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INTERNAL REVENUE SERVICE
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I. SUMMARY

On January 23, 1992, and April 8-9, 1992, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation at the Internal Revenue Service (IRS) offices in the McNamara Building in Detroit, Michigan. The evaluation was initiated by a request received in July, 1991, from the National Treasury Employees Union (NTEU) on behalf of several employees in the IRS's taxpayer service, Toll-free Telephone Area on the 18th floor of the building. The employees were concerned about poor air quality, temperature extremes, excessive noise, fire/electrical hazards, and other safety and ergonomic issues. During initial discussions with NTEU representatives, it was requested that the tax collection area (ACS) on the 21st floor also be included in the evaluation.

Environmental measurements of the carbon dioxide levels, temperature and relative humidity, and noise levels were made in several locations on the two floors included in the evaluation over the three days that NIOSH investigators were in the building. Additionally, the ventilation system was visually inspected by NIOSH investigators, and the mechanical contractor who serviced the heating, ventilating, and air-conditioning (HVAC) system was interviewed extensively about the operation of the system. Finally, employee interviews were conducted and questionnaire data collected from the employees who worked in the Toll-free Telephone Area and ACS.

The environmental sampling revealed temperature, carbon dioxide, and humidity levels that are commonly found in office buildings. The results of the questionnaire survey found prevalence rates typical to what is reported in other problem buildings. No specific exposure or environmental condition was found that would help explain the symptoms reported by employees.

No clear environmental causes for the symptoms reported by the IRS employees in the Toll-free Telephone and ACS areas were found during the NIOSH evaluation. However, several environmental deficiencies were discovered that could compromise employee comfort. Recommendations that address ventilation, humidity, noise, safety, and communication concerns are offered in Section VIII of this report.

KEY WORDS: SIC 9311 (Public Finance, Taxation, and Monetary Policy), indoor environmental quality, ventilation, medical questionnaire, office noise, IEQ, GSA.

II. INTRODUCTION

On July 13, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the National Treasury Employees Union (NTEU) Detroit Chapter No. 24 concerning Internal Revenue Service (IRS) employees. The Toll-free Telephone Area workers on the 18th floor of the McNamara Building were concerned about poor air quality, temperature extremes, fire/electrical hazards, excessive noise, and other safety and ergonomic issues. During initial discussions with the requestors, NTEU representatives requested, and IRS management agreed, that the tax collection employees in ACS on the 21st floor be included in the HHE.

An indoor environmental quality (IEQ) survey was conducted on January 22-23, 1992, on the 18th and 21st floors of the McNamara Building. Based on a preliminary review of the data, it was decided that a second evaluation with additional medical and ventilation support should be done. The second site visit occurred on April 7-9, 1992.

III. BACKGROUND

The McNamara Building is a multi-story office building located in downtown Detroit, Michigan, operated by the General Services Administration (GSA). The perimeter walls of the building are floor-to-ceiling tinted glass, with adjustable blinds to help control the amount of natural light entering the space. Both the 18th and 21st floors are carpeted, with the 18th floor having a raised, false floor to allow for telephone cable runs to the phone banks. The GSA has a contract with a mechanical firm to manage the heating, ventilating, and air conditioning (HVAC) systems in the building. Both evaluated areas, the Toll-free Telephone Area (18th floor west) and ACS (21st floor east), are open office spaces with modular office furniture which defines individual employee work areas (Figures 1 and 2). Most work areas are equipped with a telephone and a computer. Smoking was allowed in ACS during the survey, with smokers interspersed with non-smokers over the entire floor. Smoking was not allowed in the Toll-free Telephone Area on the 18th floor.

There are four air handling systems which provide cooling to floors 14 to 26, including the complaint areas. Each air handler serves a multifloor quadrant of the building. Air for cooling is supplied to each quadrant on each floor through two variable air volume (VAV) boxes. Each VAV box has one inlet damper and three outlet dampers. When the outside temperature falls below 55°F, four perimeter air handling (PAH) units draw return air from the previously mentioned air handling systems and distribute it to sill units along the perimeter after it is heated. The temperature of the heated air is determined by the outdoor temperature. Cooling is required for interior areas of the building year round. An air supply temperature of 55°F is maintained in the summer while 65°F is maintained during the winter. Each of the four air handlers used in cooling consists of a return air fan, a bank of polyester filters, a cooling coil, and an air supply fan. A return air shaft, which taps into each floor (14 to 26), draws return air from ceiling plenums. Air supplied to the occupied space returns through slots in the light fixtures. The return air shaft houses a circular air supply duct which in turn taps into the quadrant that it serves on each floor.

IV. MATERIALS AND METHODS

A. Environmental and Ventilation

The purpose of the environmental investigation was to obtain information required to classify the building, determine the condition of building systems, and document it's current indoor environmental status. Descriptive information for the building (size, construction, location, etc.), the area to be evaluated (size, type of office space, furnishings, pollutant sources, etc.), and the HVAC systems (type, specifications, maintenance schedules, etc.) were obtained. Inspections of the evaluated area and HVAC systems were conducted to determine current conditions.

During the environmental evaluation, indicators of occupant comfort were measured. These indicators were carbon dioxide concentration, temperature, relative humidity (RH), and noise. Chemical smoke was used to visualize airflow in the evaluated areas and to determine potential pollutant pathways to the areas.

Real-time CO_2 concentrations were measured using a Gastech Model RI-411A, portable CO_2 indicator. This portable, battery-operated instrument uses a non-dispersive infrared absorption detector to measure CO_2 in the range of 0-4975 ppm, with a sensitivity of ±25 ppm. Instrument zeroing and calibration were performed prior to use with zero air and a known concentration of CO_2 span gas (800 ppm).

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

The noise assessments were made with a Larson-Davis Laboratories Model 800B Precision Integrating Sound Level Meter with a Model 2540 1/2" microphone. Each octave band measurement was made with the sound level meter in the integration mode for a one-minute integration period per band. Measurements were conducted while all of the area's noisy operations were in progress and the area occupied by employees. The sound level meter was calibrated before and after measurements of the noise according to the manufacturer's instructions.

B. Medical

The medical evaluation consisted of interviews with employees and administration of a questionnaire. Eighteen interviews were conducted among employees who had notified the union that they wished to talk to the NIOSH investigators. The questionnaire was administered in the evaluated areas on floors 18 west and 21 east. Each employee present at work on April 7-9, 1992, was given a questionnaire at his or her work station and asked to complete it during the day. The questionnaire asked if the employee had experienced, while at work the last four weeks before the survey, any of the 13 symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of problem buildings. The questionnaire also asked about the frequency of occurrence of these 13 symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The final section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks preceding the questionnaire administration.

NIOSH investigators were available on the floor to answer any questions and assist the employees. The questionnaire was placed in a sealed envelope and collected at the end of the day.

V. EVALUATION CRITERIA

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

! sources of odors or contaminants,

! problems with the design or operation of the HVAC system,

! pathways between contaminant sources and the location of complaints,

! and the activities of building occupants.

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

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

A number of published studies have reported high 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 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] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related than any measured indoor contaminant or condition to the occurrence of symptoms.[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 been helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature and relative humidity, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are listed below.

A. Carbon Dioxide

Carbon dioxide 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 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, and 15 cfm/person for reception areas, 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.

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 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[24]

C. Office Noise

Noise conditions in the office setting are evaluated for their effects on speech intelligibility, telephone usage, and work interruption rather than on the risk of hearing damage as is the case for the industrial situation. Several noise criterion curves have been developed to evaluate enclosed spaces, including the Noise Criterion (NC) curves, the Preferred Noise Criterion (PNC) curves, and the Revised Criterion (RC) curves.[26] A more recent version is the Balanced Noise Criterion (NCB) curves which are used to evaluate, depending on the level of listening conditions needed, noise conditions in enclosed occupied spaces with all systems operating.[27] The NCB curves have been categorized into recommended room classifications and suggested NCB ranges for steady background noise as heard in various indoor occupied functional activity areas (Table 1)[26].

VI. RESULTS AND DISCUSSION

A. Environmental

Both floors of the evaluated area were generally designed as open office environments with desks, chairs, and short (approximately 4 feet high) partitions defining an employee's work space. Most desks had a computer and telephone for the employee's use. There were a few enclosed offices on the perimeter of the building for supervisory employees. Both evaluated areas have a centralized computer room located in the core section of the floor. During the survey periods, there were approximately 160 employees working in 12,035 square feet (sq ft) of space in the Toll-free Telephone Area and approximately 105 employees working in 10,193 sq ft of space in the ACS Area. Environmental measurements were made at six locations on the 18th floor (Toll-free Telephone Area) and at either six or seven locations (depending on the survey dates) on the 21st floor (ACS), which are shown in Figures 1 and 2.

Environmental CO_2 measurements are presented in Figures 3-6. During the January 1992 survey, the CO_2 concentrations ranged from 450 ppm during the first morning measurement period to 1000 ppm during the late afternoon period on the 18th floor (Figure 3). For the 21st floor, the range of CO_2 concentrations was from 425 ppm in the first morning measurement period to 825 ppm in the late afternoon (Figure 4). Both floors exhibited a general trend of increasing levels of CO_2 concentrations during the day, which influenced the decision by NIOSH investigators to return to the McNamara Building to expand the evaluation.

Environmental CO_2 measurements were repeated during the April 1992 survey over two days. The concentrations of CO_2 found on the 18th floor ranged from 450 ppm to 775 ppm (Figure 5) and from 325 ppm to 800 ppm on the 21st floor (Figure 6). The trend of increasing CO_2 concentrations over the day observed in January 1992 was not seen in the April 1992 survey. Rather, the concentrations remained fairly stable throughout the two days of the evaluation. With the exception of the one measurement of 1000 ppm of CO_2 found in January 1992, the CO_2 concentrations were below the ASHRAE guideline of 1000 ppm indicating that there was good ventilation in the surveyed areas.

Sequential temperature and relative humidity (RH) measurements were also taken on all three survey days at each of the evaluated locations on the two floors. The measurements were remarkably stable across all of the locations on each of the survey days, varying only by 1-2°F and 2-5% RH. The mean temperature in the building was found to be 76°F on January 23 (standard deviation [SD] = 1.0°F), 76°F on April 8 (SD = 0.6°F), and 76°F on April 9 (SD = 0.8°F). The mean RH was measured at 28% (SD = 1.1%), 27% (SD = 1.8%), and 31% (SD = 0.9%), respectively over the three survey days. The temperature and RH measured outside of the building on the three survey days ranged from 40°F to 57°F and from 54% to 82%, respectively.

Octave band noise measurements were made at four of the six evaluation locations on the 18th floor and three of the seven locations on the 21st floor. The data are presented in Figures 7 and 8. The number on the first set of bars corresponds to the measurement locations in Figures 1 and 2. The noise data show that the 500 Hertz (Hz) octave band contributes the most to the office noise. In three of the four measurement locations on the 18th floor, the NCB-45 curve is met or surpassed, while two of the three locations on the 21st floor exceed the NCB-40 curve at 500 Hz. The noise measured at this frequency band is most likely the result of employee conversations in the area, which is not a surprising finding given the amount of telephone usage necessary in these jobs. Table 1 shows that office noise of this magnitude is conducive to situations needing fair to moderately good listening conditions.

B. Ventilation

Inspection of air handling equipment on the 27th floor showed it to be clean and well maintained. The return air duct appeared to be free of contamination. The mechanical contractor who operates and maintains the ventilation systems follows, at a minimum, GSA guidelines contained in GSA's "Contract Maintenance Inspector's Handbook", a preventive maintenance two-card system. The first card is the "Preventive Maintenance Work Order" on which the procedures for equipment maintenance are outlined and the check points are specified. Also the frequency of maintenance is specified on that card. The second card has the "Machine Repair Record" or equipment repair log on one side and "Summary of Preventive Maintenance Done" on the other side. The equipment repair log specifies equipment and its location, work performed, and the dates and costs of labor and material. The preventive maintenance (PM) log is a historical record of PM for the equipment and includes, dates of work done, dates of work completed, and type of maintenance done (such as lubrication, adjustment, etc.)

Ventilation air is supplied to interior areas through T-bar ceiling diffusers. During the heating season, tempered air from the PAH units is supplied at the bottom of a bay window and is returned to the plenum above the ceiling through a soffit at the top of the window. To enhance air movement, the PHA units are operated during the cooling season. No heat is added to the air under those conditions.

Tests with smoke tubes revealed that the T-bar ceiling diffusers were functioning properly. The smoke was released at points one inch from the outlet and very close to the ceiling. The smoke patterns showed that the supply air was being discharged along the ceiling.

The four air handlers which are used for cooling have interconnected supply air return ducts. This has been incorporated in the design in order to have the capability of shutting off one or more of the four air handling units during off-peak conditions. The system design is based on the assumption that only half the space requires cooling at any one time. This assumption has proven to be incorrect.

A center damper provides air for cooling the perimeter and is controlled to maintain a 2 inch water pressure drop in the duct. The air supplied from this duct is divided in half and cools two halves of a bay window through pockets above it. Air to interior zones within the quadrant is controlled by the outlet damper on either side of the center one in the VAV box. These dampers are controlled by signals from direct acting thermostats installed on interior columns in the office space. The VAV box inlet damper closes completely when both interior thermostats are satisfied. The VAV boxes also have a means of inducing entraining return air into the primary supply air for the interior zones. This prevents overcooling of the space. However, in 1977, one fluorescent tube was taken out from each light fixture to conserve energy. This had the effect of reducing return air plenum temperatures to between 65 and 70°F (instead of the design 75 to 88°F) thus making it difficult for the induction of return air to work properly. Complaints of areas being too cold or drafty developed thereafter.

The original design of the ventilation system assumed that the occupied space would be open offices. However, enclosed offices have been built for managerial staff along some of the perimeter. This has deprived interior locations from the benefits of the perimeter cooling on air movement and temperatures.

There is heavy use of personal computers and video display terminals in the open office areas. It is highly unlikely that the designers of the ventilation systems have anticipated the cooling loads associated with the use of such equipment. Also, some of the open areas were partitioned off which could adversely affect both temperatures and air movement.

C. Medical

During this site visit, interviews were conducted with 18 employees. Most of the interviewed employees reported experiencing health symptoms while in the building. Commonly reported symptoms included nasal congestion, headache, cough and dry skin. Five of the employees reported stagnant or stale air in the building and three reported that they were bothered by cigarette smoke.

A completed questionnaire was received from 184 employees on the 18th and 21st floor. A total of 92% of the administered questionnaires were returned. Of the employees surveyed, 95 (53%) considered their job description "technical", 21 (12%) managerial, 17 (9%) secretarial or clerical, 15 (8%) professional, and 32 (18%) other.

Eighty-three percent of the respondents worked a 40-hour week and 44% replied that they worked on a computer seven or more hours a day. Twenty-two percent were current smokers, 23% were former smokers and 55% never smoked. The median age of employees was 35 years. Employees were asked about pre-existing medical conditions, allergies or sensitivities that might affect reporting of symptoms related to working at the building. These included asthma, hayfever, allergy to dust, allergy to molds, "smoke sensitivity", and "chemical sensitivity". Results are given in Table 2.

Employees were questioned about how frequently they experienced specific symptoms while working at the building. There were four categories of response: not in the last 4 weeks; 1-3 days in the last four weeks; 1-3 days per week; and almost every day. For the purpose of determining prevalence rates, symptoms reported to occur "1-3 days per week in the last four weeks" or "every or almost every workday" were considered to occur frequently and "1-3 days in the last four weeks" or "not in the last four weeks" were considered to occur infrequently. A lack of response to a given question was considered the same as an infrequent symptom. For computation of correlations, the data were left in the original categories and questions not answered were not included. Statistical analyses were performed using the Chi-Square test, unless otherwise noted.

The questionnaire results are shown in Table 3. The first column of Table I shows the number of employees reporting a particular symptom and the second column shows the percentage of the 185 respondents who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey. Nose or sinus problems; tiredness/fatigue; dry throat; strained eyes; and dry, itching or irritated eyes were the most common "frequently" reported symptoms. In addition, employees were asked whether the symptom improved when they left work. The third column of the table shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey and also reported that the symptom tended to get better when they were away from work. This latter criterion has, in some studies of indoor air quality, been used to define a "building related" symptom, but it is possible that a symptom which does not usually improve when away from the building could also be due to conditions at work.

Table 4 shows results of employee reports regarding environmental conditions at their workstations during the four weeks preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered "frequent" if they were reported to occur at work once a week or more often. Column one shows the number of employees reporting a specific environmental condition and column two the percent of all workers reporting that condition. It shows that 61% of the respondents perceived that the ventilation system was not providing sufficient air movement, 53% thought it was too dry, 40% thought it was too hot, and 17% felt that it was too cold during at least part of their work day. Fifty-six percent of the employees reported detecting tobacco smoke odors and 23% frequently sensed other unpleasant odors.

Questions about job satisfaction were also asked of the employees. Most employees responded that they were satisfied with their job; 142 employees (78%) categorizing themselves as either "very satisfied" or "somewhat satisfied". Seventeen percent responded that they were "not too satisfied" and only 10 employees (5%) responded that they were "not at all satisfied" with their job.

Risk factors for reported symptoms

Kendall Tau b correlations were computed between reported symptoms and environmental perceptions. The frequency of each of the 10 most prevalent symptoms (irritated eyes, nose/sinus problems, tiredness/fatigue, strained eyes dry throat, headache, dizziness, cough, sore throat, and concentration problems) was statistically significantly correlated with the frequency of feeling too hot, too dry, and feeling that there was too little air in the work area. Kendall Tau b correlation coefficients ranged from 0.14 to 0.40 with all $p \leq 0.05$. The presence of odors (chemical or tobacco) on the floor was statistically significantly correlated ($p \leq 0.05$) with eye problems (strained or irritated eyes), dizziness, shortness of breath, and chest tightness. Allergies to dust and molds were statistically significantly correlated ($p \leq 0.05$) with nose or sinus problems, dry throat, cough, wheezing, and headache.

These correlations serve merely as an indication of an association between two variables. One cannot determine an odds ratio using these correlations, nor can one make an assumption of cause and effect. These correlations are useful as a guide for determining what employees perceive as problems in their work areas and for determining what individual medical conditions (allergies, asthma etc.) might be related to symptoms reporting.

These findings illustrate the role of perceived environmental conditions and symptoms. Symptoms appear to be related to the individual perception of improper humidity and temperature levels in the work environment regardless of measured parameters (which varied little), as different people may report similar symptoms with completely different perceptions of their environment. A building may be too hot for some employees and may be too cold for others.

In addition, it is conceivable that an area of a floor might be, at times, hotter than another and that might result in these seemingly contradictory responses. At the time of the NIOSH investigation, the building had relative humidity levels that were below or at the low end of the ASHRAE thermal comfort guideline, and the majority of employees (59%) did report that the building was too dry. Each floor had been broken down into zones that correspond with the environmental measurements. This breakdown would have allowed for analyzing questionnaires with respect to environmental conditions within a floor, should large differences in environmental conditions have occurred between zones on the same floor. This was not the case in the building in Detroit, as measured environmental parameters were similar throughout the building.

Females were more likely to report the symptoms cough (chi square= 4.9, p=0.03), nose or sinus problems (chi square=17.9, p= <0.001), and dry throat (chi square=10.2, p=0.001). Although many of the responses to environmental variables asked on the questionnaire correlated with symptoms, most of these variables are not medically plausible risk factors for the particular symptom. Being female should not be a risk factor for a dry throat in an office building nor, for example, should lack of building cleanliness be a risk factor for dizziness. The results, however, do give insight into how different employees perceive that they are affected by their work environment and may serve as a guide in improving that environment.

There were minimal correlations between reported symptoms and the variables describing job category, job satisfaction, education, and chair comfort. Eighty percent of respondents reported that their chair was either very comfortable or reasonably comfortable. Chair comfort was correlated only with reported tiredness and fatigue, education was correlated with the number of days that strained eyes and eye irritation were reported over the last week and job satisfaction was correlated with the number of days reported symptoms required an employee to miss work. Job satisfaction, however, was not correlated with reporting of any one of the studied symptoms.

Smoking was still allowed on the 21st floor, so it had been hypothesized that there would be greater reporting of symptoms on that floor. This was not the case, however, as the prevalence of symptoms was not statistically significantly different between floors with the exception of cough, which was reported more frequently on the 18th (non-smoking) floor; 25% of employees on the 18th floor reported they had a cough "frequently" at work as opposed to 12% on the 21st floor (chi square = 7.0, p=0.30). Employees reporting eye strain reported using a computer more hours per day (5.8) than those not reporting eye strain (3.7, p=0.002). The number of hours a computer was used per week was significantly greater on the 21st floor, with a mean of 7.0 hours on the 21st floor and 3.0 hours on the 18th floor.

There were no statistically significant differences in the prevalence of symptoms between current smokers, past smokers, or those who had never smoked. Non-smokers on the 21st floor, where smoking was permitted, did not report any greater symptom prevalence than non-smokers on the 18th floor.

Although the building humidity was below ASHRAE comfort guidelines with respect to humidity on the days NIOSH investigators conducted measurements, it must be emphasized that those measurements only reflect three days' conditions. Although NIOSH investigators were at the building on two separate occasions, including April, which is probably the time of heaviest occupation for a tax building, it is quite possible that the indoor environmental conditions might vary depending on outdoor environmental conditions and with fluctuations in the operation of the heating and cooling system. In addition, NIOSH investigators did not measure the microenvironment experienced by every worker. A given employee, in an individual office or in an office surrounded by partitions, may experience markedly different environmental conditions than that measured by NIOSH investigators. Although NIOSH investigators measured adequate ventilation in the work site, as measured by CO_2 concentration in the air, some employees reported stale air in their work space that might have been due to insufficient ventilation at their specific work location.

VII. CONCLUSIONS

The environmental sampling revealed levels of temperature, CO_2, and humidity that are commonly found in indoor environments. However, no specific exposure or environmental condition was found that would help explain the symptoms reported by employees.

The results of the questionnaire survey revealed prevalence rates typical to what is reported in other problem buildings.[29] Symptoms were associated with employee perceptions of low humidity, high temperature, and too little air. It has been estimated by the World Health Organization that up to 30% of office workers in the developed world may experience similar symptoms.[30]

VIII. RECOMMENDATIONS

The NIOSH evaluation identified some environmental deficiencies at the IRS facility in the McNamara Building. Based on the results and observations of the survey, the following recommendations are offered to correct those deficiencies and optimize employee comfort.

1. The relative humidity measurements made on the three survey days were below or at the lower acceptable range of the ASHRAE guidelines for thermal environmental conditions under wintertime settings. The measured outside RH was considerably higher than the indoor measurements, which suggests that the HVAC system is removing too much water vapor from the air. The building's mechanical contractor should investigate the indoor RH levels and correct them, if possible.

2. Electrical cords were observed running across aisles in the Toll-free Telephone Area. The cords are a potential trip hazard to people walking in the area. This practice should be changed by running any cord (electrical, telephone, or computer) under the false floor in the area.

3. The noise levels measured in the Toll-free Telephone and ACS areas revealed office environments that are suited for only fair to moderate listening conditions. If it is determined that better listening conditions are needed to conduct business with the public that the IRS serves, then the interference from nearby telephone conversations should be minimized. More definitive work areas, with higher partitions, will accomplish a reduction in noise interference between adjacent work spaces when employees are talking on the telephone or to other IRS employees simultaneously. However, it must be remembered that higher partitions may interfere with the air movement patterns from the HVAC system, which could result in extreme temperature zones or a feeling of stuffiness from a lack of air movement. Any acoustical changes must be coordinated with the building's mechanical contractor to minimize these potential effects.

4. There is a need to calculate the thermal loads in both complaint areas and in other areas on floors 14 to 26. Existing equipment does not appear capable of handling peak cooling loads. Also, the occupant density and the equipment they use may not have been foreseen by the original design. It may turn out that some existing equipment, such as cooling coils, has sufficient capacity. However, the operators of the systems feel that at least the return and supply fans are undersized.

5. Induction of return air into the air that cools interior space is not functioning as intended to prevent overcooling because of energy conservation measures (removal of one tube from light fixtures). Perhaps the use of reheat (in the form of electrical resistance heat) would work better. The reheat would come when the thermostats are satisfied. Of course, the VAV inlet dampers should not completely close when the thermostats are satisfied but should allow a minimum amount of airflow which is equivalent to 20 cfm of outside air multiplied by the number of occupants served by the VAV box. If this can be implemented, the ceiling diffusers in current use require evaluation as to their capability to provide adequate air diffusion.

6. There is a need to keep occupant density at seven per one thousand square feet and to continuously provide 20 cfm of outside air per person. The ventilation systems may not have been designed to provide 20 cfm per person, which is the currently recommended amount for office space by ASHRAE.

7. Communication between management and employees should be increased to facilitate the exchange of concerns about environmental conditions at the building. Employees should be made aware of the problems with the building and decisions that must be made by building managers to address those problems. There is also a need to educate occupants in the benefits of closing curtains on sunny days in order to assist the ventilation system in providing adequate cooling of the solar load.

8. There is no evidence that the ventilation systems were commissioned after construction was complete. This usually is done to make sure that ventilation system components are working properly and that design airflows are being delivered. This needs to be done after modifications have been implemented.

9. The quickest way to find out what the local ventilation rates are in complaint areas is to conduct tracer decay experiments. Tracer gas, such as sulfur hexafluoride, would be injected into the outside air louvers of each air handler until the concentration reaches equilibrium in the space. A sampling manifold is placed at least three duct diameters downstream from the point of injection. Integrated samples would be simultaneously obtained from outside air, supply air, and return air ducts. The sampling would be over a period of two minutes and would commence one minute after injection began. The decay in concentration is then monitored, and from that, an air change rate may be calculated and compared to ASHRAE recommended values. However, according to the building operators, the building is very leaky and the results of tracer decay will also reflect air infiltration which is a highly variable quantity depending on wind speed and inside/outside temperature difference.

   The interconnection of the supply and return ducts for the four systems on the 27th floor complicates measurement of ventilation (outside) air and other quantities. The systems could, in principle, be separated and operated as individual systems using static pressure sensors and supply fan inlet vane control based on static pressure signals in the supply ducts. Then the VAV boxes on each floor would be fully opened either manually or through manipulation of thermostats. Air flow from diffusers may be measured using flow measuring hoods.

10. The Internal Revenue Service should institute a smoking policy that provides a smoke free environment for all employees. Exposure to ETS is one of the most important indoor air quality problems, contributing both particulates and gaseous contaminants. A smoking cessation program may be necessary to assist those employees who are current smokers. If smoking is permitted, it should be restricted to designated smoking lounges.[28] These lounges should be provided with a *dedicated exhaust system* (room air directly exhausting to the outside), an arrangement which eliminates the possibility of re-entrainment and recirculation of any secondary cigarette smoke. In addition, *the smoking lounge should be*

under negative pressure relative to surrounding occupied areas. The ventilation system supplying the smoking lounge should be capable of providing at least 60 cfm of outdoor air per person. This air can also be obtained from the surrounding spaces (transfer air).

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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 1

Balanced Noise-Criterion Curves and Recommended Room Activity Requirements[26]

Type of Space and Acoustical Requirements	**NCB Range**
Private or semiprivate offices, small conference rooms, classrooms, libraries, etc. (for good listening conditions).	30 to 40
Large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc. (for moderately good listening conditions).	35 to 45
Lobbies, laboratory work spaces, drafting and engineering rooms, general secretarial areas (for fair listening conditions).	40 to 50
Light maintenance shops, industrial-plant control rooms, office and computer equipment rooms, kitchens and laundries (for moderately fair listening conditions).	45 to 55
Shops, garages, etc. (for just acceptable speech and telephone communication).	50 to 60
Work spaces where speech or telephone communication is not required, but where there must be no risk of hearing damage.	55 to 70

TABLE 2
Pre-Existing Medical Conditions
HETA 91-308
Internal Revenue Service
Detroit, Michigan
April 7-9, 1992

CONDITION	NUMBER WITH CONDITION	PERCENT
ASTHMA	17	9
HAY FEVER	43	23
ALLERGY TO DUST	53	29
ALLERGY TO MOLDS	31	17
"SENSITIVITY" TO CHEMICALS	86	47
"SENSITIVITY" TO SMOKE	100	54

TABLE 3
Symptoms Frequently Experienced During the Last 4 Weeks While at Work
HETA 91-308
Internal Revenue Service
Detroit, Michigan
April 7-9, 1992

SYMPTOM	NUMBER	PERCENT	HAVE FREQUENT SYMPTOMS THAT IMPROVE WHEN AWAY FROM WORK (percent)
Nose or sinus problems	85	46.0	24
Tiredness/fatigue	79	43	30
Dry throat	77	42	28
Strained eyes	80	43	30
Dry, itching or irritated eyes	59	32	27
Headache	58	31	23
Cough	37	20	12
Sore throat	25	14	6
Concentration problems	23	13	7
Dizziness	22	12	9
Shortness of breath	20	11	8
Chest tightness	19	10	6
Wheezing	12	7	4

TABLE 4
Employee Perceptions of Environmental Conditions
HETA 91-308
Internal Revenue Service
Detroit, Michigan
April 7-9, 1992

ENVIRONMENTAL PARAMETER	NUMBER	PERCENT
Too much air	14	7.6
Too little air	113	61.0
Too hot	74	40.0
Too cold	32	17.3
Too humid	16	8.7
Too dry	97	52.5
Tobacco odors in the workplace	103	55.7
Chemical odors in the workplace	15	8.1
Other odors in the workplace	43	23.2