional thermostats will provide little or no benefit. On the day of this evaluation, large temperature differences were not observed. However, it was overcast with scattered showers on this day, and the temperature was mild (60^{o}F).

Smoking lounges are present in the hallways on the second and third floors. These areas are in the path of the return air moving back towards the HVAC units. Therefore, air contaminants from smoking are distributed throughout the entire floor.

VII. CONCLUSIONS

1. The majority of employees included in this investigation reported health symptoms consistent with those commonly referred to as "sick building syndrome." A substantial number of these employees reported a temporal association of the symptoms with their presence in the building.

2. An adequate supply of outside air (20 cfm outside air per person) appears to be supplied by the HVAC systems.

3. Distribution of the air supply may be problematic. The HVAC systems are not properly balanced to adequately supply ventilation to all work areas throughout the building. Sharp turns or long lengths of flexible ducts may restrict air flow.

4. Respirable particulate concentrations were well below the EPA criteria for ambient respirable particulates.

5. Smoking lounges, as provided, will disseminate air contaminants throughout the work areas.

6. All areas, except one, were within the ASHRAE thermal and relative humidity comfort range for winter.

7. Temperature zones may occur due to the design of the HVAC system, especially during times of extreme outdoor temperatures.

8. Visible evidence of microbial contamination, leaking, or standing water was not apparent.

VIII. RECOMMENDATIONS

1. The entire HVAC system(s) should be balanced by a competent engineering firm that is certified for this type of service.

2. Sharp turns in the flexible ducting should be eliminated. Also, excessive lengths of ducting should be reduced, if possible. (Repositioning the flexible to the main duct junction may be necessary in some locations.)

3. An air diffuser should be installed in the back of the OFCCP area where four office cubicles are located. This area is currently without supply air ventilation in the immediate vicinity.

4. The existing smoking policy should be modified to permit smoking only in properly ventilated smoking lounges. These smoking lounges should be provided with exhaust ventilation which vents directly to the outside, reducing the possibility of reentrainment and recirculation of any secondary cigarette smoke.

5. Surveillance should continue to insure that temperature and relative humidity for all offices are maintained within the ASHRAE recommended comfort zones. Supplemental heating or cooling should be provided, if necessary.

6. A throttling valve should be installed in the BAT area to prevent the sudden influx of steam (heat). This uncontrolled influx of steam causes the temperature to surge without effective control by the thermostat.

7. Building managers should ensure that the ASHRAE recommended outside air supply rate (20 cfm per person) is maintained.

8. Building managers should ensure that HVAC air filters continue to be changed on a regular basis. ASHRAE recommends using air filters with a dust spot efficiency rating of 50 to 70% or better (3).

9. Building managers should ensure that air conditioning coil condensate trays drain properly. This is especially important during the hot season when there is significant air conditioner usage.

IX. REFERENCES

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