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I. SUMMARY

In September 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a Health Hazard Evaluation (HHE) from a group of employees of Indiana Bell Telephone Company (IBT) to conduct an indoor environmental quality (IEQ) investigation of the South Division Office of IBT Company located in Bloomington, Indiana. In response to the request, on January 7-8, 1992, NIOSH investigators: (1) performed environmental monitoring for carbon dioxide (CO_2), temperature, and relative humidity (RH); (2) evaluated the heating, ventilating, and air-conditioning (HVAC) system serving the building; (3) conducted medical interviews; and (4) reviewed a report of a previous investigation conducted by the National Energy Management Institute (NEMI).

Carbon dioxide concentrations within the building ranged from 425 to 825 parts per million (ppm), below the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) guideline of 1000 ppm for indoor environments. Indoor air temperature measurements ranged from 70°F to 74°F, within the ranges recommended by ASHRAE guidelines for the winter months. Relative humidity levels at various locations throughout the building ranged from 21% to 42%, even though outdoor levels ranged from 68% to 88%. This is a common occurrence during the winter months. Sixty percent of the RH measurements taken indoors were below the lower end of the ASHRAE guideline of 30% to 60% RH for indoor environments. HVAC system deficiencies included: (1) inadequate cooling capacity; (2) insufficient supply-air flow rates; (3) ductwork leakage; and (4) inadequate fan sizing. Medical interviews revealed that the most common symptoms were headaches, fatigue/drowsiness, and eye, nose, and throat irritation.

Based on the data obtained during this investigation, NIOSH investigators did not find any specific building problems that would clearly account for the reported employee symptoms. Recommendations are made in this report to correct HVAC system deficiencies.

KEYWORDS: SIC 8062 (office environment), indoor environmental quality, relative humidity, IEQ.

II. INTRODUCTION

On September 27, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from a group of employees at the Indiana Bell Telephone Company (IBT). The request stated that a number of employees suffered from a variety of symptoms including eye irritation, nasal irritation, nasal congestion, fatigue, skin irritation, headaches, and dizziness, which they believed to be related to their work environment. Employees of IBT asked NIOSH to conduct an indoor environmental quality (IEQ) investigation at the South Division Office in Bloomington, Indiana. In response to this request, NIOSH investigators made a visit to the South Division Office building on January 7 and 8, 1992.

III. BACKGROUND

A. Facility Description

IBT's South Division Office occupies a one-story building of over 29,500 square feet (ft^2), and employs approximately 200 workers on three, 8-hour shifts per day, 7 days per week. IBT has been in operation at the building since 1971. In 1989, the directory assistance area of the building was added to the facility. The building is comprised of small offices, large work areas, conference rooms, a photocopy room, break lounges, a designated smoking lounge, restrooms, storage areas, and mechanical rooms.

B. Description of Heating, Ventilating and Air-Conditioning Systems

Heating, ventilating, and air-conditioning (HVAC) for the building is provided by several systems. Ventilation (induction of outside air [OA]), cooling, and dehumidification are afforded primarily by six roof-mounted air-handling units (AHUs) numbered AHU-1 through AHU-6, each connected to associated ductwork, controls, and other external hardware. Every area, except for a section at the rear of the building containing the mechanical rooms, is served by one of these AHUs. Each AHU contains the following features (in the order that the air moves through them): a dampered OA-intake opening for ventilation and a mixed-air chamber where OA is mixed with "return air" (RA) from the occupied spaces; filters to remove particulate material from the mixed-air stream; an air mover (supply-air [SA] fan); and, chilled-water coils for cooling (and dehumidifying) the SA before it is distributed to the occupied spaces through a network of ducts. The chilled water for these coils is furnished by an electric-powered, mechanically-refrigerated water chiller with an air-cooled condenser. RA returns to the AHUs from plenum spaces above the suspended ceilings, which it enters from the occupied spaces through ceiling-mounted grilles. According IBT management, AHU-1 through -5 have particulate air filters rated 85% efficient, while AHU-6 has a pleated-type, 35%-efficient air filter.

Two of the AHUs are components of variable-air-volume (VAV) systems. These systems contain "VAV terminals" in their SA distribution-duct network to modulate the volumetric flowrates of cool SA to individual spaces, thus regulating temperatures in the spaces. The VAV terminals, controlled by thermostats in the individual spaces, modulate the flowrates with variable dampers. The other four AHUs are components of constant-volume (CV) systems, which provide constant volumetric flowrates of SA. This type of system can vary the SA temperature by controlling the chilled water flow through the AHU's cooling coil, to avoid over-cooling its entire service area. The CV systems also have thermostat-controlled, SA-duct-mounted "reheat" coils, through which hot water is circulated, to regulate temperatures in individual spaces served. A natural-gas-fired boiler located in one of the mechanical rooms provides hot water to the reheat coils. The SA-distribution system of AHU-3, one of the CV systems, is equipped with a steam humidifier mounted in the main SA duct near the AHU. Steam is introduced into the duct via steam-dispersion tubes.

Modulation of the variable-position OA-intake dampers on the AHUs is controlled by an Andover 256 M+ computer system, which also controls numerous other HVAC-system functions. Each OA-intake damper is positioned to provide the minimum proportion of OA in the SA needed to induct OA at the design-specified rate (assuming the SA flowrate of the AHU in question equals its design-specified level), unless the Andover system commands the damper to open further, increasing the OA proportion of the SA. The Andover system's "economizer" control mode effectuates such an increase in the OA proportion when cool OA is available to assist the AHU in handling its cooling load of internally-generated (and, often, solar) heat. When the OA temperature rises above 40°F, the Andover system begins opening the OA-intake dampers wider until they reach the fully-open position at an OA temperature of 58°F. If the temperature continues to rise, they begin to close again until they return to their minimum positions at an OA temperature of 71°F.

The Andover system is connected to a variety of sensors, allowing it to monitor numerous HVAC-system parameters and environmental parameters relevant to HVAC operations (such as the OA temperature). This is to provide proper control commands to the HVAC-system hardware. It was retrofitted to existing all-pneumatic control systems, so its commands are executed by a hybrid of direct-digital-control (DDC) and pneumatic systems.

The environmental parameters monitored by the Andover system include the concentrations of carbon dioxide (CO_2) in the RA, outdoors, and in three main office spaces: the engineering department, business office area, and telephone operators' area. As subsequently described in the Evaluation Criteria section, the indoor concentration of CO_2 (a normal constituent of exhaled breath and of the atmosphere), compared to outdoors, can be used as an indicator of ventilation effectiveness in occupied spaces. The Andover system is reportedly designed to increase the ventilation rate in any area in which the CO_2 concentration rises too high by commanding the appropriate AHU's OA-intake damper to open further, increasing the OA proportion of the SA. Reportedly, the system is programmed to initiate this increase if the indoor CO_2 concentration reaches 1000 parts per million (ppm) or higher.

In addition to CO_2 levels and OA temperatures, the Andover system also monitors chilled and hot water supply temperatures, OA humidity, air temperatures and humidities in certain occupied spaces, and other parameters. It also controls the optimum starting and stopping time for mechanical equipment such as the chilled-water pump, the temperature set points in the occupied spaces, and other functions. Reportedly, it has the flexibility and capacity to monitor and control additional parameters and functions, with increased sophistication, if the appropriate hardware is connected and the appropriate programming completed.

At the time of the NIOSH visit, the building had five operable exhaust-ventilation systems, discharging air directly to the outdoors. These serve the following areas: the restrooms; the smoking lounge (#35); conference room (#36); conference room (#37); and, the "kitchen" area (#32) off the main lounge. A sixth system for the photocopying room (#40) was not operable. These systems facilitate the removal, from the specific areas served, of air that is contaminated with odors (i.e., tobacco smoke) in comparison to air in other areas of the building. In addition, they facilitate OA exchange for the entire building by together exhausting air at a total rate that offsets (under most or all conditions; see discussion of results) a portion of the total OA-intake rate for the building. The difference between the total OA-intake rate for the AHUs and the total exhaust rate for the exhaust systems is made up by exfiltration of air to (or infiltration from) the outdoors through cracks and crevices around doors, windows, and construction materials.

Auxiliary cooling (and dehumidification) is provided to two areas (the photocopying room [#40] and one telephone-equipment room), each by an additional "DX"-type system. These systems pass recirculated room air across the "evaporator" cooling coils of an electric-powered mechanical refrigeration system with an air-cooled condenser. These systems do not provide ventilation (OA exchange) to the occupied spaces.

Heating is afforded primarily by natural-convection "radiator" units located along the building-perimeter walls, although the reheat coils in the CV systems' SA-duct networks do provide supplemental heating to the areas served by those systems. The gas-fired boiler provides hot water to the convection units, as well as to the reheat coils. The convection units do not afford ventilation (OA exchange) to the occupied spaces.

C. *Previous Evaluation*

In October and November 1991, the National Energy Management Institute (NEMI) of Indiana conducted environmental monitoring and a comprehensive evaluation of the building's HVAC system. Environmental monitoring consisted of "real-time" air monitoring for carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), hydrocarbons, nitrogen oxide, and ammonia, and time-integrated general-area air sampling for volatile organic compounds (VOCs). Except for the CO_2, air monitoring revealed no detectable amounts of any of these substances. Carbon dioxide concentrations ranged from below 500 ppm to 850 ppm, less than the American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) guideline of 1000 ppm.

NEMI concluded that there were a number of HVAC-system deficiencies. These included insufficient SA flowrates for five of the six primary AHUs (only AHU-5 had sufficient air flow); evidence of possible humidity-control problems; lack of balancing dampers in SA branch ductwork; inadequate OA-intake rates for AHUs 1, 2, and 3; potentially inadequate OA-intake rates for AHUs 4 and 6 under some operating conditions, due to the normal changes in air flowrates which occur with their VAV air-distribution systems; an inadequately sized cooling coil in AHU 1; an inadequately-sized SA-fan motor in AHU 3; and an inoperable exhaust fan for the exhaust system serving the photocopying room (#40).

IV. EVALUATION METHODS

A. Environmental

On January 7-8, 1992, NIOSH investigators performed environmental monitoring. A series of real-time measurements for CO_2 concentrations were taken at various times and locations within the building, using a calibrated Gastech® Model RI-411A, Portable CO_2 Indicator. This portable, battery-operated instrument monitors CO_2 (range 0-4975 ppm) via non-dispersive infrared absorption with a sensitivity of 25 ppm. Temperature and relative humidity (RH) measurements were also taken to evaluate thermal comfort parameters of the building, using a Vista Scientific, Model 784, battery-operated psychrometer. Dry and wet bulb temperature readings were monitored and the corresponding % RH calculated.

The six primary AHUs serving the facility were visually inspected for evidence of potential microbiological contamination (e.g., standing water, moist insulation, or accumulated debris) or other conditions (e.g., overloaded particulate air filters, or visibly malfunctioning damper motors or other equipment) which might adversely affect the building's air quality.

The design and operation of the HVAC systems were also reviewed and evaluated through discussions with IBT and NEMI personnel, as well as through an examination of NEMI's report and other system documentation.

Airflow measurements were made for four of the five operating exhaust systems in the building, using a Shortridge® Flow Hood model MN 86BP. The clearance was insufficient to properly measure the flowrate for the system serving the restrooms.

NEMI conducted air sampling and analyses shortly before the NIOSH evaluation. Therefore, NIOSH investigators felt it was unnecessary to repeat VOC sampling.

B. Medical

The NIOSH medical officer conducted private interviews with 10 current IBT workers (3 directory assistance operators, 4 service representatives, and 3 engineering clerks). Interviewed workers were randomly selected by the NIOSH medical officer from 87 day-shift workers present at the time of our investigation. During these interviews, information regarding medical symptoms and health concerns was elicited from the workers. Additionally, the NIOSH medical officer reviewed 59 questionnaires collected by an IBT employee representative prior to our site visit. Reviewed questionnaires were submitted from 12 engineering employees, 13 service representatives, and 34 directory assistance operators from among departmental staffings of about 22, 45, and 82 workers respectively.

V. EVALUATION CRITERIA

A number of published studies have reported high prevalences of symptoms among occupants of office buildings.[1-5] NIOSH investigators have completed over 700 investigations of the indoor environment in a wide variety of settings. The majority of these investigations have been conducted since 1979.

The symptoms and health complaints reported 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.

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 heating, ventilating, and air-conditioning (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] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts ($\geq$15 cubic feet per minute per person) are beneficial.[14,15] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[16,17] Design, maintenance, and operation of HVAC systems are critical to their proper functioning and provision of healthy and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either outdoor sources or indoor sources.[18]

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than the measurement of any indoor contaminant or condition.[19-21] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[21-24]

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 office 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, no cause of the reported health effects could be determined.

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.[25-27] With few exceptions, pollutant concentrations observed in the office work environment fall well below these published occupational standards or recommended exposure limits. ASHRAE has published recommended building ventilation design criteria and thermal comfort guidelines.[28-29] 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.[30]

Measurement of indoor environmental contaminants has rarely proved to be helpful, in the general case, in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proved relationship between a contaminant and a building-related illness. However, measuring ventilation and comfort indicators such as carbon dioxide (CO_2), and temperature and relative humidity, is useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for the measurements made in this investigation are presented below.

A. Ventilation Rates

ASHRAE Standard 62–1989, "Ventilation for Acceptable Indoor Air Quality," generally specifies a minimum OA-intake rate of 20 cubic feet per minute (ft^3/min, or cfm) per person for office spaces.[28] However, when more than one space is served by a common air-supply system, using this criterion to directly determine the entire system's OA-intake rate may not be correct; the ratio of OA to SA required to satisfy the ventilation and thermal control requirements usually differs from space to space, and, if this is the case, the system's OA-intake rate must be determined from the procedure specified in the ASHRAE standard's Section 6.1.3.1, "Multiple Spaces." Additionally, Section 5.4 of this standard specifies that provisions must be made to maintain acceptable indoor air quality in each occupied space served when SA flowrates are reduced (during times the spaces are occupied) by the normal operation of certain types of systems, such as VAV systems. The most certain way to assure this is to employ the minimum SA flowrate to each space when determining OA requirements with the "Multiple Spaces" procedure.

The ASHRAE standard also specifies OA requirements for other types of individual spaces, besides offices, found in this facility. For cafeteria and fast food areas (such as the non-smoking lounges), for conference rooms, and for telecommunication centers and data-entry areas, 20 cfm per person is recommended; for reception areas (such as the lobby), 15 cfm/person is recommended; and, for duplicating and printing areas, 0.05 cfm per ft^2 of floor area is recommended. In addition, "installed equipment must incorporate positive exhaust and control (as required) of undesirable contaminants (toxic or otherwise)."

For spaces such as smoking lounges and restrooms, where more air contaminants may be generated than in spaces such as offices, the ASHRAE ventilation standard does specify ventilation rates (60 cfm/person for smoking lounges and 50 cfm per water closet or urinal for restrooms), but it also designates a different method for delivering the specified rates. This method calls for mechanically exhausting the comparatively contaminated air directly outside at the specified rate, and allowing comparatively uncontaminated "transfer air" from nearby areas to flow into the space to make up for the exhausted air. Recirculation of contaminated air from smoking lounges, restrooms, and similar spaces back to common air-supply systems is not recommended. Since this method does not necessarily require the air entering such spaces to be composed partially of fresh OA, the recommended ventilation rates for these spaces do not directly affect the determination (with the "Multiple Spaces" procedure) of OA requirements for common air-supply systems. However, the total OA-intake rate to an office building or a wing of offices should be somewhat greater than the total rate at which exhausted air is removed (by all exhaust systems combined) so that a slight "positive static pressure" is maintained in the office building, compared to the surroundings. This induces air to flow outward to, rather than inward from, the surroundings through available openings such as gaps around doors and in construction materials.

Carbon dioxide (CO_2) is a normal constituent of exhaled breath; measurement of CO_2 concentrations can be used as a screening technique to evaluate whether fresh air is being introduced into an occupied space at an adequate rate. Indoor-air CO_2 concentrations are normally higher than the generally-constant ambient-air CO_2 concentration, which usually ranges from 300 to 350 ppm. When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[28] Elevated CO_2 concentrations suggest that the concentrations of other indoor air contaminants may also be increased.

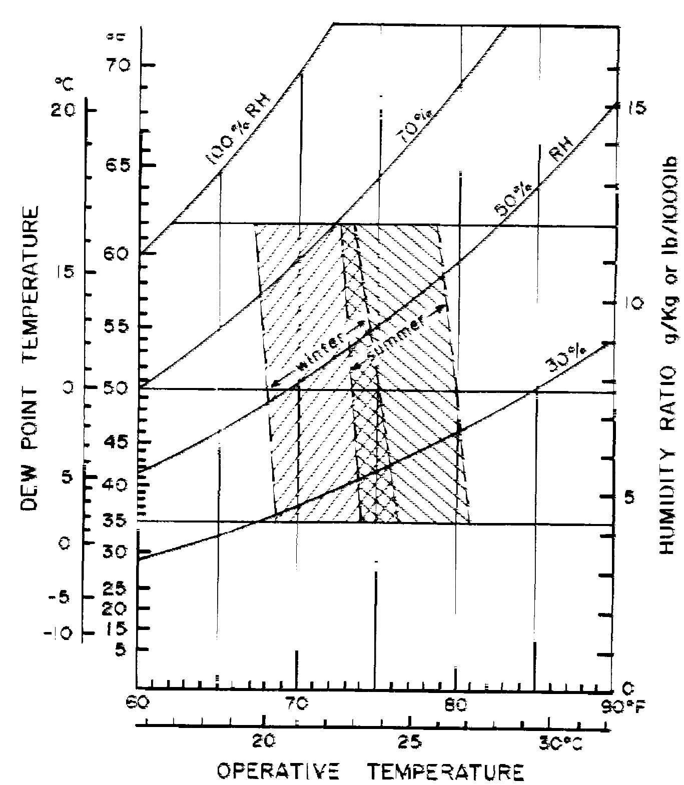

Figure 1: ASHRAE 55-1981

B. *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 (see Figure 1) specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[29] ASHRAE further recommends maintaining relative humidities between 30% and 60% "to minimize growth of allergenic or pathogenic organisms."[28]

VI. RESULTS AND DISCUSSION

A. Environmental

Ventilation Rates. Results of real-time measurements are presented in Table I. Carbon dioxide concentrations within the building ranged from 425 to 825 ppm, below the ASHRAE consensus standard of 1000 ppm for indoor environments. Outdoor CO_2 concentrations remained constant at 425 ppm throughout the day. These findings suggest that the ventilation rates for the occupied areas were sufficient on the day of the measurements. However, since outdoor air temperatures exceeded 40°F during much of the day of the NIOSH evaluation, the AHUs' economizer controls were increasing the AHUs' OA-intake rates above their minimums during much of that day. The findings do not characterize the adequacy of the ventilation rates during warm or very cold weather when the OA-intake rates should return to their minimums, nor do they provide any indication of the ability of the control system to correctly increase ventilation rates in response to elevated CO_2 levels.

NEMI investigators estimated actual minimum OA-intake rates for each AHU at the time of their investigation, and compared these with the minimum rates required according to their computer model. This analysis indicated that the actual minimum OA-intake rates for AHUs-1, -2, and -3 were too low, by substantial margins.

However, NEMI did not utilize the Multiple Spaces procedure of the ASHRAE ventilation standard to determine the required minimum OA-intake rates for those AHUs serving multiple spaces (which includes all of the primary AHUs except for AHU-2). Instead, they simply summed the calculated "effective" OA requirements for each space served by a given AHU, and, rather than adjusting the result to account for the varying effective proportions of OA needed in the SA provided to each space, they assumed that "general occupant diversity combined with air mixing should allow for adequate fresh air throughout the building." In most cases, this results in an underestimation of the minimum OA-intake rate which would be recommended under the Multiple Spaces procedure. For example, for AHU-5, NEMI estimated the required OA-intake rate to be 1100 cfm (19.9% of the model-specified SA flowrate of 5536 cfm). However, the application of the Multiple Spaces procedure in this case indicates that the SA should consist of 29.7% OA, for an OA-intake rate of 1640 cfm (assuming office area #27 to be the "critical space," with a required effective OA proportion of 52.9% in its SA [based upon NEMI model-specified rates of 200 cfm for effective OA delivery and 378 cfm for SA to the area]). NEMI estimated the actual OA-intake rate to be 1200 cfm for this AHU.

Similar results are obtained by applying the Multiple Spaces procedure to the model-specified flowrates for AHUs-1, -3, -4, and -6. Furthermore, the model-specified SA flowrates for AHUs-4 and -6 represent the maximums that their VAV air-distribution systems must provide for thermal control, but during normal operation of the systems these rates often will be reduced by the modulation of the VAV terminals. In fact, the VAV terminals reportedly have no minimum SA flowrate. Therefore, if a space became cool enough, SA flow could be nearly stopped. Since the effective OA needs of the individual spaces are constant, the required effective proportions of OA in their SA increase as their SA flowrates are reduced. However, these systems do not automatically increase the proportion of OA in their SA in response to the decreased SA flowrates.

To summarize the above information, the OA-intake rates for all six of the primary AHUs are potentially insufficient under some operating conditions, but no evidence of insufficient ventilation was found under the specific conditions existing during the NIOSH survey.

The NEMI investigators measured the airflow rates for the exhaust ventilation systems in the building. The NIOSH investigators repeated these measurements, and compared the results with design-specified values. The following are the exhaust-fan numbers for the systems, the areas served, and the design-specified, NEMI-measured, and NIOSH-measured flowrates (in cfm):

		Design	NEMI	NIOSH
EF-1	Restrooms (#30 & 31)	1575	553	(NA)
EF-2	Smoking lounge (#35)	480	212	226
EF-3	Conference room #36	780	124	132
EF-4	Conference room #37	1620	218	237
EF-5	"Kitchen" area (#32)	350	196	204
EF-6	Photocopying room (#40)	1045	Not operable	

The total exhaust flowrates for the building, based on the above, are: 5850 cfm, design-specified; 1303 cfm, NEMI-measured (2348 cfm if EF-6 were reactivated at the design flowrate); and, 1352 cfm, NIOSH-measured (NEMI value used for EF-1; 2397 cfm if EF-6 were reactivated). Currently, the total OA-intake rate for the building is estimated by NEMI at 4036 cfm, but this could fall to a minimum of 2600 cfm due to VAV operation. NEMI's model-specified rates would provide a total ranging from 3640 cfm to 5140 cfm, and adjusting these using the Multiple Spaces procedure would further increase the total. However, if the design-specified total exhaust flowrate of 5850 cfm were achieved, it might exceed even the upgraded total OA-intake rates mentioned here. This would create a condition of "negative static pressure" in the building compared to the surroundings, which can lead to humidity-control problems, draftiness, and other problems.

NEMI's model-specified SA flowrate to the smoking lounge is 570 cfm, which exceeds the exhaust-air flowrate from this room. Therefore, executing the model specifications will put this room under positive static pressure compared to the surrounding rooms, which is not recommended for a smoking lounge.

Temperature and Relative Humidity. As shown in Table I, indoor air temperature measurements ranged from 70 to 74°F, within the range recommended by ASHRAE for occupant comfort during the winter months. Relative humidity measurements indicate low humidity levels at various locations throughout the building, a situation which is common in indoor environments during colder months. RH ranged from 21 to 42% indoors and from 68 to 88% outdoors. Sixty percent of the RH measurements taken indoors were below the lower end of the ASHRAE guideline of 30 to 60% RH specific for indoor environments. Relative humidity levels in areas (conference room #37 and lounge #33) served by AHU #3 (which is the only AHU equipped with a humidifier) were consistently higher than humidity levels in areas served by the other five AHUs. Relative humidity levels in areas served by AHU #3 were all within the ASHRAE guideline of 30 to 60%, while humidity levels in other areas were usually below the lower end of the ASHRAE guideline. These findings suggests that the humidifier within AHU #3 was effective in increasing the humidity to acceptable levels.

Visual Inspection. The visual inspection of the six primary AHUs serving the building did reveal a small amount of debris in the condensate tray of AHU-3, in an apparent "low spot" that may not drain. Otherwise, it revealed no evidence of potential microbiological contamination problems (e.g., standing water, moist insulation) or other problems (e.g., overloaded particulate air filters, or visibly malfunctioning damper motors or other equipment) which might adversely affect the building's air quality. In fact, each air handling unit appeared clean and well maintained. Evidence of outdoor contaminant sources or re-entrainment was not discovered.

B. Medical

Questionnaires collected by an IBT employee representative from 59 workers prior to our site visit were reviewed. Approximately 58% of the workers reported at least one of the following symptoms: headaches, fatigue/drowsiness, and/or eye, nose, and throat irritation. Approximately 30% reported difficulty concentrating during work, 18% reported symptoms of flu-like illness, and 17% reported skin irritation. Evaluation of the NIOSH questionnaires revealed that symptoms of headaches and nose, throat, and skin irritation were greater among service representatives and directory assistance operators than engineering personnel.

Of the ten workers interviewed, the symptoms reported to be most commonly associated with the workplace were: (1) headaches; (2) fatigue/drowsiness; and (3) eye, nose, and throat irritation. The most common environmental complaints reported by employees were: (1) inadequate temperature regulation; (2) excess dust accumulation; (3) inadequate ventilation; and (4) insufficient air humidification. Other issues of concern to the workers included inadequate lighting for job task demands among engineering personnel and difficulty adjusting the volume on headphones used by directory assistance operators and service representatives. The directory assistance operators and service representatives generally felt that the ergonomic design and lighting of their workstations were good.

VII. CONCLUSIONS AND RECOMMENDATIONS

Interviewed workers reported a number of symptoms consistent with, but not specific for, workplace exposure to airborne allergens and irritants. These types of symptoms (headaches; eye, nose, and throat irritation; and fatigue) are frequently encountered in indoor work environments. Reported periods of inadequate ventilation and temperature regulation (not seen during this investigation) may contribute to symptoms of headaches and fatigue/drowsiness (see above "Evaluation Criteria" section). However, on the basis of data obtained during this investigation, the NIOSH investigators did not find any specific building problems that would clearly account for the reported employee symptoms. The following recommendations, based upon the observations made during the investigation, may improve conditions in the building:

1. In section 2.3 of the NEMI report, and in more detail in section 4.4, the NEMI investigators provided a comprehensive set of conclusions and recommendations. Seven numbered, specific "Conclusions and Recommendations" were provided that include modifications of the HVAC system. The NIOSH investigators did not attempt to verify the findings from the computer modelling performed by the NEMI investigators, but the conclusions and recommendations that they have provided in regard to cooling capacities, SA flowrates, ductwork, dampers, and fan sizing seem reasonable and consistent with their findings. The NIOSH investigators agree that duct systems should be inspected for excessive leakage and sealed as required. On the other hand, it is not clear how the NEMI investigators reached the conclusion that, because many of the areas served by AHU-3 have intermittent and variable occupancy levels, its existing humidifier is adequate in spite of its lack of capacity to meet the model-specified requirements. They did not explain why they believe that the intermittent occupancy reduces humidification needs. Furthermore, the use of humidification devices in general can lead to IEQ problems, so caution must be employed for continued use of this humidifier. This is further discussed in a subsequent recommendation.

2. The conclusions and recommendations in the NEMI report also include seven numbered, specific "Follow-up Analysis" items for further investigative work. These seem to be reasonable and appropriate measures to further assess and improve HVAC-system operations, considering the findings and uncertainties to date.

3. The conclusions and recommendations in the NEMI report also include "(s)ix additional follow-up investigations." One of these, regarding changes to the chilled-water control valves on the VAV-type AHUs for better humidity control during the cooling season, seems reasonable. Another of these calls for consideration of installing additional humidifiers to serve the entire building. The NIOSH investigation revealed evidence of low relative humidity levels in much of the building during the heating season; while this is a common condition, additional humidification might be helpful in reducing IEQ complaints. However, caution must be exercised in any decision to utilize humidification devices because these can create other types of IEQ problems. For example, some types of humidifiers have standing water, and some tend to allow water to condense inside the air-handling hardware, which may result in the growth of microorganisms in these moist areas. This is not a characteristic problem with steam humidifiers, such as the one mounted in the SA-distribution system of AHU-3. However, this type of humidifier can be a

source of IEQ complaints if it utilizes boiler steam, and if boiler additives are present in the steam. The use of humidifiers can also cause condensation problems with the building's exterior surfaces. As NEMI further recommends, modifications to the building envelope must be considered if additional humidification is to be employed; this should include attention to doors and windows.

4. To conform with the provisions of the ASHRAE ventilation standard specific for duplicating and printing areas, described previously, the existing exhaust system (with EF-6) in the photocopying room (#40) should be repaired and/or reconnected. NEMI also made this recommendation as one of its "(s)ix additional follow-up investigations,"despite reporting minimal amounts of air contaminants generated in the photocopying room.

5. The airflow rate of the exhaust system (with EF-2) for the smoking lounge (#35) should be increased by enough so that at least it exceeds, by 5% to 10%, the model-specified SA flowrate to the room (570 cfm). The maximum typical occupancy of the room and the ASHRAE ventilation-standard recommendation of 60 cfm/person should be considered to determine if the flowrate should be increased even higher. Similarly, the airflow rate of the exhaust system (with EF-1) for the restrooms (#30 & #31) should be increased to at least 700 cfm (based upon the ASHRAE-recommended 50 cfm per urinal or water closet, of which there are 14); this would exceed the total of the model-specified SA flowrates to these rooms, as it should. The NIOSH investigators have no specific information to indicate that the measured airflow rates for EFs-3, -4, or -5 are insufficient or that the design-specified rates must be met.

6. Proper OA-intake rates for each of the five primary AHUs serving multiple spaces should be determined using the Multiple Spaces procedure, and other relevant provisions of the ASHRAE ventilation guideline (see also the earlier discussion). The AHUs should be adjusted to provide these OA-intake rates, and measurements of these rates should be made to assure that they are correct.

   For the VAV systems of AHUs-4 and -6, provision should be made to increase OA-intake rates to accommodate the reductions in SA flowrates to individual spaces which occur during normal operation, and the resulting increase needed in the proportion of OA in the systems' SA as this occurs. The NEMI investigators suggest, as one of their "(s)ix additional follow-up investigations," accomplishing this by adding OA fans to these AHUs. However, this may not be necessary if the Andover computer system could be programmed to open the OA-intake dampers wider in response to a decreased SA flowrate for the AHU. However, neither of these solutions actually responds to the decrease in SA flowrates to <u>individual</u> areas. If feasible, it would be preferable to program the Andover system to increase OA intake in response to the decrease in individual-space SA flowrates by monitoring the operation of the VAV terminals. Reportedly, the Andover system has the flexibility and capacity to monitor and control additional parameters and functions, with increased sophistication, if the appropriate hardware is connected and the appropriate programming completed. Alternatively, consideration could instead be given to increased use of the Andover system's CO_2 monitors to perform this function. Perhaps additional CO_2 monitoring devices could be added to monitor more areas, and the system re-programmed to phase in higher OA-intake rates when the CO_2 concentration reaches 800 ppm. The accuracy and precision of the CO_2 monitoring devices should be verified periodically.

7. The last of the "(s)ix additional follow-up investigations" recommended in the NEMI report is the consideration of converting the four CV-type air-handling systems to the VAV type. The report did not explain the benefits of such a conversion, but one benefit might be better temperature control during the cooling season since the CV systems use hot-water "reheat" coils to regulate temperatures in individual spaces served by these systems. During the warm months when the boiler is not activated, the reheat coils do not operate and these systems have no control over individual-space temperatures, only on the average for their entire service areas. The obvious disadvantage to such a conversion is the difficulty in assuring continuously adequate ventilation rates to all spaces with a VAV system, and the need for more complex controls and hardware to circumvent this weakness, as described above.

8. Before making the changes described in the previous recommendations, ensure that the total, minimum (considering VAV operation) OA-intake rate for the building will always exceed the total exhaust-air flowrate. Ideally, the former should exceed the latter by 5 to 10%.

9. Reportedly, AHUs-1 through -5 have particulate air filters rated 85% efficient, while AHU-6 has a pleated-type, 35%-efficient air filter. It would be desirable to upgrade the filter in AHU-6 to a high efficiency particulate air (HEPA) filter if this improvement is compatible with the AHU and distribution system.

10. Since a small amount of debris was found in the condensate tray of AHU-3, in an apparent "low spot" that may not drain, this AHU should be cleaned, and then inspected rather frequently during the first few weeks of the cooling season to determine if poor drainage leads to a recurrent buildup of debris, and needs correction. Also, maintenance should be performed to assure that the evaporator coils, condensate trays, etc. of the auxiliary "DX"-type cooling systems are kept clean, dry, and free of debris, by periodic inspections and cleanings just as is done with the six primary AHUs.

11. Any workers with chronic or worsening symptoms should be evaluated by their primary physicians regarding their medical condition and ability to perform their job. A workplace exposure is only one of a number of possible explanations for the symptoms reported during the survey.

12. Communication about health and safety concerns between workers and management should continue. Ideally, periodic group meetings including all employees should be held to address ongoing issues of concern. A valuable aspect of group meetings is to provide for discussion of feelings of anxiety, frustration, and uncertainty. It is difficult for both management and labor to deal with the fact that a specific exposure that accounts for all the workers' symptoms may never be found. Other ways to enhance communication may include dissemination of a health & safety newsletter and posted notices. The formation of a health and safety committee should be considered. The utilization of a health and safety committee for effective communication will be most successful if it represents the diverse interests of the workplace (e.g., management officials, health & safety administrators, and facility

personnel)[31] and accurate accounts of the discussions are rapidly transmitted to all workers.

Communications efforts should be educational. The difference between odors and toxic effects and the safe handling of any chemicals used in the workplace (e.g., cleaning fluids) should be explained as well. Workers and management personnel should be kept well informed of the procedures for logging and responding to health complaints, should they occur. Further, effective communications should counter rumors and misinformation with factual information. Finally, employees need to be apprised of any new developments or plans regarding health and safety issues.

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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 I
Indoor Air Quality Data
Indiana Bell Telephone
Bloomington, Indiana
January 8, 1993
HETA 91-402

Location	Time	CO_2* (ppm)***	Temperature (°F)	RH*** (%)	# of Occupants
Photocopy Room #40	6:51	475	72	27	0
	10:45	625	73	26	2
	1:02	650	72	28	1
	6:40	625	73	30	2
Engineering Area #44	6:58	475	72	26	2
	10:48	625	73	27	15
	1:05	675	73	27	16
	5:43	575	74	30	2
Administrative Office	7:03	425	73	26	0
	10:51	525	71	27	1
	1:10	625	73	28	1
	5:46	575	74	31	0
Lobby #38	7:05	425	70	28	0
	10:57	625	73	34	3
	1:12	575	71	28	0
	5:58	575	70	32	0
Conference Room #37	7:07	425	70	35	0
	10:54	525	70	38	0
	1:14	675	71	36	5
	5:54	725	72	42	15
Lounge #33	7:10	450	72	33	0
	10:57	625	73	34	3
	1:15	725	73	32	11
	5:56	575	73	38	3
Office #11	7:21	475	72	30	0
	11:00	625	73	29	0
	5:58	575	74	31	0

* CO_2 = carbon dioxide
** ppm = parts per million parts of air
*** RH = relative humidity

--Continued--

Table I (Continued)

Indoor Air Quality Data

Indiana Bell Telephone
Bloomington, Indiana
January 8, 1993

HETA 91-402

Location	Time	CO_2* (ppm)***	Temperature (°F)	RH*** (%)	# of Occupants
Office #3	7:30	525	73	26	0
	11:09	825	74	27	3
	1:35	775	74	27	1
Office #5	6:03	675	74	32	0
	1:21	650	74	28	1
	5:52	525	73	29	0
Operator Area #10	7:30	525	73	26	0
	11:09	825	74	27	3
	1:32	775	74	29	20
	6:02	650	73	32	14
Business Office	7:35	475	74	21	7
	11:13	675	74	22	37
	1:19	625	74	24	27
	5:50	550	73	29	8
Office #25	7:37	425	74	21	0
	11:16	650	73	22	1
	1:39	600	74	23	2
Lounge area #21	7:24	475	73	28	0
	11:01	650	72	30	1
	1:26	700	73	29	3
	6:00	600	73	33	1
Outdoors	9:45	425	39	68	--
	11:29	425	41	81	--
	1:45	425	39	79	--
	6:10	425	45	88	--

* CO_2 = carbon dioxide
** ppm = parts per million parts of air
*** RH = relative humidity