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## I. SUMMARY

On August 16, 1989, the National Institute for Occupational Safety and Health (NIOSH) conducted a Health Hazard Evaluation (HHE). This survey was at the Hertz Corporation building near O'Hare International Airport in Chicago, Illinois. The survey was conducted in response to employees' complaints about the thermal and environmental conditions in the building. The occupants also reported health symptoms including headache, sinus, eye and respiratory problems, and stiff or aching muscles. An industrial hygiene and ventilation evaluation were performed.

Real-time carbon dioxide ($CO_2$) and wet and dry bulb temperatures were measured as part of the survey. Inspections of the air-handling unit (AHU) and other ventilation components were also conducted. Smoke tubes were used to evaluate air movement in the building. Symptom questionnaire results were included with the request. These were used to identify problem areas.

Indoor temperature measurements averaged 72, 75, 75, and 74 °F compared to outdoor measurements of 70, 74, 76, and 76 °F for morning, mid-morning, early afternoon, and late afternoon, respectively. (Ranges were 71 to 72, 72 to 75, 74 to 77, and 72 to 76 °F, respectively). Indoor humidity measurements averaged 57, 47, 47, and 52% compared to outdoor measurements of 73, 53, 46, 49% for the same respective periods. (Ranges were 54 to 61, 42 to 50, 42 to 51, and 49 to 56%, respectively). Most of the indoor $CO_2$ measurements on the day of the survey were 600 parts per million (ppm), compared to consistent outside air measurements of 400 ppm. The temperature, humidity, and $CO_2$ measurements were not remarkable when compared to consensus standards applicable to these kinds of measurements developed by the American Society of Heating, Refrigeration and Air Conditioning Engineers.

Investigation of the ventilation system revealed conditions that could have lead to the thermal comfort complaints. The investigation also found several possible bioaerosol sources in the outside air duct, supply duct lining,and a computer room cooling unit and furnishings. Damp furnishings in the computer room may have resulted from a leak in a drain pipe. Smoking was allowed in the building.

Employee complaints in the Hertz building appear to be due to thermal comfort and potential bioaerosol problems, based on the comments in the questionnaires and the investigation of the ventilation system. A discussion of the problems is presented in Section VI (see pages 10-15) and recommendations are given in Section VII (see pages 15-17).

**Keywords:** SIC Code 4119 (Automobile Rental with Drivers), Indoor Air Quality, Office Buildings, Carbon Dioxide, Temperature, Relative Humidity, Environmental Tobacco Smoke, Ventilation.

## II. INTRODUCTION

In April 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE). This request was received from the employees at a Hertz Rental Car Corporation building near Chicago's O'Hare International Airport. Employee comfort complaints, gleaned from health symptom questionnaires (included with the request), included temperature being too hot or too cold, lack of air circulation, noticeable odors, dust in the air, and disturbing noises. Reported health symptoms included headache, sinus problems, stuffy or runny nose, tired or burning eyes, stiff neck, fatigue, chronic respiratory infections, sneezing, and stiff muscles.

On August 16, 1989, an environmental evaluation was conducted. The survey included wet and dry bulb temperature measurements, carbon dioxide ($CO_2$) measurements, and an inspection of the ventilation system. Results of the survey were presented in a meeting with the office manager at the end of the survey.

## III. BACKGROUND

1. Building Construction

   The Hertz building is a single story concrete, block, and glass construction, within eyesight and approximately northeast of O'Hare International Airport. Nearly the entire perimeter of the building is floor to ceiling glass. The front of the building faces approximately southeast. Floor area of the building is about 5800 $ft^2$.

   In the building there are customer service, office, computer, and utility areas. Customer service areas consist of two counter areas. One occupies the entire southwest part, and the other approximately two-thirds of the southeast part of the building. The back half of the building is office space. There is one enclosed office in the northeast corner of the building, and two enclosed offices along the southeastern side of the building. An enclosed kitchenette and storage room are along the southeastern edge of the office area. A hallway is located along the northwest side of the building. Bathrooms, a computer room, and a furnace and storage room are located in the center part of the building. Entrances with ante-areas are located on the southwestern and southeastern faces of the building. A single door entrance is along the northwestern face of the building.

2. Ventilation System Description

   One air handling unit (AHU), located on the roof, serves the entire building. This unit is a package unit with return and supply fans, heating and cooling coils, and refrigeration system.

   Outside air enters the unit through a horizontal plenum and flows through a regulating damper and filter bank. The return air plenum is parallel to the outside air plenum. Air is supplied to the return air plenum by a return fan located in the unit. Return air is either exhausted from the unit through exhaust air dampers, or flows through a filter bank. The air dampers are located in the plenum downstream of the return air fan. The constant volume, supply fan is located downstream of the filter bank. The outside and return air mix in the filter bank and supply air plenum. A heating and cooling coil are located downstream of the supply fan. Air then flows through zonal dampers into the supply air system.

The AHU supplies air to five ducts, designated as zones one through five. Four of these zones cover the perimeter of the building. One covers the core of the building. The perimeter zones are supplied air via underfloor ducts which appear to be integral with the building slab. Air to these ducts travels from the AHU to the ducts through fiberglass-lined metal ducts. The core zone is supplied air via above ceiling fiberglass-lined metal and flexible fiberglass ducts.

Electronic humidification systems were found on the ducts of the systems. The building management reported that the humidifiers were not used. The reason for discontinued use could not be recalled.

Perimeter supply air is supplied to terminals located at the base of the glass panels which form most of the building's outside walls. These terminals consist of a plenum with opposed-blade balancing dampers and fixed-blade louvers. The louvers are supposed to direct the airflow up the glass surface.

One other cooling unit is located in the computer room. This unit only cools and recirculates air into the room.

Air is supplied to the core of the building through ceiling diffusers. The ceiling diffusers are located throughout the building except in the bathrooms, the furnace/storage room, and the halls. Diffusers are typical fixed-louver ceiling types.

Air is returned to the AHU through ceiling grilles and a ducted return system.

Airflow to the various zones is controlled through electronic zonal dampers in the AHUs. The positions of the dampers are set by thermostats in the building. Electronic output of these thermostats vary with temperature sensed by the thermostat. Setpoint on the thermostats can be changed with an allen key.

Both bathrooms have exhaust fans located in the ceiling. The fans exhaust air into the ceiling space above the bathroom.

## IV. EVALUATION DESIGN

Temperature measurements were made at four general locations in the building four times during the day of the survey. Measurements were made using a battery-operated psychrometer. Three measurement locations were chosen in areas occupied by most of the employees. The fourth location was in the building manager's office. Wet and dry bulb temperatures were measured and the corresponding relative humidity was determined using the manufacturer-supplied curve.

Carbon dioxide ($CO_2$) measurements were taken at the same locations and times as the temperature readings. Ambient readings were taken outside the building two times during the day. Real-time $CO_2$ levels were measured using Draeger detector tubes. A calibrated amount of air is drawn through the chemical-specific media in the tubes using the pump. The chemical of interest, in this case $CO_2$, causes a color change in the media. The length of the stain corresponds to the concentration of the chemical in the air. The concentration is visually read using graduations corresponding to different concentrations on the tube.

A smoke tube was used at all of the outside and inside doors of the building. This was used to determine whether the spaces were under positive or negative pressure and where the airflows in the building.

The outside air plenum, filters, coils, condensate pans, fans, and plenum interiors of the AHU were inspected. The were inspected for potential air contaminant sources and general condition. As part of the inspection, a pocket level was used to determine the tilt of the condensate pans relative to their drains. In addition, the interior of the supply ducts serving the perimeter zones and the condition of the thermostats were inspected.

Questionnaires submitted with the request were taken from Reference 31 in the "References" section (see page 20). Eleven questionnaires were sent with the request. Twelve employees were reported on the request to work in the building.

## 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. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[28-29] 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.[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.

1. Carbon Dioxide Concentrations

Carbon dioxide ($CO_2$) is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, 15 cfm/person for reception areas, and 60 CFM/person for smoking lounges, and provides estimated maximum occupancy figures for each area.[28]

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.

ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, specifies that indoor $CO_2$ levels be less than 1000 ppm.[32] This level is based on odor perception and comfort. It is far below the ACGIH Threshold Limit Value (TLV) of 5000 ppm for industrial environments, and the levels at which adverse health effects would be expected. ASHRAE Standard 62-1989 also recommends ventilation rates of 20 cubic feet per minute (cfm) per person of outside air for offices. This is based on a
specified number of occupants per 1000 $ft^2$ of occupied area. By ventilating the building with the proper amount of outside air, ASHRAE believes that $CO_2$ levels can be kept to less than 1000 ppm. And other contaminants, except for unusual sources, will be kept at acceptable levels. This standard further specifies that the outdoor air meet applicable Environmental Protection Agency (EPA) standards. Applicable standards for outdoor air by EPA and other organizations for certain contaminants are listed in the ASHRAE 62-1989.

2. Thermal Comfort

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.[29]

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended thermal comfort guidelines for building occupants.[29] The perception of comfort is related to: one's metabolic heat production, the transfer of heat energy to or from the environment, physiological adaptation, and body temperature. Heat transfer between the body and the environment is influenced by such factors as: the air temperature, humidity and movement, temperature and heat radiating properties of the body and surrounding surfaces, and insulative properties of clothing. The American National Standards Institute ANSI/ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[29]

The conditions for thermal comfort are presented in a chart in ANSI/ASHRAE Standard 55-1981 (Figure 2, ASHRAE Thermal Comfort Chart, in the standard). This chart is for "persons clothed in 'typical' summer or winter clothing, at light, mainly sedentary, activity." The abscissa values on the chart are operative temperatures. Operative temperature is approximately the same as normal room (dry bulb) temperature unless there is significant radiated heat from, or to, the occupant. Other parameters, such as air velocity around the person's body, change in temperature relative to time, and other factors influence feelings of comfort. Therefore, several factors must be considered when assessing thermal comfort.

3. Ventilation System Inspection

Criteria for the inspection of ventilation systems relative to preventing indoor air quality problems, mostly, do not exist. Inspections are made to identify potential contaminant sources (microbiological, particulate, or volatile organic chemical), conditions suitable for contaminant generation, sources of problems reported by occupants (odors and comfort), and conformance with current standards, codes, and acceptable practices.

# VI. RESULTS AND DISCUSSION

1. Environmental Evaluation

Temperatures during the first reading for the day (about 8:00 a.m.) averaged 72 °F compared to an outside reading of 70 °F. Mid-morning (about 10:00 a.m.) and early afternoon (about 1:25 p.m.) readings averaged 75 °F compared to outside readings of 74 and 76 °F, respectively. The last readings (about 4:30 p.m.) averaged 74 °F compared to an outside reading of 76 °F. Humidity readings taken at the same times as the temperatures averaged 57, 47, 47, and 52% compared to outside readings of 73, 53, 46, and 49%, respectively.

All of the temperature and relative humidity levels on the day of the survey were about the middle of the comfort range on the ASHRAE comfort chart. However, thermal comfort-type complaints were listed on every questionnaire. This discrepancy leads to the assumption that conditions on the day of the survey were not typical. This may also involve some factor not accounted for in the readings. One possible explanation for the discrepancy was that radiant heat due to the large areas of glass in the building was not accounted for in the temperature measurements. In addition, conditions found in the heating and ventilating system further showed that thermal comfort problems were possible.

Carbon dioxide ($CO_2$) measurements on the day of the survey were 600 ppm at most locations, (500 ppm at one location for one reading). Outside $CO_2$ measurements were a constant 400 ppm. These $CO_2$ levels indicate that adequate outside air was entering the building on the day of the survey. However, several questionnaire responses complained about stale air, indicating that, at times, enough outside air was not being supplied to the building. Occupants may also complain of stale air if air temperature is too high or if air movement is too little.

Two factors could have influenced the $CO_2$ measurements on the day of the survey. First, the building did not have a constant occupant density. This building could possibly have a much larger number of transient occupants (customers) due to the nature of the business. Customer loads on the day of the survey were relatively light. On very busy days, larger occupant loads could elevate $CO_2$ concentrations. Second, the temperatures were in the range that may have caused the AHU's economizer system to operate. If the economizer was working, more outside air could be entering the building than during times of temperature extremes.

2. Ventilation System Inspection

The following are findings from inspection of the ventilation system:

a. The outside air entrance and plenum were lined with fiberglass insulation. The lining was pulling away from the wall of the duct. The insulation was also wet and moldy, apparently, due to rain entering the outside air duct. The mold growth and decaying condition of the insulation could release bioaerosols or other contaminants, such as fibrous glass. These could be circulated into the building via the AHU. Since the type of filters used in the AHU (discussed later) were not very efficient, they may not capture many of these contaminants.

   Outside air ducts and plenums are not usually insulated. The air in the plenum is normally at the same temperature as the outside air. In addition, horizontal entrances usually have some method for preventing rain from entering them, such as angled entrances or louvers. Horizontal entrances are also usually designed for a low air velocity to prevent rain from being pulled into the duct.

b. The location of the exhaust air dampers, near the outside air intake, made recirculation of exhaust air possible. Exhausts from the building should be located to minimize recirculation.

c. Passive electrostatic filters were used in the AHU. Test results have shown that passive electrostatic filters have a very low efficiency (<20%), according to the ASHRAE Dust Spot Test, the standard test for filter media (ASHRAE Standard 52-76[33]).

   ASHRAE recommends that filters with Dust Spot Test efficiencies of 35 to 60% be used in office buildings[34]. Current practice for office buildings is to use filters with efficiencies in the 85% range[35]. Filters of this efficiency should effectively filter contaminants of interest, such as pollen, mold spores, or particulates from combustion.

An additional problem with passive electrostatic filters is their metal frame (a feature which makes the filter cleanable). Air (and contaminants in the air) can bypass the filter between the frame and holder. Metal frames usually do not have a gasket to form a tight seal between the filter and the frame. Gaskets, in these cases, are usually mounted on the filter frames, and tend to wear out and fall off with time. Filters, manufactured with gaskets, installed properly, effectively prevent bypassing and eliminate the problems with worn gaskets.

Old pieces of former filters were found in the filter plenum, despite the new appearance of the filters in the unit. Indicating that the filters may not have been well maintained in the past. Filters should be inspected frequently for their condition. Replacement of the filters should be based on manufacturer's recommended maximum pressure drop across the filter bank and not according to a set period.

d. The condensate pan was tilted toward the drain on one side and away from the drain on the other, indicating that the pan may have been bowed in the middle. Standing water was on the side of the pan away from the drain. Debris was widespread across the bottom of the pan. In addition, slimy material was oozing off the coil into the pan on the side opposite the drain.

   Water was standing at the condensate pan drain. Debris about 1/4" deep surrounded the entrance to the drain. Drainage was slow even though the debris was moved, indicating that the drain may have been partially blocked or improperly constructed.

   Coils and condensate pans should be routinely cleaned and pans should be constructed so they drain properly (no standing water) and rapidly. The combination of debris and water serve as substrate upon which mold, bacteria, algae, and other biologicals can grow and possibly generate bioaerosols. These bioaerosols can be allergic or infective agents. Since the generation of bioaerosols is downstream of the filter, bioaerosols can readily be carried into the building.

e. The vertical ducts for the perimeter units had access doors to allow inspection of the duct interiors. The insulative liners for these ducts were frayed, coated with dirt, and had water marks where water may have run down the duct. Mold appeared to have been growing on the liner. The ducts continued under the building slab where the potential for water incursion existed.

f. Each of the supply ducts had volume dampers. All the dampers were either fully or nearly fully open. Their settings indicated that the system could have been out of balance because the duct runs obviously did not have equal pressure drops.

g. The damper settings for the perimeter air terminals were found to range widely, even those next to each other. In general, the setting for dampers near each other should be about the same. Some of the dampers were also missing. These dampers are important because they help regulate the airflow to the various terminals by equalling the pressure drop between terminals in one zone. If a damper is missing or set too far open, that terminal will get more air than design. In return, it will rob air from other terminals in that zone and possibly other zones.

   Pieces of fiberglass and other debris were found in the plenums beneath the terminals. In addition, the air coming from some of the terminals had a mold odor.

h. Thermostats were not set uniformly. One thermostat was disabled so that the zonal damper for the area was be continuously set wide open. The settings and apparent tampering by the building occupants indicated that thermal comfort problems existed in the building. These may have been the result of problems with the air handling system (poor maintenance, improper air balance, etc.), and/or improper design of the current system.

   The zonal control system is a constant volume system which inherently has air balance problems because of its inability to regulate airflow between its different zones. When one zonal damper closes, the air that has been going to that zone is shunted to other zones to a certain extent. Even though the units usually have a bypass system for each zonal damper. On the other hand, when all of the zonal dampers are open, airflow to all the zones will be reduced.

   Changing air flows coupled with a control system which did not properly respond to overall thermal load changes or which was not properly sized for the thermal loads could have led to the occupants' complaints that the building was frequently either too hot and too cold.

3. <u>Other Observations</u>

During inspection of the computer room, the carpeting and the lower wall near the cooling unit were water-soaked. The water was reportedly due to a finger-sized hole in the P-trap of the sink in the kitchenette. (During the survey, a plumber had been called to repair the problem.) However, inspection of the cooling unit showed that water and debris were in the unit's condensate pan. Insulation on the pan access door and around the pan was wet and showed signs of mold growth. In addition, the pan was drained by a sump-type pump whose outlet ran up-hill from the pump. When the pump was turned off, the water in the drain line could run back down-hill. It could run out of the pump, possibly overflowing the pan.

Smoking was allowed in the building. Several employees complained about the smoking in their questionnaire responses. NIOSH believes that environmental tobacco smoke (ETS) is a human carcinogen and the risk of cancer should be decreased by minimizing employee exposure. NIOSH favors having employers assess conditions that may result in employee exposure to ETS and take steps to reduce exposures to the lowest feasible concentration. The best way to control worker exposure to ETS is to eliminate tobacco use from the workplace and to implement a smoking cessation program.

Until smoking can be eliminated, employers should protect nonsmokers from ETS by isolating smokers. Isolation of smokers should be accomplished by designating separate, enclosed areas with their own ventilation. Air from these areas should be exhausted directly outside and not recirculated within the building. Or they should be mixed with the general dilution ventilation for the building. Recirculation of exhaust into the building should be prevented. ASHRAE recommends that 60 cfm of outside air be supplied to the area; however, this air can be clean air from other parts of the building. The smoking area should be kept under negative pressure relative to surrounding areas. Warning signs should be posted at the entrances to the workplace in both English and the predominant language of non-English-reading employees. These signs should state that smoking is permitted only in designated areas. Designated smoking areas should be clearly identified by signs.

The bathroom exhausts recirculate their air inside the building. Even though the bathroom exhaust is blown into the ceiling space, this air, containing contaminants from the bathroom, can get into the general air inside the building. Bathroom exhaust, as well as utility closet exhaust, should be ducted outside the building where it cannot recirculate back into the building.

The building was found to be under positive pressure. This should be continued because infiltration of contaminated air into the building is minimized.

Several questionnaires contained complaints about cleaning of carpets during occupied hours. Some of the chemicals used in cleaning, including carpet cleaning, are known irritants. If the building is not adequately ventilated with outside air during cleaning, these chemicals could build to concentrations where they are irritating to building occupants. Even if cleaning is performed at night, inadequate ventilation of the building could lead to concentrations of chemicals in the air. These chemicals are irritating to occupants entering the building the next day. Any activity which involves irritating or odorant chemicals, including cleaning, should be performed during unoccupied or minimal occupancy times. In addition, the building should be ventilated with outside air during the operations. The operations should be performed far enough ahead of time that their chemicals have time to reach concentrations which are not irritating to the occupants.

## VII. RECOMMENDATIONS

1. The current ventilation system and controls should be reviewed by a mechanical design and controls firm. This analysis would be for the system's adequacy in maintaining the thermal comfort of the occupants under the varying conditions placed on the building. Changes should be made if deemed necessary.

2. The insulation in the outside air duct should be removed. The AHU should not be running during removal or post-removal cleanup. In addition, the design of the outside air duct should be corrected so water does not enter.

3. Filters of the highest efficiency possible without effecting airflows should be installed in place of the current passive electrostatic filters. Filters should not allow bypassing and should be maintained as discussed in the previous section (see pages 11-12).

4. The inside of the air handling system including the coils and condensate pan should be cleaned. The condensate pan should be fixed so all of pan drains properly and rapidly. Cleaning of the coils and pan should be routinely performed according to the manufacturer's recommendations or more often, as dictated by experience.

5. The moldy and frayed insulative lining in the duct or the entire ductwork downstream of the AHU should be replaced. Since both solutions are equally effective, the choice of alternative may be based on the cost. Installation of new insulation or ductwork should be according to the Thermal Insulation Manufacturer's Association (TIMA) and the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) standards.

6. The underfloor ducts and plenums for the perimeter terminals should be inspected for standing water and debris. Debris, if found, should be cleaned from the ducts and plenums, and standing water problems corrected. Mold sources, if found, should also be corrected or removed.

7. The thermostats in the building should be calibrated and replaced if defective.

8. A smoking policy and smoking areas should be established as discussed in the previous section (see pages 14-15).

9. The bathrooms should have an exhaust system which exhausts outside the building as discussed in the previous section (see page 15).

10. Carpets should be cleaned during times of minimum occupancy and at a time when the carpets will have time to dry thoroughly before maximum occupancy. The air handling system should be ventilating the building during any cleaning in the building.

11. Water-damaged carpeting and wallboard should be replaced in the computer room. Insulation in the cooling unit in the computer room should be replaced and the unit's drain pan and coil cleaned. Drainage problems for the unit should be corrected. This unit should be placed on a routine cleaning schedule.

12. The outside airflow rate should be checked so that it meets the 20 cfm\person criteria recommended by ASHRAE for office spaces. For systems with economizers, actual measurement of the minimum outside airflow rate is made when the outside air damper is in minimum position. Setting of the flow rate according to a percentage of the damper position or other indirect means may only

be used as a rough initial setting. Verification of the flow rate needs to be made by direct measurement of the airflow.

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