INDOOR AIR QUALITY AND MOLD REMEDIATION SERVICE TECHNIQUES

A Desktop Reference and Training Guide for IAQ and Mold Remediation
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Preface

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The information in this course is intended for educational purposes only. Procedures described are for use only by qualified air conditioning and refrigeration service technicians. This training course is not a substitute for any Manufacturer's Operating Manual.

Take safety precautions when using all equipment. Improper use of equipment can cause explosion and serious personal injury. Always read the entire Manufacturer's Operator Manual before turning on any equipment for the first time. Use extreme caution when working with molds, spores and other airborne or surface contaminants, since inhalation of these air contaminants can cause serious medical problems, including death. Do not use any protective equipment if you do not understand its operation and it is not in perfect working order. **Where procedures described in this manual differ from those of a specific equipment manufacturer, the equipment manufacturer's instructions should be followed.** Again, misuse of safety or protective equipment can cause personal injury.

Technical and legislative information presented in this book is current as of the date of publication. Due to rapidly advancing technology and changing regulations, no representation can be made for the future accuracy of the information. Visit the EPA's Indoor Air Quality Building Page at http://www.epa.gov/iaq/ for the latest details.

Disclaimer

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The manual was intended to serve as a training manual to help technicians successfully pass Mainstream's Indoor Air Quality Technician (IAQ Tech) certification examination. This training manual is the first step in the learning process; technicians are urged to obtain additional information from the local health department, product manufacturers, the EPA website and ASHRAE. The manual is not intended to teach building remediation or air conditioning/refrigeration system installation, troubleshooting, or repair. Experienced service technicians will notice that a lot of information is not new on the topic of indoor air quality; most of the procedures for maintaining clean and dry building envelopes have been in use for years. However, with today's tighter building envelopes, these skills must now be applied more diligently than ever.

Users of this manual should also be aware of available information that is not included here. The intent is to present a basic introductory course concentrating on practical, basic information that is most needed and can be readily applied on the job with the most effective results. The reader is encouraged to seek additional information from OSHA, EPA and other parties referenced at the end of this manual. This manual should be the first step in a continual training program. Please visit our website at www.qwik.com for the latest information and products.

This manual is in a continual state of evolution and revision, partly because of the changing EPA regulations and partly because of the information feedback from technicians in the field. If there are sections of this manual that require improvement, or there are missing areas that you believe to be important, please write us a short note and we will see that the improvements are incorporated into future editions. In the past, we have received very useful comments and suggestions from HVAC/R technicians in the field, and to all those who have helped in the past, we owe a sincere debt of gratitude. Suggestions on the improvement of this course or any Mainstream product will always be welcomed. To submit suggestions, comments or complaints, please write to Robert P. Scaringe, Ph.D., P.E., IAQ Tech Certification Program, Mainstream Engineering Corporation, Pines Industrial Center, 200 Yellow Place, Rockledge, Florida 32955.

Mainstream Engineering Corporation assumes no liability for the use of information presented in this publication. This information is presented for educational purposes only. Manufacturer's Operator Manuals must be consulted for the proper operation of any piece of equipment. **This manual is not intended to teach fundamental air conditioning or refrigeration system techniques or safety practices. Likewise, this manual is not intended to teach safe mold remediation practices or mold handling techniques. Rather, the purpose of this manual is to point out the significant issues involved with working with these substances and how the HVAC system can affect indoor air quality. This manual assumes the technician possesses both EPA-Approved Section 608 certification and PM Tech certification.** If you do not yet hold these certifications, please visit our website at www.qwik.com to obtain this training first.

IAQ Examination Information

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In the last several years, a growing body of scientific evidence has indicated that the air within buildings can be more seriously polluted than the outdoor air. It is also clear that HVAC systems are the primary mechanism to condition and clean the air in buildings and commercial buildings. Likewise, problems in the HVAC system are also the primary factor in resulting problems associated with indoor air quality. In a properly constructed building, it is the HVAC system that can most significantly affect the quality and cleanliness of the indoor air. **Therefore, the HVAC technician is the ideal individual to implement Indoor Air Quality improvements in a structure.** Clearly, the HVAC Technician, after being trained in IAQ matters, is the individual best suited to service, adjust, inspect, and clean the HVAC's network of ducting, heat exchangers, condensate pans, humidifiers and blowers. With this in mind, this training program was developed.

This Training and Certification program is designed to help advance the fundamental principles necessary to improve the quality of conditioned air inside buildings. Certification is available on-line at www.qwik.com.

The **IAQ Tech certification** exams consist of 25 questions. Technicians can take the IAQ Tech certification exam as many times as necessary (passing grade is 21 correct out of the 25 questions or 84%). The exams are open-book and technicians have a maximum of three hours to complete each exam. If you retake the exam, you will automatically be given a different set of questions from the test bank.

IAQ Tech certification is needed to offer the full warranty benefits of Mainstream's Qwik**Products**™ to your customers. Three types of certification are available: **Apprentice**, **Journeyman**, and **Master** IAQ Tech. Prior to obtaining any of Mainstream's IAQ certifications, the technician must have an EPA 608 certification from an EPA-approved certifying agency, such as Mainstream.

The IAQ Tech certification exam is available on-line. You can take the exam online when you are ready. The exam questions are related to Indoor Air Quality and the proper use of Qwik**Products**™ and the Air Conditioning system to improve indoor air quality and prevent mold formation.

Mainstream reserves the right to revoke the IAQ Tech certification given to any individual, at any time, and without prior notice, for excessive customer complaints, unethical or illegal service practices, failure to meet Mainstream's professional requirements, or any other reason deemed justifiable by Mainstream employees. Mainstream is under no legal obligation to disclose the reason for the revocation.

Levels of IAQ Tech Certification

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Apprentice IAQ Tech

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This certification requires:

a) EPA Section 608 certification from Mainstream or any other EPA-approved testing organization,

b) successfully completing the IAQ Tech exam with a score of 84% or better.

Documentation to prove EPA certification may be necessary if Mainstream does not already have this documentation. If you pass your exam and the exam status reads "PASSED", you must provide Mainstream with proof of 608 certification.

Journeyman IAQ Tech

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This certification includes all the requirements of the Apprentice IAQ Tech (above) plus at least five years verifiable experience in the HVAC/R trades. Documentation to substantiate this experience is required. However, if you hold a Journeyman PM Tech certification you will automatically be issued a Journeyman IAQ certification as well.

Master IAQ Tech

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This certification includes all the requirements of the Apprentice IAQ Tech plus at least 10 years verifiable experience in the HVAC/R trades. Documentation to substantiate this experience is required. However, if you hold a Master PM Tech certification you will automatically be issued a Master IAQ certification as well.

Definitions

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Allergen	Substance (such as dust mites, mold or mold spores that can cause an allergic reaction
APR	Air purifying respirator
ASTM	American Society for Testing and Materials
Biocide	Substance or chemical that kills organisms such as molds
Building Occupants	Describes people who spend extended time periods in the building. Clients and visitors are also occupants; they may have different tolerances and expectations from those who spend their entire workdays in the building, and are likely to be more sensitive to odors.
Building Related Illness (BRI)	Refers to illness brought on by exposure to the building air, where symptoms of diagnosable illnesses are identified (e.g., certain allergies or infections) and can be directly attributed to environmental agents in the air. Legionnaire's disease and hypersensitivity pneumonitis are examples of BRI that can have serious, even life-threatening consequences.
Dew Point	If the air is gradually cooled while maintaining the moisture content constant, the relative humidity will rise until it reaches 100%. This temperature, at which the moisture content in the air will saturate the air, is called the dew point. If the air is cooled further, some of the moisture will condense.
Dry-build Temperature	The temperature of the air measured with a dry thermocouple or thermometer with a dry bulb. The Dry-Bulb and Wet-Bulb temperatures can be used together to determine relative humidity.
EPA	Environmental Protection Agency
Fungi	Fungi are neither animals nor plants and are classified in a kingdom of their own. Fungi include molds, yeasts, mushrooms, and puffballs. In this document, the terms fungi and mold are used interchangeably. Molds reproduce by making spores. Mold spores waft through the indoor and outdoor air continually. When mold spores land on a

	damp spot indoors, they may begin growing and digesting whatever they are growing on. Molds can grow on virtually any organic substance, providing moisture and oxygen are present. It is estimated that more than 1.5 million species of fungi exist.
Fungicide	Substance or chemical that kills fungi
HEPA	High-Efficiency Particulate Air
Hypersensitivity	Great or excessive sensitivity
Humdity	The water vapor mixed with air in the atmosphere
Humidity Ratio	Also known as Specific Humidity, the pounds of water contained in a pound of dry air
IAQ	Indoor Air Quality
MERV	Minimum Efficiency Reporting Value
Mold	Molds are a group of organisms that belong to the kingdom Fungi. In this document, the terms fungi and mold are used interchangeably. There are over 20,000 species of mold.
mVOC	Microbial volatile organic compound, a chemical made by a mold that may have a moldy or musty odor
NIOSH	National Institute for Occupational Safety and Health
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PAPR	Powered air purifying respirator
PPE	Personal Protective Equipment
Relative Humidity	The ratio of weight of water in the air relative to the maximum weight of water that can be held in saturated air
Remediate	Fix
Sensitization	Repeated or single exposure to an allergen that results in the exposed individual becoming hypersensitive to the allergen

Spore	Molds reproduce by means of spores. Spores are microscopic; they vary in shape and size (2-100 micrometers). Spores may travel in several ways- they may be passively moved (by a breeze or water drop), mechanically disturbed (by a person or animal passing by), or actively discharged by the mold (usually under moist conditions or high humidity).
Stack Effect	The pressure driven flow produced by convection (the tendency of warm air to rise)
UL	Underwriters Laboratories
Wet-bulb Temperature	The temperature of the air measured with a wet thermocouple or thermometer with a wet bulb. The Dry-Bulb and Wet-Bulb temperatures can be used together to determine relative humidity.

Section I:

The Basics of Indoor Air Quality

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Introduction

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In the last several years, a growing body of scientific evidence has indicated that the air within buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors. In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor air pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

Asthma afflicts about 20 million Americans, including 6.3 million children. Since 1980, the largest growth in asthma cases has been in children under five. In 2000 there were nearly two million emergency room visits and nearly half a million hospitalizations due to asthma, at a cost of almost $2 billion, and causing 14 million school days missed each year.

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in buildings. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the building. High temperature and humidity levels can also increase concentrations of some pollutants.

Pollutant Sources

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Introduction

There are many sources of indoor air pollution in any building. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides and outdoor air pollution.

The relative importance of any single source depends on how much of a particular pollutant is given off and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and products like air fresheners, candles and scented oils release pollutants more or less continuously. Other sources, related to activities carried out in the building, release pollutants intermittently. These include smoking, the use of un-vented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

Factors Affecting Indoor Air Quality

Recent EPA studies have identified indoor air pollution as one of the most important environmental risks to the nation's health. With the advancement of modern technology, the number and types of contaminants released into indoor air have increased dramatically.

The indoor environment in any building is a result of the interaction between the site, climate, building system (original design and later modifications in the structure and mechanical systems), construction techniques, contaminant sources (building materials and furnishings, moisture, processes and activities within the building and outdoor sources), and building occupants.

Four elements are involved in the development of indoor air quality problems:

1. **Source:** There is a source of contamination or discomfort indoors, outdoors, or within the mechanical systems of the building.
2. **HVAC:** The HVAC system is not able to control existing air contaminants and ensure thermal comfort (temperature and humidity conditions that are comfortable for most occupants).
3. **Distribution:** One or more pollutant pathways connect the pollutant source to the occupants and a driving force exists to move pollutants along the pathway(s).
4. **Occupants:** Building occupants are present.

It is important to understand the role that each of these factors may play in order to prevent, investigate, and resolve indoor air quality issues.

Sources of Indoor Air Contaminants

Indoor air contaminants can originate within the building or be drawn in from outdoors. If contaminant sources are not controlled, IAQ problems can arise, even if the HVAC system is properly designed and well maintained.

It may be helpful to think of air pollutant sources as fitting into one of the following categories. The examples given for each category are not intended to be a complete list.

Sources: Outside Building

Contaminated Outdoor Air

- pollen, dust, fungal spores
- industrial pollutants
- general vehicle exhaust

Emissions from nearby sources

- exhaust from vehicles on nearby roads, parking lots, garages, or loading docks
- odors from trash cans or dumpsters
- re-entrained (drawn back into the building) exhaust from the building itself or from neighboring buildings
- unsanitary debris near the outdoor air intake

Soil Gas

- radon
- leakage from underground fuel tanks

- contaminants from previous uses of the site (e.g., landfills) pesticides

Exterior Moisture or standing water - promoting excess microbial growth

- rooftops after rainfall
- water accumulation at outlet of the Condensate Drain
- crawl space

Sources from Equipment

HVAC system

- dust or dirt in ductwork or other components
- microbiological growth in drip pans, humidifiers, ductwork, coils
- improper use of biocides, sealants, and/or cleaning compounds
- improper venting of combustion products
- refrigerant leakage

Non-HVAC equipment

- emissions from office equipment (volatile organic compounds, ozone) supplies
- emissions from shops, kitchens, bathrooms, labs, cleaning processes
- elevator motors and other mechanical systems

Sources from Human Activities

Personal Activities

- smoking
- body odor
- cosmetic odors

Housekeeping Activities

- cleaning materials and procedures
- emissions from stored supplies or trash
- use of deodorizers, candles and fragrances
- airborne dust or dirt

Maintenance Activities

- microorganisms in mist from improperly maintained cooling towers
- airborne dust or dirt
- volatile organic compounds from use of paint, caulk, adhesives, and other products
- pesticides from pest control activities
- emissions from stored supplies

Sources from Building Components and Furnishings

Locations that produce or collect dust or fibers

- textured surfaces such as carpeting, curtains, and other textiles
- open shelving
- old or deteriorated furnishings
- materials containing damaged asbestos

Unsanitary conditions and water damage

- microbiological growth on or in soiled or water-damaged furnishings
- microbiological growth on or in wet air ducts
- standing water from clogged or poorly designed drains
- standing water from poorly installed humidifiers
- dry traps that allow the passage of sewer gas

Chemicals released from building components or furnishings

Other Sources

Accidental events

- spills of water or other liquids
- microbiological growth due to flooding or to leaks from roofs and piping
- fire damage

Special use areas and mixed use buildings

- smoking lounges
- laboratories
- print shops, art rooms
- exercise rooms
- beauty salons
- food preparation areas

Redecorating/remodeling/repair activities

- emissions from new furnishings
- dust and fibers from demolition
- odors and volatile organic and inorganic compounds from paint, caulk, adhesives
- microbiological contaminants from demolition or remodeling activities

Indoor air often contains a variety of contaminants that are far below any standards or guidelines for occupational exposure. Given our present knowledge, it is difficult to relate complaints of specific health effects to exposure to specific pollutant concentrations, especially since the significant exposures may be to low levels of pollutant mixtures.

HVAC System Design and Operation

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The HVAC system includes all heating, cooling and ventilation equipment serving a building: furnaces or boilers, chillers, cooling towers, air handling units, exhaust fans, ductwork, filters, and steam (or heating water) piping. Most of the HVAC discussion in this course applies to central HVAC systems.

A properly designed and functioning HVAC system provides thermal comfort (cooling and dehumidification or heating and humidification), and filters the air. In addition, commercial HVAC systems also; distribute adequate amounts of outdoor air to meet ventilation needs of all building occupants and isolate and remove odors and contaminants (through pressure control and exhaust fans).

Thermal Comfort

A number of variables interact to determine whether people are comfortable with the temperature of indoor air. The activity level, age and physiology of each person affect the thermal comfort requirements of that individual.

Uniformity of temperature is important to comfort. When the heating and cooling needs of rooms within a single zone change at different rates, rooms that are served by a single thermostat may be at different temperatures. Temperature stratification is a common problem caused by convection, the tendency of light and warm air to rise, and heavier and cooler air to sink. If the air is not properly mixed by the ventilation system, the temperature near the ceiling can be several degrees warmer than at floor level. Even if the air is properly mixed, un-insulated floors over unconditioned spaces can create moisture problems, and discomfort in some climate zones. Large fluctuations of indoor temperature can also occur when controls have a wide dead band (a temperature range within which neither heating nor cooling takes place). Adjusting the thermostats dead band or replacing the thermostat with a new thermostat that uses a narrower dead band or an improved anticipating control algorithm, such as a PID controller, can easily remedy some of these problems. The installation of a dehumidifier to a central AC system can provide reduced humidity.

Radiant heat transfer may cause people located near very hot or very cold surfaces to be uncomfortable even though the thermostat setting and the measured air temperature are within the comfort range. Buildings with large window areas sometimes have acute problems of discomfort due to radiant heat gains and losses. The locations where complaints are usually made can shift during the day as the sun angle changes. Large vertical surfaces can also produce significant natural convection flows resulting in complaints of drafts. Adding insulation to walls helps to moderate the temperature of interior wall surfaces. Closing curtains reduces heating from direct sunlight and isolates building occupants from exposure to window surfaces (which, lacking insulation, are likely to be much hotter or colder than the walls).

Humidity is a factor in thermal comfort. Raising relative humidity reduces the ability to lose heat through perspiration and evaporation, so that the effect is similar to raising the temperature. Humidity extremes can also create other IAQ problems. Excessively high or low relative humidity can produce discomfort, while high relative humidity can promote the growth of mold and mildew. To prevent mold and mildew the relative humidity must be less than 55% in all areas of the building.

Pollutant Pathways and Driving Forces

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Airflow patterns in buildings result from the combined action of mechanical ventilation systems, human activity, and natural forces. Pressure differentials created by these forces move airborne contaminants from areas of relatively higher pressure to areas of relatively lower pressure through any available opening.

The HVAC system is generally the predominant pathway and driving force for air movement in buildings. However, all of a building's components (walls, ceilings, floors, penetrations, HVAC equipment and occupants) interact to affect the distribution of contaminants. For example, as air moves from supply registers or diffusers to return air grilles, it is diverted or obstructed by partitions, walls and furnishings, and redirected by openings that provide pathways for air movement. The movement of people throughout the building also has a major impact on the movement of pollutants. Some of the pathways change as doors and windows open and close. It is useful to think of the entire building--the rooms and the connections (e.g., chases, corridors, stairways, elevator shafts) between them--as part of the air-distribution system.

Natural forces exert an important influence on air movement between zones and between the building's interior and exterior. Both the stack effect and the wind can overpower a building's mechanical system and disrupt air circulation and ventilation, especially if the building envelope is leaky.

Stack effect is the pressure-driven flow produced by natural convection (the tendency of warm air to rise). The stack effect exists whenever there is an indoor-outdoor temperature difference and becomes stronger as the temperature difference increases. As heated air escapes from upper levels of the building, indoor air moves from lower to upper floors, and replacement outdoor air is drawn into openings at the lower levels of buildings. The resulting airflow can transport contaminants between floors by way of stairwells, elevator shafts, utility chases, or other openings. Stack effects can be so strong as to prevent ground floor doors from closing; instead they are blown inward by the replacement air rushing into the building.

Wind effects are transient and create local areas of high pressure (on the windward side) and low pressure (on the leeward side) of buildings. Depending on the leakage openings in the building exterior, wind can affect the pressure relationships within and between rooms.

The basic principle of air movement from areas of higher pressure to areas of relatively lower pressure can produce many patterns of contaminant distribution. Air moves from areas of higher pressure to areas of lower pressure through any available openings. A small crack or hole can admit significant amounts of air if the pressure differentials are high enough (which may be very difficult to assess).

Even when the whole building is maintained under positive pressure, there is always some location (for example, the outdoor air intake) that is under negative pressure relative to the outdoors. Entry of contaminants may be intermittent, occurring only when the wind blows from a particular direction. The interaction between pollutant pathways and intermittent or variable driving forces can lead to a single source causing IAQ complaints in areas of the building that are distant from each other and from the source.

Ventilation

If too little outdoor air enters a structure, pollutants can accumulate to levels that can pose health and comfort problems. Unless they are built with special mechanical means of ventilation, buildings are designed and constructed to minimize the amount of outdoor air that can "leak" into and out of the building. The tighter the building, the higher the pollutant levels, when compared to buildings with more outdoor air leakage.

Outdoor air enters and leaves a building through infiltration, natural ventilation and mechanical ventilation. In the process known as infiltration, outdoor air flows into the building through openings, joints and cracks in walls, floors and ceilings, and around windows and doors. In natural ventilation, air moves through opened windows and doors. Air movement associated with infiltration and natural ventilation is caused by indoor and outdoor air temperature differences and by wind. Finally, there are a number of mechanical ventilation devices, from outdoor-vented fans that intermittently remove air from a single room, such as bathrooms and kitchen, to air handling systems that use fans and duct work to continuously remove indoor air and distribute filtered and conditioned outdoor air to strategic points throughout the building. The rate at which outdoor air replaces indoor air is described as the *air exchange rate*. When there is little infiltration, natural ventilation, or mechanical ventilation, the air exchange rate is low and pollutant levels can increase.

Types of Duct Work

While commercial air ducts are fabricated from sheet metal, most modern residential air duct systems are constructed of fiberglass duct board or sheet metal ducts that are lined on the inside with fiberglass duct liner. Since the early 1970s, a significant increase in the use of flexible duct has occurred. Flexible duct is generally lined internally with plastic or some other type of material. Internal insulation provides better acoustical (noise) control. Flexible duct is very low cost. These products are engineered specifically for use in ducts or as ducts themselves, and are tested in accordance with standards established by Underwriters Laboratories (UL), the American Society for Testing and Materials (ASTM), and the National Fire Protection Association (NFPA).

Many insulated duct systems have operated for years without supporting significant mold growth. Keeping them reasonably clean and dry is generally adequate. However, there is substantial debate about whether porous insulation materials (e.g., fiberglass) are more prone to microbial contamination than bare sheet metal ducts. If enough dirt and moisture are permitted to enter the duct system, there may be no significant difference in the rate or extent of microbial growth in internally lined or bare sheet metal ducts. However, treatment of mold contamination on bare sheet metal is much easier. **Once fiberglass duct liner is contaminated with mold, cleaning is not sufficient to prevent re-growth and there are no EPA-registered biocides for the cleaning of porous duct materials. We agree with the EPA, that in this situation the replacement of the wet or moldy fiberglass duct material is required.**

Clearly, all experts agree that moisture should not be present in ducts and if moisture is present, the potential exists for biological contaminants to grow and distribute throughout the building. Controlling moisture is the only effective way to prevent biological growth on any type of air ducts.

Strategies to Prevent Biological Growth in HVAC Systems

- Correct any water leaks or standing water.
- Remove standing water under cooling coils of air handling units by making sure that drain pans slope toward the drain. Always use a pan tablet to prevent scum deposits which can clog a condensate drain line. Consider installing a pan tablet dispenser so the equipment owner can add pan tablets as needed.
- If humidifiers are used, they must be properly maintained.
- Air handling units should be installed for easy, direct access to the heat exchange components and drain pans, thereby allowing proper cleaning and maintenance.
- Fiberglass insulation, duct board, or any other material that is wet or visibly moldy (or if an unacceptable odor is present) should be removed and replaced.
- Steam cleaning and other methods involving moisture should not be used on any kind of ductwork.

Mold

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Introduction

Molds produce tiny spores to reproduce. Mold spores waft through the indoor and outdoor air continually. When mold spores land on a damp spot indoors, they may begin growing and digesting whatever they are growing on in order to survive. There are molds that can grow on wood, paper, carpet and foods. When excessive moisture or water accumulates indoors, mold growth will occur, particularly if the moisture problem remains undiscovered or ignored. There is no practical way to eliminate all molds and mold spores in the indoor environment; the way to control indoor mold growth is to control moisture and humidity.

The key to mold control is moisture control. It is important to dry water-damaged areas and items within 24-48 hours to prevent mold growth. If mold is a problem in a building, remove the mold, wet materials and the excess water. Fix leaky plumbing or other sources of water. Clean and kill mold on hard surfaces with a hard surface cleaner that contains an EPA registered biocide (following label instructions). Absorbent (porous) materials (such as fiberglass insulation, fiber duct board, ceiling tiles and carpet) that become wet or moldy must be replaced.

Black Mold

Black Mold, also known as **Stachybotrys Chartarum (atra)** is a greenish-black fungus found worldwide that colonizes particularly well in high-cellulose material, such as straw, hay, wet leaves, dry wall, carpet, wall paper, fiber-board, ceiling tiles, thermal insulation, etc. Back Mold (**Stachybotrys Chartarum)**, before drying, is wet and slightly slimy to touch. There are about 15 species of Stachybotrys found worldwide.

<u>This toxic mold grows in areas where the relative humidity is above 55%.</u> This type of fungus does not grow on plastic, vinyl, concrete products, or ceramic tiles. **<u>It is not found in the green mold on bread or the black mold on the shower tiles</u>.** The toxic mold environmental risk may be one of the next major real estate "due diligence" concerns, especially in property development areas where major flooding has occurred.

The problem is that this mold can be found not only where there has been flooding, but also in numerous minor water releases due to plumbing failures, condensate overflow, condensation from cold refrigerant or water lines, and water leaks and accidental water spills that were not cleaned up within 48 hours. This toxic mold concern could also be a problem where fires occurred, due to the massive amount of water normally used to extinguish a building fire.

It is important to keep in mind that mold is only a toxic risk or hazard if a person breathes or comes into contact with the mold or the spores. Wet mold is not an indoor air quality health risk, but there is a significant potential for the mold to dry and then be release into the air.

Visual Mold Detection

There may be a visual appearance of black mold in a visible water damage area, but be aware that there may be hidden water damage and mold (i.e., behind dry wall, under organic thread carpets). One should suspect hidden mold if a building smells moldy, even if the source cannot be seen, or if there has been water damage and residents are reporting health problems. Humidifiers and condensate drain pans provide both a growth medium and a distribution system for mold and mildew and should always be inspected, cleaned with a hard surface cleaner that contains a biocide. Condensate pan tablets should be used to prevent scum build-up in the condensate pan or clogging of the condensate drain line (follow all label directions). Consider adding a pan tablet dispenser.

Hidden Mold

In some cases, indoor mold growth may not be obvious. It is possible that mold may be growing on hidden surfaces, such as the inside of duct work that is wet, the back side of dry wall, wallpaper, or paneling, the top of ceiling tiles, the underside of carpets and pads, etc. Possible locations of hidden mold can include pipe chases and utility tunnels (with leaking or condensing pipes), walls behind furniture (where condensation forms), condensate drain pans inside air handling units, porous thermal or acoustic liners inside ductwork, or roof materials above ceiling tiles (due to roof leaks or insufficient insulation). Some building materials, such as dry wall with vinyl wallpaper over it or wood paneling, may act as vapor barriers, trapping moisture underneath their surfaces and thereby providing a moist environment where mold can grow. It is important that building materials be able to dry. Moisture should not be trapped between two vapor barriers or mold may result.

Investigating hidden mold problems may be difficult and require caution when the investigation involves disturbing potential sites of mold growth (be sure to use personal protection equipment). For example, the cleaning of moldy air ducts can lead to a massive release of spores from mold growing in the ducts, and for this and other reasons, moldy porous air ducts should always be replaced and not cleaned.

When addressing mold problems, remember to address the source of the moisture problem, or the mold problem will simply reappear. Remember to check for high humidity and condensation problems as well as actual water leaks, maintenance issues, and HVAC system problems.

Mold Propagation

Molds can be found almost anywhere. They can grow on virtually any organic substance, as long as moisture and oxygen are present. There are molds that can grow on wood, paper, carpet, foods, and insulation. When excessive moisture accumulates in buildings or on building materials, mold growth will often occur, particularly if the moisture problem remains undiscovered or ignored. It is impossible to eliminate all molds and mold spores in the indoor environment. However, mold growth can be controlled indoors by controlling moisture indoors.

Molds reproduce by making spores that usually cannot be seen without magnification. Mold spores waft through the indoor and outdoor air continually. When mold spores land on a damp spot indoors, they may begin growing and digesting whatever they are growing on in order to survive. Molds gradually destroy the things on which they grow.

Many types of molds exist. All molds have the potential to cause health effects. Molds can produce allergens that can trigger allergic reactions or even asthma attacks in people allergic to mold. Other molds are known to produce potent toxins and/or irritants. Potential health concerns are an important reason to prevent mold growth and to remediate/clean up any existing indoor mold growth.

Since mold requires water to grow, it is important to prevent moisture problems in buildings. Moisture problems can have many causes, including uncontrolled humidity. Some moisture problems in buildings have been linked to changes in building construction practices during the 1970s, 80s, and 90s. Some of these changes have resulted in buildings that are tightly sealed, but may lack adequate ventilation, potentially leading to moisture buildup. Building materials, such as drywall, may not allow moisture to escape easily. Moisture problems may include roof leaks, landscaping or gutters that direct water into or under the building, and un-vented combustion appliances. Delayed maintenance or insufficient maintenance are also associated with moisture problems in schools and large buildings. Moisture problems in portable classrooms and other temporary structures have frequently been associated with mold problems. When mold growth occurs in buildings, adverse health problems may be reported by some building occupants, particularly those with allergies or respiratory problems. Technicians should avoid exposing themselves and others to mold-laden dusts while they conduct their cleanup activities. Caution should be used to prevent mold and mold spores from being dispersed throughout the air where they can be inhaled by building occupants.

Smoking

Although there are many potential sources of indoor air pollution, both research and field studies have shown that environmental tobacco smoke (ETS) is one of the most widespread and harmful indoor air pollutants. ETS is a combination of side stream smoke from the burning end of the cigarette, pipe or cigar and the exhaled mainstream smoke from the smoker. ETS contains over 4,000 chemicals; 43 of these chemicals are known animal or human carcinogens (chemicals that are able to cause cancer when combined with another substance). Numerous reports on smoking led to NIOSH (National Institute for Occupational Safety and Health) recommendations that smoking indoors be eliminated, or at least confined to designated areas.

Smoking areas must be separately ventilated, negatively pressurized in relation to surrounding interior spaces, and supplied with much more ventilation than non-smoking areas. The NIOSH bulletin further recommends that the air from the smoking area should be exhausted directly outdoors and not re-circulated within the building or vented with the general exhaust for the building. ASHRAE Standard 62-1989 recommends that smoking areas be supplied with 60 cubic feet per minute (60 cfm) of outdoor air per occupant; the standard also recognized that using transfer air, which is pulled in from other parts of the building, to meet the standard is common practice.

Radon

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Radon is an odorless and colorless gas that emanates naturally from the earth and rock beneath building structures and typically enters the structure from cracks in the foundation. Other sources of radon include building materials manufactured from earth and rock (that contain radon) and from well water. Radon is a gaseous radioactive element having the symbol Rn, the atomic number 86, an atomic weight of 222, a melting point of -71°C, and a boiling point of -62°C. It is an extremely toxic, colorless gas; it can be condensed to a transparent liquid and to an opaque, glowing solid; it is derived from the radioactive decay of radium and is used in cancer treatment and in radiography.

Radon cannot be seen, smelled or tasted, but it could be a problem in a building. The EPA has developed Radon Zone Maps for each state. These maps were developed using five factors to determine radon potential: indoor radon measurements; geology; aerial radioactivity; soil permeability; and foundation type. These maps can be accessed at the EPA website (http://www.epa.gov/radon/zonemap.html).

Radon is estimated to cause many thousands of deaths each year since air containing radon may cause lung cancer. In fact, the Surgeon General has warned that radon is the second leading cause of lung cancer in the United States today.

A variety of methods can be used to reduce radon in a structure. In some cases, sealing cracks in floors and walls may help to reduce radon. In other cases, simple systems using pipes and fans may be used to reduce radon. Such systems are called "sub-slab depressurization", which do not require major changes to the structure. These systems remove radon gas from below the concrete floor and the foundation before it can enter the building. Similar systems can also be installed in buildings with crawl spaces. Increased use of outside ventilation air will also reduce radon levels inside the structure, and, in many cases, may be the least expensive method and one which also solves various other IAQ problems.

Health Hazards Associated with Indoor Air Pollution

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Introduction

Health effects from indoor air pollutants may be experienced soon after exposure or, possibly, years later.

Immediate effects may show up after a single exposure or repeated exposures. These include irritation of the eyes, nose and throat, headaches, dizziness and fatigue. Such immediate effects are usually short-term and treatable. Sometimes the treatment is simply eliminating exposure to the source of the pollution, if it can be identified. Symptoms of some diseases, including asthma, hypersensitivity pneumonitis, and humidifier fever, may also show up soon after exposure to some indoor air pollutants.

The likelihood of immediate reactions to indoor air pollutants depends on several factors. Age and preexisting medical conditions are two important influences. In other cases, whether a person reacts to a pollutant depends on individual sensitivity, which varies tremendously from person to person. Some people can become sensitized to biological pollutants after repeated exposures, and it appears that some people can become sensitized to chemical pollutants as well.

Certain immediate effects are similar to those from colds or other viral diseases, so it is often difficult to determine if the symptoms are a result of exposure to indoor air pollution. For this reason, it is important to pay attention to the time and place the symptoms occur. If the symptoms fade or disappear when a person is away from the building and return when the person returns, an effort should be made to identify indoor air sources that may be the possible cause. Some effects may worsen from an inadequate supply of outdoor air or from the heating, cooling, or humidity conditions prevalent in the building.

Other health effects may appear either years after exposure has occurred or only after long or repeated periods of exposure. These effects, which include some respiratory diseases, heart disease, and cancer, can be severely debilitating or fatal. **It is prudent to improve the indoor air quality in the structure even if symptoms are not noticeable.**

While pollutants commonly found in indoor air are responsible for many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific health problems. People also react very differently to exposure to indoor air pollutants. Further research is needed to better understand which health effects result after exposure to the average pollutant concentrations found in buildings, and which result from the higher concentrations that occur for short periods of time.

Health Hazards of Mold Exposure

All molds have the potential to cause health effects. Molds produce allergens, irritants, and, in some cases, toxins that may cause reactions in humans. The types and severity of symptoms depend, in part, on the types of mold present, the extent of an individual's exposure, the ages of the individuals, and their existing sensitivities or allergies. Specific reactions to mold growth can include the following:

Allergic Reactions: Inhaling or touching mold or mold spores may cause allergic reactions in sensitive individuals. Allergic reactions to mold are common - these reactions can be immediate or delayed. Allergic responses include hay fever-type symptoms, such as sneezing, runny nose, red eyes, and skin rash (dermatitis). **Mold spores and fragments can produce allergic reactions in sensitive individuals regardless of whether the mold is dead or alive.** Repeated or single exposure to mold or mold spores may cause previously non-sensitive individuals to become sensitive. **Repeated exposure has the potential to increase sensitivity**.

Asthma: Molds can trigger asthma attacks in persons allergic (sensitized) to molds. The irritants produced by molds may also worsen asthma in non-allergic (non-sensitized) people.

Hypersensitivity Pneumonitis: Hypersensitivity pneumonitis may develop following either short-term (acute) or long-term (chronic) exposure to molds. The disease resembles bacterial pneumonia and is uncommon.

Irritant Effects: Mold exposure may cause irritation of the eyes, skin, nose, throat, and lungs, and sometimes can create a burning sensation in these areas.

Opportunistic Infections: People with weakened immune systems (i.e., immune-compromised or immune-suppressed individuals) may be more vulnerable to infections by molds (as well as more vulnerable than healthy persons to mold toxins). *Aspergillus fumigatus,* for example, has been known to infect the lungs of immune-compromised individuals. These individuals inhale the mold spores, which then start growing in their lungs. *Trichoderma* has also been known to infect immune-compromised children. Healthy individuals are usually not vulnerable to opportunistic infections from airborne mold exposure. However, molds can cause common skin diseases, such as athlete's foot, as well as other infections such as yeast infections.

A major concern with mold is that the mold can be hidden behind walls and deep in air ducts making it difficult to remove all the mold from the structure. Diligence should be exerted to remove and dispose of any porous materials that have been contaminated by mold because they cannot be cleaned effectively. However, **hard non-porous ductwork and other surfaces can be cleaned** with a hard surface cleaner. S*ection III Treatment of IAQ Problems* provides greater details on the various treatment methods.

Currently, most health organizations consider exposure to Stachybotrys mold as a health hazard. Also, keep in mind that most responses leading to testing, investigations, and abatement of the Stachybotrys toxic mold are due directly to occupant complaints or documented detrimental health effects. Stachybotrys mold may evolve to a point where it is regarded with the same caution, response and liability concerns as those attributed to lead-base paint and asbestos. Health hazards and risks associated with concern to exposure to Stachybotrys are currently considered as short-term effects. Alternatively, exposure to radon gas in buildings is considered a long-term health risk and is not considered a short-term hazard.

Molds can produce toxic substances called mycotoxins. Some mycotoxins cling to the surface of mold spores; others may be found within spores. More than 200 mycotoxins have been identified from common molds, and many more remain to be identified. Some of the molds that are known to produce mycotoxins are commonly found in moisture-damaged buildings. Exposure pathways for mycotoxins can include inhalation, ingestion, or skin contact. Although some mycotoxins are well known to affect humans and have been shown to be responsible for human health effects, for many mycotoxins, little information is available. The information on the human health effects of inhalation exposure to mycotoxins (which is available) is typically derived from studies performed in the workplace. Information on ingestion exposure, for both humans and animals, is more abundant--a wide range of health effects has been reported following ingestion of moldy foods including liver damage, nervous system damage, and immunological effects.

Many symptoms and human health effects attributed to inhalation of mycotoxins have been reported, including: mucous membrane irritation, skin rash, nausea, immune system suppression, acute or chronic liver damage, acute or chronic central nervous system damage, endocrine effects, and cancer. More studies are needed to clarify the health effects related to most mycotoxins. However, it is clearly prudent to avoid exposure to molds and mycotoxins.

Some molds can produce several toxins, and some molds produce mycotoxins only under certain environmental conditions. The presence of mold in a building does not necessarily mean that mycotoxins are present or that they are present in large quantities.

Aflatoxin B_1 is perhaps the most well-known and studied mycotoxin. It can be produced by the molds *Aspergillus flavus* and *Aspergillus parasiticus* and it is one of the most potent carcinogens known. Ingestion of aflatoxin B_1 can cause liver cancer. There is also some evidence that inhalation of aflatoxin B_1 may cause lung cancer. Aflatoxin B_1 has been found on contaminated grains, peanuts and other human and animal foodstuffs. However, ***Aspergillus flavus*** **and** ***Aspergillus parasiticus*** **are not commonly found on building materials or in indoor environments**.

Aspergillus versicolor and *Stachybotrys atra (chartarum),* are known to produce potent toxins under certain circumstances. Stachybotrys produces a mycotoxin that causes animal and human mycotoxicosis. This type of mold is thought to be a possible cause of the "sick building syndrome". In May 1997, *The Journal of the American Medical Association* carried a news article titled "Floods carry potential for toxic mold disease". Children's exposure to air-borne Stachybotrys spores is thought to most likely cause pulmonary hemorrhage (bleeding in the lungs). Please be aware that there is no threshold dangerous spore exposure level established by the U.S. EPA or any other health administrations. There are ongoing epidemiology studies being conducted. There is reference information related to a 1994 incident in Cleveland, Ohio, where 45 cases of pulmonary hemorrhage in young infants occurred. Sixteen of the infants died. In addition, many departments of health administration in states across the U.S., as well as the Center for Disease Control (CDC), list the following as symptoms associated with exposure to Stachybotrys mold spores:

1) Respiratory problems, such as wheezing, and difficulty in breathing

2) Nasal and sinus congestion
3) Eyes-burning, watery, reddened, blurry vision, light sensitivity
4) Dry, hacking cough
5) Sore throat
6) Nose and throat irritation
7) Shortness of breath
8) Chronic fatigue
9) Skin irritation
10) Central nervous system problems (constant headaches, memory problems, and mood changes)
11) Aches and pains
12) Possible fever
13) Diarrhea
14) Possible hemosiderosis
15) Immune suppression

Health Hazards of Microbial Volatile Organic Compounds (mVOCs)

Some compounds produced by molds are volatile and are released directly into the air. These are known as microbial volatile organic compounds (mVOCs). Because these compounds often have strong and/or unpleasant odors, they can be the source of odors associated with molds. Exposure to mVOCs from molds has been linked to symptoms such as headaches, nasal irritation, dizziness, fatigue and nausea. Research on mVOCs is still in the early phase.

Health Hazards of Glucans (Fungal Cell Wall Components) (also known as ß-(1 3)-D-Glucans)

Glucans are small pieces of the cell walls of molds that may cause inflammatory lung and airway reactions. These glucans may affect the immune system when inhaled. Exposure to very high levels of glucans or dust mixtures, including glucans, may cause a flu-like illness known as Organic Dust Toxic Syndrome (ODTS). This illness has been primarily noted in agricultural and manufacturing settings.

Health Hazards of Spores

Mold spores are microscopic (2-10 μm) and are naturally present in both indoor and outdoor air. Molds reproduce by means of spores. Some molds have spores that are easily disturbed and waft into the air and settle repeatedly with each disturbance. Other molds have sticky spores that cling to surfaces and become dislodged by brushing against them or by other direct contact. Spores may continue to grow for years after they are produced. In addition, whether or not the spores are alive, the allergens in and on them may remain allergenic for years.

Health Hazards of Radon

Radon gas decays into radioactive particles that may become trapped in the lungs as a person breathes. As they break down further, these particles release small bursts of energy. This could damage lung tissue and lead to lung cancer over the course of one's lifetime. Not everyone exposed to elevated levels of radon will develop lung cancer, and the amount of time between exposure and the onset of the disease may be many years.

Like other environmental pollutants, there is some uncertainty about the magnitude of radon health risks. However, we know more about radon risks than risks from most other cancer-causing substances. This is because estimates of radon risks are based on studies of cancer in humans (underground miners, for example). Additional studies on more typical populations are under way. Smoking combined with radon is an especially serious health risk.

Children are reportedly at greater risk than adults of certain types of cancer from radiation, but there is currently no conclusive data on whether children are at greater risk than adults from radon.

An individual's chances of getting lung cancer from radon depend mostly on:

- The level of radon in a person's building
- The amount of time spent in a person's building
- Whether a person is a smoker or has ever smoked

Symptoms and Complaints Typically Related to IAQ Problems

Groups that may be particularly susceptible to the effects of indoor air contaminants include, but are not limited to:

- Allergic or asthmatic individuals
- People with respiratory disease
- People whose immune systems are suppressed due to chemotherapy, radiation therapy, or diseases from other causes
- Contact lens wearers

The effects of IAQ problems are often non-specific symptoms rather than clearly defined illnesses. Symptoms commonly attributed to IAQ problems include headache, fatigue, sinus congestion, cough, sneezing, dizziness and nausea. All of these symptoms, however, may also be caused by other factors, and are not necessarily due to air-quality deficiencies.

"Health" and "comfort" are used to describe a spectrum of physical sensations. For example, when the air in a room is slightly too warm for a person's activity level, that person may experience mild discomfort. If the temperature continues to rise, discomfort increases and symptoms such as fatigue, stuffiness and headaches may appear.

The term, Sick Building Syndrome (SBS), is sometimes used to describe cases in which building occupants experience acute health and comfort effects that are apparently linked to the time they spend in the building, but in which no specific illness of cause can be identified. The complaints may be localized to a particular room or zone, or may be widespread throughout the building. Many different symptoms have been associated with SBS, including respiratory complaints, irritation and fatigue. **Analysis of air**

samples often fails to detect high concentrations of specific contaminants. The problem may be caused by any or all of the following:

- The combined effects of multiple pollutants at low concentrations
- Other environmental stressors (e.g., overheating, poor lighting, noise)
- Ergonomic stressors
- Job-related psychosocial stressors (e.g., overcrowding, labor-management problems)
- Unknown factors
- Building Related Illness (BRI) refers to illness caused by exposure to the building air, where symptoms of diagnosable illnesses are identified (e.g., certain allergies or infections) and can be directly attributed to environmental agents in the air. Legionnaire's Disease and hypersensitivity pneumonitis are examples of BRI that can have serious, even life threatening, consequences
- A small percentage of the population may be sensitive to a number of chemicals in indoor air, each which may occur at very low concentrations. The existence of this condition, which is known as Multiple Chemical Sensitivity (MCS), is a matter of controversy. MCS is not currently recognized by the major medical organizations, but medical opinion is divided, and further research is needed

Section II:

Strategies to Control Indoor Air Pollution

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Source Control

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Usually the most effective way to improve indoor air quality is to eliminate individual sources of pollution or to reduce their emissions. Some sources, like those that contain asbestos, can be sealed or enclosed; others, like gas stoves, can be adjusted to decrease the amount of emissions. In many cases, source control is also a more cost-effective approach to protecting indoor air quality than increasing ventilation which may increase energy costs. Specific sources of indoor air pollution in a building are listed later in this section. For most indoor air quality problems in the building, source control is the most effective solution.

Ventilation

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Most commercial air-handling units distribute a blend of outdoor air and recirculated indoor air. HVAC designs may also include units that introduce 100% outdoor air or that simply transfer air within the building. Uncontrolled quantities of outdoor air enter buildings through windows, doors and gaps in the exterior construction.

Thermal comfort and ventilation needs are met by supplying "conditioned" air (a blend of outdoor and recirculated air that has been filtered, heated or cooled, and sometimes humidified or dehumidified.) Large buildings often have interior ("core") spaces in which constant cooling is required to compensate for heat generated by occupants, equipment, and lighting, while perimeter rooms may require heating or cooling depending on outdoor conditions.

One technique for controlling odors and contaminants is to dilute them with outdoor air. Dilution can work only if there is a consistent and appropriate flow of supply air that mixes effectively with room air. The term "ventilation efficiency" is used to describe the ability of the ventilation system to distribute supply air and remove internally generated pollutants. Researchers are currently exploring ways to measure ventilation efficiency and interpret the results of those measurements.

Another technique for isolating odors and contaminants is to design and operate the HVAC system so that pressure relationships between rooms are controlled. This control is accomplished by adjusting the air quantities supplied to and removed from each room. If more air is supplied to a room than is exhausted, the excess air leaks out of the space and the room is said to be under positive pressure. If less air is supplied than is exhausted, air is pulled into the space and the room is said to be under negative pressure.

A third technique is to use local exhaust systems (sometimes known as dedicated exhaust ventilation systems) to isolate and remove contaminants by maintaining negative pressure in the area around the contaminant source. Local exhaust can be linked to the operation of a particular piece of equipment (such as kitchen range) or used to treat an entire room (such as a smoking lounge or custodial closet). Air should be exhausted to the outdoors, not recirculated, from locations that produce significant odors and high concentrations of contaminants (such as copy rooms, bathrooms, kitchens and beauty salons).

Spaces where local exhaust is used must be provided with make-up air and the local exhaust must function in coordination with the rest of the ventilation system. Under some circumstances, it may be acceptable to transfer conditioned air from relatively clean parts of a building to comparatively dirty areas and use it as make-up air for a local exhaust system. Such a transfer can achieve significant energy savings.

Air cleaning and filtration devices designed to control contaminants are found as components of HVAC systems (for example, filter boxes in ductwork) and can also be installed as independent units. The effectiveness of air cleaning depends upon proper equipment selection, installation, operation and maintenance. Caution should be used in evaluating the many new technological developments in the field of air cleaning and filtration.

One approach to lowering the concentrations of indoor air pollutants in a structure is to increase the amount of outdoor air coming indoors. Most building heating and cooling systems, including forced air heating or cooling systems, do not mechanically bring fresh air into the houses, whereas commercial buildings typically have a means to mechanically draw fresh air into the structure. ASHRAE Standard 62.2 represents the minimum requirements for residential ventilation and acceptable indoor air quality. Best or good practice may require going beyond those minima. Traditionally, residential ventilation has been provided by natural ventilation and infiltration. Sherman and Matson (1997) showed that most older buildings are leaky enough so that infiltration (air leaks from outside) alone can meet the minimum requirements of ASHRAE Standard 62.2. However, houses built to new standards have substantially tighter envelopes and there is insufficient infiltration to meet even the minimum ventilation standards. Furthermore, simply meeting the minimum standard is not always sufficient to adequately dilute all contaminants.

For today's modern, single-family dwellings a whole-house mechanical ventilation system may be necessary when individuals with allergies or chemical sensitivities occupy the building or when there are unusual sources of impurities. Advanced designs of new buildings are featuring mechanical systems that bring outdoor air into the building. Some of these designs include energy-efficient heat recovery ventilators (also known as air-to-air heat exchangers). Typical total ventilations requirements are at least the larger of 7.5 CFM per person (based on Normal Occupancy) and 1 CFM per 100 square feet of floor space. The intermittent exhaust flow rates for kitchens are 100 CFM and 50 CFM for utility rooms, bathrooms, etc. The continuous exhaust flow rate for kitchens is five air changes per hour and 20 CFM for utility rooms, bathrooms, etc.

Air Handler

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As air is circulated through the structure via heating, ventilating, and/or air conditioning (HVAC) systems, particulate matter will accumulate inside the system where, especially in cooling systems, they serve as medium for bacteria and fungal growth. The dispersion of microbes such as bacteria, virus, mold, and fungus can be the source of sickness to exposed occupants in the climate-controlled area. For example, Legionella pneumophilia has been found to exist in such an environment and has been linked to Legionnaire's disease. Other microbes may contribute to "sick building" or "sick building" syndrome. Many people are also allergic to the molds and fungus entrained in the dwelling's ventilation system as the air passes over contaminated condensate drain water and wet evaporator cooling coils. **For this reason, it is very important that evaporator coils be cleaned and disinfected at least once per cooling season and the condensate pan be treated with a biocide to stop the breading of bacteria, virus, mold and fungus, which can be entrained into the conditioned air and carried throughout the building.**

Air Filtration

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Introduction

There are many types and sizes of air cleaners on the market, ranging from relatively inexpensive tabletop models to sophisticated, expensive whole-building systems. Some air cleaners are highly effective at particle removal, while others, including most tabletop models, are much less so. Air cleaners are generally not designed to remove gaseous pollutants.

The effectiveness of an air cleaner depends on how well it collects pollutants from indoor air (expressed as a percentage efficiency rate) and how much air it draws through the cleaning or filtering element (expressed in cubic feet per minute). A very efficient collector with a low air-circulation rate will not be effective, nor will a cleaner with a high air-circulation rate with a less efficient collector. The long-term performance of any air cleaner depends on maintaining it according to the manufacturer's directions.

At present, EPA does not recommend using air cleaners to reduce levels of radon and its decay products. The effectiveness of these devices is uncertain because they only partially remove the radon decay products and do not diminish the amount of radon entering the building. EPA plans to additionally research whether air cleaners are, or could become, a reliable means of reducing the health risk from radon.

Types of air cleaners or air filtration include:

- Mechanical filters, including, the typical furnace or AC filter
- Electronic air cleaners (for example, electrostatic precipitators) which trap charged particles using an electrical field
- Ion generators that act by charging the particles in a room. The charged particles are then attracted to walls, floors, draperies, etc., or a charged collector
- "Hybrid" devices, which contain two or more of the particle removal devices discussed above

Mechanical Filtration

There are essentially two methods to purify or filter the air, mechanical filtration and electrostatic filtration. With mechanical filtration, a filter permits air to pass through a porous, typically fiber-like, material that essentially blocks the path and ideally captures these particles. Since the pores between fibers are typically larger than the airborne particles the filter relies on the random chance that the particle will get caught on a fiber. If the thickness of the filter is increased or the pores are made smaller through the use of a tighter fiber weave, then the resistance to the passage of air increases, thereby increasing the pressure loss, reducing the airflow and ultimately decreasing the system's cooling capacity and efficiency.

An alternate method designed for the purpose of increasing particulate removal efficiency without decreasing pore size or increasing fiber density is electrostatic attraction. Active electrostatic filters, commonly referred to as electronic air filters, impart a high-voltage charge between plates and any charged particles passing through are electrostatically withdrawn from the passing air and captured on the charged collection plate. This type of electrostatic system (discussed in the next subsection) normally suffers from a rapid decrease in performance as the collection plate becomes dirty and therefore insulated.

To alleviate the need for an applied voltage but still obtain the advantages of electrostatic dust removal, passive electrostatic systems have been developed. A passive electrostatic system relies on dielectric (non-conducting) fibers that harbor electrostatic charges produced from air friction as the air is drawn through the filter. Air passing through dielectric fibers generates friction that induces a static charge that builds up to become substantial enough to draw out any passing charged particles, namely dust. This is the principal behind electrostatic filters used in HVAC systems. The passive electrostatic filter behaves similarly to active electrostatic filters whereby dust is drawn from the air and attracted to the fibers by electrostatic forces this time without the need for external electrical power. Typically, because of their high cost, this type of passive electrostatic filter is cleaned and reused rather than discarded when dirty. However, by their nature, theses filters are difficult to get perfectly clean and their performance degrades after the first use. There are also disposable electrostatic filters, however, in most cases, a careful inspection of the package will reveal that these disposable filters are not fabricated from 100% electrostatic fibers but instead only contain some electrostatic fibers, thereby making their effectiveness questionable.

Mainstream's PuraClean® Filter Spray has been demonstrated to be an alternative to electrostatic filters, and can be applied to ordinary disposable filters. PuraClean® Filter Spray creates a passive low-cost electrostatic filter from an ordinary low-cost disposable filter. In this way the low-cost filter could be disposed instead of cleaned. PuraClean® is a liquid formulation, which, after application to an ordinary non-electrostatic filter (such as a metallic filter, disposable spun-glass filter, or foam filter), will produce a dielectric filter surface (insulating surface) and transform an ordinary filter into a passive electrostatic filter.

The only true measure of a filter's effectiveness is the Minimum Efficiency Reporting Value (MERV). Most filters are labeled with a MERV rating number, which measures a filter's ability to trap particles ranging in size from 3.0 microns to 10.0 microns. Residential filters commonly have MERV ratings of 1-12. The higher the MERV rating, the more efficient the filter is and the more particles it can filter.

MERV is an industry standard rating, so it can be used to compare filters made by different companies.

- A MERV rating of 6 means the filter is 35% to 50% minimum efficient at capturing the measured particles
- A MERV rating of 8 means the filter is 70% to 85% minimum efficient at capturing the measured particles
- A MERV rating of 11 means the filter is 85% to 95% minimum efficient at capturing the measured particles

When sprayed on typical disposable filters, PuraClean® Filter Spray demonstrates an increase of up to 300% in particle capture, *with no significant increase in pressure drop*. **In ASHRAE 52.2 testing, the MERV rating of non-electrostatic filters improved by as much as 65% by using PuraClean®, see Figure 1.** PuraClean®'s technology garners these dramatic results by converting non-electrostatic surfaces into electrostatic surfaces. A more efficient filter also means the evaporator coil will stay cleaner, which translates into improved energy efficiency and improved cooling capacity.

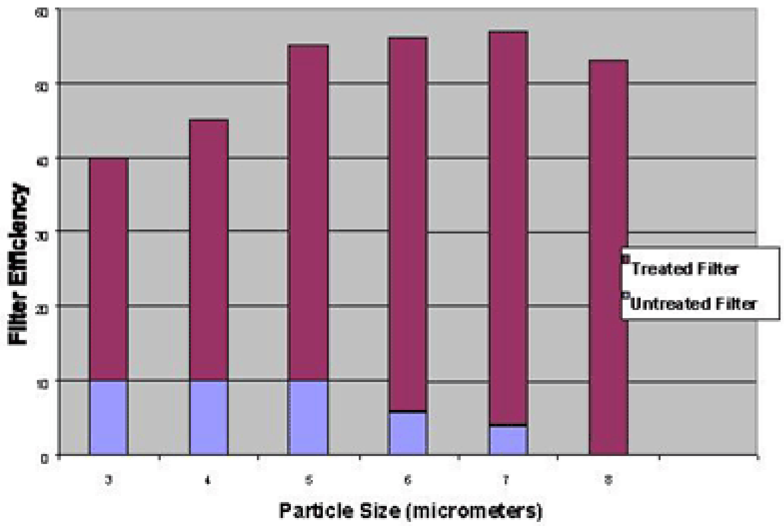

Figure 1. PuraClean® Improvements to Filter Efficiency
(Based on Independent Laboratory test data using the ASHRAE 52.2 test procedure)

Electronic Air Cleaners

There are a number of companies that offer Electronic Air Cleaners. These devices have a positively or negatively charged grid that charges the contaminants in the air and an oppositely charged or grounded collection surface to which the contaminants are attracted. These filters have very good initial filtration effectiveness and very little pressure drop, but the filtration efficiency decreases rapidly due to build-up on the collection plate, which essentially insulates the collection plate and stops the filtration. Also, as the collection plate becomes insulated, the charged contaminants are then attracted to other grounded surfaces, such as walls, ceilings, furniture, etc., thereby causing staining of these surfaces

Houseplants

Over the past few years, there has been some publicity suggesting that houseplants have been shown to reduce levels of some chemicals in laboratory experiments. There is currently no evidence, however, that a reasonable number of houseplants remove significant quantities of pollutants in buildings and offices. Indoor houseplants should not be over-watered because overly damp soil may promote the growth of microorganisms that may affect allergic individuals.

Key Points about Air Cleaning

- Ion generators and electronic air cleaners may produce ozone, particularly if they are not properly installed and maintained. Ozone can be a lung irritant
- Gases and odors from particles collected by the filtration device, and remain on the filter in the airflow, may be re-dispersed into the air
- The odor of tobacco smoke is largely due to gases in the smoke, rather than particles. Thus, one may smell a tobacco odor even when the smoke particles have been removed
- Some devices scent the air to mask odors, which may lead you to believe that the odor-causing pollutants have been removed
- Ion generators, especially those that do not contain a collector, or that have a dirty collector, can cause soiling of walls and other surfaces
- Maintenance costs, such as costs for the replacement of filters, may be significant in certain systems
- Several brands of ozone generators have an establishment number on their packaging. This number helps EPA identify the specific facility that produces the product. To quote the EPA from their website: "The display of this number does not imply an EPA endorsement or suggest in any way that the EPA has found the product to be either safe or effective."

Preventing Duct Contamination

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A good preventive maintenance program is essential to minimize duct contamination.

Prevent dirt from entering the system:

Use PuraClean® Filter Spray on all HVAC filters and instruct the building owner how to use PuraClean® on the filters when it's time to change them. It's important to change air filters monthly and apply PuraClean® with every filter change. We suggest an offer to sell customers a six-month or a year's supply (depending on whether annual or semiannual tune ups are done) of both filters and PuraClean® during the discussion of the services performed and before preparing the final bill for services and supplies. Filters must be changed monthly, even more frequently if they are severely loaded up with contaminants during monthly filter replacements. Explain that any contaminants removed from the conditioned air by the filter are being kept from their lungs! PuraClean® treated filters are capable of removing mold spores, in addition to dust mites and bacteria. Remember that removing moisture is the first line of defense, and a clean environment, provided by good filtration is the second line of defense. Improved filtration will also minimize the amount of dusting needed in the building. Of course, no filtration of any type will remove harmful gasses, such as carbon monoxide, or are effective at removing radon from the air.

When performing any service of a structure's heating or cooling system, always recommend the additional service work of cleaning cooling coils and drain pains for cooling systems, as well as the heat exchangers and humidifiers of heating systems. This is the most economical way for building owners to potentially avoid future IAQ problems.

Prevent Air Ducts from Getting Wet

Moisture should not be present in ducts. Controlling moisture is the most effective way to prevent biological growth in air ducts.

Moisture can enter the duct system through leaks or if the system has been improperly installed or serviced. Research suggests that condensation (which occurs when a surface temperature is lower than the dew point temperature of the surrounding air) on or near cooling coils of air conditioning units is a major factor in moisture contamination of the system. The presence of condensation or high relative humidity is an important indicator of the potential for mold growth on any type of duct.

Controlling moisture can often be difficult, but here are some steps to take:

- Repair any leaks or water damage promptly and properly. Discard any wet insulation or fiber duct board; it cannot be effectively dried.
- Pay particular attention to cooling coils, which are designed to remove water from the air and can be a major source of moisture contamination of the system, leading to mold growth. If mold is present, clean the hard surfaces of the air handler and the evaporator coils with a hard surface cleaner (ideally one that contains an EPA registered biocide). Make sure the condensate pan drains properly. The presence of substantial standing water and/or debris indicates a problem requiring immediate attention. Check any insulation near cooling coils or wet spots. Treat all drain pans with pan tablets.
- Ensure all ducts are properly sealed and insulated in all non-air-conditioned spaces (e.g., attics and crawl spaces). This will help prevent moisture due to condensation from accumulating on the duct work or entering the system. To prevent water condensation, the cooling system and associated duct work must be properly insulated.
- Verify that the AC unit is operating properly. Humidity must be maintained below 55% (ideally 30% to 50%). If humidity is a problem, consider installing a dehumidifier.

Mold

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Concern about indoor exposure to mold has increased as the public becomes aware that exposure to mold can cause a variety of health effects and symptoms, including allergic reactions.

Molds gradually destroy the things they grow on. The simple way to prevent damage to building materials and furnishings, save money, and avoid potential health risks caused by mold formation is to control moisture and thereby eliminate mold growth. **The key to mold control is moisture control.**

Molds are part of the natural environment. Outdoors, molds play a part in nature by breaking down dead organic matter, such as fallen leaves and dead trees, but indoors, mold growth should be avoided. Molds reproduce by means of tiny spores; the spores are invisible to the naked eye and float through outdoor and indoor air. **Mold may begin growing indoors when mold spores land on surfaces that are wet**. **There are many types of mold but none of them will grow without water or moisture.**

Molds spores are usually not a problem indoors, unless these mold spores land on a wet or damp spot and begin growing into mold. Molds have the potential to cause health problems. Molds produce allergens (substances that can cause allergic reactions), irritants, and in some cases, potentially toxic substances (mycotoxins). Inhaling or touching mold or mold spores may cause allergic reactions in sensitive individuals. Allergic responses include hay fever-type symptoms, such as sneezing, runny nose, red eyes, and skin rash (dermatitis).

Allergic reactions to mold are common. They can be immediate or delayed. Molds can also cause asthma attacks in people with asthma who are allergic to mold. In addition, mold exposure can irritate the eyes, skin, nose, throat, and lungs of both mold-allergic and non-allergic people. Symptoms other than the allergic and irritant types are not commonly reported as a result of inhaling mold. Research on mold and health effects is ongoing.

Mold and Indoor Air Regulations and Standards

Standards or **Threshold Limit Values (TLVs)** for airborne concentrations of mold or mold spores have not been set. Although U.S. EPA has no regulations or health standards for airborne mold contaminants, in June 2002, Congressman John Conyers, Jr. of Michigan introduced H.R. 5040 to Congress, which is called the *United States Toxic Mold Safety and Protection Act of 2002*, or the "Melina Bill."

Title I of this pending legislation directs U.S. EPA, The **Centers for Disease Control and Prevention (CDC),** and the **National Institutes of Health (NIH)** to jointly study the health effects of indoor mold growth to determine, among other things, "minimum levels of exposure at which indoor mold growth is harmful to human health." In addition, U.S.

EPA has prepared numerous guidance documents on the topics of indoor air quality and mold in buildings of all sizes.

The state of California has adopted mold-related legislation, New York City has developed guidelines for indoor mold assessment and remediation, and Canada has prepared a comprehensive guide to recognition and management of fungal contamination in public buildings. In addition, microbiological research on the health effects of mold is under way in the United States, Canada, the United Kingdom, the Netherlands and Sweden.

Mold Prevention Tips

The key to mold control is moisture control. Solve moisture problems before they become mold problems!

- Fix leaky plumbing and leaks in the building envelope as soon as possible.
- Watch for condensation and wet spots. Fix sources of moisture problems as soon as possible.
- Prevent moisture due to condensation by increasing surface temperature or reducing the moisture level in air (humidity). To increase surface temperature, insulate or increase air circulation. To reduce the moisture level in air, repair leaks, increase ventilation (if outside air is cold and dry), or dehumidify (if outdoor air is warm and humid).
- Keep heating, ventilation, and air conditioning (HVAC) drip pans clean, flowing properly, and unobstructed. Use pan tablets to help prevent deposits that can clog drain lines.
- Vent moisture-generating appliances, such as dryers, to the outside where possible.
- Maintain low indoor humidity, below 55% relative humidity (RH), ideally 30-50%, if possible. Install a Mainstream Qwik**SEER+**® control board to reduce the humidity if necessary
- Perform regular building/HVAC inspections and maintenance as scheduled
- Clean and dry wet or damp spots within 48 hours
- Do not allow foundations to remain wet. Provide drainage and slope the ground away from the foundation

Section III:

Treatment of IAQ Problems

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Identifying Air Quality Problems

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Some health effects can be useful indicators of an indoor air quality problem, especially if they appear after a person moves to a new residence, remodels or refurnishes a building, or treats a building with pesticides. If occupants have symptoms that may be related to their indoor environment, they should discuss these symptoms with their doctor or the local health department to see if they could be caused by indoor air pollution. They may also want to consult a board-certified allergist or an occupational medicine specialist for answers to their questions.

Another way to judge whether a building has or could develop indoor air problems is to identify potential sources of indoor air pollution. Although the presence of such sources does not necessarily mean that there is an indoor air quality problem, being aware of the type and number of potential sources is an important step toward assessing the air quality in a building.

A third way to decide whether an environment may have poor indoor air quality is to evaluate at the activities occurring in the location. Human activities can be significant sources of indoor air pollution. Also, look for signs of problems with the ventilation. Signs that can indicate inadequate or improper ventilation include moisture condensation on windows or walls, smelly or stuffy air, dirty central heating and air conditioning equipment, and areas where books, shoes, or other items become moldy.

Measuring Pollutant Levels

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The federal government recommends measuring the level of radon in structures. Without measurements, there is no way to tell whether radon is present because it is a colorless, odorless, radioactive gas. Inexpensive devices are available for measuring radon. EPA provides guidance as to risks associated with different levels of exposure and when the public should consider corrective action. There are specific mitigation techniques that have proven effective in reducing levels of radon in the building.

For pollutants other than radon, measurements are most appropriate when there are either health symptoms or signs of poor ventilation and specific sources or pollutants have been identified as possible causes of indoor air quality problems. Testing for many pollutants can be expensive. Before monitoring a structure for pollutants besides radon, consult the state or local health department.

Walkthrough Inspection of the Building

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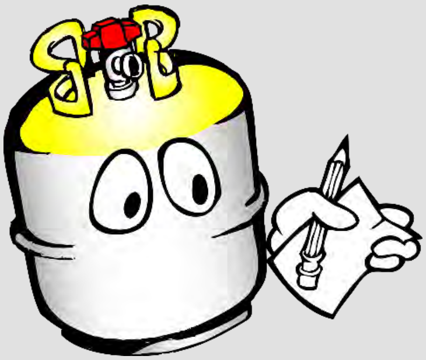
The intent of the walkthrough inspection is to acquire a good overview of occupant activities and building functions, and to look for IAQ problem indicators. Odors in inappropriate locations (e.g., kitchen odors in a lobby) may indicate that ventilation system components require adjustment or repair.

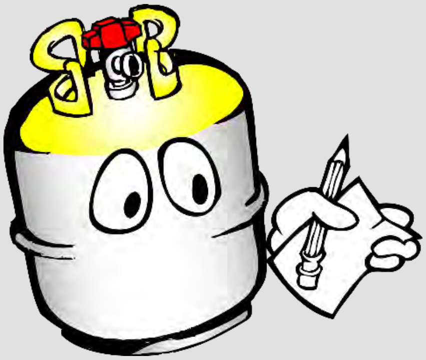
The walkthrough inspection can be used to identify areas with a potential for IAQ problems. The following are general indicators of IAQ problems:

- Odors
- Dirty or unsanitary conditions
- Visible fungal growth or moldy odors (often associated with problems of too much moisture)
- Unsanitary conditions in equipment such as drain pans and cooling towers
- Poorly-maintained filters
- Signs of mold or moisture damage at walls, ceilings and floors
- Staining and discoloration



Make sure that stains are removed after leaks are repaired so that there will be visible evidence if the leak recurs.

- Smoke damage



If a fire has occurred involving electrical equipment, determine whether polychlorinated biphenyls, PCBs, may have been released from the equipment.

- Presence of hazardous substances
- Potential for soil gas entry (e.g., unsealed openings to earth, wet earth smells)
- Unsanitary mechanical room, trash or stored chemicals in a mechanical room
- Unusual noises from light fixtures or mechanical equipment

In addition to these general indicators, some common problems deserve mention:

Inadequate maintenance: Look for signs of leaks of oil, water, or refrigerants around HVAC equipment. Dry plumbing drain traps also cause indoor air quality problems.

Signs of occupant discomfort: Notice uneven temperatures, persistent odors, drafts, and sensations of stuffiness. It is possible that occupants are attempting to compensate for an HVAC system that does not meet their needs. Look for propped-open corridor doors, blocked or taped up diffusers, popped up ceiling tiles, people using individual fans/heaters or wearing heavier/lighter clothing than normal.

Overcrowding: Future occupant density is estimated when the ventilation system for a building is designed. When the actual number of occupants approaches or exceeds this occupant design capacity, IAQ complaints may increase. At that point, the outdoor air ventilation rate will have to be increased. However, the ventilation and cooling systems may not have sufficient capacity to handle the increased loads from the current use of space.

Blocked airflow: Check for under-ventilation caused by obstructed vents, faulty dampers or other HVAC system malfunctions, or from problems within occupied space. Furniture, papers, or other materials can interfere with air movement around thermostats or block airflow from wall or floor-mounted registers. If office cubicles are used, a small space (2 to 4 inches) between the bottom of the partitions and the floor may improve air circulation.

Ceiling plenums: Lift a ceiling tile and examine the plenum for potential problems. Walls or full-height partitions that extend to the floor above can obstruct or divert air movement in ceiling plenums unless transfer grilles have been provided. If fire dampers have been installed to allow air circulation through walls or partitions, confirm that the dampers are open. Construction debris and damaged or loose material in the plenum area should be removed.

Heat Sources: Be aware of areas that contain unusual types or quantities of equipment such as copy machines or computer terminals. Also, look for instances of over illumination. High concentrations of electrical fixtures and equipment can overwhelm the ventilation and cooling systems.

Special use areas: Confirm that the HVAC system maintains appropriate pressure relationships to isolate and contain odors and contaminants in mixed-use buildings and around special use areas. Examples of special use areas include attached parking garages, loading docks, print shops, smoking lounges, janitorial closets, storage areas and kitchens.

Improperly located vents, exhausts and air intakes: Check the outdoor air intakes to see whether they are located near contaminant sources (e.g., plumbing vents, exhaust outlets, dumpsters, loading docks or other locations where vehicle engines run idle).

Unsanitary mechanical rooms: See if the space containing the HVAC system is clean and dry. Examples of problems include cleaning or other maintenance supplies stored in mechanical room; dust and dirt buildup on floors and equipment; and moisture in mechanical rooms because of inadequate insulation, lack of conditioned air, or failure to provide for air movement. Unsanitary conditions in a mechanical room are particularly problematic if un-ducted return air is dumped into and circulated through a mechanical room.

Determination of Relative Humidity

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Humidity is something we hear about daily in weather reports. Humidity is to blame for that muggy, steam-room feeling experienced on certain summer days. Humidity can be measured in several ways, but relative humidity is the most common. In order to understand relative humidity, it is helpful to first understand absolute humidity.

Absolute humidity is the mass of water vapor divided by the mass of dry air in a volume of air at a given temperature. The hotter the air is, the more water it can contain.

Relative humidity is the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature). A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more water vapor.

Individuals are very sensitive to humidity; the body relies on the evaporation of sweat to provide cooling for the body. The process of sweating is the body's attempt to keep cool and maintain its current temperature. If the air is at 100-percent relative humidity, sweat will not evaporate into the air. As a result, a person may feel much hotter than the actual temperature when the relative humidity is high. If the relative humidity is low, we feel much cooler than the actual temperature because our sweat evaporates easily and cools us off.

People tend to feel most comfortable at a relative humidity of about 45%. To avoid any mold problems, **<u>it is recommended that the indoor humidity always be maintained below 55% (ideally between 30% and 50%) relative humidity</u>**.

The simplest method of determining the relative humidity is to measure the wet bulb and dry-bulb air temperatures inside the structure and use a Psychrometric Chart (Figure 2) to determine the relative humidity. The relative humidity is determined from the intersection of the appropriate wet and dry bulb temperatures that are measured in the structure. Both temperature measurements must be made at the same location and it is the relative humidity at that location which is obtained. Figure 2 contains a small chart for normal sea-level elevation; similar charts have also been prepared for other altitudes. ASHRAE Fundamentals, as well as many air conditioning handbooks, contain a complete set of Psychrometric Charts.

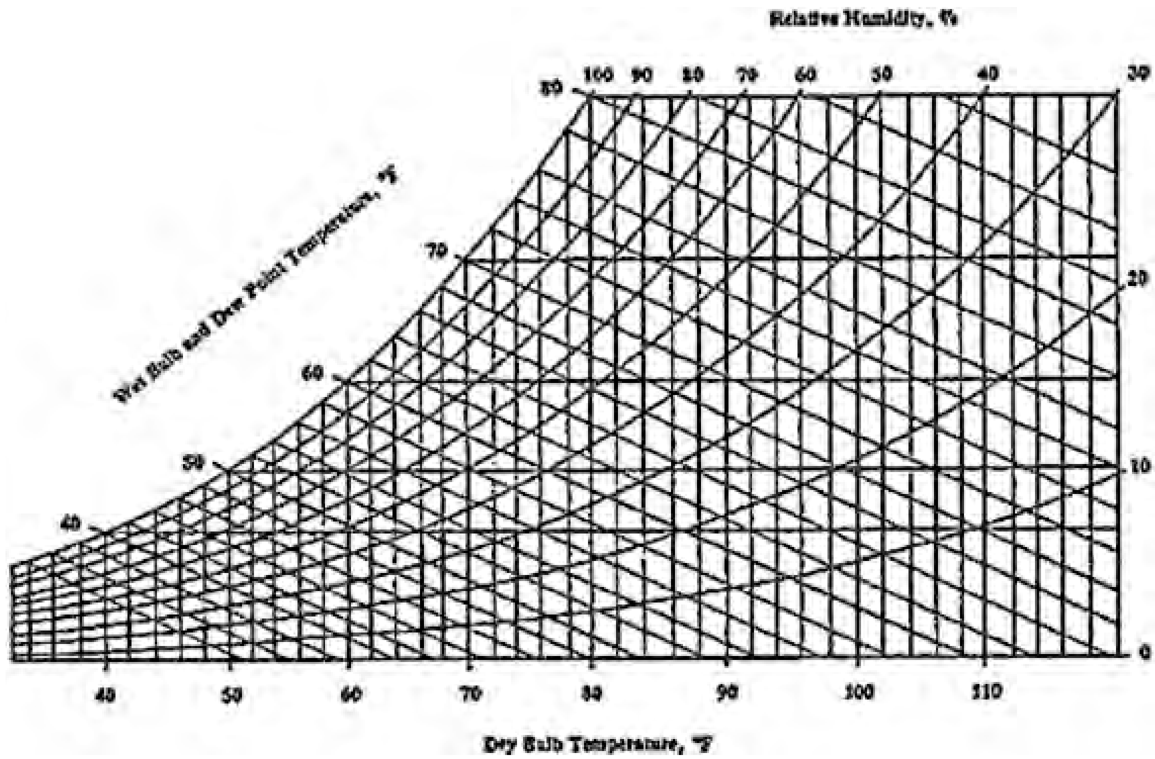

Figure 2. Simplified Psychrometric Chart

At first glance, a psychrometric chart appears complex; however, by separating the various lines and scales on the chart, the use of the chart can be easily described. The four steps for determining the relative humidity from a Psychrometric Chart are described below:

Step 1. Measure the dry-bulb and wet-bulb air temperatures

Dry-bulb air temperature is the air temperature determined by an ordinary thermometer or thermocouple. Alternatively, the wet-bulb temperature reflects the cooling effect of evaporating water. Wet-bulb temperature can be determined by passing air over a thermometer whose bulb (the base of the thermometer) is wet (the bulb has been wrapped with a small amount of moist cloth). If a thermocouple is used, instead of a thermometer, the sensor tip of the thermocouple is wrapped with a moist cloth. The cooling effect of the evaporating water causes a lower temperature compared to the dry bulb air temperature. To get an accurate wet-bulb temperature, the air must blow past the wet-bulb thermometer; using a fan to blow the air, or using a sling psychrometer can accomplish this.

The sling psychrometer consists of two thermometers mounted side-by-side on a holder which can be whirled through the air. The dry-bulb thermometer is bare and the wet-bulb thermometer is covered by a wick (cloth) that is kept wet with clean water. After being whirled for a sufficient time, the wet-bulb thermometer reaches its equilibrium point (reaches a steady value) and both the wet- and dry-bulb temperatures can be read. Readings should be taken as quickly as possible. Rapid movement of the air past the wet-bulb is necessary to get dependable readings. *Figure 3* shows a simple sling psychrometer.

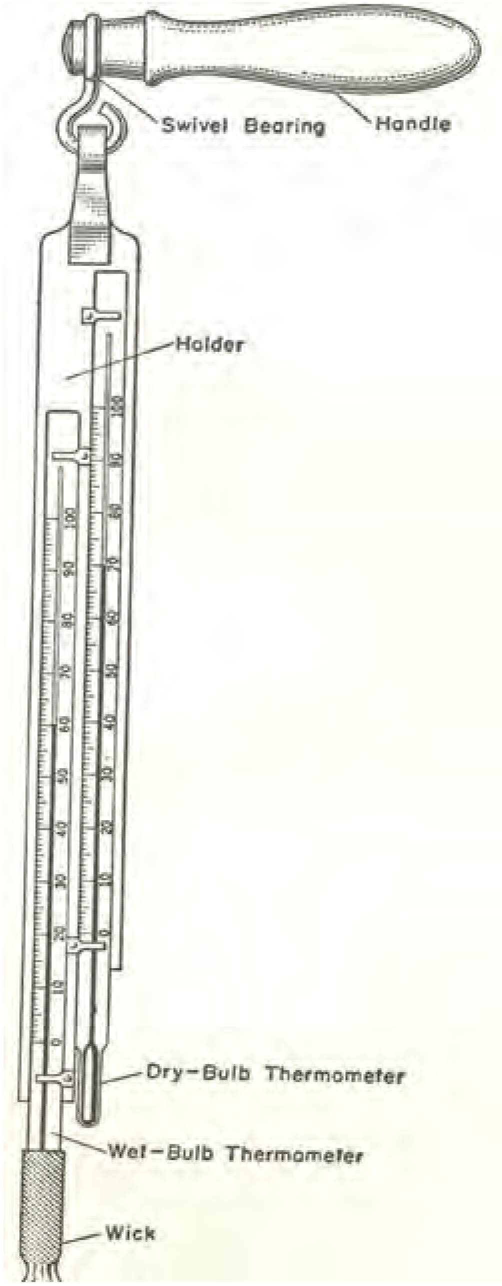

Figure 3. Sling Psychrometer

Step 2. Find the location of the measured dry-bulb air temperature on the Psychrometric Chart.

Dry-bulb air temperature is the air temperature determined by an ordinary thermometer or thermocouple. This scale is located on the horizontal (x-axis) base of the chart as shown in Figure 4 below.

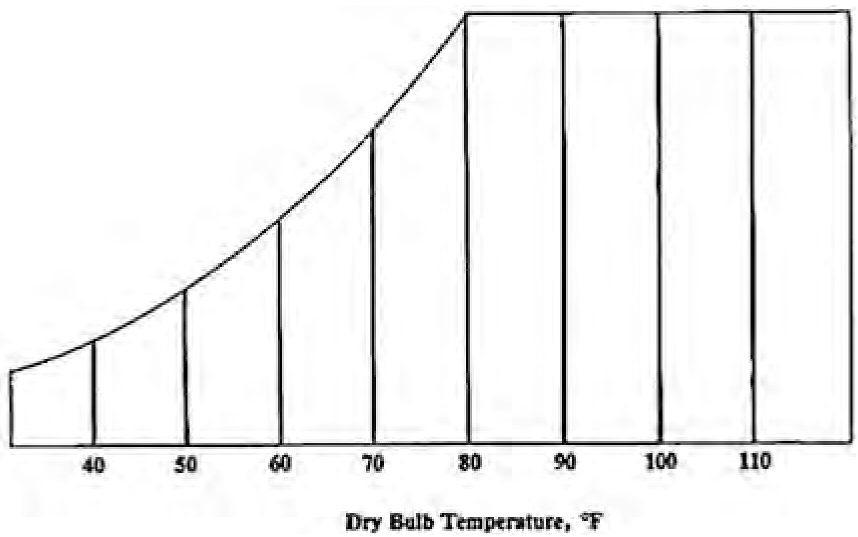

Figure 4. Dry-bulb temperature lines on the Psychrometric Chart

Step 3. Find the location of the measured wet-bulb air temperature on the Psychrometric Chart.

Wet-bulb temperature reflects the cooling effect of evaporating water. The wet-bulb temperature scale is located along the curved upper left portion of the chart. The sloping lines indicate equal wet-bulb temperatures. See Figure 5 below.

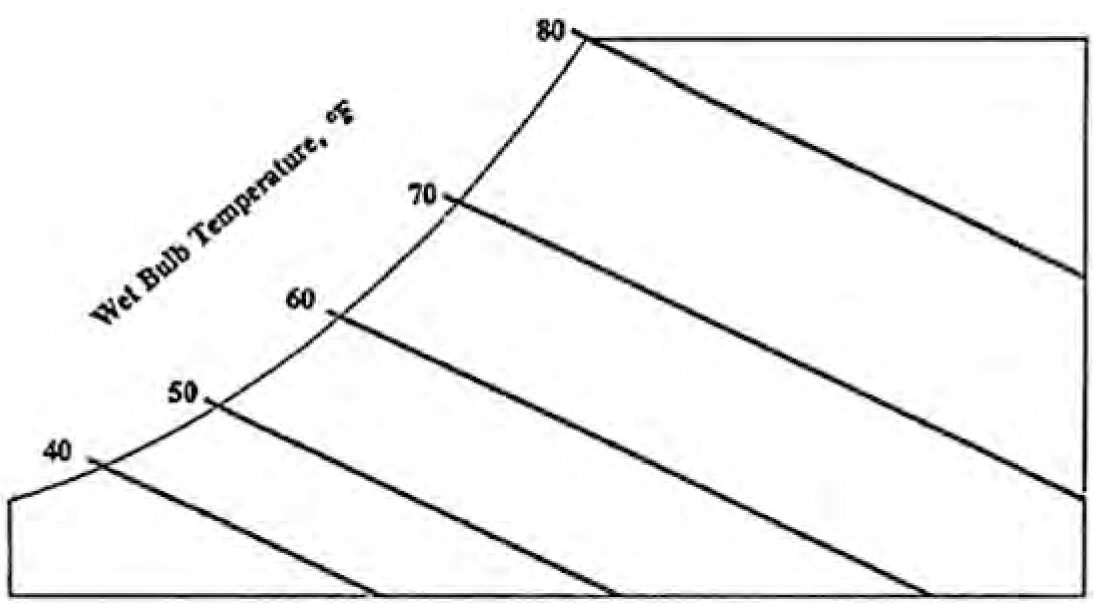

Figure 5. Wet-bulb temperature lines on the Psychrometric Chart

Step 4. Determine the Relative Humidity as the intersection of the wet-bulb and dry-bulb air temperature lines.

Lines representing conditions of equal relative humidity sweep from the lower left to the upper right of the Psychrometric Chart, as shown in Figure 6. The 100% relative humidity (saturation) line is also the Dew Point line. The line for zero percent relative humidity falls along the dry-bulb temperature scale line. Therefore, to determine the Relative Humidity, the intersection of wet-bulb and dry-bulb temperature lines is found on the Psychrometric Chart and then the relative humidity is read off the chart at this location.

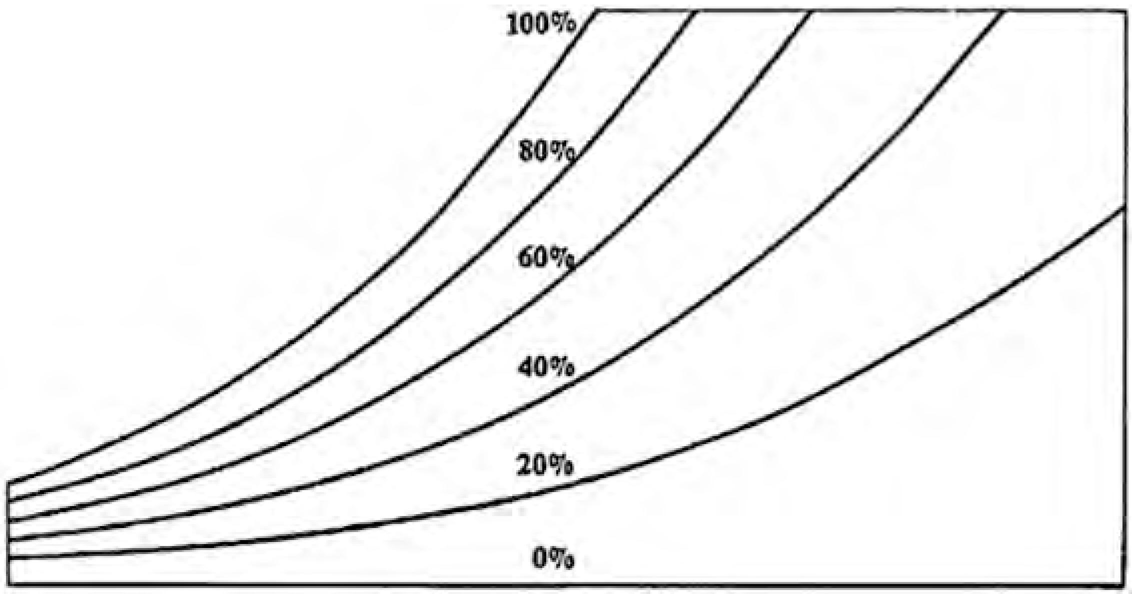

Figure 6. Relative humidity lines on the Psychrometric Chart

For example, with a measured 80°F dry-bulb temperature and 67°F wet-bulb temperature as shown in Figure 7, the relative humidity is 50%. Also, note that the dew point for this case is 60°F, which means any surface in the building whose surface is below 60°F, such as a poorly insulated AC line or duct work will condense moisture from the air (sweat) and will be a site for mold growth. This is why air ducts and refrigeration lines must be completely insulated.

The versatility of the psychrometric chart lies in the fact that by knowing just two properties of moist air, the other properties can be determined. Therefore, if there are some cool surfaces that cannot be insulated and must not condense water, such as cold water lines inside the floor of the structure, the dew point temperature and dry-bulb air temperature can be used to determine the maximum relative humidity to be allowed in the structure. This training manual only provides a simplified or abridged version of the psychrometric chart. A full chart also includes scales for absolute humidity or the weight of water per unit weight of air, density, enthalpy and a correction for varying atmospheric pressure. Psychrometric Charts that cover higher and lower temperature ranges are also available.

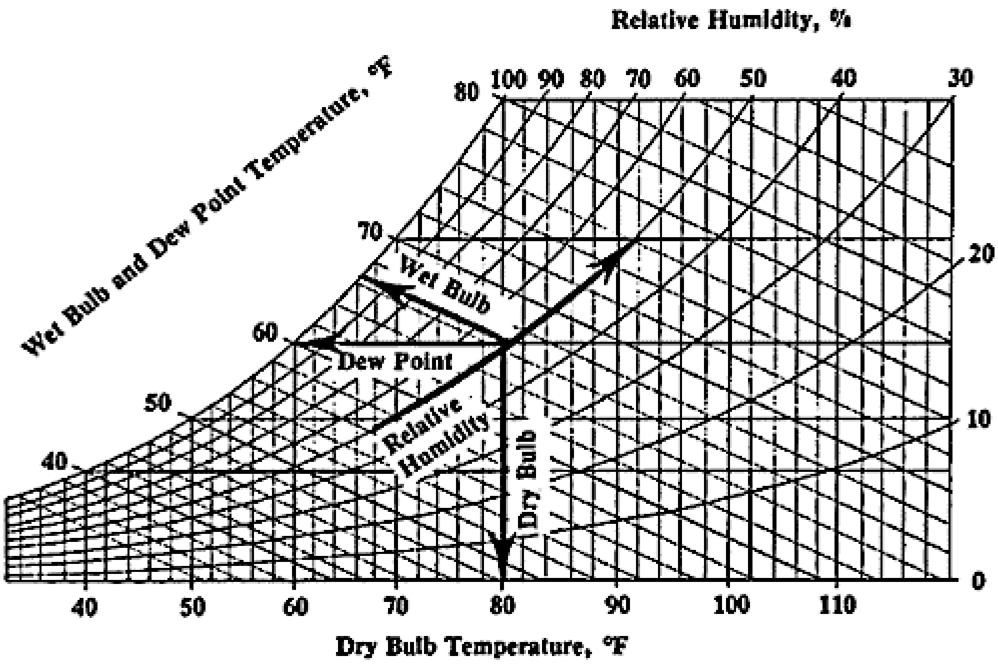

Figure 7. Example Case - Relative Humidity Determination

Tables have also been created to determine the Relative Humidity from the wet-bulb and dry-bulb temperatures. While the Psychrometric Chart is the best means of determining all the properties of moist air from only two measured values, some people prefer the simplicity of using a table to determine relative humidity. Table 1 shows one such table for normal temperatures and pressures, which was adapted from the *Old Farmer's Almanac* (www.almanac.com/weathercenter).

Table 1. The Psychrometric Table

Dry-Bulb Temperature °F	Temperature Difference Between Dry-Bulb and Wet Bulb Temperature °F									
	4°F	5°F	6°F	7°F	8°F	9°F	10°F	11°F	12°F	4°F
	Relative Humidity									
40°F	68%	60%	52%	45%	37%	29%	22%	15%	7%	68%
50°F	74%	67%	61%	55%	49%	43%	38%	32%	27%	74%
60°F	78%	73%	68%	63%	58%	53%	48%	43%	39%	78%
70°F	81%	77%	72%	68%	64%	59%	55%	51%	48%	81%
80°F	83%	79%	75%	72%	68%	64%	61%	57%	54%	83%
90°F	85%	81%	78%	74%	71%	68%	65%	61%	58%	85%

Dew Point Temperature Measurement

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As stated in the prior example, the Dew Point temperature is the temperature below which moisture will condense out of air. Water will condense on a surface, such as the external surface of an air duct, a cold pipe or a can of soda, which is at or below the dew point temperature of the air. The dew point temperature scale is located along the same curved portion of the chart as the wet-bulb temperature scale. However, horizontal lines indicate equal dew point temperatures, as shown in Figures 7 and 8.

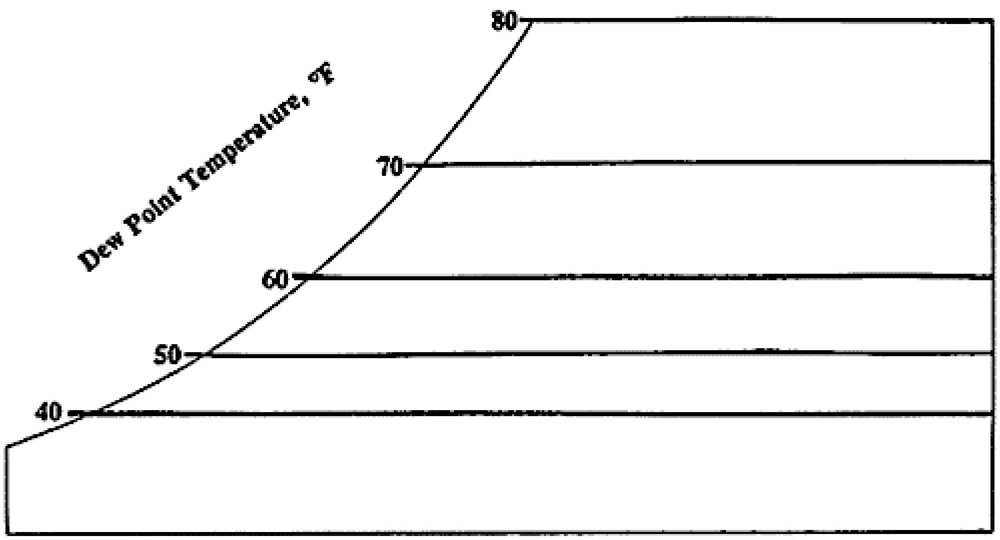

Figure 8. Dew-Point Temperature lines on the Psychrometric Chart

Facility Operation and Maintenance

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Indoor air quality can be affected both by the quality of maintenance and by the materials and procedures used in operating and maintaining the building components including the HVAC system.

Facility staff familiar with building systems in general and with the features of their building in particular are an important resource in preventing and resolving indoor air quality problems. Facility personnel can best respond to indoor air quality concerns if they understand how their activities affect indoor air quality. It may be necessary to change existing practices or introduce new procedures in relation to:

Equipment operating schedules: Confirm that the timing of occupied and unoccupied cycles is compatible with actual occupied periods, and that the building is flushed by the ventilation systems before occupants arrive. ASHRAE 62-1989 provides guidance on lead and lag times for HVAC equipment. **In hot, humid climates, ventilation may be needed during long unoccupied periods to prevent mold growth.**

Control of odors and contaminants: Maintain appropriate pressure relationships between building usage areas. Avoid recirculation of air from areas that are strong sources of contaminants (e.g., smoking lounges, chemical storage areas, beauty salons). Provide adequate local exhaust for activities that produce odors, dust or contaminants, or confine those activities to locations maintained under negative pressure (relative to adjacent areas). Make sure that paints, solvents and other chemicals are stored and handled properly, with adequate (direct exhaust) ventilation provided. If local filter traps and adsorbents are used, they require regular maintenance.

Ventilation quantities: Compare outdoor air quantities to the building design goal and local and state building codes and make adjustments as necessary. It is also informative to see how the ventilation rate compares to ASHRAE 62-1989, since that guideline was developed with the goal of preventing IAQ problems. Because of recent IAQ litigation, many HVAC system designers view ASHRAE Standard 62-89, Ventilation Standard for Acceptable Indoor Air Quality, as a minimum ventilation standard that must be met, in addition to local codes. If a building designer fails to conform to appropriate ASHRAE standards, claims of negligence and strict product liability may result. Also, building regulations in many states reference ASHRAE 62-89 for ventilation requirements.

HVAC equipment maintenance schedules: Inspect all equipment regularly (per recommended maintenance schedule) to ensure that it is in good condition and is operating as designed. Most equipment manufacturers provide recommended maintenance schedules for their products. Components exposed to water require scrupulous maintenance to prevent microbiological growth.

Strategies for Responding to Water Damage

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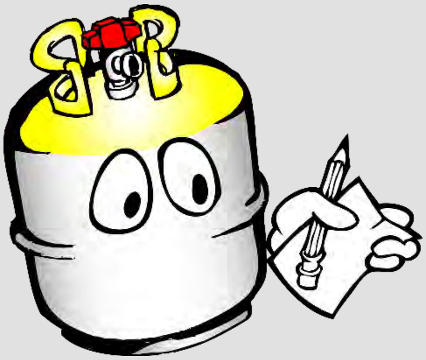
Table 2 presents strategies for responding to water damage within 24-48 hours. These guidelines are designed to help avoid the need for remediation of mold growth by taking quick action before growth starts. If mold growth is found on the materials listed in Table 2, refer to Table 3 for guidance on remediation. Depending on the size of the area involved and resources available, professional assistance may be needed to dry an area quickly and thoroughly.



Tables 2 and 3 contain general guidelines. Their purpose is to provide basic information for technicians to assess the extent of the damage and then to determine whether the additional mold remediation specialists need to be contracted for the clean-up.

Table 2. Water Damage Cleanup and Mold Prevention

Guidelines for Response to Clean Water Damage within 24-48 Hours to Prevent Mold Growth[1]	
Water-Damaged Material	**Actions**
Wet books and papers	For non-valuable items, discard books and papers. Photocopy valuable/important items, discard originals. Freeze (in frost-free freezer or meat locker) or freeze-dry.
Wet carpet and under carpet backing - Replace under carpet and dry Carpet within 24-48 hours [2]	Remove water with water extraction vacuum. Reduce ambient humidity levels with dehumidifier. Accelerate drying process with fans.
Wet ceiling tiles[3]	Discard and replace.
Wet fiberboard[3]	Cut out wet sections and replace..
Metal ducts	Clean with a hard surface cleaner (that contains a biocide) and allow to dry.
Wet cellulose insulation[3]	Discard and replace.
Concrete or cinderblock surfaces	Remove water with water extraction vacuum. Accelerate drying process with dehumidifiers, fans, and/or heaters.
Wet fiberglass insulation	Discard and replace.
Non-porous Hard surfaces	Clean with a hard surface cleaner (that contains a biocide) and allow to dry; scrub if necessary.
Upholstered furniture	Remove water with water extraction vacuum. Accelerate drying process with dehumidifiers, fans, and/or heaters.
Wallboard (drywall and gypsum board)	May be dried in place if there is no obvious swelling and the seams are intact. If not, remove, discard, and replace. Ventilate the wall cavity, if possible.
Window drapes	Follow laundering or cleaning instructions

	recommended by the manufacturer.
Wood surfaces	Remove moisture immediately and use dehumidifiers, gentle heat, and fans for drying. (Use caution when applying heat to hardwood floors.) Treated or finished wood surfaces may be cleaned with mild detergent and clean water and allowed to dry. Wet paneling should be pried away from wall for drying.

(1) If mold growth has occurred or materials have been wet for more than 48 hours, consult Table 2 guidelines. Even if materials are dried within 48 hours, mold growth may have occurred.

These guidelines are for damage caused by clean water. If the water source is contaminated with sewage, or chemical or biological pollutants, then Personal Protective Equipment and containment are required by OSHA. An experienced professional Hazardous Material Handling Expert should be consulted. Do not use fans before determining that the water is clean or sanitary.

(2) The subfloor under the carpet or other flooring material must also be cleaned and dried. See the appropriate section of Table 1 for recommended actions depending on the composition of the subfloor.

(3) A hard surface cleaner (with biocide) is only to be used on hard, non-porous surfaces. If metal ducts have a fiberglass insulation inner liner, then wet sections of the liner need to be replaced.

Controlling Mold

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Introduction

It is impossible to eliminate all mold and mold spores indoors; some mold spores will be found floating through the air and in dust. The mold spores will not grow if moisture is not present. Indoor mold growth can and should be prevented or controlled by controlling moisture indoors. If there is mold growth in a structure, remove the mold and wet materials, including duct board and insulation, treat the surfaces with the proper products and fix the water problem. If the mold is cleaned-up, but the water problem is not fixed, the mold problem will recur. Keep indoor relative humidity below 55% (ideally between 30 and 50% relative humidity).

Mold Remediation Guidelines

Table 3 presents remediation guidelines for building materials that have or are likely to have mold growth. The guidelines in Table 3 are designed to protect the health of occupants and clean-up personnel during remediation. These guidelines are based on the area and type of material affected by water damage and/or mold growth.

If possible, remediation activities should be scheduled during off-hours when building occupants are less likely to be affected.

Although the level of personal protection suggested in these guidelines is based on the total surface area contaminated and the potential for technician and/or occupant exposure, professional judgment should always play a part in any remediation decisions. These remediation guidelines are based on the size of the affected area to make it easier for technicians to select appropriate techniques, not on the basis of health effects or research showing there is a specific method appropriate at a certain number of square feet. The guidelines have been designed to help construct a remediation plan. The technician must use professional judgment and experience to adapt the guidelines to particular situations. When in doubt, caution is advised.

In cases where a particularly toxic mold species has been identified or is suspected, when extensive hidden mold is expected (such as behind vinyl wallpaper or in the HVAC system), when the chances of the mold becoming airborne are estimated to be high, or sensitive individuals (e.g., those with severe allergies or asthma) are present, a significantly more cautious and conservative approach to remediation should be followed. Always make sure to protect yourself and building occupants from exposure to mold or mold spores. If anyone reports health concerns, consult a health professional immediately. For immediate health concerns, call 911.

Table 3. Guidelines for Remediating Buildings with Mold Growth Caused by Clean Water*

SMALL AREA - Total Surface Area Affected Less Than 10 square feet (ft^2)			
Material	**Cleanup Methods(2)**	**Personal Protective Equipment(1)**	**Containment**
Books and papers	- HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
Carpet and backing	-Wet vacuum - HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
Concrete or cinderblock	- Wet vacuum - HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
Hard surface, porous flooring (linoleum,	- Wet vacuum - Damp	Minimum: - N-95 respirator - Gloves	None required

ceramic tile, vinyl)	wipe - HEPA vacuum	- Goggles	
Non-porous, hard surfaces (plastics, metals)	- Wet vacuum - Damp wipe - HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
Upholstered furniture and drapes	- Wet vacuum - HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
Wallboard (drywall and gypsum board)	- HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
Wood surfaces	- Wet vacuum - Damp wipe - HEPA vacuum	Minimum: - N-95 respirator - Gloves - Goggles	None required
MEDIUM AREA - Total Surface Area Affected Between 10 and 100 ft^2			
Material	**Cleanup Methods(2)**	**Personal Protective Equipment(1)**	**Containment**
Books and papers	- HEPA vacuum	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Carpet and backing	- Wet vacuum - HEPA vacuum - Discard	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Concrete or cinder block	- Wet vacuum - HEPA vacuum	Limited or Full Use professional judgment, consider potential for	Limited Use professional judgment, consider potential for remediator/occupant

		remediator exposure and size of contaminated area.	exposure and size of contaminated area.
Hard surface, porous flooring (linoleum, ceramic tile, vinyl)	- Wet vacuum - Damp wipe - HEPA vacuum	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.
Non-porous, hard surfaces (plastics, metals)	- Wet vacuum - Damp wipe - HEPA vacuum	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Upholstered furniture and drapes	- Wet vacuum - HEPA vacuum - Discard	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Wallboard (drywall and gypsum board)	- HEPA vacuum - Discard	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.
Wood surfaces	- Wet vacuum - Damp wipe - HEPA vacuum	Limited or Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Limited Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
LARGE - Total Surface Area Affected Greater Than 100 ft^2 or Potential for Increased Occupant or Remediator Exposure During Remediation Estimated to be Significant			

Material	Cleanup Methods(2)	Personal Protective Equipment(1)	Containment
Books and papers	- HEPA vacuum	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Carpet and backing	- Wet vacuum - HEPA vacuum - Discard	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Concrete or cinder block	- Wet vacuum - HEPA vacuum	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Hard surface, porous flooring (linoleum, ceramic tile, vinyl)	- Wet vacuum - Damp wipe - HEPA vacuum - Discard	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Non-porous, hard surfaces (plastics, metals)	- Wet vacuum - Damp wipe - HEPA vacuum	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Upholstered furniture and drapes	- Wet vacuum - HEPA vacuum - Discard	Full Use professional judgment, consider potential for	Full Use professional judgment, consider potential for remediator/occupant

		remediator exposure and size of contaminated area.	exposure and size of contaminated area.
Wallboard (drywall and gypsum board)	- HEPA vacuum - Discard	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.
Wood surfaces	- Wet vacuum - Damp wipe - HEPA vacuum - Discard	Full Use professional judgment, consider potential for remediator exposure and size of contaminated area.	Full Use professional judgment, consider potential for remediator/occupant exposure and size of contaminated area.

(1) Use professional judgment to determine prudent levels of Personal Protective Equipment and containment for each situation, particularly as the remediation site size increases and the potential for exposure and health effects rises. Assess the need for increased Personal Protection Equipment, if, during the remediation, more extensive contamination is encountered than was expected. Consult Table 2 if materials have been wet for less than 48 hours, and mold growth is not apparent.

These guidelines are for damage caused by clean water. If you know or suspect that the water source is contaminated with sewage, or chemical or biological pollutants, then the Occupational Safety and Health Administration (OSHA) requires PPE and containment. A HAZMAT certified professional should be contracted.

(2) Select method most appropriate to situation. Since molds gradually destroy the things they grow on, if mold growth is not addressed promptly, some items may be damaged such that cleaning will not restore their original appearance. Please note that these are guidelines; other cleaning methods may be preferred by some professionals.

Cleanup Methods

Method 1: Wet vacuum. For porous duct materials, some mold spores/fragments will remain in the material. Replacement of this porous duct material is always recommended.

Method 2: Clean nonporous surfaces with a hard surface cleaner that contains a biocide. Whether dead or alive, mold is allergenic, and some molds may be toxic. Mold can generally be killed and removed from nonporous (hard) surfaces by wiping with a hard surface cleaner that contains a biocide. Instructions for using any hard surface cleaner should always be read and followed. Porous materials that are wet and have mold growing on them will have to be discarded because the molds will infiltrate porous substances and grow on or fill in empty spaces or crevices, making it impossible to remove these molds completely.

Method 3: High-efficiency particulate air (HEPA) vacuum after the material has been thoroughly dried. Dispose of the contents of the HEPA vacuum in sealed plastic bags.

HEPA (High-Efficiency Particulate Air) vacuums are recommended for final cleanup of remediation areas after materials have been thoroughly dried and contaminated materials removed. HEPA vacuums are also recommended for clean-up of dust that may have settled on surfaces outside the remediation area. Care must be taken to assure that the filter is properly seated in the vacuum so that all the air must pass through the filter. When changing the vacuum filter, wear PPE to prevent exposure to the mold that has been captured. The filter and contents of the HEPA vacuum must be disposed of in well-sealed plastic bags.

Method 4: Discard water-damaged materials and seal in plastic bags while inside of containment, if present. HEPA vacuum area after it is dried.

Building materials and furnishings that are contaminated with mold growth and are not salvageable should be double-bagged using 6-mil polyethylene sheeting. These materials can usually be discarded as ordinary construction waste. It is important to package mold contaminated materials in sealed bags before removal from the containment area to minimize the dispersion of mold spores throughout the building. Large items that have heavy mold growth should be covered with polyethylene sheeting and sealed with duct tape before they are removed from the containment area.

Personal Protective Equipment (Ppe)

Minimum: gloves, N-95 respirator, goggles/eye protection
Limited: gloves, N-95 respirator or half-face respirator with HEPA filter, disposable overalls, goggles/eye protection
Full: gloves, disposable full body clothing, head gear, foot coverings, full-face respirator with HEPA filter

Containment

Limited: Use polyethylene sheeting ceiling to floor around affected area with a slit entry and covering flap; maintain area under negative pressure with HEPA filtered fan unit. Block supply and return air vents within containment area.

Full: Use two layers of fire-retardant polyethylene sheeting with one airlock chamber. Maintain area under negative pressure with HEPA filtered fan exhausted outside of building. Block supply and return air vents within containment area.

Table developed from literature and remediation documents including *Bioaerosols: Assessment and Control* (American Conference of Governmental Industrial Hygienists, 1999) and *IICRC S500, Standard and Reference Guide for Professional Water Damage Restoration* (Institute of Inspection, Cleaning and Restoration, 1999).

Safety Tips during Mold Removal

- Do not touch mold or moldy items with bare hands
- Do not get mold or mold spores in eyes.
- Do not breathe in mold or mold spores.
- Consult Table 3 and text for Personal Protective Equipment (PPE) and containment guidelines.
- Consider using PPE when disturbing mold. The minimum PPE is an N-95 respirator, gloves and eye protection.

Mold Sampling

Mainstream manufactures a Surface-sample Mold Test Kit, known as the Qwik**Treat**™ **MoldTest**™ Kit, for use by trained HVAC/R technicians when identification of a mold is desired. For situations where litigation is involved, the source(s) of the mold contamination is unclear, or health concerns are a problem, consider sampling as part of a site evaluation. Surface sampling may also be useful in order to determine if an area has been adequately cleaned. Sampling should be done only after developing a sampling plan that includes a confirmable theory regarding suspected mold sources and routes of exposure. Attempt to determine what is occurring and how to prove or disprove it before sampling is conducted!

The results of sampling may have limited use or application. Sampling may help locate the source of mold contamination, identify some of the mold species present, and differentiate between mold and soot or dirt. Pre- and post-remediation sampling may also be useful in determining whether remediation efforts have been effective. Since no EPA or other federal threshold limits have been set for mold or mold spores, air sampling cannot be used to check a building's compliance with federal mold standards. Sample analyses should follow analytical methods recommended by the American Industrial Hygiene Association (AIHA) or the American Conference of Governmental Industrial Hygienists (ACGIH). Types of samples include air samples, surface samples, bulk samples (chunks of duct board, carpet, insulation, wall board, etc.), and water samples from condensate drain pans, humidifiers or cooling towers. Surface sample testing is an ideal method of identifying molds that are actually growing in the structure.

Keep in mind that testing for mold provides temporary information, much like a snapshot. When properly performed, surface sampling will reveal what was growing on a particular surface at the moment when the sample was taken.

Key Points to Remember about Mold:

If the duct board is wet or moldy or the insulation on sheet metal air ducts gets wet or moldy, they cannot be effectively cleaned and they must be removed and replaced.

- If the conditions causing the mold growth in the first place are not corrected, mold growth will recur. Treating with biocides, such as those contained in a hard surface cleaner, will kill the mold growth, but the mold will eventually return if the moisture problem is not resolved. It is critical to solve the moisture problem.
- Duct cleaning has never been shown to actually prevent health problems. Furthermore, research studies do not conclusively demonstrate that particle levels in buildings increase because of dirty air ducts or decrease after cleaning. This is because much of the dirt that may accumulate inside air ducts adheres to duct surfaces and does not necessarily enter the living space. It is important to keep in mind that dirty air ducts are only one of many possible sources of particles that are present in buildings. Pollutants enter a structure both from outdoors and indoor activities, such as cooking, cleaning, smoking, or ordinary movement within a building. There is no evidence that a light amount of dust or other particulate matter in air ducts poses any risk to health. Conversely, any mold observed must be removed. For hard surfaces, that means cleaning with a hard surface cleaner while for porous surfaces the moldy porous material must be removed--mold on porous surfaces cannot be effectively treated, it must be removed.
- **The EPA does not recommend that air ducts be cleaned** because of the continuing uncertainty about the benefits of duct cleaning. Any service provider or advertiser who asserts that the EPA recommends routine duct cleaning or makes claims about the health benefits should be reported to the EPA.
- The EPA does recommend fuel burning furnaces, stoves or fireplaces be inspected for proper functioning and serviced before each heating season to protect against carbon monoxide poisoning. Research also suggests that cleaning dirty cooling coils, fans and heat exchangers can improve the efficiency and capacity of heating and cooling systems and remove the food sources on which molds and bacteria rely.
- Do not paint or caulk moldy surfaces; clean and dry surfaces before painting. Paint applied over moldy surfaces is likely to peel.
- The purpose of mold remediation is to remove the mold to prevent human exposure and damage to building materials and furnishings.
- Be sure to clean up the mold contamination, not just kill the mold. Dead mold is still allergenic, and some dead molds are potentially toxic.
- The use of chlorine bleach is not recommended to kill mold. For hard, non-porous surfaces, use a hard surface cleaner, and for porous fibrous insulation and fiberboard the material must be replaced. Chemical biocides can only be used on hard, non-porous surfaces. Never use any of these compounds when immune-compromised individuals are present. Remember, biocides are toxic to

humans, as well as to mold. Appropriate PPE should be used. Read and follow label precautions.

- Never mix chlorine bleach solution with any other cleaning solutions or detergents that contain ammonia; toxic fumes could be produced.
- It is not possible or desirable to sterilize an area; a background level of mold spores will always remain in the air (roughly equivalent to the level in outside air). These spores will not grow if the moisture problem in the building has been resolved.
- When using fans to dry or ventilate, be careful not to distribute mold spores throughout an unaffected area.
- Fungicides are commonly applied to outdoor plants, soil, and grains as a dust or spray – examples include hexachlorobenzene, organomercurials, pentachlorophenol, phthalimides, and dithiocarbamates.**Do not use fungicides developed for use for mold remediation or for any other indoor situation. Death could occur without warning!**

Air Duct Cleaning

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In this manual, duct cleaning does not refer to the cleaning of the registers grilles and diffusers, furnace heat exchangers and A/C cooling coils, condensate drain pans (drip pans), humidifiers, fan motors and housings, or the air handling unit housing. Rather duct cleaning refers to the cleaning of the actual porous or non-porous duct itself.

If not properly installed, maintained and operated, portions of the heating, air conditioning or ventilating system can become contaminated with particles of dust, pollen or other debris. If moisture is present, the potential for microbiological growth is increased and spores from such growth may be released into the building's living space. As discussed previously, these contaminants can cause allergic reactions or other symptoms in certain people who are exposed to them.

Chemical biocides designed to kill microbiological contaminants should not be applied to the inside of porous ductwork because the EPA has not yet determined the safety of such an approach. No product is EPA certified for this use, in part, because the EPA has not resolved these issues. Since biocides kill living organisms, they could cause serious health problems if inhaled by the service technician or the building occupants. These health concerns are especially serious if pregnant woman or small children are exposed**. All biocide products should never be used in a fashion that would allow the service technician or the occupants any possibility of inhalation.**

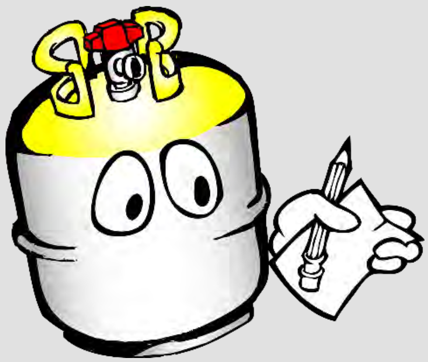
Chemical treatments (sealants or other encapsulants) are available that can encapsulate or cover the inside surfaces of the air ducts and equipment housings to prevent the release of dirt particles or fibers from ducts, however**, these products should only be applied after the system has been properly cleaned of all visible**

<u>dust or debris and any wet or moldy sections removed and replaced.</u> Cleaning products that contain biocides (essentially poisons) must be registered with the EPA and display the EPA-Registration number on the packaging. Products that will kill mold while also encapsulating or sealing porous surfaces that contain mold preventing biocides are not registered with the EPA, since the biocide is encapsulated into the cured surface. Follow all label directions.

Never make general claims about the health benefits of duct cleaning--such claims are unsubstantiated. If improperly done, duct cleaning can dislodge dirt and mold causing health problems. Do not recommend duct cleaning as a *routine* part of heating and cooling system maintenance. Never claim to be certified by the EPA in duct cleaning. **The EPA neither establishes duct-cleaning standards nor certifies, endorses, or approves duct cleaning companies**. Check with the state department of professional regulation; many states including Arizona, Arkansas, California, Florida, Georgia, Michigan and Texas require air duct cleaners to hold special licenses. Other states may require them as well.

The information about the potential benefits and possible problems of air duct cleaning is limited, and the EPA is still investigating the issues. In general, conditions in every structure are different; it is impossible to generalize about whether or not air duct cleaning would be beneficial at a specific location. Use common sense and training to assess each individual situation. Generally speaking, if no one in the structure is reporting any unexplained allergies, unexplained symptoms or unexplained illnesses and if, after a visual inspection of the systems and ductwork, there is no clear indication that the system or the air ducts are contaminated with large deposits of dust or any mold (no musty odor or visible mold growth), it is probably not necessary to clean the air ducts. Therefore, **<u>while routine duct cleaning is not recommended, the evaporator coil, humidifier, and condensate drain pan should always be cleaned and the condensate drain line or condensate pump checked for proper operation.</u>** After cleaning the evaporator coil and humidifier water box, a hard surface cleaner should be used to kill and remove mold and other growths, Pan tablets should be added to prevent the future accumulation of any type of scum. Use a hard surface cleaner on any hard surfaces where mold may be suspected.

It is normal for the return registers to become dusty as dust-laden air is pulled through the grate. This does not indicate that the air ducts are contaminated with heavy deposits of dust or debris; the registers and the duct region surrounding the registers can be easily removed and cleaned. This is always a recommended practice, as is cleaning the evaporator coil, humidifier, and condensate pan.



If building occupants are experiencing unusual or unexplained symptoms or illnesses they should discuss the situation with their doctor, including the question of whether these symptoms could be the result of indoor air pollution.

Some equipment owners may want their air ducts cleaned simply because it seems logical that air ducts will become dirty over time and should occasionally be cleaned. While the debate about the value of periodic duct cleaning continues, no evidence suggests that such cleaning would be detrimental, provided that it is done properly. However, if a service technician fails to follow proper duct cleaning procedures, duct cleaning can cause indoor air problems. For example, an inadequate vacuum collection system can release more dust, dirt and other contaminants. A careless or inadequately trained service provider can also damage the air ducts or heating and cooling system. Table 4 presents a duct-cleaning checklist.

Mainstream recommends the following duct cleaning and treatment procedure:

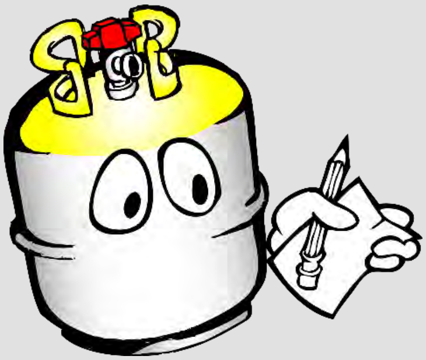
1) Inspect the duct work for any air leaks. Conditioned air that leaks into unconditioned spaces, while wasting money, can also lead to condensation and moisture problems on the ductwork.

2) Inspect the duct work for improper or missing insulation in un-conditioned spaces. Cool exterior duct surfaces in unconditioned spaces, while wasting money, can also lead to condensation and moisture problems on the ductwork.

3) Inspect the duct work and mastic seals for any signs of exterior mold or condensation. This can be caused by insufficient thermal insulation of the ductwork or air leaks from the ducts. If mold is found, it must be removed completely, along with any other wet insulation or fiberboard. Any non-porous surfaces including metal ducts should be cleaned and treated with a hard surface cleaner. Make sure any replacement duct work areas are fully insulated. For fiber-board ducts, the moisture could have soaked through to the inside surface, causing mold formation on the inside of the duct. The entire wet or moldy section of duct board must be replaced. In summary, replace all wet or moldy porous materials. Alternatively, clean any non-porous hard surfaces with a hard surface cleaner.

4) Inspect the interior of the ductwork at all registers and returns. Wearing protective equipment and with the air handler off, vacuum out any loose debris and look for signs of mold. Use a high-suction vacuum with a HEPA filter to

remove any loose debris. If mold is found in any porous material, the material must be cut out and replaced.



Whenever mold is discovered, the moisture source must be identified and repaired, and the wet or moldy area replaced and treated.

5) Inspect the air handler for the presence of mold or excessive contamination. Check that the blower wheel is free spinning to avoid reduced airflow. A hard surface cleaner can be used to kill and remove mold from any of these hard surfaces. Use a pan tablet in the condensate pan, humidifier or condensate line tablet dispenser to prevent the build-up of scum, which could clog the condensate line and result in local flooding and future mold growth.

Unresolved Issues of Duct Cleaning

Does duct cleaning prevent health problems?

The bottom line is: no one knows. There are examples of ducts that have become badly contaminated with a variety of materials that may pose risks to one's health. In these cases, the duct system can serve as a means to distribute these contaminants throughout a building. Obviously, in these cases, duct cleaning makes sense. However, a light amount of dust in the air ducts is normal. It is also normal for the air return register to become dusty as dust-laden air is pulled through it. The register should be cleaned periodically. However, duct cleaning is not considered to be a necessary part of yearly maintenance of a properly maintained heating or cooling system. Research continues in an effort to evaluate the potential benefits of air duct cleaning.

However, a properly maintained heating or cooling system maintenance routine must include regular cleaning of drain pans, use of Pan Treatment Tablets during the cooling system and at least annual cleaning of the furnace heat exchanger and A/C evaporator coils, regular (at least monthly) filter changes using PuraClean® and annual inspections of both the furnace and cooling system prior to the beginning of a new heating or cooling season. The furnace inspection should include a heat exchanger leak test.

Should chemical biocides or ozone be sprayed into air ducts?

Some chemical companies try to sell products for air duct cleaning that claim a chemical biocide should be applied to the entire inside surface of the air ducts to kill bacteria (germs), and fungi (mold) and prevent future biological growth. Typically, anything that kills living organisms like bacteria and fungi is also not healthy for humans, so the widespread spraying of such compounds into the air is not a good idea, unless the building is unoccupied for a substantial period of time after the spraying (and even then these killing compounds could be distributed on eating surfaces and food supplies). Exposure in this case is even more of a problem for pregnant or nursing women and small children. Of course, the technician performing the spraying must wear protective breathing apparatus. It is exactly because of the unknown variables that the EPA has not approved any substance for this type of application. There are always ample mold spores and bacteria in the air, therefore, a one-time killing of the bacteria and mold will not prevent a recurring problem because new bacteria and mold spores will simply start re-growing in the water and dirt remaining in the duct work. The removal of the source of water and dirt (the food supply) is the only real solution to preventing recurring problems.

Both the EPA and Mainstream recommend the removal of any wet or moldy duct board or fiberglass insulation.

Some manufacturers propose to introduce ozone to kill biological contaminants. Ozone is a highly reactive gas, meaning it is a highly corrosive gas that is regulated in the outside air as a lung irritant. **It is not recommended to purposely introduce ozone into the air due to the corrosive and toxic properties of this gas.** There are many components of the air handling system that would be adversely affected by a corrosive gas. There is no logical reason for the widespread introduction of either chemical biocides or ozone into the duct work. The following are among the possible problems with biocide and ozone application in air ducts:

- Little research has been conducted to demonstrate the effectiveness of most biocides and ozone when used inside ducts. Simply spraying or otherwise introducing these materials into the operating duct system may cause much of the material to be transported through the system and released into other living areas of the structure.
- Some people may react negatively to the biocide or ozone, causing adverse health reactions.

EPA regulates chemical biocides under federal pesticide laws. EPA must register a product for a specific use before it can be legally used for that purpose. The specific use(s) must appear on the pesticide (e.g., biocide) label, along with other important information. It is a violation of federal law to use a pesticide product in any manner inconsistent with the label directions.

EPA currently registers a small number of products specifically for use on the inside of bare sheet metal air ducts. A number of products are registered for use as sanitizers on hard surfaces, which includes the interior of bare sheet metal ducts. While many such products may be used legally inside of unlined non porous ducts if all label directions are followed, some of the directions on the label may be inappropriate for use in ducts and therefore those products should not be used inside air ducts. For example, if the directions indicate, "rinse with water", the added moisture could stimulate mold growth. There are no products currently registered by the EPA for cleaning fibrous (porous) air ducts, porous flexible ducts or metal ducts with internal fiberglass insulation, even though some manufacturers may claim otherwise. This is partly because the EPA currently has no approved method to test the **safety** and effectiveness of such products.

Before using any product claimed to be EPA-registered, check with the EPA. Also, if the product is registered, it is only to be used according to the instructions printed on the can because it has been tested and deemed safe only for that method of use. Some companies have offered flyers or pamphlets that offer instructions that are substantially different from the labeled instructions. However, it is a violation of federal law to use an EPA-registered product in any manner inconsistent with the label directions. Failure to follow label instructions can introduce potential liability issues for the IAQ technician.

Do sealants prevent the release of dust and dirt particles into the air?

Manufacturers of products marketed to coat and encapsulate duct surfaces claim that they prevent dust and dirt particles inside air ducts from being released into the air. Actually, any duct surface should be thoroughly cleaned before any sealant is applied. The use of sealants to coat the duct surfaces is appropriate for the repair of damaged fiberglass insulation or when combating fire damage within ducts. Sealants should never be used on wet or dirty ducts either to cover actively growing mold, or to cover debris in the ducts. Sealants should only be applied after replacement of wet or moldy sections and system cleaning. A duct sealant, like many paints, is combined with a biocide to help prevent recurrence of mold on the surfaces. These duct sealants should not be indiscriminately sprayed into entire duct systems, since the vapors are harmful to breathe. Follow all label directions.

Key Points about Duct Cleaning:

- Open access ports or doors to allow the entire system to be cleaned and inspected.
- Inspect the system before cleaning to be sure that there are no asbestos-containing materials (e.g., insulation, register boots, etc.) in the heating and cooling system. Asbestos-containing materials require specialized procedures and should not be disturbed or removed except by specially trained and equipped Asbestos Removal Contractors.
- Use vacuum equipment that exhausts particles outside of the building or use only high-efficiency particle air (HEPA) vacuuming equipment if the vacuum exhausts inside the building.
- Protect carpet and furnishings during cleaning.
- Use well-controlled brushing of duct surfaces in conjunction with contact vacuum cleaning to dislodge dust and other particles.
- Use only soft-bristled brushes for fiberglass duct board and sheet metal ducts internally lined with fiberglass. (Although flex duct can also be cleaned using soft-bristled brushes, it can be more economical to simply replace accessible flex duct.)
- Take care to protect the duct work, including sealing and re-insulating any access holes made or used so they are airtight.

Table 4. Post-cleaning Checklist

Post-cleaning Checklist		Yes	No
General	Did you obtain access to and clean the entire heating and cooling system, including ductwork and all components (drain pans, humidifiers, coils, and fans)?		
	Did you demonstrate to the building owner that the duct work and plenums are clean?		
Heating	Is the heat exchanger surface visibly clean?		
Cooling Components	Are both sides of the cooling coil visibly clean?		
	If you point a flashlight into the cooling coil, does light shine through the other side? It should, if the coil is clean.		
	Are the coil fins straight and evenly spaced (as opposed to being bent over and smashed together)?		
	Is the coil drain pan completely clean and draining properly?		
	Have you installed a pan tablet in the condensate drain pan and the humidifier water box?		
Blower	Are the blower blades clean and free of oil and debris?		
	Is the blower compartment free of visible dust or debris?		
Plenums	Is the return air plenum free of visible dust or debris?		
	Do filters fit properly and are they the proper efficiency as recommended by HVAC system manufacturer?		
	Did you treat the air filters with PuraClean Filter Spray?		
	Is the supply air plenum (directly downstream of the air handling unit) free of moisture stains and contaminants?		
Metal Ducts	Are interior ductwork surfaces free of visible debris? (Select several sites at random in both the return and supply sides of the system.)		
Fiberglass	Is all fiberglass material in good condition (i.e., free of tears and abrasions, and well adhered to underlying materials)?		
Access Doors	Are newly installed access doors in sheet metal ducts attached with more than just duct tape (e.g., screws, rivets, mastic, etc.)?		
	With the system running, is air leakage through access doors or covers very slight or non-existent?		

Air Vents	Have all registers, grilles, and diffusers been firmly reattached to the walls, floors and/or ceilings?		
	Are the registers, grilles and diffusers visibly clean?		
System Operation	Does the system function properly in both the heating and cooling modes after cleaning?		

Determining when the Job is Complete

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- The water or moisture problem is completely fixed and any residual moisture is dried up.
- All mold is completely removed. Use professional judgment to determine if the clean-up is sufficient. Visible mold, mold-damaged materials, and moldy odors should not be present.
- Be sure to revisit the site(s) shortly after remediation-there should be no signs of water damage or mold growth.
- People should be able to occupy or re-occupy the spa.

Communication Strategies

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Communication with Building Occupants

Communication with building occupants is essential for successful IAQ treatments and mold remediation. Some occupants will naturally be concerned about indoor air quality and mold growth in their building and the potential health impacts. The perceptions of health risks may increase if occupants feel that information is being withheld from them. The status of the building investigation and treatment should be openly communicated, including information on any known or suspected health risks.

Mold in Schools

Special communication strategies may be desirable when treating a mold problem in a school. Teachers, parents and other locally affected groups should be notified of significant issues immediately after they are identified. Consider holding a special meeting to provide parents with an opportunity to learn about the problem and ask questions of school authorities. It is advisable to ensure that the school is vacated during remediation.

For more information on investigating IAQ and remediation in schools, refer to the U.S. EPA's *IAQ Tools for Schools* kit and the asthma companion piece for the *IAQ Tools for Schools* kit, titled *Managing Asthma in the School Environment.*

Small remediation efforts will usually not require a formal communication process, but be sure to take individual concerns seriously and use common sense when deciding whether formal communications are required. Individuals managing medium or large remediation efforts should make sure they understand and address the concerns of building occupants and communicate clearly what has to be done, as well as any possible health concerns.

Communication approaches include regular memos and/or meetings with occupants (with time allotted for questions and answers), depending on the scope of the remediation and the level of occupant interest. Inform the occupants about the size of the project, planned activities, and remediation timetable. Send or post regular updates on the remediation progress, and send or post a final memo when the project is completed or hold a final meeting. Try and resolve issues and occupant concerns as they occur. When building-wide communications are frequent and open, those managing the remediation can direct more time toward resolving the problem.

If possible, remediation activities should be scheduled during off-hours when building occupants are less likely to be affected. Communication is important if occupants are relocated during remediation. The decision to relocate occupants should take into consideration the size of the area affected, the extent and types of health effects exhibited by the occupants, and the potential health risks associated with debris and activities during the remediation project. When considering the issue of relocation, be sure to inquire about, accommodate, and plan for individuals with asthma, allergies, compromised immune systems, and other health-related concerns. Ease the relocation process and give occupants an opportunity to participate in the resolution of the problem by clearly explaining the work process and work schedules. Notify individuals of relocation efforts in advance, if possible.

Liability Issues

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There will be some people, especially children, that will exhibit more severe adverse reactions, including death, lung tissue damage, and memory loss when exposed to molds. The severity of the reaction depends on the chemical sensitivity, genetic disposition, predisposing health history (such as allergies, asthma, smoking, etc.). For some, the exposure to the toxic mold spores may just be a "health risk" and to others, it may be a viable "health hazard" (potential life-threatening and loss of "quality of life"). Given the magnitude of this issue, there is a potential liability concern.

IAQ Technicians should not make claims or representations that "all the mold or mold spores have been removed", or that "the area is completely treated and safe." Mold spores are always in the air. The best that can be done is the removal of the source of moisture and the removal of any existing mold. Advise occupants to check with their doctor concerning any existing or future risks associated with inhabiting the structure.

It is wise to instruct the building occupants that mold and air quality testing can be performed, and they should seek the advice of their physician concerning this and other tests. Inform the building occupants that they should also check with their local county or city health department for additional health-related guidance.

Contact local county or city health departments in the service area to determine if there are any additional procedures (and licenses) that they specifically recommend.

It is also wise to obtain proper liability insurance before performing any IAQ-related services. There are already several major lawsuits concerning toxic mold exposure in residential and commercial buildings throughout the United States. Do not take this matter lightly; toxic mold can be deadly. Be careful to protect yourself and the building occupants from exposure and serious medical consequences.

Make it clear to the building owner and occupants that if the source of moisture causing the mold growth is not removed, nothing will stop the recurrence of the problem. Some technicians have included this information as a part of their work order estimate. It is a good idea to have the building owner sign to acknowledge a statement such as this.

Section IV:

Safety

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Personal Protective Equipment (PPE)

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If the remediation job disturbs mold and the mold becomes airborne, then the risk of respiratory exposure increases. Actions that are likely to stir up mold include removal of moldy duct insulation and fiberboard, removal of building insulation, breakup of moldy porous materials such as wallboard; invasive procedures used to examine or remediate mold growth in a duct work and wall cavities; actively stripping or peeling wallpaper to remove it; and using fans to dry items.

Spraying of biocides will also introduce potentially toxic substances into the air, and possibly into the lungs of service technicians and occupants. Biocides should never be sprayed into operating systems, since this would make these toxic chemicals airborne and significantly more dangerous.

The primary function of **Personal Protective Equipment (PPE)** is to avoid inhaling mold and mold spores and to avoid mold contact with the skin or eyes. The following sections discuss the different types of PPE that can be used during remediation activities.

All individuals using certain PPE equipment, such as half-face or full-face respirators, must be trained, must have medical clearance, and must be fit-tested by a trained professional. In addition,the use of respirators must follow a complete respiratory protection program as specified by the Occupational Safety and Health Administration.

Skin and Eye Protection

Always use gloves and eye protection when cleaning up mold or applying mold treatment and duct sealant products!

Gloves are required to protect the skin from contact with mold allergens (and in some cases mold toxins) and from potentially irritating disinfection and sealing compounds. Long gloves that extend to the middle of the forearm are recommended. The glove material should be selected based on the type of materials being handled.

To protect the eyes, use properly fitted goggles or a full-face respirator with HEPA filter. Goggles must be designed to prevent the entry of dust and small particles. Safety glasses or goggles with open vent holes are not acceptable.

Respiratory Protection

Respirators protect cleanup workers from inhaling airborne mold, mold spores and dust.

Minimum Respiratory Protection

When cleaning up a small area affected by mold, use an N-95 respirator. This device covers the nose and mouth, will filter out 95% of the particulates in the air, and is available in most hardware stores.

Limited Respiratory Protection

Limited PPE includes use of a half-face or full-face air-purifying respirator (APR) equipped with a HEPA filter cartridge. These respirators contain both inhalation and exhalation valves that filter the air and ensure that it is free of mold particles. Note that half-face APRs do not provide eye protection. **In addition, the HEPA filters do not remove vapors or gases (no filter removes vapors or gases)**. Always use respirators approved by the National Institute for Occupational Safety and Health.

Full Respiratory Protection

In situations where high levels of airborne dust or mold spores are likely or when long-term exposures are expected (cleanup of large areas), a full-face, Powered Air Purifying Respirator (PAPR) is recommended. Full-face PAPRs use a blower to force air through a HEPA filter. The HEPA-filtered air is supplied to a mask that covers the entire face or a hood that covers the entire head. The positive pressure within the hood prevents unfiltered air from entering through penetrations or gaps. Individuals have to be trained to use the respirators before they begin remediation. The use of these respirators must be in compliance with OSHA regulations.

Disposable Protective Clothing

Disposable clothing is recommended during a medium or large remediation project to prevent the transfer and spread of mold to clothing and to eliminate skin contact with mold.

Limited: Disposable paper overalls can be used.

Full: Mold-impervious disposable head and foot coverings, and a body suit made of a breathable material, such as TYVEK®, should be used. All gaps, such as those around ankles and wrists, should be sealed (many remediators use duct tape to seal clothing).

Containment

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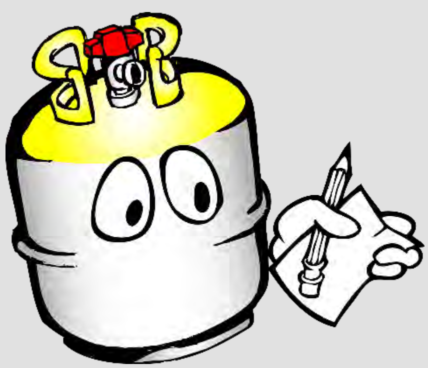
The purpose of containment during remediation activities is to limit release of mold into the air and surroundings in order to minimize the exposure of remediators and building occupants to mold. Mold and moldy debris should not be allowed to spread to areas in the building beyond the contaminated site.

The two types of containment, recommended in Table 2, are limited and full. The larger the area of moldy material, the greater the possibility of human exposure and the greater the need for containment. In general, the size of the area helps determine the level of containment. However, a heavy growth of mold in a relatively small area could release more spores than a lighter growth of mold in a relatively large area. Choice of containment should be based on professional judgment. The primary object of containment should be to prevent occupant and remediator exposure to mold.



A remediator may decide that a small area that is extensively contaminated and has the potential to distribute mold to occupied areas during cleanup should have full containment, whereas a large wall surface that is lightly contaminated and easily cleaned would require only limited containment.

Limited Containment

Limited containment is generally recommended for areas involving between 10 and 100 square feet of mold contamination. The enclosure around the moldy area should consist of a single layer of minimum 6-mil, fire-retardant polyethylene sheeting. The containment should have a slit entry and covering flap on the outside of the containment area. For small areas, the polyethylene sheeting can be affixed to floors and ceilings with duct tape. For larger areas, a steel or wooden stud frame can be erected and polyethylene sheeting attached to it.

All supply and air vents, doors, chases, and risers within the containment area must be sealed with polyethylene sheeting to minimize the migration of contaminants to other parts of the building. Heavy mold growth on ceiling tiles may impact HVAC systems if the space above the ceiling is used as a return air plenum. In this case, containment should be installed from the floor to the ceiling deck, and the filters in the air-handling units serving the affected area may have to be replaced once remediation is finished.

The containment area must be maintained under negative pressure relative to surrounding areas. This will ensure that contaminated air does not flow into adjacent areas. This can be done with a HEPA-filtered fan unit exhausted outside of the building. For small, easily contained areas, an exhaust fan ducted to the outdoors can also be used. The hard surfaces of all objects removed from the containment area should be cleaned with a hard surface cleaner prior to removal. The remediation guidelines outlined in Table 2 can be implemented when the containment is completely sealed and is under negative pressure relative to the surrounding area.

Full Containment

Full containment is recommended for the cleanup of mold contaminated surface areas greater than 100 square feet, or in any situation in which it appears likely that the occupant space would be further contaminated without full containment.

Double layers of minimum 6-mil fire-retardant polyethylene sheeting should be used to create a barrier between the moldy area and other parts of the building. A decontamination chamber or airlock should be constructed for entry into and exit from the remediation area. The entryways to the airlock from the outside and from the airlock to the main containment area should consist of a slit entry with covering flaps on the outside surface of each slit entry.

The decontamination chamber or airlock should be large enough to hold a waste container and allow a person to put on and remove PPE. While in this chamber, all contaminated PPE, except respirators, should be placed in a sealed bag. Respirators should be worn until remediators are outside the decontamination chamber. PPE must be worn throughout the final stages of HEPA vacuuming and hard surface cleaner damp-wiping of the contained area. PPE must also be worn during HEPA vacuum filter changes or cleanup of the HEPA vacuum.

Containment Tips

- Always maintain the containment area under negative pressure.
- Use exhaust fans (to the outdoors) and ensure that adequate makeup air is provided.
- If the containment is working, the polyethylene sheeting should billow inwards on all surfaces. If it flutters or billows outward, containment has been lost. Find and correct the problem before continuing remediation activities.

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