

Final Technical Report

**Evaluation of the James Lawrence King Justice Building,
Miami, Florida**

Submitted to: General Services Administration (Southeast Sunbelt Region)



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August 18, 2002

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II. Executive Summary

The objective of this report is to report on a study of the James Lawrence King Federal Building and Courthouse in Miami, Florida. Lessons learned and recommendations to supplement the facility manager's knowledge of "the mold problem" are also included. Management of moisture intrusion and mold growth indoors is a science currently under heavy debate. This report and included guidelines condense current knowledge of management practices and integrates state of the art recommendations of the leading professional organizations surrounding this science.

The Southeast Sunbelt Region of the General Services Administration (GSA) owns and operates buildings located in the state of Florida and eight other states in the region. The purpose of this study was to select a GSA building representative of the facilities operating in this sub-tropical climate and generate recommendations that, when implemented, will consistently maintain an indoor environment that is detrimental to microbial proliferation but satisfactory to tenants and the public. The study investigated the methods of humidity control, HVAC operational procedures, HVAC system design and/or retrofit options, and building envelope technology.

The findings of the studies conducted indicate the building operators need to consistently monitor the moisture levels and perform repairs to the buildings as needed to prevent future problems. Possible moisture sources may be chronically high humidity and/or moisture intrusion that may be occurring around deteriorated caulking on the exterior of the building. On the average, other indoor air quality (IAQ) parameters were within acceptable ranges established by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Humidity levels were slightly above the EPA recommendation for minimizing microbial growth. Afternoon carbon dioxide concentrations approached the ASHRAE recommended limit in some areas.

Recommendations

Provide a slight increase in outside air to the building, conduct further long-term investigations of the chronic humidity levels, repair deteriorated caulking on the exterior of the building, and use high efficiency particulate air filtered vacuums for cleaning.

Successful mold control in buildings located in hot and humid climates involves close attention to the HVAC performance in terms of ventilation, dehumidification, pressurization and filtration. Table 1 summarizes the specific findings and recommendations.

Table 1. HVAC System Review and Summary

Category	Criteria	Findings	Recommendations
Ventilation	ASHRAE 62-1999 requires 15 CFM per person.	Outside air dampers were operated so that increasing CO ₂ levels during afternoon time period were observed.	Modify systems to provide code required ventilation quantity, but with proper moisture control
Dehumidification	Provide supply (discharge) air at dew point temperatures less than 60° F.	Present control sequence adjusts discharge air temperature based on space return air temperature, allowing discharge air temperatures to rise above recommended levels	Revise control algorithm to supply 55° F during summer conditions when outside air temperature is > 60° F. This will tend to overcool core spaces and will require modifications to core VAV boxes.
Pressurization	Maintain building at least 2 Pascals positive with respect to outdoors.	Building is operating in a negative pressure mode, with the most negative floor at grade.	Modify the air handling systems to provide adequate outdoor air to maintain positive building pressurization.
Filtration	ASHRAE recommends at least 35% or MERV-8 for general commercial buildings. GSA buildings should have 85% or MERV-13 filters.	Filters presently used are MERV-8 or less, but are not the type recommended for hot humid climates. Filters are changed on the basis of time, not filter loading, which means that the filters may not reach their design capture efficiency prior to change out. In addition, the beverage board frames support the growth of mold/mildew.	Use extended surface filters suitable for hot, humid climate, with synthetic media, pleated or short bag configuration that will have higher initial efficiency and remain in place longer with more dust holding capacity.

Best Practices for Optimizing Indoor Air Quality in Buildings

Commercial building design, construction, and operational measures necessary to create a good indoor air environment are well established. This list is based on the recommendation of the research participants, contributors, and the references shown at the end of this report.

- Understanding relationships between ventilation, indoor air pollutant sources, and airborne concentrations.
- Designing and operating a building from “cradle to grave” considering indoor air quality concepts.
- Designing, optimizing, and operating the ventilation system for optimum indoor environment.
- Identifying and understanding indoor pollutant sources.

- Developing and implementing indoor pollutant source control strategies.
- Developing and implementing materials selection and specification minimizing indoor air pollutants.
- Understanding and following construction practices that optimize indoor air quality.
- Following operation and maintenance practices that optimize the indoor environment.
- Designing and implementing change of use, renovation, and de-mounting practices that minimally impact and optimize the indoor environment.
- Developing a plan and manual for optimizing and maintaining the indoor environment throughout the life of the building, including communication with and training of the building occupants and maintenance staff.

The best practices are extremely important for preventing and controlling microbial growth in buildings. The design and operation of a building is critical for preventing microbial growth, including:

- Sealing of the building shell to prevent moisture intrusion, which can be a major problem in a building located near an ocean and eliminating moisture sources through roof repair, flashing modification, installation of a drainage layer beneath cladding, and control of soil moisture entry.
- Providing proper and continuous dehumidification of the building supply air controlling the dew point temperatures to less than 60° F and indoor relative humidity between 30% and 60% RH, as specified in ASHRAE Standard 2001.
- Pressurizing the building to the outside to help prevent moisture intrusion into the building.
- Understanding the moisture dynamics within the building and how they may cause moisture problems.
- Selecting building materials, such as not using vinyl wallpapers, so that moisture is not trapped behind walls and other cavities.
- Selecting non-porous building furnishings that are less likely to absorb moisture and other indoor pollutants, such as cushioned cubicles.
- Sealing all ductwork so that cold air does not escape in the plenums creating cold spots allowing moisture accumulation and minor flooding.

- Maintaining adequate and continuous ventilation throughout the building at the correct level for the occupant density for flushing of generated contaminants and moisture control.
- Following stringent operation and maintenance procedures for optimum cleanliness of the ventilation system and the interior of the building to remove any surface microbes and to remove nutrient sources (at a minimum follow the recommendations in Table 8-1 of ASHRAE Standard 62-2001 (ASHRAE 2001) and in Greening of Federal Facilities, Section 8.1 (Building Green 2001)).
- Repairing all water leaks, drippy faucets, and clogged or improper drainage areas.
- Reducing tracked in dirt and contaminants using effective track-off mats at entry points that are cleaned daily and vacuumed with machines that have HEPA filters.
- Using adequate filtration, at a minimum MERV 10, to remove outside microbes from the outdoor supply preventing distribution into the ductwork and interior of the building.
- Replacing any porous and semi-porous water damaged materials, wherever possible, and thoroughly cleaning and drying any materials that cannot be removed and replaced.
- Eliminating the use of interiorly fiberglass-lined ductwork and HVAC systems. ASHRAE Standard 62-2001 states that material surfaces in a ventilating system “shall be determined to be resistant to mold growth in accordance with a standardized test method, such as UL 181 “Mold Growth and Humidity Test,” or ASTM C1338 “Standard Test Method for Determining Fungi Resistance of Insulation Material and Facings.”

Management Support System and Action Plan

This system is designed from the viewpoint of the facility manager. It consists of a set of specific questions and procedures derived from good operation and maintenance practices, lessons learned from research, and ASHRAE guidelines. The questions followed by prescribed procedures are given to lead the manager along a systematic path toward a solution, or at least an educated guess of the direction in which the solution may lie.

The initial question one needs to answer is “why?” Specifically why is there an inquiry concerning mold? There are three general answers that will lead the FM along a specific path. As illustrated in the over view box diagram and flow chart given at the end of this section, the three classes of answers are as follows:

1. An event occurred, such as a flood or some other free water episode;
2. Mold is obviously present; or
3. There are complaints of a moldy odor or quite simply the FM needs to conduct an investigation.

If a moisture event has occurred, action to clean and dry the affected area must occur within 24 to 48 hours. The University of Minnesota publishes a website describing different methods to alleviate the excess moisture depending on the situation. Remediation procedures vary depending on whether the water was clean liquid; steam, unsanitary, or contaminated. This site is available at: www.dehs.umn.edu/iaq/flood.html.

Secondly, if it is obvious that mold is present; the FM is directed along a different pathway. Specifically, one must determine as accurately as possible how much mold is present. This determination needs to be conducted by an expert. It is recommended that the expert retained not be the contractor who will eventually perform the remediation. The New York City Department of Health & Mental Hygiene's Bureau of Environmental & Occupational Disease Epidemiology has authored "Guidelines on Assessment and Remediation of Fungi in Indoor Environments" which is commonly referred to as the "New York Protocol". Any mold remediation expert should have knowledge of this standard which can be found at:

Finally, if the answer to the question of "why" evolves from an occupant complaint or simply the need for an inspection, a separate course of action is suggested. This course of action requires the FM to conduct a series of investigations and answer a series of questions. Depending on the results of the investigations or answers to the questions, a distinct course of action is suggested. These range from fixing leaks and other areas allowing moisture to enter the buildings, to redesigning the building pressurization scheme. It is suggested that the investigations be carried out as indicated on the flow chart. This will ensure that the less expensive alternatives are carried out first. For example an investigation of tenant sources of moisture and changing tenant practices is less costly than the investigation involving the purchase of humidity control devices.

You will notice that these investigations end with using the New York protocol to abate any mold found; a following up with the source of the complaint; and, practicing general mold control strategies.

Figure 1. Mold Management Process Overview

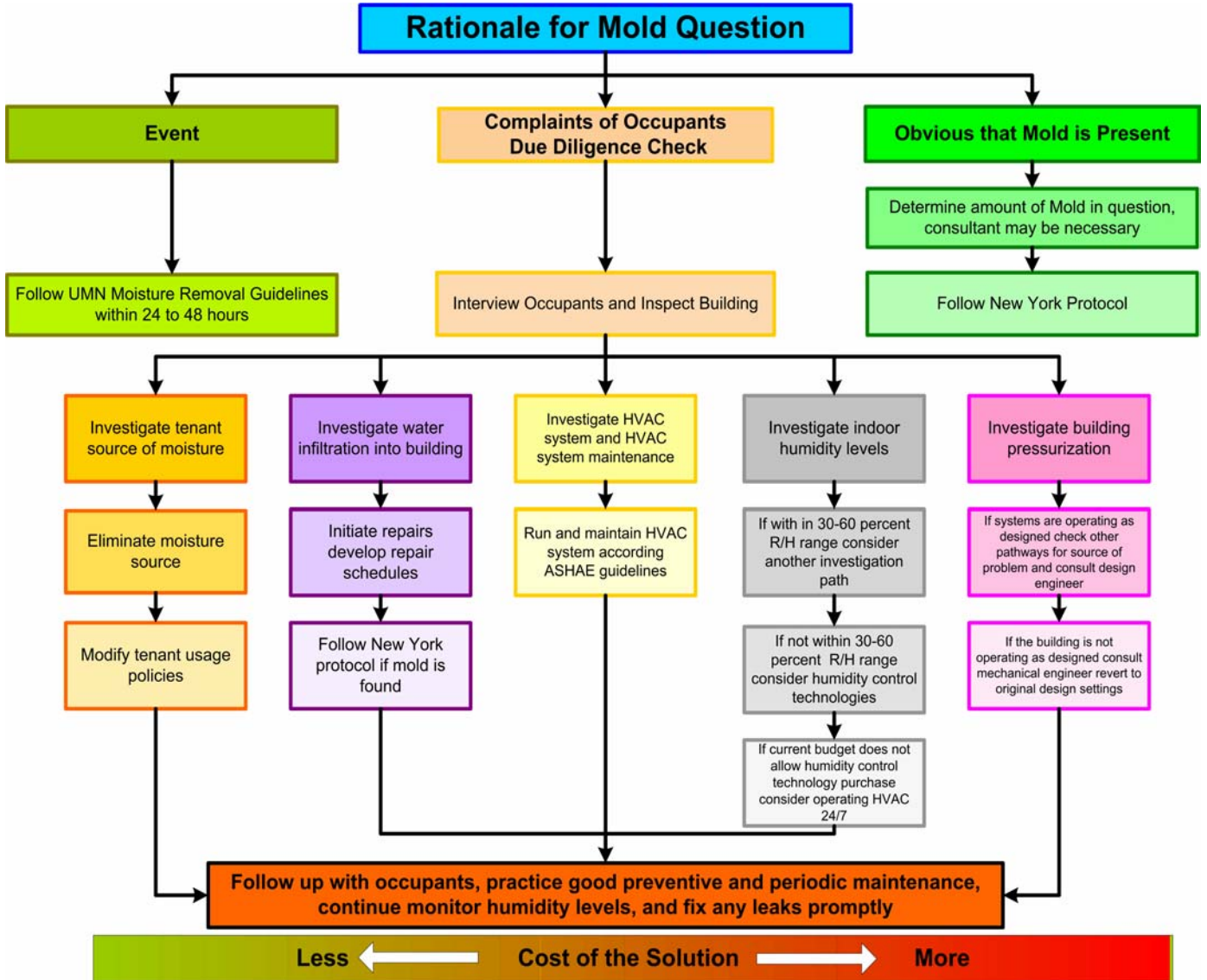


Figure 2. Mold Management Process Flow Chart

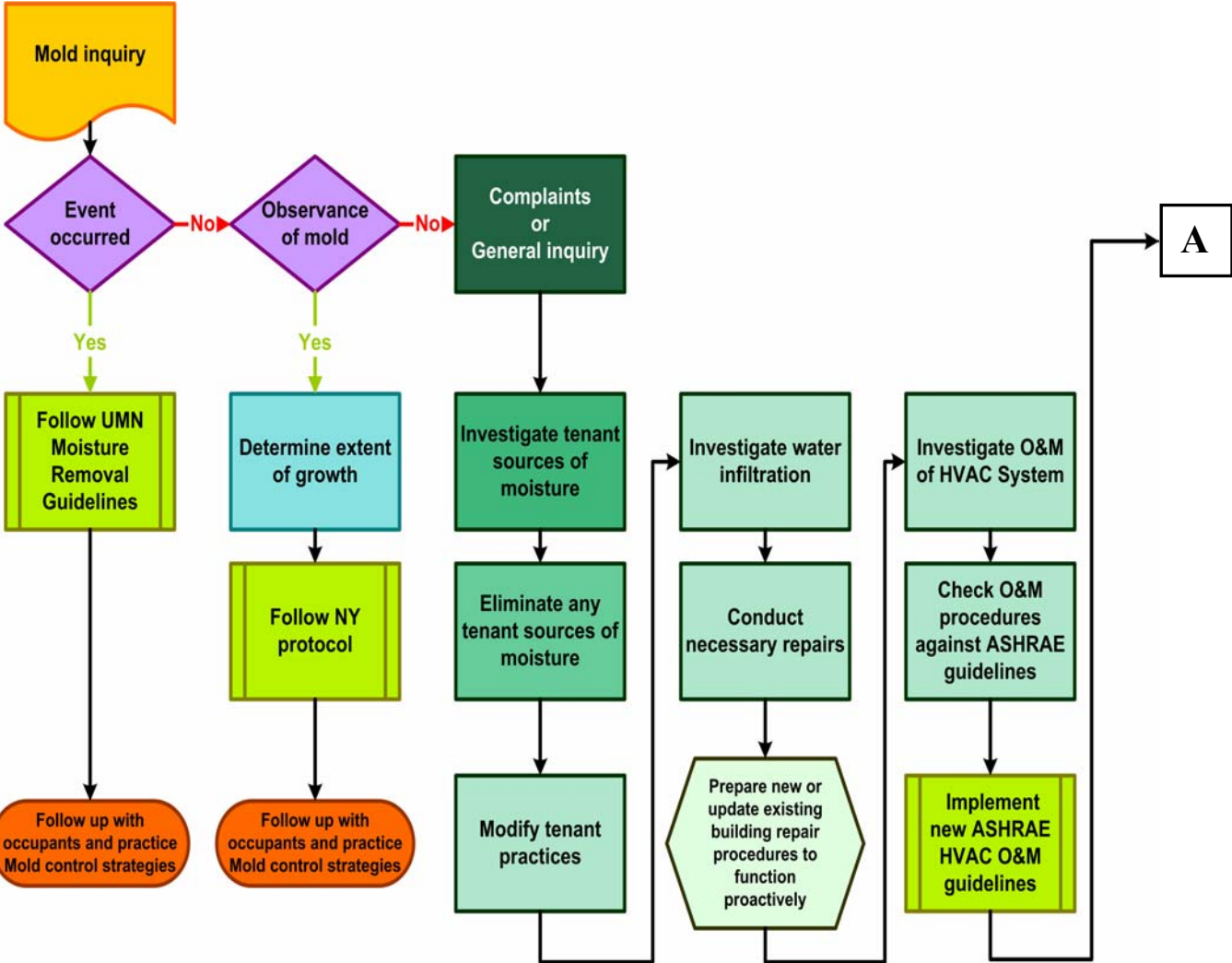
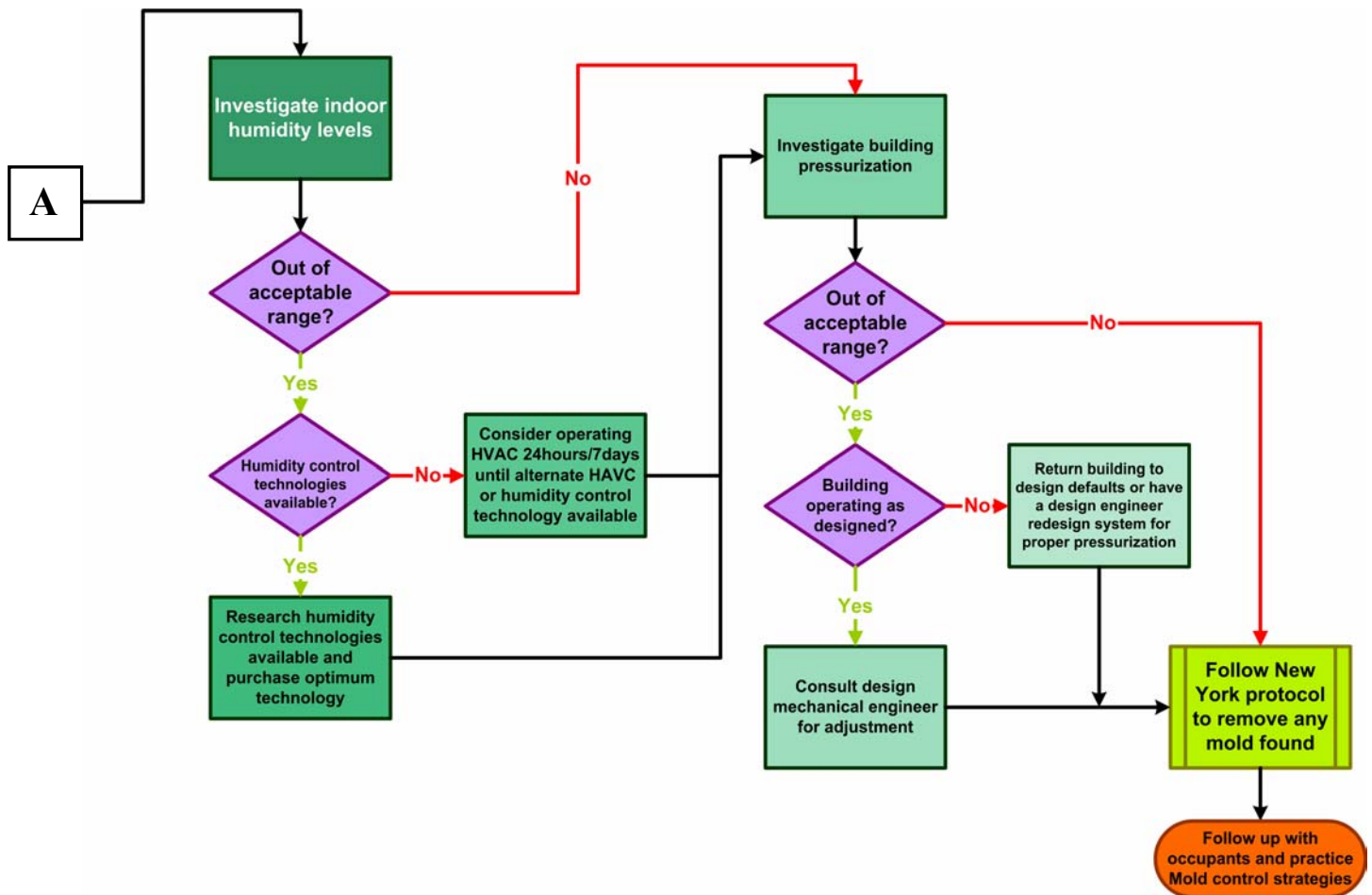


Figure 2. Mold Management Process Flow Chart (Cont.)



Mold Control Strategies

General mold control strategies are as follows:

- Maintaining the building envelope and any other possible source of moisture leaks by repairing gaps and material failures promptly.
- Maintaining building pressure at least 2 Pascals positive.
- Controlling humidity levels to supply air at dew point temperatures less than 60° F.
- Keeping HVAC coils clean and free of debris.
- Eliminate sources of standing water.
- Using higher efficiency filters and changing filters as needed.

III. INTRODUCTION AND SCOPE OF INVESTIGATION

Region 4 of the General Services Administration (GSA) owns and operates buildings located in the state of Florida. Buildings in Florida, and the coastal south, are plagued with moisture intrusion and high relative humidity such that many are now being found to harbor mold and possible mold spore contamination. The purpose of this inquiry was to study the James Lawrence King Justice Building (FL 102 IZZ) located in Miami, Florida and to provide recommendations to consistently maintain an indoor environment that is detrimental to microbial proliferation and satisfactory to tenants and the public. The James Lawrence King Justice Building in Miami, Florida was selected as a representative facility in a sub-tropical climate for this indoor air quality study.

The evaluation included investigation of: methods of humidity control, HVAC operational procedures, HVAC system design and/or retrofit options, and building envelope technology. This study is a part of GSA's preventive policy for indoor air quality problems in buildings through the implementation of a pro-active program.

Historically, many multi-story office buildings in tropical and sub-tropical climates have had problems associated with moisture intrusion and microbial proliferation. The General Services Administration, responsible for the operations and maintenance of many such buildings, sponsored this research project to provide recommendations regarding building construction, maintenance, and operations that will prevent/minimize the occurrence of microbial contamination and provide acceptable indoor environmental quality for building occupants.

The James Lawrence King Justice Building is a 12-story office/courthouse containing 247,685 square feet of gross space. The building is constructed of pre-cast concrete with steel reinforced concrete columns. Each floor is constructed of concrete on corrugated metal deck. The building is used as a Federal court and administrative offices. The layout of office space varies with some having floor to ceiling walls and some consisting of cubicles constructed of metal and fabric. The ceilings throughout the finished areas of the building are lay-in-ceiling panels. The floors are finished with carpet and terrazzo. The walls are typically wallboard construction with vinyl wallpaper applied in many areas.

Over the past several decades, human exposure to indoor air pollutants is believed to have increased due to a variety of factors, including the construction of more tightly sealed buildings, reduced ventilation rates to save energy, the use of synthetic building materials and furnishings, and the use of chemically formulated personal care products, pesticides, and household cleaners. During the past twenty-five years, interest in constructing energy-efficient buildings has increased. Some current construction practices can trap pollutants that normally form inside the building along with those brought inside with everyday traffic. Heating, cooling and ventilation systems that recycle existing indoor air and windows that do not open, can result in greater concentrations of indoor pollutants because they do not allow enough fresh outside air to dilute the trapped pollutants.

IV. QUESTIONS AND EVALUATION PROCESS

The evaluation of the building was intended to answer the following questions:

- 1) In terms of building systems, operational procedures and indoor air quality, what would one expect to see in this building? (i.e. temperature and humidity conforming to ASHRAE standards, capacity of system based on heat and occupancy load, etc.)?
- 2) What is the actual state of the building systems and indoor mold/moisture problems of this building, and what operational procedures or building conditions contribute to this state?
- 3) Identification and definition of current or potential problems that are/could contribute to an indoor mold problem.
- 4) Of the items or conditions that are not what they should be, what is the specific problem and what is the cause (or causes) of each problem?
- 5) What types of technology (current and emerging) are available to assist with moisture and humidity problems in a building? Would any be appropriate to this building? Would any be universally appropriate for buildings in a sub-tropical climate?
- 6) How are GSA's energy reduction goals and the current operational practices restricting or facilitating the maintenance of a comfortable and lower humidity indoor environment?
- 7) Recommendations for correcting the problems in this building and would these corrections correlate to other buildings with similar problems? Recommendations for design criteria that should be added or changed for future GSA buildings?

V. INVESTIGATION PROCESS

The investigators reviewed the industrial hygiene survey report, building engineering reports, drawings, and other documentation of building history, design, and operations in preparation for this project. The research team consisted of specialists in the fields of industrial hygiene, mechanical/HVAC engineering, facility management, energy engineering, architecture, and others as necessary.

This study started with developing a profile of the building, looking for potential indoor air quality problems. The study used a rough plan of the building to conduct the data collection, and reviewed the comprehensive plans for mechanical systems. A review of construction and operating records was combined with an inspection of building conditions. The study focused on potential indoor air quality concerns and identified building areas that require special attention to prevent problems in the future.

The walkthrough inspection and interview with the facility manager helped the researchers to identify potential problem areas and prioritize budgets for maintenance and future modifications. In the future, if this report is combined with information on lighting, security, and other important systems, it can become a manual for this building. The process of gathering information was as follows:

- Collected and reviewed existing records and interviewed building manager.
- Conducted a walkthrough inspection of the building, looking for unpleasant and lingering musty odors, discolored or blackened areas, damp areas, water marks, peeling or soft surfaces.
- Collected information on the HVAC system, pollutant pathways, pollutant sources, and building occupancy.

During the walk-around inspection, the investigators determined the building characteristics, discussed with building engineering personnel the proper operation of the HVAC systems, investigated the HVAC system, and collected samples to identify potential causes of the problem. The walk-around inspection of this building covered affected areas. Factors to be evaluated included inside contamination sources, and the HVAC system, e.g., location of air source, contamination, and proper operation.

A visual inspection was conducted in the majority of the occupied spaces in the building. Few areas of water damage to ceiling tiles or other interior surfaces were noted. One exception was in the Federal Court Library located in the southeast corner of the ninth floor where some water spotting was observed around the windows on the east side. Vinyl wallpaper that had reportedly been installed within the past year in the southeast corner room of the library was blistering and peeling. No areas of visible mold growth were observed. Maintenance personnel reported that the caulking between the exterior

cement panels and around the windows was deteriorating, allowing water intrusion to occur, particularly on the east side of the building¹.

Moisture measurements were conducted with a Delmhorst meter along the east wall of the ninth floor Federal Court Library. Moisture content of the wallboard was elevated in the northeast corner of the library, from the northernmost window to the corner.

The scope of work for the Indoor Air Quality (IAQ) investigation included the following tasks:

- A visual inspection of the building and the interior of selected air-handling units to evaluate sources, pathways, and receptors. Where water damage, mold, or suspect moisture was observed, surface moisture was measured.
- Measurements for temperature, humidity, carbon dioxide, and respirable particulate at one location on each of 12 floors for five consecutive days.
- Collection of six airborne culturable fungi and six airborne endotoxin samples from odd numbered floors on Tuesday, Thursday, and Saturday and even numbered floors on Wednesday and Friday. Collection of two outdoor samples each of airborne fungi and endotoxin on five consecutive days for comparison to indoor samples.
- Collection of 12 dust samples, one from each floor, for culturable fungi.
- Collection of 12 dust samples, one from each floor, for endotoxins.

¹ Personal communication with Jim Jones of General Services Administration, Miami, Florida

VI. RESULTS OF STUDY

QUESTION #1: In terms of building systems, operational procedures, and indoor air quality, what would one expect to see in this building? (i.e. temperature and humidity conforming to ASHRAE standards, capacity of system based on heat and occupancy load, etc.)?

HVAC Systems

Ventilation for the building is supplied by single-duct, variable air volume (VAV) systems. Air is circulated via a ducted supply and open return plenum. Floors 1-9 are serviced by a main air-handling unit located in the mechanical room on each respective floor. The air-handling units for floors 10-12 are located in the penthouse. Pneumatically controlled VAV boxes that operate by static pressure are located in the plenum. On every floor there are 20-21 VAV boxes that service 4 or 5 rooms, except the first floor which has 7 VAV boxes. The perimeter VAV boxes are equipped with electric reheat coils. All VAV boxes are equipped with polyester filters. The interior VAV boxes do not have a minimum set point for outside air supply. Therefore, when there is no heating or cooling load, outside air will not be provided to the interior spaces.

The comfort of building occupants is largely a function of the temperature and relative humidity in the occupied space. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standard, “Thermal Environmental Conditions for Human Occupancy” provides guidelines intended to satisfy at least 80% of the building occupants.² These guidelines, expressed for the summer and winter seasons to reflect differences in dress by building occupants, are provided in Table 2.

Table 2. ASHRAE Recommended Ranges of Temperature and Relative Humidity During Summer and Winter Months

Relative Humidity	Winter Temperature	Summer Temperature
20%	69.0 – 76.5	74.5 – 80.5
30%	68.5 – 76.0	74.0 – 80.0
40%	68.5 – 75.5	73.5 – 79.5
50%	68.5 – 74.5	73.0 – 79.0
60%	68.0 – 74.0	72.5 – 78.0

Based on the average humidity of 52.7% the average temperature of 73.3° F falls within the ranges recommended by ASHRAE for summer and winter temperatures. The average high outdoor temperature was 76.7° F over the three-day sampling period, somewhere between what might be considered summer and winter temperatures in Miami, Florida. Therefore, the average indoor temperature of 73.3° F was probably comfortable for most

² American Society for Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE 55-1992, Thermal Environmental Conditions for Human Occupancy, ASHRAE, Atlanta, GA 1992.

occupants of the building, depending on how they were dressed. The standard deviation of 1.3° F indicates that approximately 68% of the measured temperatures fell within the range of 72.0° F to 74.6° F.

Humidity levels were within the range of 30 to 60% recommended by ASHRAE to minimize growth of allergenic or pathogenic organisms.³ The Environmental Protection Agency (EPA) recommends maintaining chronic indoor humidity levels below 50% to minimize conditions for microbial growth.⁴ The average humidity of 52.7% during the study period was slightly higher than the EPA recommended value.

Carbon Dioxide

Carbon dioxide concentrations are measured during indoor air quality investigations to assess the adequacy of ventilation. As people respire, they exhale carbon dioxide. If there is not enough outside air coming into the building, the carbon dioxide levels will increase. Therefore, carbon dioxide can be used as an indicator to determine if ventilation is adequate to minimize the presence of odors from occupants and low emissions from building products. The ASHRAE standard “Ventilation for Acceptable Air Quality”, establishes 1000 parts per million (ppm) carbon dioxide as a level above which ventilation may be inadequate.⁵ Carbon dioxide concentrations measured during the morning hours over the five-day period ranged from 489 to 1052 ppm. The average concentration in the morning hours was 646 ppm with a standard deviation of 102 ppm. Afternoon carbon dioxide concentrations ranged from 548 to 1067 ppm. The average concentration during the afternoon hours was 810 ppm with a standard deviation of 164 ppm.

Carbon Monoxide

Carbon monoxide levels are measured during an indoor air quality investigation to determine if there are combustion sources within the building that are not being adequately vented or if there are outside sources, such as vehicle exhaust, entering the building. The ASHRAE ventilation standard has established 9 ppm or greater of carbon monoxide within an occupied space as being a level of concern.⁶

Fungi Sampling

Airborne Culturable Hydrophilic Fungi

In mechanically ventilated buildings, the concentration of fungi is usually lower than the outdoor concentration due to the filtration of some of the airborne spores. In naturally ventilated buildings (in the absence of building-associated sources), indoor fungal air

³ Ibid.

⁴ United States Environmental Protection Agency, Office of Air and Radiation, Indoor Environment Division, Mold Remediation in Schools and Commercial Buildings, EPA 402-K-01-001, March 2001.

⁵ American Society for Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE 62-1989, Ventilation for Acceptable Air Quality, ASHRAE, Atlanta, GA 1990.

⁶ Ibid.

concentrations may nearly equal outdoor concentrations.⁷ Indoor fungi concentrations that are higher than outdoor levels indicate that amplification has occurred indoors, usually due to a moisture source.

In environments without indoor reservoirs, amplifiers or disseminators, the types of fungi found indoors should be nearly the same as those found outdoors. Conditions where there is a significant presence of fungi in the indoor air that are not present, or are a minor component of the outdoor air, are considered as unacceptable from a health and building performance point of view.⁸

Dust Sampling for Culturable Fungi

There are no standards that indicate acceptable levels of culturable fungi in dust in indoor environments. Proposed guidelines appeared in the November 2001 edition of *The Synergist* based on presentations at the 2001 American Industrial Hygiene Conference and Exposition during the Assessment and Sampling Approaches for Indoor Microbiological Assessments forum. These proposed guidelines for culturable fungi in dust are outlined here.⁹

Normal Background	<10,000 CFU/g
Possible Contamination Source	10,000 – 100,000 CFU/g
Probable Contamination Source	>100,000 CFU/g

These guidelines were developed for the purpose of addressing concerns regarding fungal assessments and abatement and would not necessarily apply to health effects.¹⁰

These levels were also suggested in a study of carpet dust samples that came from problem and control buildings within the United States conducted by Hodgson & Scott.¹¹ Analytical results of carpet samples collected in this study suggested that total fungal concentrations greater than 100,000 CFU/g, and certainly those greater than 1,000,000 CFU/g will most likely be associated with buildings contaminated with fungi. However, total concentration alone is not always sufficient, because many samples from contaminated buildings in the Hodgson & Scott study contained less than 100,000 CFU/g. The taxa present can also be an indicator of fungal contamination. Penicillium

⁷ Shaughnessey, R., Morey, P., Cole, E., "Prevention and Control of Microbial Contamination," *Bioaerosols: Assessment & Control*, (Edited by J. Macher), Cincinnati, OH, American Conference of Governmental Industrial Hygienists, 1999.

⁸ American Industrial Hygiene Association, *Field Guide for the Determination of Biological Contaminants in Environmental Samples*, (Edited by H.K. Dillon, P.A. Heinsohn, and J.D. Miller), Fairfax, VA, AIHA, 1996.

⁹ Clark, Geoffrey A., *Assessment and Sampling Approaches for Indoor Microbiological Assessments*; the *Synergist*, Volume 12, Number 11, pp.20-21. American Industrial Hygiene Association, Fairfax, VA, November 2001.

¹⁰ *Ibid.*

¹¹ Hodgson, M., Scott R., "Prevalence of Fungi in Carpet Dust Samples in Bioaerosols, Fungi and Mycotoxins: Health Effects, Assessment, Prevention and Control," Edited by Eckardt Johanning M.D., M.Sc., 1999 Eastern New York Occupational and Environmental Health Center, Albany, NY.

spp. and *Aspergillus* spp., especially *Aspergillus versicolor*, when present as major or dominant taxa, are generally associated with problem buildings.¹²

Endotoxin Sampling

Airborne Endotoxin Sampling

Gram-negative bacteria are ubiquitous in the environment. They are associated with plants and animals, and are found in the oral cavities and intestinal tracts of mammals. They are especially plentiful in water. They have been reported in contaminated ventilation systems and humidifiers. Gram-negative bacteria have been observed in large numbers in water damaged building materials, including spray-applied fireproofing, carpet, ceiling tile, drywall, etc.¹³

Gram-negative bacteria during growth, division, death or lysis produce endotoxin. Therefore, where there are gram-negative bacteria there is endotoxin. It has been detected in the air, in dust, and in water. Endotoxin exposures are mainly through the air. Endotoxin in dust or in water must be aerosolized to cause an exposure.¹⁴

Measurements of endotoxin have been correlated with indoor air quality complaints and respiratory diseases in office buildings as well as occupational settings. The inhaled endotoxin has been associated with many pulmonary diseases. Some inhalation studies show that endotoxin can cause fever, cough, dyspnea, headache, nose and throat irritation, diffuse aches, nausea, shortness of breath, and chest tightness, acute airflow obstruction, and airway inflammation. Endotoxin exposure may also result in low lung function. In the indoor environment, chest tightness, mild fever, and flu-like symptoms experienced by building occupants, may be associated with endotoxin exposure.¹⁵

In personal communication with Dr. Chin Yang of P&K Microbiology, he indicated that common levels of endotoxin found in carpet dust are in the range of 20,000 to 25,000 EU/g. In a building that has had water damage these levels may be in the range of 40,000 to 45,000 EU/g.¹⁶ All, but two samples were at or below the range of 20,000 to 25,000 EU/g suggested by Dr. Yang as a common level in carpet dust. The two samples that exceed this level are 1115-ED-7 and 1115-ED-8. Sample 1115-ED-7 was collected on the 7th floor, from the top of a cubicle bookcase, across from room 706 and had a concentration of 52,000 EU/g. Sample 1115-ED-8 was collected on the 8th floor, from the top of a cubicle bookcase, outside room 825 and had a concentration of 37,000 EU/g. Both samples were elevated compared to other samples collected within the building.

¹² Ibid.

¹³ Castellon, R.; Olenchock, S.A.; Hankinson, J.L.; Millner, P.D.: Acute Bronchoconstriction Induced by Cotton Dust: Dose-Related Responses to Endotoxin and Other Dust Factors. *Ann Int Med* 101:157-164 (1984).

¹⁴ Clark, Geoffrey A., *Assessment and Sampling Approaches for Indoor Microbiological Assessments*; The Synergist, Volume 12, Number 11, pp. 20-21. American Industrial Hygiene Association, Fairfax, VA, November 2001.

¹⁵ Ibid.

¹⁶ Personal communication with Chin S. Yang, Ph.D, Microbiologist, of P&K Microbiology Services, Inc. Cherry Hill New Jersey. January 3, 2002.

Further investigation in these areas is suggested to assess if there is current water damage or if water damage had occurred in the past and has since been remedied.

Endotoxin exposures are mainly through the air. Endotoxin in dust or in water must be aerosolized to cause an exposure.¹⁷ Based on the airborne endotoxin concentrations measured during the five-day sampling period, airborne concentrations of endotoxin are low. To reduce the risk of endotoxin exposure, cleaning activities may be performed at off-hours when occupancy levels are low. Wet instead of dry methods for wiping surfaces may be used to reduce aerosolizing endotoxin in dusts. Using ordinary vacuum cleaners may aerosolize endotoxin found in carpet. Using high efficiency particulate air (HEPA) filter vacuums can reduce the risk of endotoxin exposure from carpet dust.

Mechanical Engineering Considerations

A review of each of the typical mechanical rooms was performed, including the ground floor, floors five, eight, nine, and the penthouse serving floors ten through twelve.

Ground Level Mechanical Room

The ground-level mechanical room houses the AHU-1, Water Chillers 1 and 2, Chilled Water Pumps 1 and 2, and Condenser Water Pumps 1 and 2. The air handler serves only the ground level rooms and is a single duct, variable air volume (VAV) central station air supply unit, complete with a chilled water cooling coil, single stage air filters, and fixed outside air connection to a mixing plenum. Outside air is extracted above the rear entry door at the soffit approximately 10 feet above grade, but adjacent to the street. This entrance also serves as a smoking area, prompting complaints from occupants when smoke is entrained into the intake. Filters were relatively clean, as well as the coil drain pan.

Two identical water chillers are piped in parallel, York Model YT-J3-K3-E1-CNF, rated at 385 nominal tons when operated on refrigerant R-11. Since R-11 has been eliminated from production, the chillers have been retrofitted (according to the operating staff) to operate on R-22 refrigerant, consistent with the EPA guidelines.

The chilled water and condenser water pumps are base-mounted, single-stage, end-suction, vertical split-face, centrifugal units. One pump is provided for each evaporator and condenser, with cross-over piping to allow either pump to serve either machine. However, no redundancy is provided by having a standby pump for unplanned maintenance activities. Water treatment for the cooling towers is also housed in the ground-level mechanical room. The water treatment system is automated, with operating tanks and chemical pumps housed at this level.

¹⁷ P&K Microbiology Services, Inc., The Environmental Microbiology Specialists, Endotoxin; Laboratory Publication distributed with laboratory results.

Typical Floor Air Handling

Floors two through nine have a single air handling room centrally located in the core of the building. Each room contains a single large, VAV, central station air handler, connected to the basement chillers through a set of vertical chilled water risers.

Outside air is extracted through a central shaft connecting all air handling units up through floor twelve. Each outside air connection is equipped with a manual fixed damper. There are no controls that monitor air flow and adjust the damper position based upon fan speed to ensure that the minimum ventilation air quantity is always being provided.

Air filters installed are 2-inch pleated media, Air Guard Model MX-40. According to the operations staff, filters are changed on a 90-day interval, regardless of condition. Visual filter pressure drop gages are not installed for verification of cleanliness. In addition, filter spacer bars that are used to keep the spaces between the filters and around the ends closed, were found missing or laying on the mechanical room floor. Operating personnel have recently (within the last seven months) changed the type of filter used, because of the accumulation of particulate that was occurring on the cooling coil. The previous filter type was a 2-inch thick “furnace filter” rated at MERV-4 or less. Operating personnel have stated that the coil cleanliness has improved.

The central station air handlers manufactured by York are the draw-through type with single-wall construction (now has deteriorated internal insulation). The internal insulation has been damaged during normal coil and drain pan maintenance activities. Coil condensate drain pans were relatively clean, but did have standing water in some locations, due to inadequate slope and side outlet drain connections. Fan speeds are controlled by a variable speed drive, as manufactured by Square-D, based upon the duct static pressure set point. Operations staff perform complete cleaning of the internal surfaces, cooling coil cleaning, lubrication of fan bearings, and belt tension adjustments at least twice annually.

Each floor has an average of 20 air terminal (VAV) boxes. The perimeter zones are equipped with single-duct, parallel, fan-powered terminals, equipped with electric reheat coils. Core areas are conditioned with static, single-duct cooling only (without reheat) terminal units. This arrangement has proven to be problematic in trying to accommodate all occupant areas with a single supply air temperature. In limiting the maximum perimeter zone temperature, the cooling supply air temperature needs to be set at 55 °F, resulting in overcooling of the core areas, which lack reheat capability.

Presently, the supply air temperature is reset based upon the average space return air temperature. This control methodology will elevate the supply air temperatures whenever possible, allowing the space’s Relative Humidity to increase. To combat overcooling the core areas, their terminal units are allowed to decrease air flow to full shut-off, violating the requirement of ventilation per ASHRAE Standard 62. The present set points for terminal units are set at 68° F for heating and 70° F for cooling. The exception to these settings are for those areas where occupant complaints require adjustment.

Rooftop Mechanical Rooms

The penthouse mechanical rooms house air handling units serving floors ten through twelve, primarily the court rooms. All air handling systems are similar to those described for floors one through nine. This floor also houses the elevator machine rooms and the cooling towers. The elevator machine rooms are conditioned with small chilled water, fan coil units without outside air supply.

The cooling tower is a two-cell (one for each chiller) induced draft unit, located adjacent to two air handling rooms. The outside air intakes appear to be adequately spaced from the discharge plume as described in the GSA guidelines. However, co-locating the towers with the air handling units on the same level is not desirable.

Outside air intake louvers have been outfitted with rain hoods that extend down to within 12 inches of the roof. This was most likely done as a response to too much water penetration through the louvers during driving rain storms. A separate ventilation fan exhausts the stairwell continuously. It was uncertain why this fan was allowed to operate at all times, but did not appear to have a time schedule assigned to keep it off when not needed. This fan, coupled with the toilet exhaust fans, could be a major contributor to building depressurization.

QUESTION #2: What is the actual state of the building systems and indoor mold/moisture problems of this building, and what operational procedures or building conditions contribute to this state?

HVAC Systems

The outside air intake for floors 1-9 is located on the ground floor in an area that is reportedly used as the smokers lounge. The outside air intake for floors 10-12 is located on the roof, near roof level. This air intake did not have a screen to prevent the entry of animals or other large objects.

The two cooling towers are located on the roof and the two chiller units are located in the 1st floor mechanical room. Review of preventive maintenance requirements indicated the cooling towers are scheduled quarterly for cleaning.

The air-handling units for floors 1, 5, 8, and 10-12 were inspected. The interior insulation inside the mixing boxes was dry and no visible microbial growth was observed. An encapsulant had been applied to the fiberglass insulation in some of the mixing boxes, presumably to help prevent deterioration. Some loose insulation was observed in the mixing box for the 8th floor AHU.

The AHUs were equipped with 40 percent efficient, two-inch pleated filters. Review of preventive maintenance requirements indicated filters are scheduled to be changed every two months. Maintenance personnel indicated filters were changed at least every three

months. Filters were observed to be in good condition with moderate particulate loading. Some gaps, allowing for air bypass, were noted in the filter bank for the 8th floor AHU. It was also noted that the filters for the 10th floor AHU would be difficult to change because of the close proximity of the filter bank to the wall.

Preventive maintenance requirements for air handling units indicate coils and drain pans are cleaned semi-annually. Coils and associated fans appeared to be in good condition and clean. Drain pans were generally clean and draining properly. The drain pan for the 8th floor AHU had a leak in the bottom. A second pan had been installed beneath the unit and equipped with a sump pump to evacuate the water. Standing water and dirt/debris were observed in the main drain pan, but no microbial growth was observed. Outside air dampers for all of the AHU units inspected appeared to be in the closed position.

Temperature and Humidity

Temperature and humidity measurements were collected at one location per floor for five consecutive days from November 13-17, 2001. It should be noted that on Saturday, November 17, 2001, occupancy levels were drastically lower than levels found during the workweek. In addition, on November 17, 2001, maintenance staff was cleaning the cooling towers on the roof of the building. Therefore, there was no cooling of the air in the building during the time measurements were collected on this day. Air handlers were operating and air was being distributed throughout the building. Temperatures in occupied spaces measured from November 13 through 16, 2001 ranged from 70.3 to 77° F with an average of 73.3° F and a standard deviation of 1.3° F. Relative humidity ranged from 42.4 to 63.3% and averaged 52.7% with a standard deviation of 4.0%. The only floor where the average relative humidity over four days exceeded one standard deviation above the mean was the 8th floor.

Carbon Dioxide

Comparing the morning average of 646 ppm with the afternoon average of 810 ppm indicates that there is a buildup of carbon dioxide within the James Lawrence King Justice Building that occurs throughout the course of the day. In addition, the readings indicate that the values within two standard deviations of the mean do surpass the ASHRAE threshold of 1000 ppm above which ventilation may be inadequate. The five areas where these concentrations were measured included two interior locations on the 3rd floor, one perimeter and one interior office on the 4th, one interior office on the 7th, and one perimeter office on the 8th floor. If there is a pattern for elevated carbon dioxide concentrations, the data is too limited to provide an indication.

Based on the average carbon dioxide levels over the five-day sampling period sufficient outside air was being introduced into the building to provide adequate ventilation in accordance with the current recommended ASHRAE standards. However, the afternoon levels approached the ASHRAE 1000 ppm threshold above which ventilation may be inadequate.

Carbon Monoxide

As indicated previously, carbon monoxide levels are measured during an indoor air quality investigation to determine if there are combustion sources within the building that are not being adequately vented; or if there are outside sources, such as vehicle exhaust, entering the building. The ASHRAE ventilation standard has established 9 ppm or greater of carbon monoxide within an occupied space as being a level of concern.¹⁸ Measurements conducted during the investigation indicated carbon monoxide concentrations ranged from 0 to 2 ppm, well below the 9 ppm level of concern.

Respirable Particulate

Indoor measurements for the concentration of airborne respirable dust over the five-day period all indicated 0.00 milligrams per cubic meter (mg/m^3) over the three days of sampling, below the instruments limit of detection. Outdoor levels ranged from 0.00 to 2.51 mg/m^3 with an average of 0.44 mg/m^3 for respirable particulate (10 micrometers in diameter and smaller). Indoor concentrations were lower than outdoor levels and below the ASHRAE recommended level and the EPA Ambient Air Quality Standard level of 0.15 mg/m^3 .¹⁹

Fungi Sampling

Airborne Culturable Hydrophilic Fungi

Samples were collected over a five-day period from November 13-17, 2001. On each of the five days eight samples were collected, six indoors and two outdoors. All outdoor samples were collected on the roof of the building. Indoor sample locations were randomly selected throughout the building by the investigator, alternating odd and even floors on a daily basis. Each indoor sample location was unique and sampling was not repeated at a location.

Samples were collected for viable airborne hydrophilic fungi on malt extract agar. These fungi are of significant concern in buildings where both water and a food source (such as carbon in wallboard paper) are present. Sample results are summarized for each location and can be found with the laboratory report, and floor plans indicating sample locations.

On November 13, 2001 measured outdoor fungi concentrations ranged from 35 to 71 colony-forming units per cubic meter (CFU/m^3) with an average level of 53 CFU/m^3 . Indoor levels ranged from 18 to 88 CFU/m^3 with an average level of 44 CFU/m^3 . On this day the average levels observed indoors were approximately eighty percent of those found outdoors.

On November 14, 2001 measured outdoor fungi levels ranged from 530 to 618 CFU/m^3 with an average level of 574 CFU/m^3 . Indoor levels ranged from less than 18 to 212

¹⁸ American Society for Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE 62-1989, Ventilation for Acceptable Air Quality, ASHRAE, Atlanta, GA 1990.

¹⁹ Ibid

CFU/m³ with an average concentration of 80 CFU/m³. On this day the average levels observed indoors were approximately fourteen percent of those observed outdoors.

On November 15, 2001 measured outdoor fungi levels ranged from 212 to 283 CFU/m³ with an average level of 248 CFU/m³. Indoor levels ranged from 35 to 177 CFU/m³ with an average concentration of 133 CFU/m³ and were approximately fifty percent of those observed outdoors.

On November 16, 2001 measured outdoor fungi levels ranged from 424 to 583 CFU/m³ with an average level of 248 CFU/m³. Indoor levels, approximately 14% of outdoor levels, ranged from 18 to 141 CFU/m³ with an average concentration of 71 CFU/m³.

On November 17, 2001 measured outdoor fungi levels were 459 CFU/m³ in both outdoor samples. Indoor levels ranged from 159 to 459 CFU/m³ with an average concentration of 327 CFU/m³. On this day the average levels observed indoors were approximately seventy-one percent of those observed outdoors.

To evaluate the biodiversity of the variety of fungi found indoors to that found outdoors a statistical test known as Spearman's non-parametric rank correlation was used. The use of this test is described by Dillon, H.K., et al. in the Field Guide for the Determination of Biological Contamination of Biological Contaminants (American Industrial Hygiene Association, Fairfax, VA 1996). Outdoor samples are compared to indoor samples by ranking the concentrations of genera found in these samples from highest to lowest and determining the Spearman correlation coefficient (r_s). Forty-three pairs of fungi were identified among the outdoor and indoor samples. The value calculated for r_s is 0.40. Based on $N=43$ the z-value was calculated to be 2.59, which results in a p-value of 0.01 for a two-tailed test. This value of 0.01 is less than the conventional $\alpha=0.05$, therefore the null hypothesis is rejected and it can be said that the biodiversity inside and outside the building are similar. A table detailing how r_s was derived for the data collected November 13-17, 2001.

A second analysis using Spearman's non-parametric rank correlation was performed, which excludes the data collected on Saturday. The reason for this is that on Saturday November 17, 2001, the cooling towers on the roof of the building were being cleaned. The air handlers within the building were still in operation, however the air was not being cooled. Saturday afternoon temperatures were approximately 3.7°F higher than those found during the workweek. Fungi levels may vary based on the conditions (i.e., temperature, humidity) at the time that sampling occurs. For example, the majority of Penicillium citrinum colony forming units over the five-day sampling period were found on Saturday, November 17.

With the Saturday, November 17th data excluded, forty pairs of fungi were identified among the outdoor and indoor samples. The value calculated for r_s is 0.33. Based on $N=40$ the z-value was calculated to be 2.06, which results in a p-value of 0.04 for a two-tailed test. This value of 0.04 is less than the conventional $\alpha=0.05$, therefore the null hypothesis is rejected and it can be said that the biodiversity inside and outside the

building are similar. A table detailing how r_s was derived for the data collected November 13-16, 2001.

The lower indoor fungi concentrations when compared to outdoor levels and the similar biodiversity found between indoor and outdoor samples indicate that most likely fungal amplification is not occurring within the James Lawrence King Justice Building due to a moisture source.

Dust Sampling for Culturable Fungi

Culturable fungi dust samples were collected from a variety of horizontal surfaces within the James Lawrence King Justice Building. Samples were collected from carpet, tops of filing cabinets, cubicle bookcases, and shelving systems. Sample areas ranged from one to three square feet. One culturable fungi dust sample was collected from each floor over the three-day period of November 13-15, 2001.

The results of samples collected in the James Lawrence King Justice Building ranged from 2,500 CFU/g to 10,933,330 CFU/g. Of the twelve samples collected, six exceeded the 100,000 CFU/g threshold for a building with probable contamination. Four samples fell within the 10,000 to 100,000 CFU/g range for a building with a possible contamination source.

Eight of the twelve samples collected had Penicillium spp. as the dominant taxa (50% or greater) and two of the twelve samples collected had Aspergillus spp. as the dominant taxa.

The elevated fungi levels (>10,000 CFU/g) observed in the dust samples collected at the James Lawrence King Justice Building and the dominance of Penicillium and Aspergillus species are characteristic of a building with a moisture source. However, airborne fungi concentrations did not indicate amplification due to a moisture source within the Courthouse at the time this sampling was performed. Other investigators have found that analysis of fungi in dust may be more representative of building conditions than airborne fungi.²⁰ This may be the result of higher humidity levels that may exist inside the building during the summer in Miami, Florida or water intrusion that may be potentially occurring through the deteriorating exterior caulk. Further studies should include measurements of fungal concentrations in dust and air during summer, when presumably humidity levels within the building may be elevated.

Sample number 1114-FD-9 had considerably higher levels of fungi in dust concentrations than any other sample with 10,933,330 CFU/g. This sample was collected on the 9th floor, on the east side of the building in the library, from a metal shelf in the center of the room. It should be noted that at the time investigators were present in the building there was a dehumidifier present in the room, indicating that humidity levels may have been a

²⁰ Hodgson, M., Pratt, A., "Comparison of Carpet Dust Samples and Air Samples for Culturable Fungi Concentrations in Microbially Contaminated and Control Buildings," Presentation at the American Industrial Hygiene Association Conference and Exposition, New Orleans, 2001.

concern of occupants. Moisture measurements collected from the drywall in the northeast corner using a Delmhorst moisture meter indicated elevated moisture levels within the drywall. The elevated fungi in dust concentration combined with the moisture measurements indicate a moisture problem may exist in this room, more specifically in the northeast corner and along the east wall. This information correlates with the reports by facility personnel that the caulking on the exterior of the building is deteriorating, resulting in moisture intrusion. Further investigation is suggested to determine if there are other potential sources of moisture that may be contributing to the amplification of fungi in the library. Also, the extent of moisture damage to the outward-facing side of the wallboard along the east wall of the library should be further investigated.

Endotoxin Sampling

Airborne Endotoxin Sampling

During the period of November 13-17, 2001, endotoxin air samples were collected from both indoor and outdoor locations at the James Lawrence King Justice Building. On each day six samples were collected indoors and two outdoors, with the exception of November 16, when only one outdoor sample was collected.

Outdoor concentrations of airborne endotoxin ranged from 0.34 to 0.85 endotoxin units per cubic meter (EU/m³), with an average outdoor concentration of 0.55 EU/m³. Indoor concentrations by comparison ranged from 0.06 to 0.69 EU/m³, with an average indoor concentration of 0.25 EU/m³.

Indoor concentrations during the sampling period were lower than those observed outdoors. The lower level of endotoxin indoors indicate that most likely gram-negative bacteria amplification is not occurring within the James Lawrence King Justice Building due to a moisture source.

Endotoxin concentrations were far below the levels of about 50 to 90 EU/m³ thought to be associated with human respiratory disease, based on studies of environments with organic dusts.²¹ However, studies showing a relationship between chronic lower-level exposure to endotoxin and health symptoms are lacking. One recent study by S.J. Reynolds et al., of six mid-western office buildings did find a correlation between low-level endotoxin concentrations (0.5-3.0 EU/m³) and health symptoms among males and females.²² Taking the airborne endotoxin levels cited in these studies into consideration the average indoor concentration in the James Lawrence King Justice Building of 0.25 EU/m³ is low. However, future studies relating to low-level airborne endotoxin and health symptoms should be reviewed to further assess the data collected in the James Lawrence King Justice Building.

²¹ Olenchok, S.A., "Health Effects of Biological Agents: The Role of Endotoxins." *Appl Occup Environ Hyg* 9:62-64 (1994).

²² Reynolds, S.J; Black, D.W.; Borin, S.S.; Breuer G.; Burmeister L.F.; Fuortes, L.J.; Smith, T.F.; Stein, M.A.; Subramanian, P.; Thorne, P.S.; Whitten P.: *Indoor Environmental Quality in Six Commercial Office Buildings in the Midwest United States. Appl Occup Environ Hyg* 16 (11): 1065-1077, (2001).

Endotoxin Dust Sampling

Endotoxin dust samples were collected from a variety of horizontal surfaces within the James Lawrence King Justice Building. Samples were collected from carpets, tops of filing cabinets cubicle bookcases, and shelving systems. Sample areas ranged from one to three square feet. One endotoxin dust sample was collected from each floor over the three-day period of November 13-15, 2001.

Endotoxin in dust concentrations in the James Lawrence King Justice Building ranged from 4,700 endotoxin units per gram (EU/g) of dust collected to 52,000 EU/g, with an average concentration of 16,850 EU/g.

Based on the airborne endotoxin concentrations measured during the five-day sampling period, airborne concentrations of endotoxin are low.

Average morning and afternoon carbon dioxide concentrations indicated adequate ventilation was being supplied to the building in accordance with ASHRAE standards. However, afternoon carbon dioxide concentrations were approaching the recommended limit and exceeded the limit in five areas. No spatial pattern in elevated carbon dioxide concentrations was evident.

Results of sampling for airborne fungi indicated indoor concentrations were not amplified. However, the concentrations and types of fungi identified in surface dust samples were characteristic of a building having a moisture source. Fungal concentrations in the dust sampled in the 9th floor Federal Court Library (10,933,330 CFU/g) were an order of magnitude higher than those detected in any of the samples. Evidence of water intrusion was noted in the library and moisture measurements indicated the wallboard in the northeast corner had a high moisture content. Visible mold growth was not observed anywhere in the building.

Based on average concentrations of airborne and surface dust endotoxin, it does not appear that amplification of gram-negative bacteria was occurring during the study period. Elevated concentrations of endotoxin were identified in dust samples from the 7th floor outside room 706 and the 8th floor outside room 825. No obvious sources of moisture were noted in these areas. Eighth floor humidity levels were relatively high, and may be contributing to elevated endotoxin concentrations in this area.

The chronic humidity in the James Lawrence King Justice Building should be maintained below 60% and ideally, below 50% to reduce the likelihood of interior surfaces becoming damp enough to support amplified microbial growth.

It appeared from observations of five of the mechanical systems, that outside air dampers were closed allowing little outside air to be mixed with the re-circulated air in the building. Providing some additional outside air to the building would likely improve the indoor air quality. However, this must be balanced with the need to maintain humidity levels below 60% and ideally 50%.

The outside air intake for floors 1-9 is located at ground level, reportedly in an area that is used for smoking breaks. A different location should be designated as a smoking area. A screen should be installed over the roof outdoor intake for floors 10-12.

HVAC Summary

The Following table provides an overview summary of HVAC system in the building.

Table 3. HVAC System Review and Summary

Category	Criteria	Findings	Recommendations
Ventilation	ASHRAE 62-1999 requires 15 CFM per person.	Outside air dampers were closed resulting in increasing CO ₂ levels during afternoon time period.	Modify systems to provide code required ventilation quantity, but with proper moisture control.
Dehumidification	Provide supply (discharge) air at dew point temperatures less than 60° F.	Present control sequence adjusts discharge air temperature based on space return air temperature, allowing discharge air temperatures to rise above recommended levels	Revise control algorithm to supply 55° F during summer conditions when outside air temperature is > 60° F. This will tend to overcool core spaces and will require modifications to core VAV boxes.
Pressurization	Maintain building at least 2 pascals positive with respect to outdoors.	Building is operating in a negative pressure mode, with the most negative floor at grade.	Modify the air handling systems to provide adequate outdoor air to maintain positive building pressurization.
Filtration	ASHRAE recommends at least 35% or MERV-8 for general commercial buildings. GSA buildings should have 85% or MERV-13 filters.	Filters presently used are MERV-8 or less, but are not the type recommended for hot humid climates. Filters are changed on the basis of time, not filter loading, which means that the filters may not reach their design capture efficiency prior to change out. In addition, the beverage board frames support the growth of mold/mildew.	Use extended surface filters suitable for hot, humid climate, with synthetic media, pleated or short bag configuration that will have higher initial efficiency and remain in place longer with more dust holding capacity.

QUESTIONS #3 and #4: Identification and definition of current or potential problems that are/could contribute to an indoor mold problem. Of the items or conditions that are not what they should be, what is the problem and what is the cause (or causes) of each problem?

The average humidity level of 52.7% measured over four days was higher than the 50% recommended by EPA for minimizing microbial growth. The average Relative Humidity of 59.7% for the 8th floor was relatively high. It was the only floor where the average Relative Humidity exceeded one standard deviation above the mean for all measurements on all floors.

The chronic humidity in the James Lawrence King Justice Building should be maintained below 60% and ideally, below 50% to reduce the likelihood of interior surfaces becoming damp enough to support amplified microbial growth.

Fungal concentrations in the dust sampled in the 9th floor Federal Court Library (10,933,330 CFU/g) were an order of magnitude higher than those detected in any of the samples. Evidence of water intrusion was noted in the library and moisture measurements indicated the wallboard in the northeast corner had a high moisture content. Visible mold growth was not observed anywhere in the building.

The two most likely sources of moisture in the building are chronically high humidity levels and or water intrusion that may be occurring around the exterior caulk that is reportedly deteriorating.

Recommendations

- Long-term monitoring of humidity over all seasons of the year to establish chronic humidity levels.
- Repair of the exterior caulk.
- Further investigation to determine if there is another source of water intrusion, particularly in the 9th floor library.

Findings

The following paragraphs summarize the findings of this report, which are segregated into subheadings pertinent to hot, humid climates.

Fresh Air Ventilation

Fresh air quantities, as designed, do not appear to be consistent with ASHRAE Standard 62 requirements. The original drawings indicate that the design intent was to provide about 10 percent of the maximum air flow rate, as outside air. Normally, at least 20 percent of the total air flow would be required. In high occupancy areas, such as

courtrooms, this amount could easily increase to 35 percent or more. The carbon dioxide readings confirm that adequate dilution air is not being provided in the occupied spaces. If the AHU air flows were modified to provide the proper amounts, it would most likely result in elevated indoor Relative Humidity levels, promoting microbial growth.

Dehumidification

The present air handling systems do not provide an active dehumidification mode, and no humidity sensors are installed to monitor floor conditions. The present supply air temperature control scheme encourages elevated Relative Humidity levels, in order to help satisfy the occupant temperature requirements. If a dehumidification sequence was installed, considerable over-cooling of the core areas would result because they are not equipped with electric reheat coils.

Pressurization

The building pressures are operating negatively on all floors tested, and it is anticipated that the other floors are also negative. The building is being influenced by exhaust systems within the building that operate continuously, wind forces, and the air handling systems. The only systems that can be controlled are the exhaust and supply air systems. These systems will need to be modified as described in the Recommendations section of this report.

Filtration

The air handling systems do not have adequate filtration efficiencies, nor are the filter assemblies currently used suitable for preventing growth of mold/mildew. The fiberglass media will provide particulate downstream of the filter due to fiber break off. The beverage board frame is also problematic with hot, humid climate, as it provides a site for microbial amplification if it becomes moist through high indoor RH.

Moisture Intrusion

Presently, moisture intrusion was apparent in the law library located on floor nine. The moisture is entering the wall assembly through degraded sealant joints, and causing mold/mildew growth in the gypsum wall board. This problem is going to increase as the joints continue to degrade, allowing more moisture into the return air plenum above the ceiling. This could eventually contaminate the air handling system, distributing the spores over the entire floor.

Temperature Controls

Temperature control systems are combination DDC/pneumatic. The pneumatic system provides actuators with opening/closing forces, as well as actuation on the air terminal units. Using pneumatic controllers for the air terminal units precludes the ability of the operations staff to monitor and control problem areas within the building. Problems are not identified until a phone call from one of the occupants alerts them. The primary problems with temperature control have to do with the design of the air distribution

system and the inability of the design to maintain comfort conditions simultaneously in all areas.

Energy Conservation

The primary means of the building's energy conserving operation are set-back control of the air handling systems, coupled with discharge air and chilled water temperature reset. Air handlers have recently changed the start/stop times based upon GSA directives. The air handlers used to be shut off at night, but have recently been left on continuously. The operations personnel shut off the chiller plant during the night time to save energy, and then manually restart the chiller early in the morning prior to occupancy. During the winter months, this methodology may work adequately to control the indoor conditions, but summer conditions could be problematic by introducing excessive moisture into the building.

Upgrading Filters

The existing air handling units have limited space for upgrade of the filters, unless a face-loaded type of filter system is used. It is recommended that the air handling units be retrofitted to install single-stage filtration with a higher efficiency (60 – 65%), non-shedding synthetic media, and larger dust holding capacity (specifically, filter modules manufactured by Viledon). This will limit the change-out of filters to no more than once per year, while improving efficiencies and reducing pressure drop. Over the average service life of the filter, the energy and maintenance cost reduction will normally pay for the increased costs of the better filtration systems.

Moisture Intrusion

The primary means of moisture intrusion is due to the degradation of the exterior envelope sealants. If the degradation continues, and the building remains depressurized, a considerable amount of damage will occur on the perimeter zones. Air will infiltrate through the joints pulling moist air into the wall cavity, allowing amplification of microbial contamination. If this process continues unabated, the potential for degradation of the indoor air quality could reach the point where areas of the building will not be suitable for occupancy.

Temperature Controls

As mentioned previously, several areas are of concern. The air terminal unit controllers should be replaced over time to become addressable points on the DDC system, to allow the operations staff to better monitor and control the zones. In addition, the air terminal units serving the core areas will require reheat to avoid overcooling.

Air handling units must have the discharge air temperature control modified to account for higher percentages of outdoor air. The air supply temperatures should be automatically controlled based upon outside air conditions, indoor humidity levels, and zone controls.

Chilled water temperatures should be maintained at 45° F unless the indoor humidity levels are being monitored and controlled. Only under these conditions should the chilled water supply temperature be elevated. As the temperature increases, the ability of the air handling systems to maintain Relative Humidity decreases significantly.

QUESTION #5: What types of technology (current and emerging) are available to assist with moisture and humidity problems in a building? Would any be appropriate to this building? Would any be universally appropriate for buildings in a sub-tropical climate?

Future Considerations

New buildings yet to be designed should follow more closely the GSA design guidelines. Many of the features listed below are considerations that need evaluation during the early design stages, with decisions based upon a life-cycle cost analysis. If the outside air is adequately pre-treated prior to introduction at the air handling systems, the choices for temperature control increase substantially, and should be given serious consideration in the sub-tropical environment.

Dehumidification Enhancements

Many methods are presently employed for dehumidification of outdoor air for buildings located in hot, humid climates. Some of these are listed below and may warrant further analysis:

Run-Around-Coil Approach to Air Handlers

This method for dehumidification uses a pumped recalculation loop connected to a hydraulic coil installed upstream and downstream of the cooling coil. By circulating fluid between each coil, the hotter upstream coil transfers reheat energy downstream of the cooling coil, allowing better discharge air temperature without overcooling.

Heat Pipe Technology

Heat pipe is a concept similar to the run-around coil concept, except it uses a closed refrigeration loop, without a pump, to transfer the energy. The disadvantage of the method is that the refrigeration loop cannot be turned off as a pump can, thus requiring reheat energy regardless if it is needed or not.

Dedicated Outdoor Air Systems

Dedicated air handling units designed only to precondition outdoor air is a common method of supplying fresh air to multiple air handlers. The dedicated unit can be constant or variable air volume, with all coils and appurtenances selected specifically for dehumidification of outside air.

Desiccant-Based Systems Preconditioning

Desiccant systems are another preconditioning method for outdoor air that uses absorption of moisture as a method for removing unwanted moisture from the outside air

stream. Natural gas is typically used to regenerate the desiccant, and return chilled water is required to return the outside air back to a dry and cooler stream of fresh air prior to delivery to the multiple air handlers. This method of preconditioning shifts the majority of the energy required for dehumidification to a fuel different than electricity, allowing potential energy cost savings, as well as lower electricity bills. Desiccant-based systems are typically used for lower applications that are typically required for commercial buildings.

Building Pressurization Techniques

There are several methods for determining how much air and what control methodologies should be used for building pressure control. Several of these are described below.

Calculating Air Quantity Requirements

The designer must first determine how much air is needed for pressure control. This can be calculated using methods presented in the ASHRAE Handbooks. In most cases, this is not done.

Control of Outdoor Air Quantities

Most important in air distribution systems is the ability to control the volume of outside air quantities, during all operating modes. This requires a method for measuring the outside air quantity, and a method for maintaining the air flow. Many cost effective means are available to the designer.

Control of Space Pressures

Space pressures may need to be monitored if active relief systems are in place that allow modulation of the relief area. In some cases, the relief systems can be passive, while others will require active control. Space pressures must be controlled when they will adversely affect air transfer between spaces, or when door opening forces will be excessive. To preclude moist air infiltration, we have found that 2 to 4 Pascals of positive pressure with respect to outdoors (during all operating modes) will provide adequate pressurization in hot, humid climates.

Temperature Controls for Occupant Comfort

Several methods for temperature control of occupied spaces will provide adequate occupant comfort. Most importantly, zoning and space air diffusion will have the largest impact and demands the most consideration during the design process.

Zoning Requirements

The GSA design guidelines are quite specific about the methods used for defining temperature control zones in buildings. The first concern is for treating the perimeter zones, those that are most affected by the outdoor conditions, with a separate air handling system. In fact, if the exterior exposures are east and west, it would be desirable to have at least two separate zones to handle the peak conditions in morning and afternoon. If the

facility is large enough, then four zones can be defined, one for each direction (north, south, east and west.) This will allow each perimeter to respond to the solar component that has the most dramatic effect on the occupied zone.

The core area needs to be conditioned with a separate air distribution system. This will allow the occupants that are not affected by solar and conduction loads to use simpler system approaches that minimize the amount of reheat required in each zone. This method coupled with pre-conditioned outdoor air will allow the supply air temperature to be elevated so that the terminal units can control space temperatures with “cooling only” type units, thus not requiring individual reheat coils. Space Relative Humidity will still need to be monitored. Courtrooms, corner offices and other special spaces will require their own temperature control zones, whether served by a separate air handling unit or not.

Space Air Diffusion

Space air diffusion, how the air is introduced into the occupied space, and how it mixes with the room air to affect ventilation and conditioning, is a major topic of disagreement. However, ASHRAE Handbooks discuss this topic at great length and should be reviewed by the designer. Of critical concern is the ability of the diffuser to affect air distribution throughout the flow range of the terminal unit. It must provide the same affect at the lowest defined flow and the highest. Only a few diffusers offer such diverse capabilities. One that deserves serious consideration by the designer is the “Valid-Air” diffuser, manufactured by Warren Technologies, Hialeah, FL. (Website address: www.warrenhvac.com). This product is designed specifically to address these issues and IAQ, and is available at a competitive price.

Technologies Table

The following table summarizes various IAQ technologies relevant to this building.

Table 4. IAQ Technologies

<i>Technology</i>	<i>Description</i>	<i>Website</i>
Desert Air Corporation	Desiccant Cooling	www.desert-aire.com
	<i>Dehumidifiers</i>	
	<i>Remote Condensers</i>	
Munters Corporation	Rotary Heat Exchangers	www.muntersinternational.com
	<i>Dehumidifiers</i>	www.muntersamerica.com
	<i>Evaporative Cooling</i>	
	<i>Moisture Control Services</i>	
Semco Incorporated	Desiccant Cooling	www.semcoinc.com
AirXchange	Desiccant Cooling	www.airxchange.com
DryKor Incorporated	Liquid Desiccant Cooling	www.drykor.com
Bry-Air Incorporated	Desiccant Dehumidifiers	http://www7.thomasregister.com/olc/bry-air

	<i>Dehumidifiers</i>	
Dri-Eaz	Dehumidifiers	www.dri-eaz.com
	<i>Moisture meters & sensors</i>	
Comfort-Aire	Dehumidifiers	www.heatcontroller.com
	<i>Air Handlers</i>	
Kathabar	Dehumidifiers	www.kathabar.com
Linric	Desiccant System Engineering and Software	www.linric.com
Novel Aire	Desiccant Cooling	www.novelaire.com
Rotor Source	Desiccant Cooling	www.rotorsource.com
VenMar	Desiccant Cooling	www.venmarvent.com
	<i>Filters</i>	
Dehumidifier Corporation of America	Dehumifiers	www.dehumidifercorp.com
	<i>De-humidistats</i>	
	<i>Temperature/Humidity Controllers</i>	
Delta Controls Incorporated	Building Control Systems	www.deltacontrols.com
Delta Control Products Incorporated	Temperature/humidity controls	www.deltacp.com
CertainTeed	Vapor barriers	www.certainteed.com
	<i>Insulation</i>	
Purolator Air Filtration	Air Filters	www.purolatorair.com
FabricAir Incorporated	Fabric Air Ducts for Temperature/Humidity Control	www.fabricair.com
Bacharach Incorporated	Relative Humidity Measurement Instrumentation	www.bacharach-inc.com
AdvanTeK Incorporated	HVAC Cold Air Distribution Systems	www.advantekinc.com
AirMax	Cold Air Distribution Systems	www.airmax.net
AirTex	Cold Air Distribution Systems	http://www.airtex.de/home_e.htm
	<i>Fabric Ducts</i>	
Airgo	Fabric ducts	http://www.jeynes.com/airgo.htm
Gorman Industries	Ductless Air Conditioning Systems	www.gormanindustries.com
LaFarge Corporation	Vapor Barriers/Vapor Retarders	www.lafargecorp.com
SealFlex Incorporated	Vapor Barriers/Vapor Retarders	www.sealflex.com

	<i>Moisture Emission Testing</i>	
Midwest Freeze-Dry, Ltd.	Freeze drying of books and papers to remove water	www.midwestfreezedryltd.com
	<i>Decontamination of mold on books and papers</i>	
Freeze Dry Company	Freeze drying of books and papers to remove water	www.freezedryco.com
Suvair	Ultraviolet Technology	www.suvair.com
Purified Tap Water	Ultraviolet Technology	www.purifiedtapwater.com
Atlantic Ultraviolet Corporation	Ultraviolet Technology	www.ultraviolet.com
Lumalier	Ultraviolet Technology	www.lumalier.com
Klean	Ultraviolet Technology	www.klean.com
Trojan Technologies	Ultraviolet Technology	www.trojanuv.com
Ecologic Technologies	Humidistats	http://cloudtops.com/afhydro2.htm
DST Humidity Control Systems	Humidity/Temperature Controllers	www.humiditycontrol.co.uk
Parameter Generation Control	Humidity/Temperature Controllers	www.humiditycontrol.com
Premier Industries Incorporated	Evaporative Cooling Equipment	www.piec.com
Dectron International	Dehumidifiers	www.dectron.com
	<i>Air Purification Products</i>	
	<i>Desiccant Cooling</i>	
Honeywell Incorporated	Sensors and Controllers	www.honeywell.com
	<i>Air cleaners</i>	
Johnsons Controls	Building Control Systems	www.johnsoncontrols.com
ControlDepot	Indoor Air Sensors	www.controldepot.net
Tek-Air	Indoor Air Sensors	www.tek-air.com
Grantham Company	Indoor Air Sensors	www.granthamcompany.com
Purafil OnGuard	Indoor Air Sensors	www.purafilonguard.com
AirGuard	Filters	www.airguard.com
Flanders	Filters	www.flanderscorp.com
CamfilFarr	Filters	www.camfilfarr.com
American Air Filter	Filters	www.aafintl.com
AprilAire	Humidistats	www.aprilaire.com
Regin Company	Humidistats	www.regin.com
Viconics Incorporated	Humidistats	www.humidistat.com
	<i>Humidification/Dehumidification</i>	

	<i>HVAC Controls</i>	
Trane Company	Indoor Air Sensors	www.trane.com
Texas Instruments	Indoor Air Sensors	www.tisensors.com
Alnor Instruments	Temperature/humidity measurement	www.flw.com
Enercorp	Indoor Air Sensors	www.enercorp.com
Yogi Goswami University of Florida	Air cleaning system (under development – not commercially available)	www.napa.ufl.edu/oldnews/dmites.htm www.napa.ufl.edu/2001news/anthrax.htm www.me.ufl.edu/SOLAR/airclean.html

QUESTION #6: How are GSA's energy reduction goals and the current operational practices restricting or facilitating the maintenance of a comfortable and lower humidity indoor environment?

Hot, humid climate design criteria will restrict or eliminate many energy conservation strategies that are acceptable in other climatic areas. However, those dealing with the envelope are particularly important to consider, as this does directly affect the performance of the HVAC system. Perimeter zones are especially sensitive to the solar considerations and day-lighting techniques. By selecting the exterior glazing properly, the perimeter zones may not experience severe peak loads, allowing more perimeter zones to be combined.

HVAC system energy conserving techniques that should be considered in hot, humid climates include:

- Combined central chiller plants using high-efficiency electric-driven, gas-driven equipment, and/or absorption technologies.
- Thermal storage for energy cost reduction, with low temperature distribution systems.
- Radiant cooling in perimeter offices.
- Variable-volume air distribution systems.
- Sensible and latent heat recovery systems.
- Dedicated outdoor air systems for preconditioning.
- Desiccant-based humidity control.
- Demand controlled ventilation schemes.

- Chilled water reset during winter months, with appropriate humidity control algorithms.
- DDC-based building automation systems.
- Night-time setback schemes, while maintaining building Relative Humidity levels and pressurization.
- Night flush or cool-down schemes with the appropriate control of Relative Humidity and pressurization.
- Cogeneration schemes where thermal loads are high.

The only caveat to any energy conserving design scenario, is that building moisture levels must be monitored and controlled at all times to avoid the growth of mold and mildew.

QUESTION #7: Recommendations for correcting the problems in this building and would these corrections correlate to other buildings with similar problems? Recommendations for design criteria that should be added or changed for future GSA buildings?

Recommendation for HVAC

The following table provides a set of recommendations for the HVAC system.

Table 5. HVAC System Review and Recommendations

Category	Criteria	Findings	Recommendations
Ventilation	ASHRAE 62-1999 requires 15 CFM per person.	Outside air dampers were closed resulting in increasing CO ₂ levels during afternoon time period.	Modify systems to provide code required ventilation quantity, but with proper moisture control.
Dehumidification	Provide supply (discharge) air at dew point temperatures less than 60° F.	Present control sequence adjusts discharge air temperature based on space return air temperature, allowing discharge air temperatures to rise above recommended levels.	Revise control algorithm to supply 55° F during summer conditions when outside air temperature is > 60°F. This will tend to overcool core spaces and will require modifications to core VAV boxes.
Pressurization	Maintain building at least 2 Pascals positive with	Building is operating in a negative pressure mode, with the most	Modify the air handling systems to provide adequate

Table 5. HVAC System Review and Recommendations

Category	Criteria	Findings	Recommendations
	respect to outdoors.	negative floor at grade.	outdoor air to maintain positive building pressurization.
Filtration	ASHRAE recommends at least 35% or MERV-8 for general commercial buildings. GSA buildings should have 85% or MERV-13 filters.	Filters presently used are MERV-8 or less, but are not the type recommended for hot humid climates. Filters are changed on the basis of time, not filter loading, which means that the filters may not reach their design capture efficiency prior to change out. In addition, the beverage board frames support the growth of mold/mildew.	Use extended surface filters suitable for hot, humid climate, with synthetic media, pleated or short bag configuration that will have higher initial efficiency and remain in place longer with more dust holding capacity.

Best Practices for Optimizing Indoor Air Quality in Buildings

Commercial building design, construction, and operational measures necessary to create a good indoor air environment are well established. These include:

- Understanding relationships between ventilation, indoor air pollutant sources, and airborne concentrations.
- Understanding simple dose response basis for health effects, which can be stated simply as “the dose makes the poison”.
- Designing and operating a building from “cradle to grave” considering indoor air quality concepts.
- Designing, optimizing, and operating the ventilation system for optimum indoor environment.
- Identifying and understanding indoor pollutant sources.
- Developing and implementing indoor pollutant source control strategies.

- Developing and implementing materials selection and specification minimizing indoor air pollutants.
- Understanding and following construction practices that optimize indoor air quality.
- Following operation and maintenance practices that optimize the indoor environment.
- Designing and implementing change of use, renovation, and de-mounting practices that minimally impact and optimize the indoor environment.
- Developing a plan and manual for optimizing and maintaining the indoor environment throughout the life of the building, including communication with and training of the building occupants and maintenance staff.

The best practices are extremely important for preventing and controlling microbial growth in buildings. The design and operation of a building is critical for preventing microbial growth, including:

- Sealing of the building shell to prevent moisture intrusion, which can be a major problem in a building located near an ocean, as is the James Lawrence Federal Justice Building, and eliminating moisture sources through roof repair, flashing modification, installation of a drainage layer beneath cladding, and control of soil moisture entry.
- Providing proper and continuous dehumidification of the building supply air controlling the dewpoint temperatures to less than 60° F and indoor relative humidity between 30% and 60% RH, as specified in ASHRAE Standard 2001.
- Pressurizing the building to the outside to help prevent moisture intrusion into the building.
- Understanding the moisture dynamics within the building and how they may cause moisture problems.
- Selecting building materials, such as not using vinyl wallpapers, so that moisture is not trapped behind walls and other cavities.
- Selecting non-porous building furnishings that are less likely to absorb moisture and other indoor pollutants, such as cushioned cubicles.
- Sealing all ductwork so that cold air does not escape in the plenums creating cold spots allowing moisture accumulation and minor flooding.

- Maintaining adequate and continuous ventilation throughout the building at the correct level for the occupant density for flushing of generated contaminants and moisture control.
- Following stringent operation and maintenance procedures for optimum cleanliness of the ventilation system and the interior of the building to remove any surface microbes and to remove nutrient sources (at a minimum follow the recommendations in Table 8-1 of ASHRAE Standard 62-2001 (ASHRAE 2001) and in Greening of Federal Facilities, Section 8.1 (Building Green 2001))²³.
- Repairing all water leaks, drippy faucets, and clogged or improper drainage areas.
- Assuring proper roof drainage so that there are no areas of rainwater pooling.
- Reducing tracked in dirt and contaminants using effective track-off mats at entry points that are cleaned daily and vacuumed with machines that have HEPA filters.
- Using adequate filtration, at a minimum MERV 10, to remove outside microbes from the outdoor supply preventing distribution into the ductwork and interior of the building.
- Replacing any porous and semi-porous water damaged materials, wherever possible, and thoroughly cleaning and drying any materials that cannot be removed and replaced.
- Eliminating the use of interiorly fiberglass-lined ductwork and HVAC systems. ASHRAE Standard 62-2001 states that material surfaces in a ventilating system “shall be determined to be resistant to mold growth in accordance with a standardized test method, such as UL 181 “Mold Growth and Humidity Test”, or ASTM C1338 “Standard Test Method for Determining Fungi Resistance of Insulation Material and Facings.”

Existing and Future Technologies

Cleanliness, prevention of moisture intrusion, dehumidification, ventilation, and filtration are the most important criteria for moisture control in a building and are the areas where technology can best be applied. There are a number of technologies that are currently available or under development. The effectiveness of many of the technologies still is under study.

Air Distribution System

The air distribution system provides many areas to apply technology to prevent and reduce moisture and indoor air quality problems in buildings. Ventilation systems that

²³ ASHRAE 2001. ASHRAE Standard 62-2001: Ventilation for Acceptable Indoor Air Quality, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

provide increased amounts of outside air continuously to the occupied zones of buildings controlling humidity levels and operate more energy efficiently are available and commonly used. Desiccant-cooling systems are being more widely employed throughout hot and humid climates such as those in Florida. Desiccant systems can be retrofitted to the conventional HVAC systems in an existing building so that the desiccant system supplements the conventional HVAC system removing the humidity loads while the HVAC air conditioner lowers the supply air temperature.

Desiccant systems can control space humidity (lowering or raising depending on the need) and improve indoor air quality by providing continuous conditioned ventilation air at improved rates; thereby flushing out pollutants from occupied zones of the buildings. At the same time desiccant systems dehumidify and increase ventilation rates while lowering energy usage.²⁴ The desiccant systems can be active or passive, although the active systems are more effective. Depending on the building location, application, and energy costs, the payback for the installation of an active desiccant system typically is three to five years. There are several companies providing active and passive desiccant systems. Upcoming desiccant systems, which should be on the market in less than two years, also will remove pollutants from outdoor supply air and re-circulated air to operate as air cleaners and continue to improve the indoor environment.

Additional technologies used for removing humidity from air include cold air distribution systems. Cold air systems distribute air at a temperature of less than 50°F. The advantage of these systems is that they are designed to control humidity without a significant difference in the type of equipment that is used, but the disadvantage is that precise digital controls and very accurate system design tools are required. A cold air distribution system requires highly efficient chillers and compressors. The cold air distribution system, when used as the originally designed ventilation system of a building, can result in an equipment cost savings since smaller sized equipment can be used, but the building system design is more critical and there is a need for increased complexity of the control system and diffusers.

Although cold air distribution systems are better able to maintain space humidity levels than conventional HVAC systems, the space humidity will increase as the fraction of outside air increases. The equipment cost savings of a cold air distribution system will be difficult to realize in a retro-fit situation on an existing building, since savings in the air distribution system will not be possible, but long-term energy usage savings may be realized. There are a number of manufacturers and distributors of cold air distribution systems.

Filtration

Microbes, including bacteria, fungi, and virus particles – can range in size from approximately <0.1 μm to 3 μm, with the widest range being between one and three microns. For this reason the filter needs to be a minimum of MERV 11, which traps particles between one and three microns. The filters are the first line of defense in a

²⁴ Bayer, C.W., R.J. Hendry, J.C. Fischer, et al. 2001. Active humidity control and continuous ventilation in schools, in Proceedings of IAQ'2001, ASHRAE, San Francisco, CA.

ventilation system to prevent building infestation by outdoor microbes. Filters, in most HVAC systems, can be upgraded to these higher efficiency filters, but care must be taken to ascertain that the backpressure does not increase to such a great level that airflow is restricted. Optimum filter maintenance is critical. The captured dirt on loaded filters provides a nutrient-base for microbes, as well as blocking air flow through the filter. More effective filters are under development, particularly in light of the threat of terrorist introduction of biological warfare agents into a building air intake. Enhanced filters are starting to become available.

Building Control Systems

The building needs a control system that allows it to operate efficiently in full and part-load situations. The use of humidistats as control systems, in addition to or instead of temperature control systems, may help this situation. The humidistat controls may be able to help maintain constant, specified humidity levels in the occupied zones of the building. The use of humidistats may allow the use of increased space temperatures and use of less cooling during unoccupied time periods, while still maintaining space humidity levels. The use of programmable electronic thermostats and humidistats will aid in the resetting of heating and cooling set points for different operating modes while maintaining space humidity.

Sensors that control the environmental conditions and ventilation rate based on CO₂ concentration, directly relatable to occupant density, VOC levels, humidity, or other parameters are under development and will be readily available in the near future. Some sensors currently are commercially available, but their actual effectiveness is dependent on the measurement. Carbon dioxide sensors can be very effective for controlling ventilation rate. Sensor-controlled “smart buildings” hold the greatest promise in the future for maintaining optimum indoor environments, and even though the effectiveness of the currently available sensors is not always the best, a measure of sensor control is possible. Installation of sensor control in the occupied zones of an existing building could be difficult and expensive, although the long-term advantages may be significant.

Air Disinfection Systems

Air disinfection by ozone or ultraviolet light currently are controversial technologies, but may be effective in areas with ongoing microbial contamination. These systems are being further developed so future versions of the technology may be more effective and safer for building occupants.

Ozone air disinfection probably is the most controversial of the technologies. Ozone is a primary air respiratory irritant so building occupants should never be exposed to it. Additionally there is major ongoing research demonstrating that irritating reaction products of common indoor air pollutants are generated during even low levels of ozone exposure. Room air cleaners that generate ozone should be avoided, but there may be advantages to using ozonation to disinfect microbially contaminated ductwork during unoccupied time periods of a building, although this has not been adequately proven. The actual concentrations of ozone needed for effective microbial kill rates have not yet been

determined, but research is ongoing. Care must be taken to totally flush out the ozone before re-occupation.

Ultraviolet Germicidal Irradiation (UVGI) is another technology under development for destroying airborne microbial contamination. There are a number of commercial units available, but their actual effectiveness is still being researched. Hospitals have used UVGI in operating rooms for several years. Hospitals have found it to be effective against airborne droplet nuclei that transmit diseases such as measles, tuberculosis, and influenza. The specific short wavelength of 253.7 nm is used and is believed to cause no serious or long-term health effects. The use of UVGI is becoming more prevalent in common indoor air settings. Research is ongoing about its effectiveness. UVGI generating fixtures are available as upper room fixtures, in-duct, and inside the HVAC unit itself. UVGI room air cleaners are under development and are usually coupled with high efficiency filtration.

A major application of UVGI in Florida courthouses may be to disinfect contaminated books and documents. Low frequency microwave irradiation or freeze-drying also may be useful decontamination methods for books and documents.

Appendix A

Legal Cases in the Indoor Air Quality

The following information has been collected from “AERIAS: Better health through indoor air quality awareness” web site at www.aerias.org. Usually sick building cases become legal cases when issues are not properly investigated and fixed. However, it has often been difficult for those affected to demonstrate a direct link between exposure to indoor air contaminants and illness. This is because the kind of health problems seen with sick building syndrome are nonspecific, which makes proving or disproving legal causation much more difficult. In addition, the measured levels of indoor air pollutants are usually lower than exposure limits set to prevent health effects in workers exposed to those chemicals. However, increasingly often these health claims related to poor indoor air are being taken seriously. In a landmark case in 1999, the Ohio State Supreme Court awarded an employee \$400,000 from her employer after she became ill from the vapors given off by the new office carpet [1].

The number of cases related to indoor air quality (IAQ) is rising substantially and the amount of damages sought is increasing [2]. Two cases involving indoor air pollution have resulted in settlements of \$25.9 million and \$35 million. One reason for these lawsuits is that there are very few laws and regulations pertaining to the sick building aspects of IAQ. As a result, more and more lawsuits are being filed by building occupants claiming health problems because of poor indoor air quality. The economic consequences of poor indoor air, whether real or perceived, are substantial. These include evacuations, investigations, lost productivity, lawsuits, and workers' compensation claims [3].

It can cost a lot to clean up buildings that have indoor air problems. If the contaminant is mold, lead or asbestos, there may need to be special procedures in place to protect cleanup workers as well as building occupants from further exposure. In some cases, the cost to clean up the contaminated building has been so expensive that the building has been torn down.

Since 1985, most insurance companies have begun writing their commercial general liability policies in a way that excludes many IAQ-related claims in order to prevent having to pay the massive costs involved in cleaning up contaminated buildings. Pollution exclusions have given insurance companies a legal tool to limit their liability in many environmental cases involving IAQ as well as lead paint, asbestos, and urea formaldehyde foam insulation. This has become especially true as the link between common molds and illnesses has become more apparent. Since many insurance companies are less likely to pay, this is opening the door to waves of lawsuits.

Nature of the lawsuits

There are many different kinds of lawsuits that occur because of sick building syndrome. For example, workers will file lawsuits against their employer and maybe the building owner. Building tenants have brought lawsuits against their landlords or building owners.

Building owners have filed lawsuits against architects, engineers, contractors, HVAC manufacturers, interior designers, carpet manufacturers, pesticide applicators, and maintenance personnel. Other lawsuits regarding indoor air quality may include defective design or improper installation of building materials or ventilation systems, negligence in maintenance or application of chemicals, and failure to warn about or failure to disclose potential indoor air quality problems [4]. Here are some specific claims made in lawsuits:

- Some lawsuits are negligence claims. These may cite violations of ASHRAE ventilation standards or local building codes. The point of these lawsuits is to show lack of due care on the part of someone like a building owner, landlord, or construction company. For example, in 1999 and 2000 at a technical college in Wisconsin, seven staffers were diagnosed with sarcoidosis, which is a potentially fatal lung disease. In addition, the school has received hundreds of complaints of sore eyes, dizziness, and nausea in recent years. The school has spent about \$2.5 million repairing and replacing ventilating equipment since 1992 trying to solve the problems. The school sued the architects for \$750,000 saying that the ventilation system was improperly designed. They accepted a \$500,000 settlement [5].
- The basis for one case in Florida was a breach of contract. In this sick building syndrome case, Martin County, Florida filed suit against the construction company that built one of its buildings because of severe mold and moisture problems. These problems became apparent shortly after the building became occupied. Employees began having health and comfort concerns. About 60% of the exterior walls had visible mold including two toxic molds. Though attempts were made to repair the leaks, they were unsuccessful, so Martin County filed suit against the contractor for failing to adequately supervise construction of the building. The construction company argued that the case should be thrown out because there were no actual damages-nobody had gotten sick from the mold. Martin County won because they were able to show that there were many defects in the construction of the building, such as improperly installed windows. The jury awarded them \$11.55 million and the verdict was upheld on appeal. Originally, the county had also filed claims against the project architect and the concrete and masonry construction company but settled those claims out of court for \$2.75 million [6].
- In a few instances, sick building cases have the potential to be covered under product liability law even though historically commercial and residential buildings have not been considered "products" for purposes of determining liability [6]. The products at issue are almost as numerous as the types of personal injuries that could be alleged. These products could possibly include things like HVAC systems, windows, and even roofs. Because laws differ in every state, the lawyers for defendants would need to check state statutes to see if the building (or improvements to it) may be legally characterized as a product in terms of a negligence or product liability suit in the case of a "sick building." However, even if the building is considered to be a product, sometimes there are time limitations [6].

- Several lawsuits have been filed under the Americans with Disabilities Act by people with chemical hypersensitivity seeking "reasonable accommodations" from employers and building owners from chemicals in the workplace [3].
- The Supreme Court of California recently held that under certain conditions damages could be awarded when plaintiffs develop fears of contracting cancer following a toxic exposure, even in the absence of any apparent health problems [7].

Examples of some sick building legal cases:

- A landmark liability case was litigated in 1990 in which two building tenants alleged loss of worker productivity and business losses due to renovations on another floor. The designers, engineers, construction contractors, equipment manufacturers, building operators, and others were subject to liability. This case was settled for an undisclosed sum [8].
- In California, a software company moved into a new, plush building. A few weeks after moving in, two accountants suddenly began having trouble breathing. They began coughing, choking, and their eyes burned with tears rolling down their faces. Within two weeks, everybody in the office began feeling sick with headaches and other problems. The owner of the company complained to building management, who did nothing to correct the problem. Some people quit rather than continue to work in the conditions. It turned out that there was remodeling being done in another part of the building where they were using strong, solvent-based adhesives to seal holes in the air ducts. As a result, the ventilation system spread the vapors throughout the entire building. After fighting indoor air problems for 18 months, the software company finally moved out of that building into a new office where the owner of the software company hired a consultant to help him keep unhealthy material out of the space and also go over the ventilation system with a fine-tooth comb. He also filed a lawsuit against the previous building's owner, architects, contractors, and managers. They settled out of court for several million dollars [9].
- In the 1992 DuPage County Courthouse case in Illinois, in which a brand new \$53 million courthouse had to be evacuated because of health problems related to sick building syndrome, the architect and contractor were sued by the county for \$4 million. In the end, however, the county received only \$120,000 for minor repairs and the jury sided with the defendants, finding that the alleged problems were caused, primarily, by the county's negligent operation and maintenance of the ventilation system. This is just one of the cases that highlights the importance of addressing indoor air issues in all stages of building design, construction, and operation.
- Toxic mold is the focus of a growing number of legal cases across the country. As a result, health problems and property damage caused by mold growing inside buildings are on the rise as one of the hottest areas in construction defect and toxic tort law.¹⁰ Consequently, negligence claims are being filed against building owners and managers for not maintaining the property; and against construction companies,

architects, plumbers, roofers and waterproofers for defective design or workmanship. Here are some examples [10]:

- In one case, the employees of a newspaper in California are suing the landlord for \$10 million for failing to make repairs that allowed several types of mold to grow, which they claim caused lung and sinus infections.
- In another California case, a condominium association is suing real estate developers, contractors and managers for personal injury and property damage caused by inadequate waterproofing that permitted toxic mold to grow.
- In New York, 500 plaintiffs are suing the owners and managers of two apartment complexes for mold contamination.
- In Illinois, parents of elementary school children are suing the school district for negligence for not taking care of flooding that resulted in mold.
- In May 1999 in Tulare County California, county officials first found out about mold in the county courthouse in this small town. The mold problem began in the late 1980s during remodeling when the windows were not sealed correctly. When it rained, water seeped in, which led to the mold growth. One of the worst areas was in one judge's chambers where a softball-sized cluster of *Stachybotrys* was later found [11]. In March 2000, that judge sued the county claiming that *Stachybotrys* made her sick with rashes, headaches and other problems. Since then about 100 other employees have also filed a lawsuit against the county, alleging that exposure to the toxic mold in the courthouse made them sick. Several of these people have developed serious lung disease.
- The employees are seeking unspecified monetary damages and an injunction against the county that would force officials to close the courthouse and remove the mold. These employees are claiming that exposure to the toxic mold *Stachybotrys* has caused rashes, headaches, breathing problems and memory loss. An additional 150 workers have filed claims against the county and 52 county employees are still on medical leave, which has forced some departments to close early and some judges to work at times without clerks. The president of the Tulare County Deputy Attorneys Association said the county could have avoided these lawsuits if officials would have closed the courthouse and cleaned up the mold when it was first reported [12].

Preventing indoor air cases from becoming legal cases

Because lawsuits are generally brought after an injury or loss, the legal system is not a good way to prevent sick building syndrome. The best way to prevent legal action is to avoid an "us versus them" attitude and work with building occupants to try to correct perceived problems. Experts in the field of IAQ agree that outraged employees can quickly become litigious employees. This can help avoid escalating the problem to legal action. Because legal action can be costly, it is important to recognize and take care of problems early so that they do not eventually end up in court. To not do anything is to risk liability.

Buildings need to be designed and constructed to minimize any moisture intrusion, which can lead to mold contamination. Molds are the reason for many personal-injury claims related to poor indoor air quality today. A ventilation system needs to be chosen that is appropriate and provides enough fresh air and proper humidity levels, given the size of the building, the activities that will go on in the building, the number of people in the building, and the climate in which the building is being constructed. Once built, building owners and operators need to have a preventive maintenance plan to keep the ventilation system in good working condition as well as to take care of any other possible indoor air concerns. Care should be taken when choosing furnishings to make sure they are as environmentally friendly and low-emitting as possible. Once occupied, building management should take a proactive position by appointing somebody to be in charge of indoor air quality-someone who makes regular inspections and quickly follows-up with any complaints. A lot of legal action could be avoided if problems had been properly addressed when they were small.

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Problems in Courthouses due to Poor Ventilation, Mold Accumulation, Remodeling and Renovation

Courthouses, like many other buildings, also have indoor air problems. Here are some examples of indoor air problems in courthouses:

Poor Ventilation

- At the 90-year-old courthouse in Arapahoe County, Colorado, dozens of workers complained of sore throats, burning eyes, headaches and dizziness. The building was closed for 12 weeks in 1991 while \$40,000 worth of tests and cleaning was conducted. However, the complaints continued, and the contaminant that was causing these complaints was never found although they did find asbestos and a poor ventilation system. They finally just tore the building down [1].
- In 1992, as soon as the DuPage County Courthouse in Wheaton, Illinois opened, over 50% of the buildings 700 occupants began complaining of symptoms related to sick building syndrome. Complaints ranged from headaches, fatigue, skin rashes, watery eyes and sore throats to nausea and vomiting. Because there were noted flaws in the design of the ventilation system that kept it from supplying enough fresh air throughout the building, the \$53 million building was evacuated, with more than 10,000 employee work hours having already been lost due to the poor indoor air quality problems. After renovations, legal fees, studies, and other costs, the county spent nearly \$6 million fixing the problems. The county filed suit against the building's designers, architects and contractors for \$4 million, claiming that the employees' health problems originated from a poorly designed ventilation system and the use of construction materials that emitted chemicals. The jury awarded the county approximately \$120,000 for certain minor repairs, but ultimately found the county responsible-as the building owner-for health-related complaints, calling the problems a result of improper operation and maintenance.
- In Canada, a judge in a Brampton courthouse was poisoned by vapors in March 2000 from bookshelves that had been refurbished using a solvent containing xylene. When the bookshelves were returned to his office, the judge began suffering from dizziness, bronchial spasms, severe headaches, tightness in his chest, and watery eyes. His physician said his immune system was shutting down because of breathing in the toxic vapors. Several other people also suffered effects from the refurbished furniture. In addition, the ventilation system was not working properly so the vapors accumulated inside the office. This courthouse, which was built in the 1960s, has been plagued with other problems. Tests by an environmental firm showed extremely high levels of carbon dioxide in several rooms, including jury deliberation rooms [2].

Mold Contamination

- In July 1999, Phoenix's municipal judges complained of lethargy and headaches. One lost his voice. The city found extensive mold contamination inside some of the old courthouse's walls. Three weeks before the judges began complaining, a pipe had burst flooding the basement. When the city was inspecting the new courthouse under construction, they also found contaminated drywall [3].
- In May 1999 in Tulare County California, county officials first found out about mold in the county courthouse in a small town in the San Joaquin Valley. The mold

problem began in the late 1980s during remodeling when the windows were not sealed correctly. When it rained, water seeped in which led to the mold growth. One of the worst areas was in the chambers of one of the judges where a softball-sized cluster of *Stachybotrys* was later found [4]. In March 2000 that judge sued the county claiming that *Stachybotrys* made her sick with rashes, headaches and other problems. Since then about 100 other employees have also filed a lawsuit against the county alleging that exposure to toxic mold in the courthouse made them sick. Several of these people have developed serious lung disease. The employees are seeking unspecified monetary damages and an injunction against the county that would force officials to close the courthouse and remove the mold. These employees are claiming that exposure to the toxic mold *Stachybotrys* has caused rashes, headaches, breathing problems and memory loss. An additional 150 workers have filed claims against the county and 52 county employees are still on medical leave, which has forced some departments to close early and some judges to work at times without clerks [5].

- At the historic 97-year old federal courthouse in downtown Tampa, there was such poor indoor air quality that 22 workers were forced to move. Among the indoor air problems in that courthouse are mold, insect debris and other particles that are causing eye irritation, throat infections and allergic reactions among some of those working there. There was mold on law books and the oak trim of the courtroom and chambers. Court clerks who used to work there have wondered whether conditions there were responsible for two reported miscarriages or one employee's heart problems. It is estimated by the Government Services Administration that it will take several years and between \$3-5 million to improve the building's air [6]. A health study recommended removing and replacing carpet, drapes, fabric and ductwork, and cleaning and disinfecting the building [7].
- In Florida, the \$32.4 million Polk County Courthouse that opened in the late 1980s had to close in 1992 because leaks and a faulty air-conditioning and ventilation system led to mold growth. This mold caused illnesses among many of the 580 people who worked there. The reconstruction costs, relocation costs, attorneys' fees and Workers' Compensation payments totaled more than \$ 40 million. The county sued companies involved in building the courthouse and received settlements totaling \$ 47.8 million. After a massive cleanup, it reopened three years later. However, in August 1998 air-conditioning lines above the ceiling of the public defender's office on the third floor began leaking and mold began growing again [8].

Remodeling and Renovations

- In December 1999, the new \$107-million Los Angeles Airport Courthouse opened. Soon after, dozens of employees began complaining of chronic headaches, rashes, fatigue, breathing difficulties and general malaise. After conducting months of interviews and tests, the researchers said that the health problems were real and were partly due to leftover construction dust and the lingering smells of new paint, carpeting, and furnishings. On top of that was the employees' reluctance to leave their old building a few blocks from the beach where windows opened for the new building

in an industrial district less than a mile from airport runways. Employees also complained about inadequate ventilation, lack of privacy in the open floor plan, more noise, and more sun glare on computer screens [9].

- Elsewhere in Massachusetts, a \$6.3 million waterproofing project was begun in the summer of 1993 to correct leaks at the Suffolk County Courthouse. Contractors were removing each brick and coating the building with a chemical compound meant to prevent wind and water from seeping in, but they were never able to finish the job. The vapors from the chemical poisoned dozens of employees, who suffered medical ailments including headaches, coughing, fatigue, nausea, enlarged livers, and asthma. By the time the project was halted a year later, the chemical had been applied to half the building's exterior. State officials relocated about 200 courthouse workers after numerous complaints about poor indoor air quality. Since then, numerous measures have been taken to improve air quality at the Pemberton Square courthouse including an \$800,000 overhaul of the building's ventilation system. In January 1999, 29 courthouse workers settled a negligence lawsuit for \$3 million with the private companies involved in the waterproofing job [10].

An IAQ Nightmare

- The courthouse in Norfolk County Massachusetts has been a true indoor air nightmare. Workers in the 100-year old building have complained for years of itchy eyes, sinus problems, fatigue, dizziness, bronchitis, and headaches. Some also point to abnormally high incidences of cancer among courthouse workers. Studies have found airborne asbestos, lead paint, stopped-up air vents, and mildew. In 1997, 240 pounds of debris and nine dead pigeons were removed from the building's ductwork. A few years ago, it was discovered that a pipe had been discharging raw sewage into one corner of a busy file storage room. Raw sewage can contain infectious diseases like hepatitis A. The only sources for fresh air were windows and doors, and for security reasons, many remained closed [11]. Occasionally pigeons have been known to fly around inside the building. This is dangerous because their excrement can carry the spores to diseases such as histoplasmosis and cryptococcosis.

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Case Against Insurance Company

The following part is collected from Claims Magazine written Everett L. Herndon, Jr. and Chin S. Yang. In February 2000, a Texas grand jury found reason to continue a criminal investigation of child endangerment charges against an insurance company for its handling of a water damage claim. This investigation was prompted by a criminal complaint filed by the policyholder and follows the filing of a \$100 million lawsuit in 1999 against the same company for its handling of the claim. The policyholders say that the insurance company did not act properly or in a timely manner following the water damage claim. The allegation is that the house is now uninhabitable.

The family claims that, following the water damage, and while they were still living in the house during repairs, they were coughing up blood. The husband, the family claims, is now suffering from a cognitive dysfunction, among other injuries.

The problem? Mold. *Stachybotrys chartarum* (a.k.a. atra) to be specific. The mold developed following a water damage loss in 1998. The policyholders allege that neither the insurance company nor the company's expert informed the family that the home contained the deadly mold until their health was irreversibly damaged.

Is the Texas case merely an extreme example? Or is it a harbinger of things to come?

Many lawsuits have been filed and are being filed around the country involving the improper handling of covered water damage losses that have resulted in mold growth so extensive and severe as to present potentially serious - and in too many cases, actual - health hazards, not only to the occupants of the building involved but possibly to anyone who unwittingly enters the structure. Furthermore, mold growth can cause damage to building materials, such as paper and wood products. Mold contamination and growth may also pose a disclosure issue during a real estate transaction.

According to the Insurance Information Network of California and the Western Insurance Information Service, both sponsored by insurance companies, water damage from frozen and broken water pipes ranks second, behind hurricanes, in terms of the number of homes damaged and the amount of claim costs in the U.S. Damage from water is the most prevalent, yet least recognized, catastrophe. in addition to broken and frozen water pipes,

we have to include losses from flood, rain, leaks and surface water, as well as water damage from putting out fires.

Some of these losses are covered, some are not. If the water damage is the result of a covered loss, the resultant damage, mold (including fungi, mildew, etc.), is probably also covered and must be considered in preparing the scope of damages and costs of repair.

The consensus of opinion from the EPA, FEMA, the Centers for Disease Control (CDC), mycologists and microbiologists is that mold may start to grow and spread 24 to 48 hours in structures damaged by water. Mold can grow exponentially, given the right conditions of temperature, moisture and food sources, such as sheetrock.

Appendix B

Related Technical Reports to the Indoor Air Quality (OSHA's web site at www.osha-slc.gov)

The following section provides a number of technical reports related to the Indoor Air Quality directly from OSHA's web site at www.osha-slc.gov. Concerns with Indoor Air Quality (IAQ) have increased since energy conservation measures were instituted in office buildings during the 1970s minimizing the infiltration of outside air and contributing to the buildup of indoor air contaminants. IAQ generally refers to the quality of the air in an office environment. Other terms related to IAQ include Indoor Environmental Quality (IEQ) and "Sick Building Syndrome." Complaints about IAQ range from simple complaints such as the air smelling odd to more complex, where the air quality causes illness and lost work time. It may not be easy to identify a single reason for IAQ complaints because of the number and variety of possible sources, causes, and varying individual sensitivities. The following part shows technical reports in four areas: Recognition, Evaluation, Control, and Compliances.

Recognition

- IAQ problems can be caused by ventilation system deficiencies, overcrowding, tobacco smoke, microbiological contamination, outside air pollutants, and off gassing from materials in the office and mechanical equipment. Related problems also may include comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels, as well as adverse ergonomic conditions, and job-related psycho-social stressors. Typical symptoms may include headaches, unusual fatigue, itching or burning eyes, skin irritation, nasal congestion, dry or irritated throats, and nausea.
- *Mold Remediation in Schools and Commercial Buildings*. EPA (2001, March). This document presents guidelines for the remediation/cleanup of mold and moisture problems in schools and commercial buildings; these guidelines include measures designed to protect the health of building occupants and remediators. It has been designed primarily for building managers, custodians, and others who are responsible for commercial building and school maintenance. It should serve as a reference for potential mold and moisture remediators. Using this document, individuals with little or no experience with mold remediation should be able to make a reasonable judgment as to whether the situation can be handled in-house. It will help those in charge of maintenance to evaluate an in-house remediation plan or a remediation plan submitted by an outside contractor. Contractors and other professionals who respond to mold and moisture situations in commercial buildings and schools may also want to refer to these guidelines.
- *Guidelines on Assessment and Remediation of Fungi in Indoor Environments*. New York City Dept. of Health (2000, November). The focus of this guidance document

addresses mold contamination of building components (walls, ventilation systems, support beams, etc.) that are chronically moist or water damaged.

- Indoor Air Quality Investigation, OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 2 (1999, January 20), 19 pages. Contains guidelines for IAQ investigations, recommendations on sampling instrumentation and methods, as well as guidelines for employers to prevent or alleviate IAQ problems. Discusses acute health effects of major indoor air contaminants.
- EPA's Indoor Air Quality Home Page. Introduction to IAQ; common pollutants; IAQ in homes, schools, and offices; IAQ publications; IAQ hotlines; and IAQ links.
- Indoor air Quality Information Clearing House. The Indoor Air Quality Information Clearinghouse (IAQINFO) is an easily-accessible, central source of information on indoor air quality. It is created and supported by the U.S. Environmental Protection Agency (EPA).
- EPA Fact Sheet - Ventilation and Air Quality in Offices (1990, July), 2 pages. Overview of sources of indoor air pollution, health problems and ventilation, control, ventilation standards and building codes, ventilation system problems and solutions, air cleaners, economic considerations, and resolving problems.
- The Inside Story - A Guide to Indoor Air Quality. EPA Document #402-K-93-007 (1995, April), 8 pages. Comprehensive online booklet on indoor air quality concerns.
- CPSC Publications - Indoor Air Quality. Index of Consumer Product Safety Commission publications related to IAQ.
- NIOSH/Fact Sheet/Indoor Environmental Quality (1997, June), 1 page. Provides an overview of indoor environmental quality issues.

Evaluation

- Methods used in an IAQ investigation may include: identification of pollutant sources; evaluation of the heating, ventilating, and air conditioning (HVAC) system performance; observation of production processes and work practices; measurement of contamination levels and employee exposure; medical testing or physical examinations; employee interviews; and review of records of medical tests, job histories and injuries and illnesses.
- PathCon Technical Bulletin 2.4, A Suggested Air Sampling Strategy for Microorganisms in Office Settings. Sampling strategy for analyzing air samples for fungi and bacteria in office settings. Includes two protocols: the 7-plate protocol and the 4-plate protocol.

- Investigating Office-Related Complaints. OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 2, Appendix III:2-1 (1999, January 20). The synergistic effect of multiple stressors appears to indicate that building-related problems may be more than an air quality problem.
- Sampling and Analytical Methods. OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 2, Appendix III:2-2 (1999, January 20). Analytical methods for potential IAQ contaminants.

Control

- NIOSH/EPA Building Air Quality (BAQ) Action Plan. DHHS (NIOSH) Publication No. 98-123 (1998, June), EPA Publication No. 402-K-98-001. An easy-to-use 8-step BAQ action plan for use by building owners and managers. Should be used in conjunction with Building Air Quality: A Guide for Building Owners and Facility Managers. DHHS (NIOSH) Publication No. 91-114 (1991, December), EPA Publication No. 400/1-91/003.
- Ventilation Investigation. OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 3 (1999, January 20), 31 pages. Guidelines for investigation of ventilation systems including health effects, standards and codes, investigation guidelines, and prevention and control.

Compliance

- Federal Register - 59:15968-16039. Indoor Air Quality (1994, April 5), 70 pages. By this notice, the Occupational Safety and Health Administration (OSHA) proposes to adopt standards addressing indoor air quality.
- Indoor Air Quality in the Workplace [Long-Term Actions]. OSHA Unified Agenda (2001, May 14). OSHA was petitioned in May 1987 by Action on Smoking and Health (ASH), Public Citizen, and the American Public Health Association to issue an emergency temporary standard on environmental tobacco smoke (ETS) in the workplace. In March 1992, OSHA was petitioned by the AFL-CIO to establish workplace IAQ standards. In December 1992, ASH again petitioned for rulemaking on ETS. After reviewing and analyzing available information, OSHA published a proposed rule on April 5, 1994. The proposal would require employers to write and implement indoor air quality compliance plans that would include inspection and maintenance of current building ventilation systems to ensure they are functioning as designed.

Appendix C

Glossary of Terms (From www.aerias.org)

This glossary of terms is provided by the AERIAS: Better health through indoor air quality awareness, at its web site: www.aerias.org.

ABSOLUTE HUMIDITY: the amount of water vapor in a given volume of air.

ABSORPTION: the process of one substance entering into the inner structure of another.

ACALCULIA: a dysfunction in calculation ability.

ACCEPTABLE INDOOR AIR QUALITY: The physical and chemical nature of indoor air (as delivered to the breathing zone of the building occupants) which produces a complete state of mental, physical, and social well-being of the occupants, not merely the absence of disease and sickness.

ACGIH: The American Conference of Governmental Industrial Hygienists is a community of professionals who work to advance worker health and safety through education and the development and dissemination of scientific and technical knowledge.

ACH: Air Changes per Hour is the number of changes of outdoor air per unit of time.

ACID AEROSOL: Acidic liquid or solid particles that are small enough to become airborne. High concentrations of acid aerosols can be irritating to the lungs and have been associated with some respiratory diseases, such as asthma.

ACTIVATED CHARCOAL: A highly absorbent form of carbon used to remove odors and toxic substances from liquids or gases.

ACUTE: Health effects which show up a short length of time after exposure. An acute exposure runs a relatively short course.

ACUTE EXPOSURE: a single exposure to a toxic substance that results in biological harm or death; usually characterized as lasting no longer than a day.

ACUTE TOXICITY: the ability of a substance to cause poisonous effects resulting in severe biological harm or death soon after a single exposure or dose. Any severe poisonous effect resulting from a short-term exposure.

ADSORPTION: the adhesion of a thin film of liquid or gases to the surface of a solid substance.

AEROSOL: a gaseous medium containing suspended particles.

AGRAPHIA: a disorder marked by loss of the ability to write.

AHAM: Association of Home Appliances Manufacturers.

AIHA: American Industrial Hygiene Association.

AIR CLEANING SYSTEM: A device or combination of devices applied to reduce the concentration of airborne contaminants such as microorganisms, dust, fumes, respirable particles, other particulate gases, and vapors in air.

AIR-CONDITIONING: the process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness, and distribution.

ALA: American Lung Association is the oldest voluntary health organization in the United States. Founded in 1904 to fight tuberculosis, ALA today fights lung disease in all its forms, with special emphasis on asthma, tobacco control and environmental health.

ALDEHYDES: Reactive organic compounds that contain HC=O group such as formaldehyde and hexanal.

ALGAE: simple rootless plants that grow in sunlit waters at the level of how many nutrients are available.

ALLERGEN: A substance capable of causing an allergic reaction because of an individual's sensitivity to that substance.

ALLERGIC RHINITIS: inflammation of the mucous membranes of the nose.

ALLERGY (adj. allergic): an abnormal response of a hypersensitive person to chemical and physical stimuli; allergic manifestations of major importance occur in about 10 percent of the population (adjective form: ALLERGIC).

ALLERGY, CHEMICAL: adverse reaction to a chemical resulting from previous sensitization to that chemical or one structurally similar.

AMBIENT AIR: the outdoor air surrounding an object.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS:
See ACGIH.

AMERICAN LUNG ASSOCIATION: See ALA.

AMERICAN PUBLIC HEALTH ASSOCIATION: See APHA.

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS: See ASHRAE.

AMERICAN THORACIC SOCIETY: See ATS.

ANEMIA: Too few red blood cells in the bloodstream, resulting in not enough oxygen to tissues and organs.

ANIMAL DANDER: tiny scales of animal skin.

ANTIBODY: A protein substance produced in the blood or tissues in response to a specific antigen, such as a bacterium or a toxin. Antibodies destroy or weaken bacteria and neutralize organic poisons, thus forming the basis of immunity.

ANTIGEN: A substance that when introduced into the body stimulates the production of an antibody. Antigens include toxins, bacteria, foreign blood cells, and the cells of transplanted organs.

APHA: The American Public Health Association consists of a group of public health professionals concerned with a broad set of issues affecting personal and environmental health, including federal and state funding for health programs, pollution control, programs and policies related to chronic and infectious diseases, a smoke-free society, and professional education in public health.

APHONIA: loss of the voice resulting from disease, injury to the vocal cords, or various psychological causes, such as hysteria

ASBESTOS: A naturally occurring mineral fiber that can cause cancer.

ASHRAE: American Society of Heating, Refrigerating and Air-conditioning Engineers is an international organization with the goal of conducting research, writing standards and publications, and providing continuing education to the public regarding heating, ventilation, air-conditioning and refrigeration systems.

ASTHMA: common disease of the lower respiratory system with episodic bronchial restrictions.

ASTM: American Society for Testing Materials.

ATAXIA: loss of the ability to coordinate muscular movement.

ATS: The American Thoracic Society is an independently incorporated, international, educational and scientific society that helps to prevent and fight respiratory disease around the globe through research, education, patient care, and advocacy.

BACTERIUM (pl. **BACTERIA**): Microorganisms, mostly single-celled; their DNA is naked rather than being enclosed in a nucleus.

BAKE-OUT: A process to flush out volatile organic compounds by elevating the temperature in an unoccupied fully-furnished and ventilated building.

BAQ: Building Air Quality refers to the quality of air in a building.

BENZENE: A major organic intermediate and solvent derived from coal or petroleum.

BENZOPYRENE: a yellow, crystalline, aromatic hydrocarbon, that is a carcinogen found in coal tar and cigarette smoke.

BIOAEROSOL: An airborne organic contaminant that is either generated by or is itself a living organism; examples of bioaerosols are fungi, bacteria, viruses, protozoa, pollen, animal dander, insect emanations, microbial endotoxins, and human skin scales.

BIOCIDE: any poison that kills a living organism.

BIOHAZARD: a combination of the words biological and hazard; organisms or products of organisms that present a risk to humans.

BREATHING ZONE: the area of a room in which occupants breathe as they stand, sit, or lie down.

BRI:Building-Related Illness: This term is used when symptoms of a disease from several occupants of a building can be directly linked to specific airborne contaminants in that building. This differs from SBS because with SBS no specific illness or cause can be identified.

BUILDING AIR QUALITY: See BAQ.

BUILDING ENVELOPE: outer walls, windows, doors, etc. of a building or the "building shell.

BUILDING RELATED ILLNESS: See BRI.

BYSSINOSIS: An occupational respiratory disease caused by the long-term inhalation of cotton, flax, or hemp dust and is characterized by shortness of breath, coughing, and wheezing. It is also called brown lung disease.

CADR: Clean Air Delivery Rate is the amount of clean air measured in cubic feet per minute (cfm) that an air cleaner delivers to a room.

CARBON BLACK: Any of various finely divided forms of carbon derived from the incomplete combustion of natural gas or petroleum oil and used to reinforce rubber and as an ingredient in inks, paints, crayons, and polishes.

CARBON DIOXIDE (CO₂): an odorless, colorless gas that is a product of human respiration.

CARBON MONOXIDE (CO): an odorless, colorless gas that is a product of incomplete combustion.

CARBON MONOXIDE POISONING: a poisoned state in which carbon monoxide gas has been breathed and soaked up by the blood. Too much carbon monoxide limits the ability of the blood to transport oxygen. It is treated by removing the patient from the source right away and giving oxygen.

CARBOXYHEMOGLOBIN: A compound produced when carbon monoxide links with red blood cells. It is breathed into the lungs and enters the bloodstream. It blocks the sites on the cells that carry oxygen. Oxygen in the blood decreases and, when it decreases too much, suffocation and death result.

CARCINOGEN: a substance that can cause or contribute to cancer.

CDC: Centers for Disease Control and Prevention, located in Atlanta, Georgia, USA, is an agency whose purpose is to promote health and quality of life by preventing and controlling disease, injury, and disability.

CENTRAL NERVOUS SYSTEM: See CNS.

CFC: Chlorofluorocarbon is any of various halocarbon compounds consisting of carbon, hydrogen, chlorine, and fluorine, once used widely as an aerosol propellant and a refrigerant. CFCs are believed to cause depletion of the atmospheric ozone layer.

CFM: Cubic Feet per Minute is the amount of air, in cubic feet, that flows through a given space in one minute.

CFU: Colony Forming Unit is enough spores, hyphae or bacteria to form a colony.

CHEMICAL SENSITIZATION: Evidence suggests that some people may develop health problems characterized by effects such as dizziness, eye and throat irritation, chest tightness, and nasal congestion that appear whenever they are exposed to certain chemicals. People may react to even trace amounts of chemicals to which they have become "sensitized."

CHEMISORB: to take up and hold, usually irreversibly, by chemical forces.

CHLOROFLUOROCARBON: See CFC.

CLEAN AIR DELIVERY RATE: See CADR.

CNS: Central Nervous System is the portion of the vertebrate nervous system consisting of the brain and spinal cord.

COLONY: a single point of growth of mold or bacteria.

COLONY FORMING UNIT: See CFU.

COMBUSTION: burning or rapid oxidation accompanied by a release of energy.

COMPLIANCE TESTS: used to determine whether a product complies with a defined program specification such as State of Washington or EPA. A compliance or certification sheet is supplied with the test report.

CONCENTRATION: the quantity of one part in a defined amount of another (ex. ppm, ppb).

CONIDIUM (pl. CONIDIA): an asexual spore that is released when mature.

CONIDIOPHORE: a hypha with specialized cells that produce conidia.

CONSUMER PRODUCT SAFETY COMMISSION: See CPSC.

CONTAMINANT: any physical, chemical, biological, or radioactive substance that can adversely affect air, water or soil.

COOLING COIL: an arrangement of pipe or tubing that transfers heat from air to a refrigerant or brine.

CPSC: Consumer Product Safety Commission is an independent federal agency formed to protect the public against unreasonable risks of injuries and deaths associated with consumer products.

CREOSOTE: A yellowish to greenish-brown oily liquid containing phenols and creosols, obtained from coal tar and used as a wood preservative and disinfectant. It can cause severe neurological disturbances if inhaled in strong concentrations.

CUBIC FEET PER MINUTE: See CFM.

CYANOSIS: a bluish discoloration of the skin and mucous membranes; a sign that oxygen in the blood is dangerously diminished (as in carbon monoxide poisoning).

DEHUMIDIFICATION: the condensation of water vapor from air by cooling below the dewpoint or removal of water vapor from air by chemical or physical methods.

DEHUMIDIFIER: (1) An air cooler or washer used for lowering the moisture content of the air passing through it; (2) An absorption or adsorption device for removing moisture from air.

DEMENTIA: an organic mental disorder characterized by a general loss of intellectual abilities involving impairment of memory, judgment and abstract thinking as well as changes in personality.

DERMATITIS: inflammation of the skin.

DILUTION: additional supply of outdoor air introduced to reduce concentration of indoor pollutants.

DUCT: a passageway made of sheet metal or other suitable material, not necessarily leaktight, used for conveying air or other gas at low pressures.

DUST: an air suspension (aerosol) of particles of any solid material, usually with particle size less than 100 micrometers.

DUST MITE: a microscopic arachnid, commonly *Dermatophagoides pteronyssinus* or *Dermatophagoides farinae*.

DUST MITE ALLERGEN: allergenic proteins (antigens) derived from dust mites
EMFs: Electromagnetic Fields.

EMISSION: pollution discharge from a source.

EMISSION FACTOR: a single point quantitative measurement of gaseous or particle emission from a material source as determined by an environmental chamber.

EMISSION PROFILE (DECAY CURVE): used to measure how emissions decay or decrease over time. It can be used to predict exposure concentrations, such as those required by the State of Washington.

EMISSION RATE: the actual rate of release of volatile vapors from a product over time.

EMLAP: The Environmental Microbiology Laboratory Accreditation Program, which is associated with AIHA, is designed specifically for laboratories involved in analyzing microbiological samples to evaluate exposures in a variety of workplaces. Participation assists the laboratory in maintaining high quality standards.

EMPHYSEMA: chronic pulmonary disease characterized by loss of lung function after many alveolar walls have been destroyed, with resulting enlargement of the air space. Emphysema patients have reduced capacity for gas exchange in the lungs.

ENDOTOXIN: a toxin produced by certain bacteria and released upon destruction of the bacterial cell.

ENVIRONMENTAL CHAMBER: a controlled, non-reactive testing device of known volume with dynamically maintained air change rate, temperature, and humidity.

ENVIRONMENTAL PROTECTION AGENCY: See EPA.

ENVIRONMENTAL TOBACCO SMOKE: See ETS.

EPA: The United States Environmental Protection Agency is a federal agency established to coordinate programs aimed at reducing pollution and protecting the environment.

ERGONOMIC: design factors, as for the workplace, intended to maximize productivity by minimizing operator fatigue and discomfort.

ETS: Environmental Tobacco Smoke is a mixture of smoke from the burning end of a cigarette, pipe, or cigar and smoke exhaled by the smoker (also secondhand smoke or passive smoking).

EVAPORATION: change of state from liquid to vapor.

EXFILTRATION: air leakage outward through cracks and other openings such as ceilings, floors and walls of a space or building.

EXHAUST AIR: air removed from a space and not reused therein.

FASCICULATIONS: muscular twitching of adjoining groups of muscle fibers.

FDA: The Food and Drug Administration is the U.S. Agency responsible for the regulation of biotechnology food products. The major laws under which the agency has regulatory powers include the Food, Drug and Cosmetic Act, and the Public Health Service Act.

FEVER: an abnormal temperature of the body above 98.6°F (37°C). Exercise, anxiety, and dehydration may increase the temperature of healthy people. Infection, nerve disease, cancer, anemia, and many drugs may cause fever. No single theory explains why the temperature is increased.

FIBROMYALGIA: a chronic disorder characterized by widespread musculoskeletal pain, fatigue, and multiple tender points. "Tender points" refers to tenderness that occurs in precise, localized areas, particularly in the neck, spine, shoulders, and hips. People with this syndrome may also experience sleep disturbances, morning stiffness, irritable bowel syndrome, anxiety, and other symptoms.

FLUSH OUT: period in which a building's HVAC system is operated at maximum outdoor air in order to remove contaminants from the space.

FOOD AND DRUG ADMINISTRATION: See FDA.

FORMALDEHYDE: a volatile organic compound that is a natural product of human metabolism, a byproduct of the combustion process, and an important industrial chemical used to produce synthetic urea- and phenol-formaldehyde.

FRUITING STRUCTURE (OF MOLDS): conidiophores or other structures that produce spores.

FTC: Federal Trade Commission.

FUMES: airborne solid particles usually less than 1 micrometer in size formed by condensation of vapors, sublimation, distillation, calcination, or chemical reaction.

FUNGAL PROPAGULES: spores or hyphal fragments capable of producing colonies.

FUNGUS (pl. FUNGI): non-photosynthesizing parasitic lower plants that secrete enzymes and absorb food, producing and living inside branched tubes called hyphae (includes molds, mildew, yeasts, and mushrooms).

FUNGICIDE: biocides used to control, prevent, or kill fungi.

GAO: The General Accounting Office is an investigative arm of Congress that examines the use of public funds, evaluates federal programs and activities, and provides analyses, options, recommendations, and other assistance to help the Congress make effective oversight, policy, and funding decisions.

GAS: a state of matter in which substances exist in the form of nonaggregated molecules, and which, within acceptable limits of accuracy, satisfies the ideal gas laws; usually a highly superheated vapor.

GERMICIDE: an agent capable of killing germs.

GRAM-NEGATIVE BACTERIA: in gram-staining, gram-negative bacteria incorporate the counterstain (pink) rather than the primary stain (purple), because of a lack in peptidoclycan in the cell wall. The pathogenic nature of gram-negative bacteria is usually associated with certain components of their cell walls, particularly the lipopolysaccharide (endotoxin) layer.

GRAM-POSITIVE BACTERIA: characterized by their blue-violet color reaction in the gram-staining procedure. The blue-violet color reaction is caused by crystal violet, the primary gram-stain dye. A distinguishing factor among gram-positive bacteria is that roughly 90% of their cell wall is comprised of peptidoglycan.

HARDBOARD: like particleboard, it is made from particles and shavings of wood glued together with synthetic resin. Its density, however, is higher than particleboard or MDF. Hardboard has multiple uses in the building/construction and furniture industries.

HEPA: High Efficiency Particulate Air (filter) is a disposable, extended medium, dry type filter with a particle removal efficiency of no less than 99.97 percent for 0.3 micrometer particles.

HEPATITIS: inflammation of the liver, caused by infectious or toxic agents and characterized by jaundice, fever, liver enlargement, and abdominal pain.

HISTOPLASMOSIS: a disease caused by the inhalation of spores of the fungus *Histoplasma capsulatum*, most often asymptomatic but occasionally producing acute pneumonia or an influenzalike illness and spreading to other organs and systems in the body.

HUD: Department of Housing and Urban Development is the federal department that administers federal programs dealing with better housing and urban renewal; created in 1965.

HUMIDIFIER: a device to add moisture to the air.

HUMIDIFIER FEVER: ("Ventilation Fever") a respiratory illness caused by exposure to toxins from microorganisms found in wet or moist areas in humidifiers and air-conditioners.

HUMIDITY: water vapor in the air.

HVAC: Heating, Ventilation, and Air-Conditioning system is a system concerned with the temperature, humidity, cleanliness, and distribution of air.

HYALINE (OF MOLDS): colorless.

HYDROCARBONS: common organic compounds that contain carbon and hydrogen.

HYPERREFLEXIA: exaggeration of reflexes.

HYPERSENSITIVITY: the immune system's exaggerated response to an allergen.

HYPERSENSITIVITY PNEUMONITIS: a group of respiratory diseases, including humidifier fever that involves inflammation of the lungs. Most forms of hypersensitivity pneumonitis are caused by the inhalation of organic dusts, including molds.

HYPHAE: single threads of a fungal body, also used for certain bacteria (actinomycetes).

HYPOKINESIA: decreased muscular activity.

HYPOXIA: deficiency in the amount of oxygen reaching body tissues.

IAQ: Indoor Air Quality refers to the quality of the air in the indoor environment. This may also be referred to as Indoor Environmental Quality (IEQ). Typical symptoms of poor IAQ include headaches, unusual fatigue, itching or burning eyes, skin irritation, nasal congestion, dry and/or irritated nose or throat, and nausea.

IARC: International Agency for Research on Cancer.

IEQ:Indoor Environmental Quality refers to all the factors that influence the working environment including such things as lighting and air temperature.

IMMUNE SYSTEM: all internal structures and processes providing defense against disease-causing organisms such as viruses, bacteria, fungi, and parasites.

INCUBATION PERIOD: the development of an infection from the time the pathogen enters the body until signs or symptoms first appear.

INDOOR AIR: the air within an indoor structure such as residence, office building, any public or private building, and transportation vehicle.

INDOOR AIR QUALITY: See IAQ.

INDOOR ENVIRONMENTAL QUALITY: See IEQ.

INFILTRATION: air leakage inward through cracks and other openings such as ceilings, floors and walls of a space or building.

INH: a trademark used for the drug isoniazid; an orally administered drug used to treat tuberculosis infection in people without active disease. INH is also administered in combination with other drugs to treat active tuberculosis.

INSECTICIDE: any material or agent capable of killing insects.

ION: an electrically charged atom. An atom that has lost one or more of its electrons is left with a positive electrical charge; those that have gained one or more extra electrons are left with a negative charge.

IRRITANT: physical, biologic, or chemical stressors that induce acute symptoms and inflammation of the tissue.

ISO: An organization, the International Organization for Standardization, which sets standards in many businesses and technologies, to improve quality.

ISONIAZID: See INH.

JAUNDICE: yellowish discoloration of the whites of the eyes, skin, and mucous membranes caused by deposition of bile salts in these tissues. It occurs as a symptom of various diseases, such as hepatitis, that affect the processing of bile.

LASSITUDE: a state or feeling of weariness, diminished energy, or listlessness.

LEGIONNAIRES' DISEASE (or Legionnaire's): illness produced by Legionella pneumophila bacteria that can affect lungs and other body systems.

LETHARGY: a condition of abnormal drowsiness or inactivity; a great lack of energy; lack of interest.

MAKEUP AIR: outdoor air supplied to replace exhaust air and exfiltration

MALaise: a vague feeling of discomfort or uneasiness.

MAN-MADE MINERAL FIBERS: generic term denoting fibrous inorganic substances made primarily from rock, clay, slag, or glass.

MASS PSYCHOGENIC ILLNESS: See MPI.

MATERIAL SAFETY DATA SHEET: See MSDS.

MCS: Multiple Chemical Sensitivity is an unexplained condition where a person reports sensitivities and adverse reactions to low levels of chemicals.

MDF: Medium Density Fiberboard is a type of particleboard-it is made of wood particles glued together by synthetic resin, with a medium density, as opposed to hardboard. They are typically found in 4' x 8' sheets, with 3/4" thickness, and are commonly used in furniture and cabinetry.

MENINGITIS: inflammation of the meninges of the brain and the spinal cord, most often caused by a bacterial or viral infection and characterized by fever, vomiting, intense headache, and stiff neck.

METHANE: a colorless, flammable gas created by anaerobic decomposition of organic compounds.

METHEMOGLOBINAEMIA: an inability of the blood to carry oxygen and can cause headaches, fatigue, dizziness, and a blue color to the skin and lips.

METHYLENE CHLORIDE: a chlorinated hydrocarbon that has been used as an inhalation anaesthetic and acts as a narcotic in high concentrations. Its primary use is as a solvent in manufacturing and food technology.

METHYL TERTIARY BUTYL ETHER: See MTBE.

MICROBIAL VOCs: See MVOCs.

MICROGRAM (μg): one microgram is equal to one thousandth (1/1,000) of a milligram or one millionth (1/1,000,000) of a gram.

MICROMETER (μm): one micrometer is equal to one thousandth (1/1,000) of a millimeter or one millionth (1/1,000,000) of a meter.

MICROORGANISM: a microscopic organism, especially a bacterium, fungus, or a protist.

MITE: See Dust mite.

MOLD: a common term for microscopic forms of fungi; a growth of fungi forming a furry patch, as on stale bread or cheese. See also spore.

MPI: Mass Psychogenic Illness is where persons experience similar symptoms traceable to psychological factors. Symptoms typically include fainting, nausea, headaches and dizziness.

MSDS: Material Safety Data Sheets provide necessary, helpful, and useful information on the properties of a chemical or chemical product.

MTBE: Methyl Tertiary Butyl Ether is a fuel oxygenate which enhances the octane in gasoline and decreases carbon monoxide emission by increasing burning efficiencies.

MUCOUS MEMBRANES: lining of the hollow organs of the body, notably the nose, mouth, stomach, intestines, bronchial tubes, and urinary tract.

MULTIPLE CHEMICAL SENSITIVITY: See MCS.

MUTAGEN: any substance that can cause a change in genetic material.

MVOCs: Microbial Volatile Organic Compounds are volatile chemicals produced by the metabolism of fungi and bacteria.

MYALGIA: pain in one or more muscles.

MYCOTOXIN: toxins produced by certain molds; natural exposures to these toxins are poisonous to man and animals.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH: See NIOSH.

NATIONAL INSTITUTES OF HEALTH: See NIH.

NATIONAL TOXICOLOGY PROGRAM: See NTP.

NATURAL VENTILATION: the movement of air into and out of a space through intentionally provided openings, such as windows and doors, or through non-powered ventilators or by infiltration.

NEGATIVE PRESSURE: condition that exists when less air is supplied to a space than is exhausted from the space, so the air pressure within that space is less than that in surrounding areas.

NEUROTOXIC: chemicals that cause central nervous system (CNS) problems such as dizziness, headaches and ability to think clearly.

NIH: The National Institutes of Health is a nonregulatory U.S. Federal agency that has oversight of research activities that the agency funds.

NIOSH: National Institute for Occupational Safety and Health is the agency in the Centers for Disease Control (CDC) of the U.S. Department of Health and Human Services that researches safety and health hazards in the workplace and makes recommendations to improve conditions. Unlike OSHA, they have no enforcement powers.

NOEL: The No Observable Effect Level is the highest dose level that has not been associated with an observable harm in humans or test animals.

NOSOCOMIAL INFECTIONS: the type of infections that are acquired in hospitals

NTP: The National Toxicology Program is a Federal agency that coordinates toxicology research and testing activities within the Department; provides information about potentially toxic chemicals to regulatory and research agencies and the public; and strengthens the science base in toxicology.

OCCUPATIONAL HEALTH and SAFETY ADMINISTRATION: See OSHA.

OCCUPIED ZONE: the area within 6 feet of the floor and not within 1 foot of the walls or fixed air-conditioning equipment. As this is the area of occupancy, it is desirable to avoid excessive draft velocities and temperature differences within this space.

ODOR: a quality of gases, liquids or particles that stimulates the olfactory organ.

OFF-GASSING: the production of gases from the chemical deterioration of a substance over time.

OSHA:Occupational Safety and Health Administration is the agency in the U.S. Department of Labor that enforces safety and health regulations in private workplaces to ensure safe and healthy working conditions.

OUTDOOR AIR: air taken from the external atmosphere and, therefore, not previously circulated through any system.

OXIDATION: a reaction in which oxygen combines with another substance.

OZONE (O₃): a reactive form of oxygen that is a strong mucous membrane and pulmonary irritant.

PAHs: Polycyclic Aromatic Hydrocarbons are natural products of the incomplete combustion of carbon compounds.

PARESTHESIA: a skin sensation, such as burning, prickling, itching, or tingling, with no apparent physical cause.

PARTICULATE: a state of matter in which solid or liquid substances exist in the form of aggregated molecules or particles. Airborne particulate matter is typically in the size range of 0.01 to 100 micrometers.

PARTICULATE MATTER: a suspension of fine solid or liquid particles in air, such as dust, fog, fume, mist, smoke, or sprays. Particulate matter suspended in air is commonly known as an aerosol.

PARTS PER BILLION: See PPB.

PARTS PER MILLION: See PPM.

PATHOGEN: any microorganism capable of causing disease

PCBs: Polychlorinated Biphenyls are any of a family of industrial compounds produced by chlorination of biphenyl, noted primarily as an environmental pollutant that accumulates in animal tissue with resultant pathogenic and teratogenic effects.

PCM: Per Cubic Meter, for example, is the number of CFUs in a one-meter cube of air.

PEL:Permissible Exposure Level is an exposure limit that is published and enforced by OSHA as a legal standard.

PERCHLOROETHYLENE: a colorless, nonflammable organic solvent, used in dry-cleaning solutions and as an industrial solvent.

PERMISSIBLE EXPOSURE LEVEL: See PEL.

PESTICIDE: a chemical used to kill pests (as rodents or insects).

pH: means used to express the degree of acidity or alkalinity of a solution with neutrality indicated as seven.

PICOCURIE (pCi): a unit for measuring radioactivity often expressed as picocuries per liter (pCi/L) of air.

PLENUM: a condition, as in an occupied room, in which the pressure of the air is greater than that of the outside atmosphere; as, a plenum may exist in a hall ventilated by a fan blower.

PLUG FLOW: a flow regime where the flow is predominately in one direction and contaminants are swept along with the flow.

PNAs: Polynuclear Aromatics, synonymous to PAHs.

PNEUMONIA: a swelling of the lungs, commonly caused by breathed-in bacteria (*Diplococcus pneumoniae*). Parts of the lungs become plugged with a fiber-like fluid. Pneumonia may also be caused by Rickettsiae, viruses, and fungi. Symptoms of pneumonia are severe chills, a high fever (which may reach 105°F), headache, cough, and chronic pain. Breathing often becomes painful, shallow, and rapid.

POLLUTANT: an airborne contaminant associated with illness.

POLYCHLORINATED BIPHENYLS: See PCBs.

POLYCYCLIC AROMATIC HYDROCARBONS: See PAHs.

POLYVINYL CHLORIDE: See PVC.

PONTIAC FEVER: a milder illness of Legionnaires' disease. Persons with Pontiac fever experience fever and muscle aches and do not have pneumonia. They generally recover in 2 to 5 days without treatment.

POSITIVE PRESSURE: condition that exists when more air is supplied to a space than is exhausted, so the air pressure within that space is greater than that in surrounding areas.

POTABLE WATER: water that is safe for human consumption.

PPB: Parts Per Billion is 1 part in 1,000,000,000. The difference between 1 ppm and 1 ppb is important-it is like the difference between \$1 and \$1000.

PPM: Parts Per Million is a unit of concentration often used when measuring levels of pollutants in air, water, body fluids, etc. One ppm is 1 part in 1,000,000. The common unit, µg/liter, is equal to ppm.

PRESSED WOOD PRODUCTS: a group of materials used in building and furniture construction that are made from wood veneers, particles, or fibers bonded together with an adhesive under heat and pressure.

PSI: Pollution Standards Index, or Pounds per Square Inch.

PULMONARY FIBROSIS: chronic inflammation and progressive fibrosis of the pulmonary alveolar walls, with steadily progressive difficulty in breathing, resulting finally in death from lack of oxygen or heart failure.

PVC: Polyvinyl Chloride is a common thermoplastic resin, used in a wide variety of manufactured products, including rainwear, garden hoses, phonograph records, and floor tiles.

RADIOALLERGOSORBENT TEST: See RAST.

RADON: a known human carcinogen; is a naturally occurring, radioactive gas that is colorless, odorless, and tasteless. It comes from the natural decay of uranium, a radioactive metal found in soil and rock in the earth's crust. Radon is found in low amounts in soils all over the world at varying low levels.

RADON DECAY PRODUCTS (radon daughters or progeny): the result of the decaying of radon; they can be breathed into the lung where they continue to release radiation as they further decay.

RAST: Radioallergosorbent test is an allergy test done on a sample of blood. The aim with RAST, as with skin tests, is to check for allergic sensitivity to specific substances.

RECIRCULATED AIR: air removed from the conditioned space and intended for reuse as supply air.

RELATIVE HUMIDITY: See RH.

REPRODUCTIVE TOXICANT: an agent that causes birth defects or other reproductive harm.

RESPIRABLE PARTICLES: particles that penetrate into and are deposited in the non-ciliated portion of the lung. Particles greater than 10 micrometers aerodynamic diameter are not respirable. Peak deposition of respirable particles occurs within the size range of 0.2 to 5 micrometers.

RETURN AIR: air removed from a space to be then recirculated or exhausted.

RH: Relative Humidity is the ratio of the amount of water in the air at a given temperature to the maximum amount it could hold at that temperature; expressed as a percentage.

RHINITIS: inflammation of nasal mucous membranes; "runny nose."

SAPROTROPHIC FUNGI: fungi that obtain nutrition from dead organisms.

SBS: Sick Building Syndrome refers to when many occupants in a building or in the same part of a building experience immediate health problems that seem to be due to the building, but no specific illness or cause can be identified. (Contrast with BRI).

SENSITIZATION: an allergic condition that usually affects the skin or lungs. Once exposure to a substance has caused a reaction, the individual may be sensitized to it, and further exposure may elicit an adverse reaction even at low levels.

SICK BUILDING: a building whose occupants complain of health and comfort problems that can be related to working or being in a building.

SICK BUILDING SYNDROME: See SBS.

SILICOSIS: a lung disease caused by inhaling particles of silica or quartz or slate.

SINGLE POINT TEST: used to compare emission levels across products, compare to a baseline, evaluate source of odor, or see what VOCs and levels are associated with a product. A single point cannot accurately predict exposure concentrations.

SINK: a material that can adsorb volatile chemicals or biocontaminants with subsequent re-emission

SINUSITIS: a swelling of one or more nasal sinuses. It may be a complication of an upper respiratory infection, dental infection, allergy, a change in atmosphere, as in air travel or underwater swimming, or a defect of the nose.

SOIL GASES: gases that enter a building from the surrounding ground (e.g., radon, volatile organics, pesticides).

SOLVENT: substances that can dissolve other substances. Though water is sometimes called the "universal solvent," most people mean organic solvents when they refer to these chemicals.

SOURCE CONTROL: strategy for reducing airborne contaminants by removing or reducing emitting materials or activities.

SPORE: a small, usually single-celled reproductive body that is highly resistant to dehydration and heat and is capable of growing into a new organism, produced especially by certain bacteria, fungi, algae, and non-flowering plants.

STACK EFFECT: pressure-driven airflow produced by convection as heated air rises, creating a positive pressure area at the top of a building and a negative pressure area at the bottom of a building. The stack effect can overpower the mechanical system and disrupt ventilation and circulation in a building. Example: When smoking occurs at building entrances, it is sucked back into the building, chimney-style, because of the suction from the revolving doors.

SUPPLY AIR: that air delivered to the conditioned space and used for ventilation, heating, cooling, humidification or dehumidification.

SURFACTANT: a substance capable of reducing the surface tension of a liquid in which it is dissolved [syn: wetting agent, surface-active agent].

SYNERGISM: the working together of two or more things (i.e. chemicals) to produce an effect greater than the sum of their individual effects.

TERATOGEN: any medication, chemical, infectious disease, or environmental agent that might interfere with the normal development of a fetus and result in the loss of a pregnancy, a birth defect, or a pregnancy complication.

THERMOTOLERANT: able to grow at high temperatures (e.g. 37°C).

THRESHOLD LIMIT VALUE: See TLV.

TLV: Threshold Limit Value is the air concentration of chemical substances to which healthy workers can be exposed for 8-hour work days during a 40-hour work week without suffering an adverse effect. A table of these values and accompanying precautions is published annually by the ACGIH.

TOLUENE: a colorless flammable liquid obtained from petroleum or coal tar; used as a solvent for gums and lacquers and in high-octane fuels.

TOTAL SUSPENDED PARTICULATE: the mass of particulates suspended in a unit of volume of air when collected by a high volume sampler.

TOTAL VOLATILE ORGANIC COMPOUNDS: See TVOC.

TOXICITY: inherent ability of a chemical to adversely affect living organisms.

TOXICOLOGY: study of harmful effects of chemicals on living organisms.

TOXIN: a substance produced by a living organism that injures tissues or alters the functions of another organism.

TUBERCULOSIS: an infectious disease of human beings and animals caused by the tubercle bacillus and characterized by the formation of nodules on the lungs and other tissues of the body, often developing long after the initial infection. In the lungs, it is characterized by the coughing up of mucous and sputum, fever, weight loss, and chest pain.

TVOC: Total Volatile Organic Compounds are the sum of all volatile organics collected and analyzed by a defined analytical method.

UEL: Upper Explosive Limit is the highest concentration (expressed in percent vapor or gas in the air by volume) of a substance that will burn or explode when an ignition source is present.

UPPER EXPLOSIVE LIMIT: See UEL.

UPPER RESPIRATORY TRACT: structures that conduct air into the lungs, including the nasal cavity, mouth, pharynx, and larynx.

VAPOR: any gas below its critical temperature; barely visible or cloudy diffused matter, such as mist, fumes, or smoke, suspended in the air.

VENTILATION: the process of supplying and removing air by natural or mechanical means to and from any space; such air may or may not be conditioned.

VENTILATION AIR: the portion of supply air that is outdoor air plus any recirculated air that has been treated for the purpose of maintaining acceptable indoor air quality.

VENTILATION RATE: the rate at which indoor air enters and leaves a building. It is expressed in one of two ways: the number of changes of outdoor air per unit of time (air changes per hour, or "ach") or the rate at which a volume of outdoor air enters per unit of time (cubic feet per minute, or "cfm").

VERMICULITE: any of a group of micaceous hydrated silicate minerals related to the chlorites and used in heat-expanded form as insulation and as a planting medium.

VIRUS (adj. VIRAL): an infectious agent that contains either RNA or DNA in its core surrounded by a protein shell, is able to alternate between intracellular and extracellular states, and replicates only when present in living cells.

VOCs: Volatile Organic Compounds: Chemicals containing carbon are called organic. Volatile means that they evaporate or get into the air easily which make them easier to breathe in. Examples of common VOCs include benzene and trichlorethylene.

VOLATILE ORGANIC COMPOUNDS: See VOCs.

WATER ACTIVITY: a measure of the amount of water held within materials.

WHO: The World Health Organization is a United Nations agency that coordinates international health activities and helps governments improve health services.

XEROTOLERANT: able to grow under relatively dry conditions (damp rather than wet).

XYLENE (also XYLOL): any of three flammable isomeric hydrocarbons, obtained from wood and coal tar; a mixture of xylene isomers used as a solvent in making lacquers and rubber cement and as an aviation fuel.

Appendix D

Construction Resource Center College of Architecture Georgia Institute of Technology

The Construction Resource Center (CRC) at Georgia Tech conducts and coordinates research activities and conducts customized continuing education courses in construction related disciplines. Its primary focus is to serve architecture, engineering, construction, real estate development, material and related areas by working on real world practical projects with the private and government sectors. Over the years the center staff consisting of Georgia Tech faculty and research scientists have conducted research activities funded by industry, government, the military, and others.

CRC provides three specific services to business, government and industrial markets. Primarily, the CRC conducts technological research for organizations with particular design and build concerns. In addition, the center is equipped and available to specialize in continuing education courses, workshops and symposiums.

Research:

The research associates with the CRC are available to conduct long or short-term research projects. Short mini-studies are a cost effective way for organizations in our industry to benefit from the wide range of available expertise within the CRC as an out-source for special project problem solving.

Continuing Education:

The faculty members associated with CRC are available to design, develop and implement general and customized continuing education programs or courses. CRC will also provide a forum for the industry and government to discuss problems, needs, opportunities and solutions.

Partnering:

The main goal of the CRC is to partner with government and industry for the development, transfer and application of advanced technologies for enhancing the effectiveness and efficiency of organizations and projects.

Appendix E

List of On-Line Resources

Water and Air The right mix

<http://www.facilitiesnet.com/fn/NS/NS3m1ai.htm>

Indoor Air Quality: Tools for Schools

<http://www.epa.gov/iaq/schools/tools4s2.html>

<http://www.epa.gov/iaq/schools/tools4s2.html>

Healthy Building Design for the Commercial, Industrial, and Institutional Marketplace

<http://www.hlturner.com/Indoor%20Air%20Quality/healthybldgs.htm>

IAQ Breathing Room: The Long View of IAQ

<http://www.facilitiesnet.com/fn/NS/NS3e8eb.html>

Healthy Advice or Alarmist Literature? National Education Association Handbook Creates Unease in Cleaning and Maintenance Industry

<http://www.cmmonline.com/article.asp?indexid=2340609>

Preventing Child Exposures to Environmental Hazards: Research and Policy Issues.

<http://www.cehn.org/cehn/symposium.html>

Guide to School Health and Safety Committees: How To Promote Child and Adult Environmental Health Protection

http://www.healthyschools.org/guides_materials.html

Environmental Protection Agency Indoor Air Quality Information

<http://www.epa.gov/iaq/iaqinfo.html>

Envirosources

<http://www.envirosources.com/>

Mold Resources

<http://www.epa.gov/iaq/pubs/moldresources.html>

National Registry of Environmental Professionals

<http://www.nrep.org/>

University of Minnesota, Environmental Health and Safety

<http://www.dehs.umn.edu/iaq/flood.html>

New York City Protocol

www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html#enviro

Appendix F

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