APPENDICIES

Building Air Quality

Printed on Recycled Paper

Appendix A:
Common IAQ Measurements - A General Guide

The following is a brief introduction to making measurements that might be needed in the course of developing an IAQ profile or investigating an IAQ complaint. Emphasis has been placed on the parameters most commonly of interest in non-research studies, highlighting the more practical methods and noting some inappropriate tests to avoid. Most of the instruments discussed in this section are relatively inexpensive and readily available from many local safety supply companies. Consult the guidance in *Section 6* on pages 72-73 before determining whether to proceed with air sampling.

SELECTING MEASUREMENT DEVICES

The growing interest in indoor air quality is stimulating the development of instruments for IAQ research and building investigations. As you evaluate the available measurement devices, it may be helpful to consider the following criteria:

Ease of use
- portability
- direct-reading vs. analysis required
- ruggedness
- time required for each measurement

Quality assurance
- availability of service and customer support
- maintenance and calibration requirements

Output
- time-averaged vs. instantaneous readings
- sensitivity
- compatibility with computer or data logging accessories

Cost
- single use only vs. reusable
- purchase vs. rental

OVERVIEW OF SAMPLING DEVICES

Air contaminants of concern in IAQ can be measured by one or more of the following methods:

Vacuum Pump:
A vacuum pump with a known airflow rate draws air through collection devices, such as a *filter* (catches airborne particles), a *sorbent tube* (which attracts certain chemical vapors to a powder such as carbon), or an *impinger* (bubbles the contaminants through solution in a test tube). Tests originated for industrial environments typically need to be adjusted to a lower detection limit for IAQ work. Labs can be asked to report when trace levels of an identifiable contaminant are present below the limit of quantification and detection.

In adapting an industrial hygiene sorbent tube sampling method for IAQ, the investigator must consider at least two important questions. First: are the emissions to be measured from a product's end use the same as those of concern during manufacturing? Second: is it necessary to increase the air volume sampled? Such an increase may be needed to detect the presence of contaminants at the low concentrations usually found in non-industrial settings. For example, an investigator might have to increase sampling time from 30 minutes to 5 hours in order to detect a substance at the low concentrations found during IAQ investigations. In cases where standard sampling methods are changed, qualified industrial hygienists and chemists should be consulted to ensure that accuracy and precision remain acceptable.

Direct-reading Meter:
Direct-reading meters estimate air concentrations through one of several detection principles. These may report specific

chemicals (e.g., CO_2 by infrared light), chemical groups (e.g., certain volatile organics by photoionization potential) or broad pollutant categories (e.g., all respirable particles by scattered light). Detection limits and averaging time developed for industrial use may or may not be appropriate for IAQ.

Detector tube kit:
Detector tube kits generally include a hand pump that draws a known volume of air through a chemically treated tube intended to react with certain contaminants. The length of color stain resulting in the tube correlates to chemical concentration.

Personal monitoring devices:
Personal monitoring devices (sometimes referred to as “dosimeters”) are carried or worn by individuals and are used to measure that individual’s exposure to particular chemical(s). Devices that include a pump are called “active” monitors; devices that do not include a pump are called “passive” monitors. Such devices are currently used for research purposes. It is possible that sometime in the future they may also be helpful in IAQ investigations in public and commercial buildings.

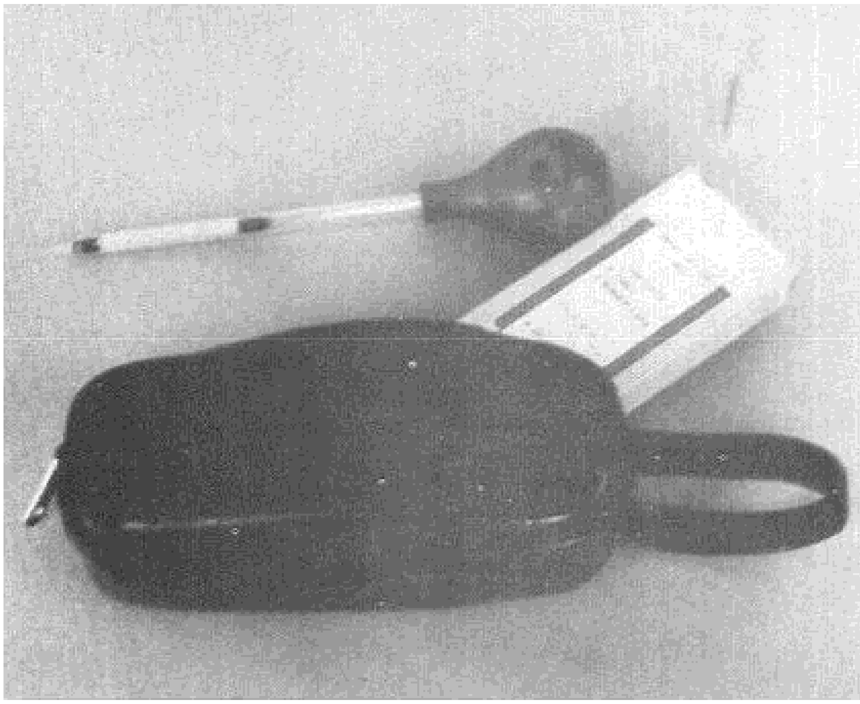
SIMPLE VENTILATION/COMFORT INDICATIONS

Thermal Comfort: Temperature and Relative Humidity

The sense of thermal comfort (or discomfort) results from an interaction between temperature, relative humidity, air movement, clothing, activity level, and individual physiology. Temperature and relative humidity measurements are indicators of thermal comfort.

Methodology

Measurements can be made with a simple thermometer and sling psychrometer or with electronic sensors (e.g., a thermohygrometer). Accuracy of within + or - 1°F is recommended for temperature measure-



Above: A smoke tube, which is one type of chemical smoke device. Used to observe patterns of air movement and the direction (negative or positive) of pressure differences. Below: A microman-ometer. Used for measuring pressure differentials to learn about airflow. Provides quantitative data, as compared to the qualitative information provided by chemical smoke.

ments. For each measurement, time should be allowed for the reading to stabilize to room conditions. Refer to the specifications for the measuring device; some take several minutes to stabilize. Electronic relative humidity (RH) meters must be calibrated frequently.

Indoor relative humidity is influenced by outdoor conditions. A single indoor measurement may not be a good indication of long-term relative humidity in the building. Programmable recording sensors can be used to gain an understanding of temperature or humidity conditions as they change over time.

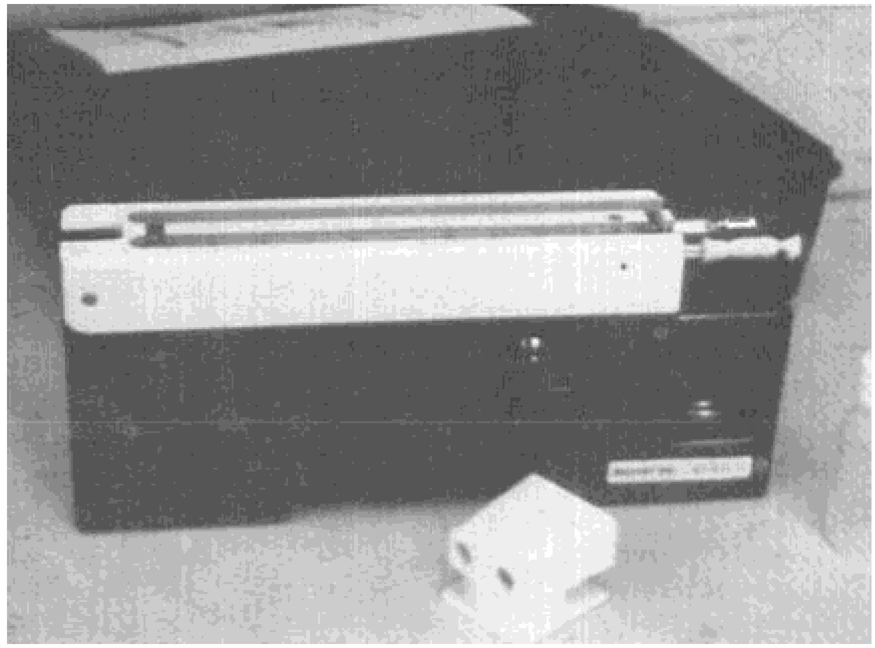
Using the Results

Temperature and humidity directly affect thermal comfort. They may also provide indirect indications of HVAC condition and the potential for airborne contamination from biological or organic compounds. There is considerable debate among researchers, IAQ professionals, and health professionals concerning recommended levels of relative humidity; however, the humidity levels recommended by different organizations generally range between 30% and 60% RH.

Comparison of indoor and outdoor temperature and humidity readings taken during complaint periods can indicate whether thermal discomfort might be due to extreme conditions beyond the design capacity of HVAC equipment or the building envelope.

Measure next to thermostats to confirm calibration. Measure at the location of complaints to evaluate whether or not temperature and humidity at that location are within the comfort zone (see Figure 6-2 on page 57).

Readings that show large variations within the space may indicate a room air distribution or mixing problem. Readings that are highly variable over time may indicate control or balance problems with the HVAC systems.



A psychrometer. Used to measure dry bulb and wet bulb temperatures and to determine relative humidity based upon a psychometric chart. The NIOSH protocol for indoor air investigations always includes measurement of indoor and outdoor relative humidity. There are two types of psychrometers: aspirated (with a fan) or sling (without a fan).

Tracking Air Movement with Chemical Smoke

Chemical smoke can be helpful in evaluating HVAC systems, tracking potential contaminant movement, and identifying pressure differentials. Chemical smoke moves from areas of higher pressure to areas of lower pressure if there is an opening between them (e.g., door, utility penetration). Because it is heatless, chemical smoke is extremely sensitive to air currents. Investigators can learn about airflow patterns by observing the direction and speed of smoke movement. Puffs of smoke released at the shell of the building (by doors, windows, or gaps) will indicate whether the HVAC systems are maintaining interior spaces under positive pressure relative to the outdoors.

Methodology

Chemical smoke is available with various dispensing mechanisms, including smoke "bottles," "guns," "pencils," or "tubes." The dispensers allow smoke to be released in controlled quantities and directed at specific locations. It is often more informative to use a number of small puffs of smoke as you move along an air pathway rather than releasing a large amount in a single puff. (*Note:* Avoid direct inhalation of chemical smoke, because it can be irritating. Do not release smoke directly on smoke detectors.)

Using the Results

Smoke released mid-room: Observation of a few puffs of smoke released in mid-room or mid-cubicle can help to visualize air circulation within the space. Dispersal of smoke in several seconds suggests good air circulation, while smoke that stays essentially still for several seconds suggests poor circulation. Poor air circulation may contribute to sick building syndrome complaints or may contribute to comfort complaints even if there is sufficient overall air exchange.

Smoke released near diffusers, grilles: Puffs of smoke released by HVAC vents give a general idea of airflow. (Is it in or out? Vigorous? Sluggish? No flow?) This is helpful in evaluating the supply and return system and determining whether ventilation air actually reaches the breathing zone. (For a variable air volume system, be sure to take into account how the system is designed to modulate. It could be on during the test, but off for much of the rest of the day.) "Short-circuiting" occurs when air moves relatively directly from supply diffusers to return grilles, instead of mixing with room air in the breathing zone. When a substantial amount of air short-circuits, occupants may not receive adequate supplies of outdoor air and source emissions may not be diluted sufficiently.

Carbon Dioxide (CO_2) as an Indicator of Ventilation

CO_2 is a normal constituent of the atmosphere. Exhaled breath from building occupants is an important indoor CO_2 source. Indoor CO_2 concentrations can, under some test conditions, provide a good indication of the adequacy of ventilation. Comparison of peak CO_2 readings between rooms, between air handler zones, and at varying heights above the floor, may help to identify and diagnose various building ventilation deficiencies.

Methodology

CO_2 can be measured with either a direct-reading meter or a detector tube kit. The relative occupancy, air damper settings, and weather should be noted for each period of CO_2 testing.

CO_2 measurements for ventilation should be collected away from any source that could directly influence the reading (e.g., hold the sampling device away from exhaled breath). Individual measurements should be short-term. As with many other measurements of indoor air conditions, it is advisable to take one or more readings in "control" locations to serve as baselines for comparison. Readings from outdoors and from areas in which there are no apparent IAQ problems are frequently used as controls. Outdoor samples should be taken near the outdoor air intake.

Measurements taken to evaluate the adequacy of ventilation should be made when concentrations are expected to peak. It may be helpful to compare measurements taken at different times of day. If the occupant population is fairly stable during normal business hours, CO_2 levels will typically rise during the morning, fall during the lunch period, then rise again, reaching a peak in mid-afternoon. In this case, sampling in the mid- to late-afternoon is recommended. Other sampling times may be necessary for different occupancy schedules.

Using the Results

Peak CO_2 concentrations above 1000 ppm in the breathing zone indicate ventilation problems. Carbon dioxide concentrations below 1000 ppm generally indicate that ventilation is adequate to deal with the routine products of human occupancy.

However, there are several reasons not to conclude too quickly that a low CO_2 reading means no IAQ problem exists. Problems can occur in buildings in which measured CO_2 concentrations are below 1000 ppm. Although CO_2 readings indicate good ventilation, for example, if strong contaminant sources are present, some sort of source control may be needed to prevent IAQ problems. Errors in measurement and varying CO_2 concentrations over time can also cause low readings that may be misleading.

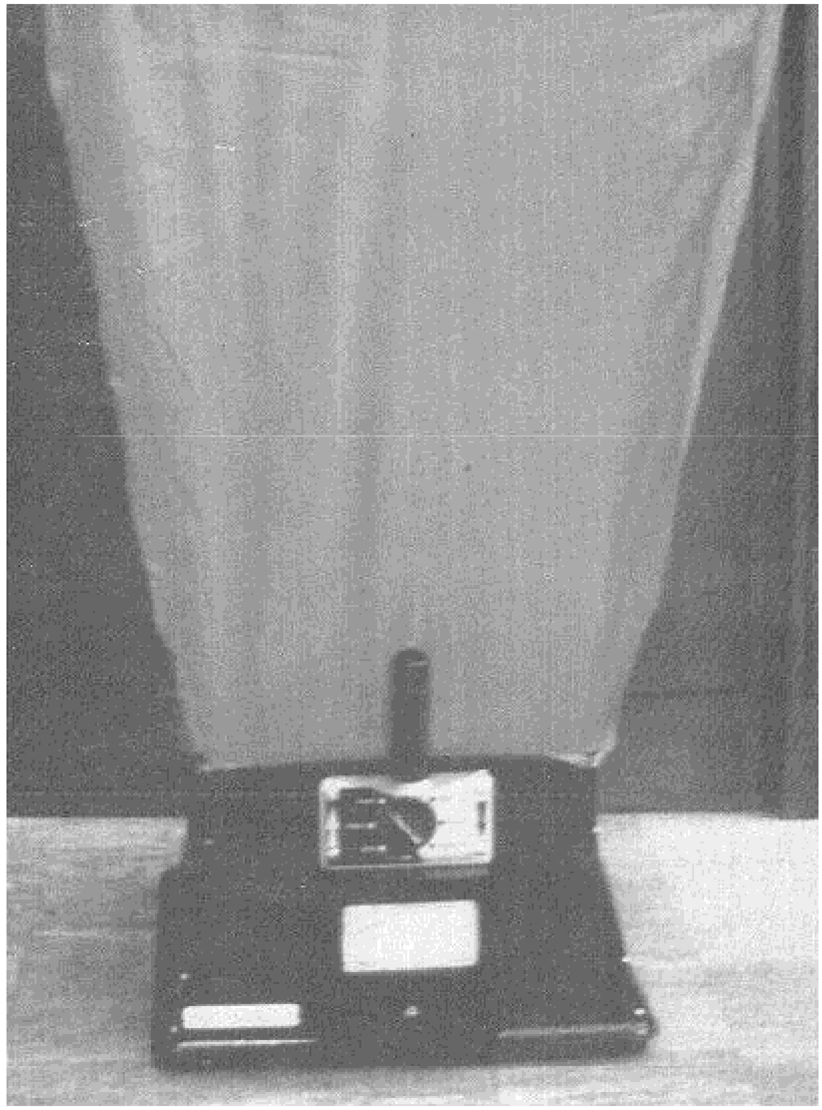
Elevated CO_2 may be due to various causes alone or in combination, such as: increased occupant population, air exchange rates below ASHRAE guidelines, poor air distribution, and poor air mixing. A higher average CO_2 concentration in the general breathing zone (at least two feet from exhaled breath) than in the air entering return grilles is an indication of poor air mixing. Smoke tubes and temperature profiles will help to clarify air circulation patterns.

If CO_2 measurements taken before the occupied period begins are higher than outdoor readings taken at the same time, there may be an operating problem with the HVAC system. Potential problems include the following:

- ventilation terminated too early the evening before (as compared with the occupancy load on the space)
- combustion by-products from a nearby roadway or parking garage are drawn into the building
- a gas-fired heating appliance in the building has a cracked heat exchanger

Outdoor CO_2 concentrations above 400 ppm may indicate an outdoor contamination problem from traffic or other combustion sources. Note, however, that detector tubes cannot provide accurate measurements of CO_2 in hot or cold weather.

Measuring Airflow

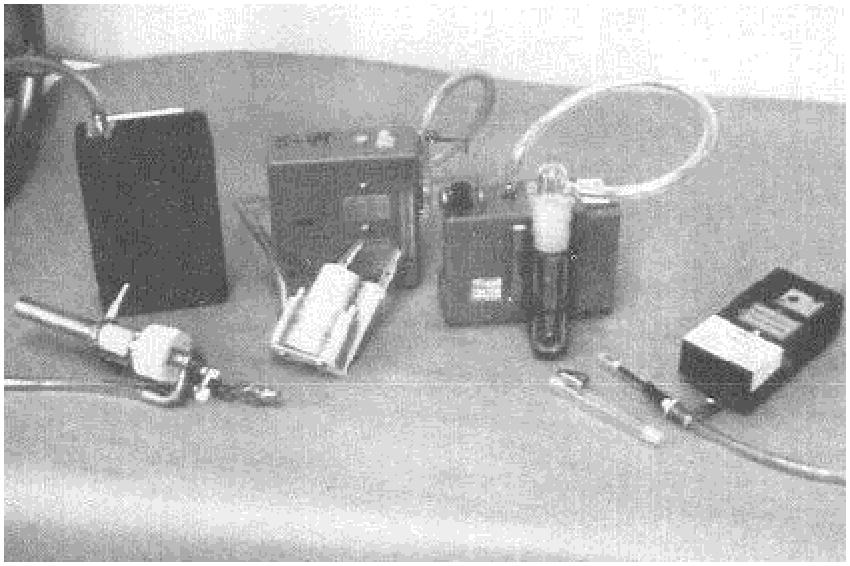


A flow hood. Used to measure the total air flow (outdoor plus recirculated air) from a diffuser.

Measurements of airflow allow investigators to estimate the amount of outdoor air that is entering the building and to evaluate HVAC system operation. The most appropriate measurement technique depends on the characteristics of the measurement location.

Methodology

Airflow quantities can be calculated by measuring the velocity and cross-sectional area of the airstream. For example, if air is moving at 100 feet per minute in a 24” x



A vacuum pump with attachments for sampling with a filter, a sorbent tube, and an impinger. Use in a non-industrial setting may require a larger volume of air. Consult with qualified industrial hygienists and chemists if adapting sampling methods.

12” duct, the airflow is:

100 feet/minute x 2 square feet duct area = 200 cubic feet/minute

Air velocity can be measured with a pitot tube or anemometer. Air velocity within an airstream is likely to vary considerably. For example, it is extremely difficult to measure air velocity at supply diffusers because of turbulence around the mixing vanes. The best estimates of air velocity can be achieved by averaging the results of a number of measurements. ASTM Standard Practice D 3154 provides guidance on making such measurements. This method is available from ASTM. (See *Appendix G* for ASTM’s address and phone number.) The cross-sectional area of the airstream is sometimes easy to calculate (e.g., in a straight run of rectangular ductwork), but can be very complicated at other locations such as mixing boxes or diffusers.

Flow hoods can be used for direct measurement of airflows at locations such as grilles, diffusers, and exhaust outlets. They are not designed for use in ductwork.

Using the Results

Airflow measurements can be used to determine whether the HVAC system is operating according to design and to identify potential problem locations. Building investigations often include measurements of outdoor air quantities, exhaust air quantities, and airflows at supply diffusers and return grilles.

Estimating Outdoor Air Quantities

Outdoor air quantities can be evaluated by measuring airflow directly. Investigators often estimate the proportion of outdoor air quantities using techniques such as thermal mass balance (temperature) or CO_2 measurements. Estimation of outdoor air quantity using temperature measurements is referred to as “thermal balance” or sometimes “thermal mass balance.”

Thermal Balance: Methodology

Use of this test requires the following conditions:

1. Airstreams representing return air, outdoor air, and mixed air (supply air before it has been heated or cooled) are accessible for separate measurement. Some systems are already equipped with an averaging thermometer that is strung diagonally across the mixed air chamber; the temperature is read out continuously on an instrument panel. Some panels read out supply, return, outdoor, and/or mixed air temperature.

2. There is at least a several degree temperature difference between the building interior and the outdoor air.

3. Total air flow in the air handling system can be estimated either by using recent balancing reports or pitot tube measurements in ductwork. As an alternative, the supply air at each diffuser can be estimated (e.g., using a flow measuring hood), and the results can be summed to calculate total system air flow.

Temperature measurements can be made with a simple thermometer or an electronic sensor. Several measurements should be taken across each airstream and averaged.

It is generally easy to obtain a good temperature reading in the outdoor air and return airstreams. To obtain a good average temperature reading of the mixed airstream, a large number of measurements must be taken upstream of the point at which the airstream is heated or cooled. This may be difficult or impossible in some systems.

The percentage or quantity of outdoor air is calculated using thermal measurements as shown to the right.

Methodology: Carbon Dioxide Measurements

CO_2 readings can be taken at supply outlets or air handlers to estimate the percentage of outdoor air in the supply airstream. The percentage or quantity of outdoor air is calculated using CO_2 measurements as shown to the right.

Using the Results

The results of this calculation can be compared to the building design specifications, applicable building codes, or ventilation recommendations such as ASHRAE 62-1989 (see page 136 in *Appendix B*) to see whether under-ventilation appears to be a problem.

ESTIMATING OUTDOOR AIR QUANTITIES

Using Thermal Mass Balance

$$\textbf{Outdoor air (percent)} = \frac{T_{\text{return air}} - T_{\text{mixed air}}}{T_{\text{return air}} - T_{\text{outdoor air}}} \times 100$$

Where: T = temperature (degrees Farenheit)

Using Carbon Dioxide Measurements

$$\textbf{Outdoor air (\%)} = \frac{C_S - C_R}{C_O - C_R} \times 100$$

Where: C_S = ppm CO_2 in the supply air (if measured in a room), or
C_S = ppm of CO_2 in the mixed air (if measured at an air handler)
C_R = ppm of CO_2 in the return air
C_O = ppm of CO_2 in the outdoor air

(All these concentrations must be measured, not assumed.)

Converting Percent To CFM

$$\textbf{Outdoor air (in cfm)} = \frac{\text{Outdoor air (percent)}}{100} \times \text{total airflow (cfm)}$$

Where: cfm = cubic feet per minute

The number used for total airflow may be the air quantity supplied to a room or zone, the capacity of an air handler, or the total airflow of the HVAC system. Note: The actual amount of airflow in an air handler is often different from the quantity in design documents.

AIR CONTAMINANT CONCENTRATIONS

Volatile Organic Compounds (VOCs)

Hundreds of organic (carbon-containing) chemicals are found in indoor air at trace levels. VOCs may present an IAQ problem when individual organics or mixtures exceed normal background concentrations.

Methodology: Total Volatile Organic Compounds (TVOCs)

Several direct-reading instruments are available that provide a **low sensitivity** "total" reading for different types of organics. Such estimates are usually presented in parts per million and are calculated with the assumption that all chemicals detected are the same as the one used to calibrate the instrument. A photoionization detector is an example of a direct-reading instrument used as a screening tool for measuring TVOCs.

A laboratory analysis of a sorbent tube can provide an estimate of total solvents in the air. Although methods in this category report "total volatile organic compounds" (TVOCs) or "total hydrocarbons" (THC), analytical techniques differ in their sensitivity to the different types of organics. (For discussion of measurement devices and their sensitivity, see *Overview of Sampling Devices* on page 109.)

Using the Results

Different measurement methods are useful for different purposes, but their results should generally not be compared to each other. Direct-reading instruments do not provide sufficient sensitivity to differentiate normal from problematic mixtures of organics. However, instantaneous readouts may help to identify "hot spots," sources, and pathways. TVOCs or THC determined from sorbent tubes provide more accurate average readings, but are unable to distinguish peak exposures. A direct-reading instrument can identify peak exposures if they happen to occur during the measurement period.

Methodology: Individual Volatile Organic Compounds (VOCs)

High concentrations of individual volatile organic compounds (VOCs) may also cause IAQ problems. Individual VOCs can be measured in indoor air with a moderate degree of sensitivity (i.e., measurement in parts per million) through adaptations of existing industrial air monitoring technology. Examples of **medium sensitivity** testing devices include XAD-4 sorbent tubes (for nicotine), charcoal tubes (for solvents), and chromosorb tubes (for pesticides). After a sufficient volume of air is pumped through these tubes, they are sent to a lab for extraction and analysis by gas chromatography. Variations use a passive dosimeter (charcoal badge) to collect the sample or a portable gas chromatograph onsite for direct injection of building air. These methods may not be sensitive enough to detect many trace level organics present in building air.

High sensitivity techniques have recently become available to measure "trace organics" — VOCs in the air (i.e. measurements in parts per billion.) Sampling may involve Tenax and multiple sorbent tubes, charcoal tubes, evacuated canisters, and other technology. Analysis involves gas chromatography followed by mass spectroscopy.

Using the Results

Guidelines for public health exposure (as opposed to occupational exposure) for a few VOCs are available in the World Health Organization (WHO) Air Quality Guidelines for Europe. These guidelines address noncarcinogenic and carcinogenic effects. Occupational exposure standards exist for many other VOCs. No rule-of-thumb safety factor for applying these occupational limits to general IAQ is currently endorsed by EPA and NIOSH.

Measurement of trace organics may identify the presence of dozens to hundreds of trace VOCs whose significance is difficult to determine. It may be helpful to compare levels in complaint areas to levels in outdoor air or non-complaint areas.

Formaldehyde

Formaldehyde is a VOC that has been studied extensively. Small amounts of formaldehyde are present in most indoor environments. Itching of the eyes, nose, or throat may indicate an elevated concentration. Sampling may be helpful when relatively new suspect materials are present.

Methodology

A number of measurement methods are available. Sensitivity and sampling time are very important issues in selecting a method; however, many methods allow detection of concentrations well below 0.1 ppm (see *Using the Results* below). Measurement of short-term peaks (around a two-hour sample time) is ideal for evaluating acute irritation. Dosimeters may accurately record long-term exposure but may miss these peaks.

Two commonly used methods that are generally acceptable for IAQ screening involve impingers and sorbent tubes. Other appropriate methods are also available.

Using the Results

Various guidelines and standards are available for formaldehyde exposure. Several organizations have adopted 0.1 ppm as guidance that provides reasonable protection against irritational effects in the normal population. Hypersensitivity reactions may occur at lower levels of exposure. Worst-case conditions are created by minimum ventilation, maximum temperatures, and high source loadings.

Biological Contaminants

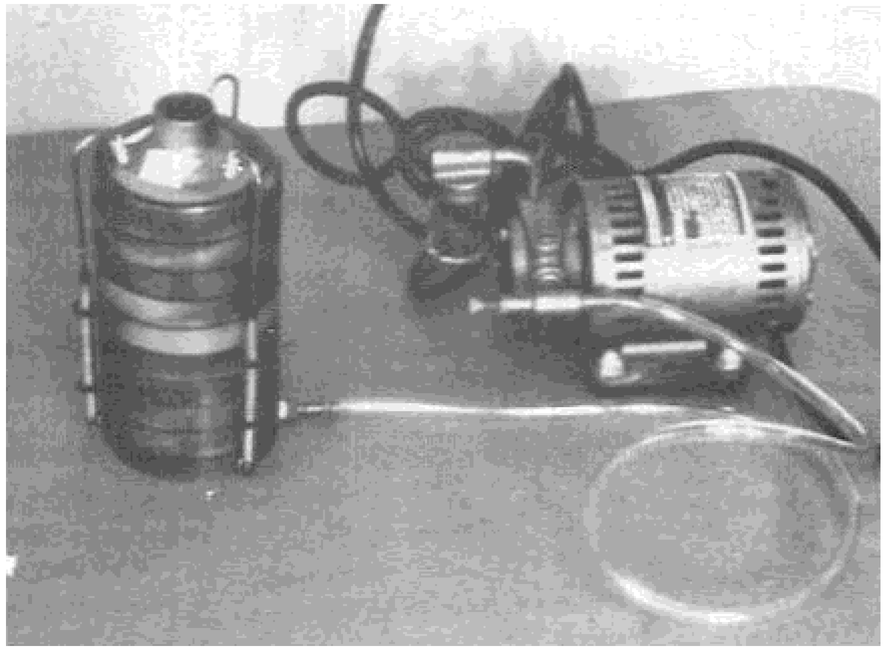
Human health can be affected by exposure to both living and non-living biological contaminants. The term "bioaerosols" describes airborne material that is or was living, such as mold and bacteria, parts of living organisms (e.g., insect body parts), and animal feces.

Testing for biological contaminants should generally be limited to:

- cases where a walkthrough investigation or human profile study suggests microbiological involvement
- cases in which no other pollutant or physical condition can account for symptoms

Methodology

Inspection of building sanitary conditions is generally preferred over sampling, because direct sampling can produce misleading results. Any sampling should be accompanied by observations of sanitary conditions and a determination as to whether any health problems appear likely to be related to biological contamination.

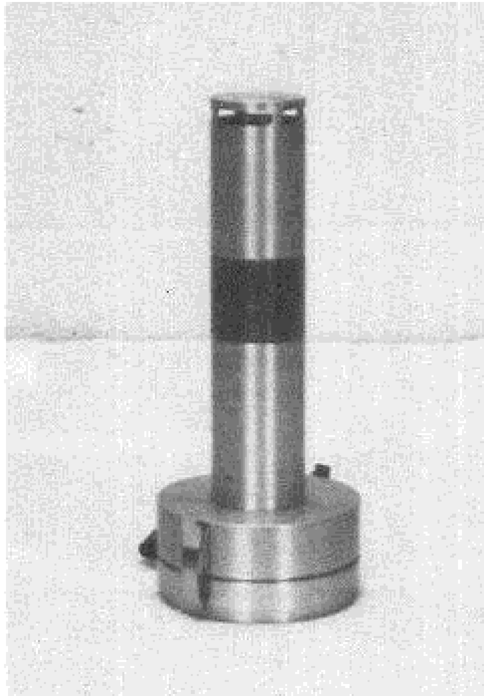


A viable impactor. Used to sample for biologicals. Training is required in order to analyze the results.

No single technique is effective for sampling the many biological contaminants found in indoor environments. A variety of specific approaches are used to retrieve, enumerate, and identify each kind of microorganism from water, surfaces, and air. Other specific methods are used for materials such as feces or insect parts. The utility of these techniques depends upon their use by professionals who have a thorough understanding of the sample site and the target organism.

Where air sampling is desired, several approaches are available. The most common type of air sampler uses a pump to pull air across a nutrient agar, which is then incubated. Any bacterial or fungal colonies that subsequently grow can be counted and identified by a qualified microbiologist. Different types of agar and incubation temperatures are used to culture different types of organisms. Only living organisms or spores in the air are counted by this method. Settling plates, which are simply opened to room air and then incubated, are sometimes used to identify which bioaerosols are present in different locations. The drawbacks to this technique are that it does not indicate the quantity of bioaerosols present and that only the

High-flow indoor particulate sampler. Used to measure particles 10 microns and smaller that are readily inhaled.



bioaerosols that are heavy enough to fall out onto the agar will be recorded.

Using the Results

Quantities and types of bioaerosols can vary greatly over time in any given building, making sampling results difficult to interpret. Comparison of relative numbers and types between indoors and outdoors or between complaint areas and background sites can help to establish trends; however, no tolerance levels or absolute guidelines have been established. Low bioaerosol results by themselves are not considered proof that a problem does not exist, for a variety of reasons:

- the sampling and identification techniques used may not be suited to the type(s) of bioaerosols that are present
- biological growth may have been inactive during the sampling period
- the analysis technique used may not reveal non-living bioaerosols (e.g., feces, animal parts) that can cause health reactions

Airborne Dust

Particles and fibers suspended in the air generally represent a harmless background but can become a nuisance or cause serious health problems under some conditions.

Methodology

A variety of collection and analytical techniques are available. Dust can be collected by using a pump to draw air through a filter. The filter can then be weighed (gravimetric analysis) or examined under a microscope. Direct readouts of airborne dust are also available (such as using meters such as those equipped with a "scattered light" detector).

Using the Results

IAQ measurements for airborne dust will be well below occupational and ambient air guidelines except under the most extreme conditions. Unusual types or elevated amounts of particles or fibers can help identify potential exposure problems.

Combustion Products

Combustion products are released by motor vehicle exhaust, tobacco smoke, and other sources, and contain airborne dust (see the previous section) along with potentially harmful gases such as carbon monoxide and nitrogen oxides.

Methodology

Direct-reading meters, detector tubes, and passive dosimeters are among the techniques most commonly used to measure carbon monoxide and nitrogen oxides.

Using the Results

Comparison with occupational standards

will reveal only whether an imminent danger exists. Any readings that are elevated above outdoor concentrations or background building levels may indicate a mixture of potentially irritating combustion products, especially if susceptible individuals are exposed.

Other Inorganic Gases

Although they are not routinely sampled in most IAQ studies, a variety of other gases may be evaluated where conditions warrant. Examples might include ammonia, ozone, and mercury.

Methodology

EPA, NIOSH, and ASTM references should be consulted for specific sampling techniques. Detector tubes or impinger methods are applicable in some cases.

Using the Results

No generalization can be applied to this diverse group of substances.

Appendix B:
HVAC Systems and Indoor Air Quality

This appendix provides information about specific HVAC system designs and components in relation to indoor air quality. It also serves as introductory material for building owners and managers who may be unfamiliar with the terminology and concepts associated with HVAC (heating, ventilating, and air conditioning) system design. Further detailed information can be found in ASHRAE manuals and guides and in some of the guidance developed by other trade and professional associations. (See *Guidelines of Care Developed by Trade Associations* in Section 5.) Additional information can be obtained using *Appendix G* or through discussion with your facility engineer.

BACKGROUND

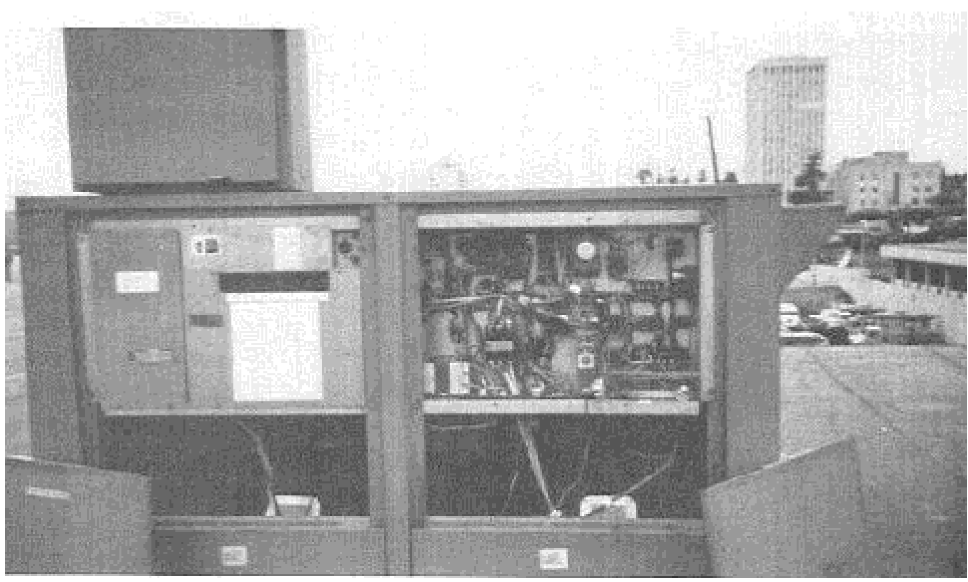
All occupied buildings require a supply of outdoor air. Depending on outdoor conditions, the air may need to be heated or cooled before it is distributed into the occupied space. As outdoor air is drawn into the building, indoor air is exhausted or allowed to escape (passive relief), thus removing air contaminants.

The term "HVAC system" is used to refer to the equipment that can provide heating, cooling, filtered outdoor air, and humidity control to maintain comfort conditions in a building. Not all HVAC systems are designed to accomplish all of these functions. Some buildings rely on only natural ventilation. Others lack mechanical cooling equipment (AC), and many function with little or no humidity control. The features of the HVAC system in a given building will depend on several variables, including:

- age of the design
- climate
- building codes in effect at the time of the design
- budget that was available for the project
- planned use of the building
- owners' and designers' individual preferences
- subsequent modifications

HVAC systems range in complexity from stand-alone units that serve individual rooms to large, centrally controlled systems serving multiple zones in a building. In large modern office buildings with heat gains from lighting, people, and equipment, interior spaces often require year-round cooling. Rooms at the perimeter of the same building (i.e., rooms with exterior walls, floors, or roof surfaces) may need to be heated and/or cooled as hourly or daily outdoor weather conditions change. In buildings over one story in height, perimeter areas at the lower levels also tend to experience the greatest uncontrolled air infiltration.

Working with the electrical components of an HVAC system involves the risk of electrocution and fire. A knowledgeable member of the building staff should oversee the inspection of the HVAC controls.



Some buildings use only natural ventilation or exhaust fans to remove odors and contaminants. In these buildings, thermal discomfort and unacceptable indoor air quality are particularly likely when occupants keep the windows closed because of extreme hot or cold temperatures. Problems related to underventilation are also likely when infiltration forces are weakest (i.e., during the "swing seasons" and summer months).

Modern public and commercial buildings generally use mechanical ventilation systems to introduce outdoor air during the occupied mode. Thermal comfort is commonly maintained by mechanically distributing conditioned (heated or cooled) air throughout the building. In some designs, air systems are supplemented by piping systems that carry steam or water to the building perimeter zones. As this document is concerned with HVAC systems in relation to indoor air quality, the remainder of this discussion will focus on systems that distribute conditioned air to maintain occupant comfort.

Roles of the HVAC System Operator and Facility Manager

The system operator(s) and facility manager(s) (or IAQ manager) are among the most significant factors in determining whether IAQ problems will occur in a properly designed, constructed, and commissioned HVAC system. HVAC systems require preventive maintenance and prompt repairs if they are to operate correctly and provide comfortable conditions. The operator(s) must have an adequate understanding of the overall system design and its limitations. The HVAC system capacity and distribution characteristics should be evaluated before renovations to the building, changes in its occupancy, or changes in the use of an area.

System operators must be able to respond appropriately to occupant complaints. For example, if an occupant complains that it is too cold or too hot and the observed (measured) conditions are outside of the ASHRAE comfort zone, then the HVAC system needs to be evaluated. Sometimes the problem can be relieved by fine tuning or repairing the HVAC system, but in some cases the system cannot perform as expected, and a long-term solution must be investigated.

TYPES OF HVAC SYSTEMS

Single Zone

A single air handling unit can only serve more than one building area if the areas served have similar heating, cooling, and ventilation requirements, or if the control system compensates for differences in heating, cooling, and ventilation needs among the spaces served. Areas regulated by a common control (e.g., a single thermostat) are referred to as zones. Thermal comfort problems can result if the design does not adequately account for differences in heating and cooling loads between rooms that are in the same zone. This can easily occur if:

- The cooling load in some area(s) within a zone changes due to an increased occupant population, increased lighting, or the introduction of new heat-producing equipment (e.g., computers, copiers).
- Areas within a zone have different solar exposures. This can produce radiant heat gains and losses that, in turn, create unevenly distributed heating or cooling needs (e.g., as the sun angle changes daily and seasonally).

Multiple Zone

Multiple zone systems can provide each zone with air at a different temperature by heating or cooling the airstream in each zone. Alternative design strategies involve delivering air at a constant temperature while varying the volume of airflow, or modulating room temperature with a supplementary system (e.g., perimeter hot water piping).

Constant Volume

Constant volume systems, as their name suggests, generally deliver a constant airflow to each space. Changes in space temperatures are made by heating or cooling the air or switching the air handling unit on and off, not by modulating the volume of air supplied. These systems often operate with a fixed minimum percentage of outdoor air or with an "air economizer" feature (described in the *Outdoor Air Control* discussion that follows).

Variable Air Volume

Variable air volume systems maintain thermal comfort by varying the amount of heated or cooled air delivered to each space, rather than by changing the air temperature. (However, many VAV systems also have provisions for resetting the temperature of the delivery air on a seasonal basis, depending on the severity of the weather). Overcooling or overheating can occur within a given zone if the system is not adjusted to respond to the load. Underventilation frequently occurs if the system is not arranged to introduce at least a minimum quantity (as opposed to percentage) of outdoor air as the VAV system throttles back from full airflow, or if the system supply air temperature is set too low for the loads present in the zone.

BASIC COMPONENTS OF AN HVAC SYSTEM

The basic components of an HVAC system that delivers conditioned air to maintain thermal comfort and indoor air quality are:

- outdoor air intake
- mixed-air plenum and outdoor air control
- air filter
- heating and cooling coils
- humidification and/or de-humidification equipment

TESTING AND BALANCING

Modern HVAC systems typically use sophisticated, automatic controls to supply the proper amounts of air for heating, cooling, and ventilation in commercial buildings. Problems during installation, operation, maintenance, and servicing the HVAC system could prevent it from operating as designed. Each system should be tested to ensure its initial and continued performance. In addition to providing acceptable thermal conditions and ventilation air, a properly adjusted and balanced system can also reduce operating costs and increase equipment life.

Testing and balancing involves the testing, adjusting, and balancing of HVAC system components so that the entire system provides airflows that are in accordance with the design specifications. Typical components and system parameters tested include:

- all supply, return, exhaust, and outdoor airflow rates
- control settings and operation
- air temperatures
- fan speeds and power consumption
- filter or collector resistance

The typical test and balance agency or contractor coordinates with the control contractor to accomplish three goals: verify and ensure the most effective system operation within the design specifications, identify and correct any problems, and ensure the safety of the system.

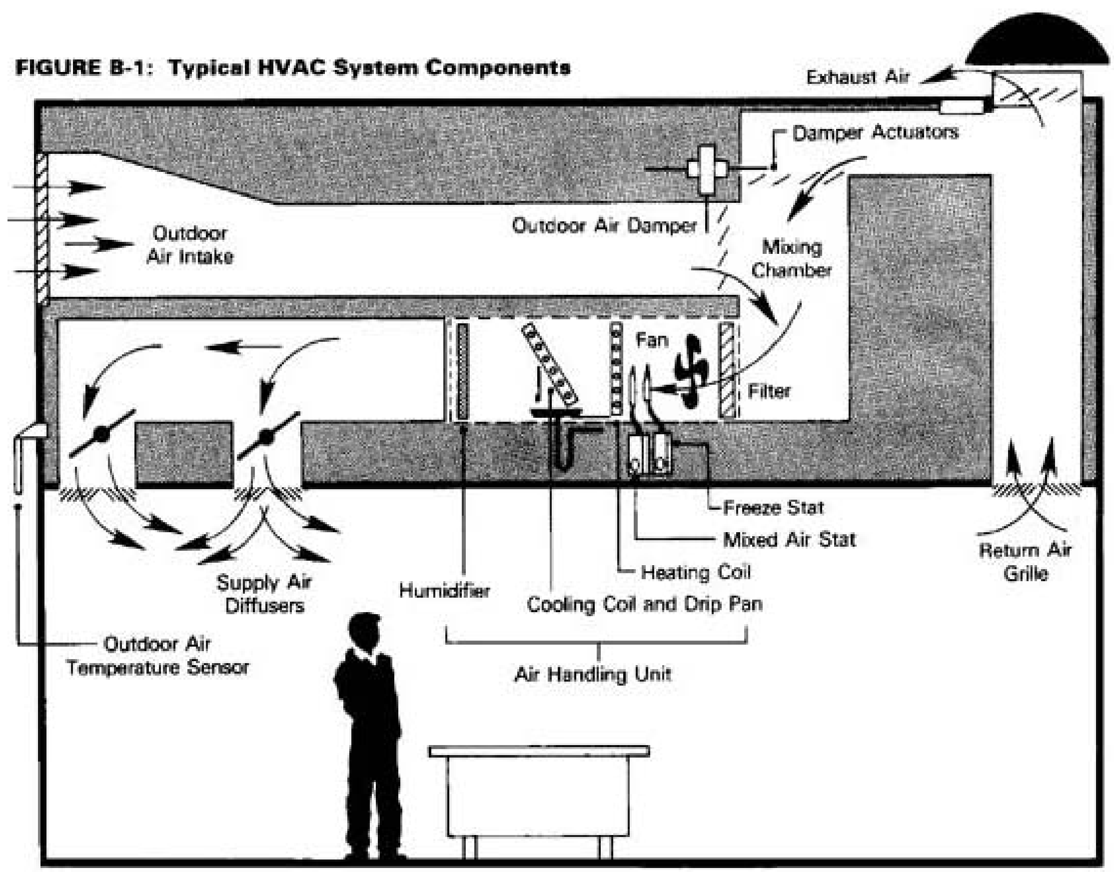
A test and balance report should provide a complete record of the design, preliminary measurements, and final test data. The report should include any discrepancies between the test data and the design specifications, along with reasons for those discrepancies. To facilitate future performance checks and adjustments, appropriate records should be kept on all damper positions, equipment capacities, control types and locations, control settings and operating logic, airflow rates, static pressures, fan speeds, and horsepowers.

Testing and balancing of existing building systems should be performed whenever there is reason to believe the system is not functioning as designed or when current records do not accurately reflect the actual operation of the system. The Associated Air Balance Council recommends the following guidelines in determining whether testing and balancing is required:

- When space has been renovated or changed to provide for new occupancy.
- When HVAC equipment has been replaced or modified.
- When control settings have been readjusted by maintenance or other personnel.
- After the air conveyance system has been cleaned.
- When accurate records are required to conduct an IAQ investigation.
- When the building owner is unable to obtain design documents or appropriate air exchange rates for compliance with IAQ standards or guidelines.

Because of the diversity of system types and the interrelationship of system components, effective balancing requires a skilled technician with the proper experience and instruments. Due to the nature of the work, which involves the detection and remediation of problems, it is recommended that an independent test and balance contractor be used and that this contractor report directly to the building owner, facility manager, or IAQ manager.

FIGURE B-1: Typical HVAC System Components



Courtesy Terry Brennan
Camroden Associates
Oriskny, N.Y.

- supply fan
- ducts
- terminal device
- return air system
- exhaust or relief fans and air outlet
- self-contained heating or cooling unit
- control
- boiler
- cooling tower
- water chiller

The following discussion of these components (each of which may occur more than once in any total HVAC system) emphasizes features that affect indoor air quality. It may be helpful to refer to this section when using the **HVAC Checklists**.

The illustration above shows the general relationship between many of these components; however, many variations are possible.

Outdoor Air Intake

Building codes require the introduction of outdoor air for ventilation in most buildings. Most non-residential air handlers are designed with an outdoor air intake on the return side of the ductwork. Outdoor air introduced through the air handler can be filtered and conditioned (heated or cooled) before distribution. Other designs may introduce outdoor air through air-to-air heat exchangers and operable windows.

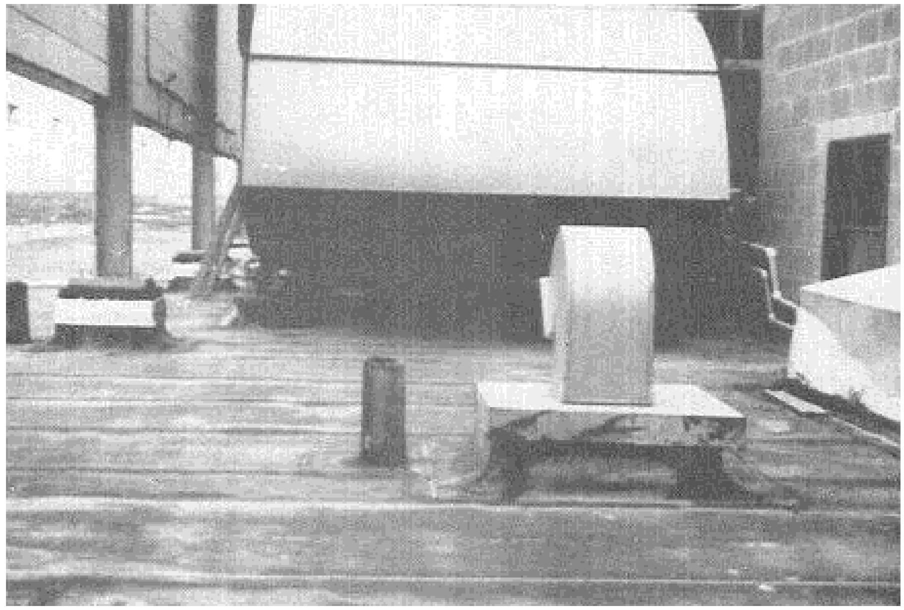
Indoor air quality problems can be produced when contaminants enter a building with the outdoor air. Rooftop or wall-mounted air intakes are sometimes located adjacent to or downwind of building exhaust outlets or other contaminant sources. Problems can also result if debris (e.g., bird droppings) accumulates at the intake, obstructing airflow and potentially introducing microbiological contaminants.

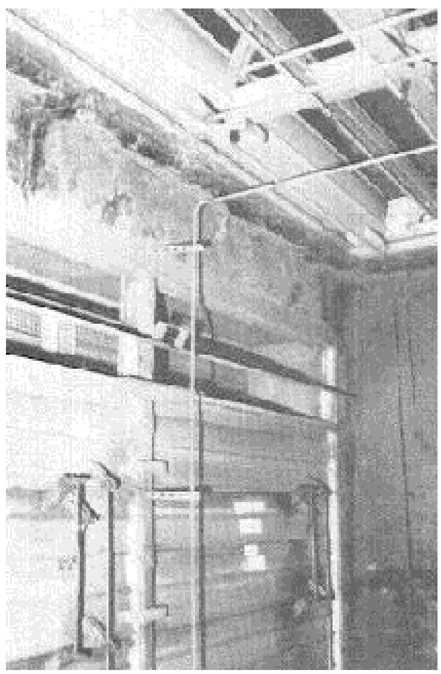
If more air is exhausted than is introduced through the outdoor air intake, then outdoor air will enter the building at any leakage sites in the shell. Indoor air quality problems can occur if the leakage site is a door to a loading dock, parking garage, or some other area associated with pollutants.

Mixed-Air Plenum and Outdoor Air Controls

Outdoor air is mixed with return air (air that has already circulated through the HVAC system) in the mixed-air plenum of an air handling unit. Indoor air quality problems frequently result if the outdoor air damper is not operating properly (e.g., if the system is not designed or adjusted to allow the introduction of sufficient outdoor air for the current use of the building. The amount of outdoor air introduced in the occupied mode should be sufficient to meet needs for ventilation and exhaust make-up. It may be fixed at a constant volume or may vary with the outdoor temperature.

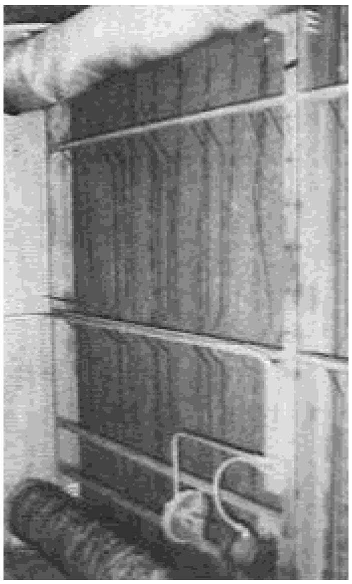
When dampers that regulate the flow of outdoor air are arranged to modulate, they are usually designed to bring in a minimum amount of outdoor air (in the occupied mode) under extreme outdoor temperature conditions and to open as outdoor temperatures approach the desired indoor temperature. Systems that use outdoor air for cooling are called “air economizer cooling” systems. Air economizer systems have a mixed air





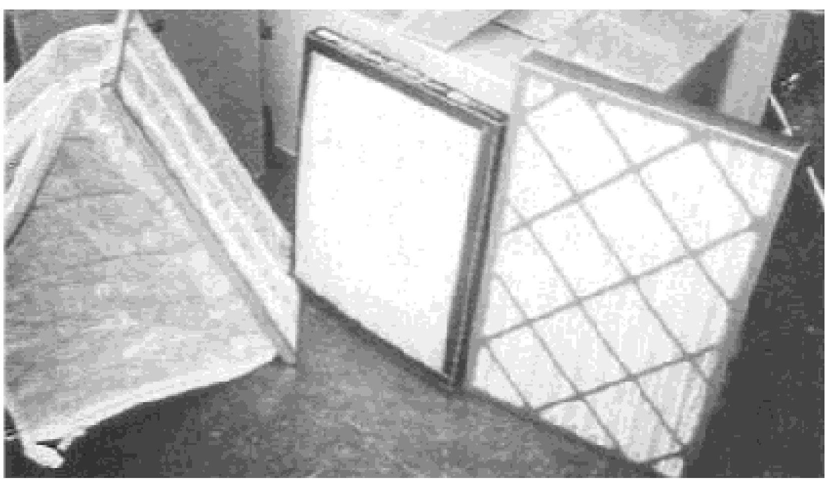
Above: *The air intake in the background is located too close to the sanitary vents (the straight pipes to the left and in the center foreground) and the bathroom exhaust vent (next to the sanitary vent on the right side).* ***Below:*** *The return air dampers in this mixed-air plenum are open (top), but the outdoor air damper (left) is almost completely closed. Complaints in the building indicate that under-ventilation is a problem.*

temperature controller and thermostat that are used to blend return air (typically at 74°F) with outdoor air to reach a mixed air temperature of 55° to 65°F. (Mixed air temperature settings above 65°F may lead to the introduction of insufficient quantities of outdoor air for office space use.) The mixed air is then further heated or cooled for delivery to the occupied spaces.



Air economizer systems have a sensible or enthalpy control that signals the outdoor air damper to go to the minimum position when it is too warm or humid outdoors. Note that economizer cycles which do not provide dehumidification may produce discomfort even when the indoor temperature is the same as the thermostat setting.

If outdoor air make-up and exhaust are balanced, and the zones served by each air handler are separated and well defined, it is possible to estimate the minimum flow of outdoor air to each space and compare it to ventilation standards such as ASHRAE 62-1989. Techniques used for this evaluation include the direct measurement of the outdoor air at the intake and the calculation of the percentage of outdoor air by a temperature or CO_2 balance. Carbon dioxide measured in an occupied space is also an indicator of ventilation adequacy. Some investigators use tracer gases to assess ventilation quantities and airflow patterns. There are specific methods for each of these assessments. See *Appendix A* for more information.



Proper air filtration can play an impor-tant role in protecting the rest of the HVAC system and in maintaining good indoor air quality in occupied spaces. Air filters should be selected and main-tained to provide maximum filtration, while not overtaxing the supply fan capability or leading to "blow out" situa-tions with no air filtration. Shown above are roll filter (top) and bag, panel, and pleated filters (below).

Many HVAC designs protect the coils by closing the outdoor air damper if the airstream temperature falls below the setpoint of a freezestat. Inadequate ventilation can occur if a freezestat trips and is not reset, or if the freezestat is set to trip at an excessively high temperature. Stratification of the cold outdoor air and warmer return air in the mixing plenums is a common situation, causing nuisance tripping of the freezestat. Unfortunately, the remedy often employed to prevent this problem is to close the outdoor air damper. Obviously, solving the problem in this way can quickly lead to inadequate outdoor air in occupied parts of the building.

Air Filters

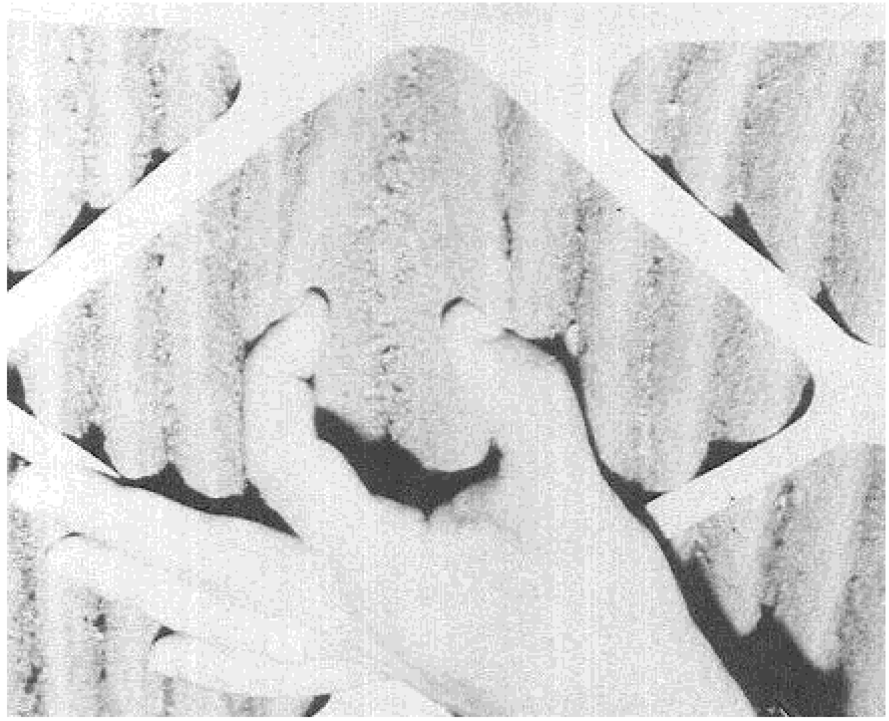
Filters are primarily used to remove particles from the air. The type and design of filter determine the efficiency at removing particles of a given size and the amount of energy needed to pull or push air through the filter. Filters are rated by different standards and test methods such as dust spot and arrestance which measure different aspects of performance. See the discussion of ASHRAE Standard 52-76 on page 138 of this appendix.

Low efficiency filters (ASHRAE Dust Spot rating of 10% to 20% or less) are often used to keep lint and dust from clogging the heating and cooling coils of a system. In order to maintain clean air in occupied spaces, filters must also remove bacteria, pollens, insects, soot, dust, and dirt with an efficiency suited to the use of the building. Medium efficiency filters (ASHRAE Dust Spot rating of 30% to

60%) can provide much better filtration than low efficiency filters. To maintain the proper airflow and minimize the amount of additional energy required to move air through these higher efficiency filters, pleated-type extended surface filters are recommended. In buildings that are designed to be exceptionally clean, the designers may specify the equipment to utilize both a medium efficiency pre-filter and a high efficiency extended surface filter (ASHRAE Dust Spot rating of 85% to 95%). Some manufacturers recommend high efficiency extended surface filters (ASHRAE Dust Spot rating of 85%) without pre-filters as the most cost effective approach to minimizing energy consumption and maximizing air quality in modern HVAC VAV systems that serve office environments.

Air filters, whatever their design or efficiency rating, require regular maintenance (cleaning for some and replacement for most). As a filter loads up with particles, it becomes more efficient at particle removal but increases the pressure drop through the system, therefore reducing airflow. Filter manufacturers can provide information on the pressure drop through their products under different conditions. Low efficiency filters, if loaded to excess, will become deformed and even “blow out” of their filter rack. When filters blow out, bypassing of unfiltered air can lead to clogged coils and dirty ducts. Filtration efficiency can be seriously reduced if the filter cells are not properly sealed to prevent air from bypassing.

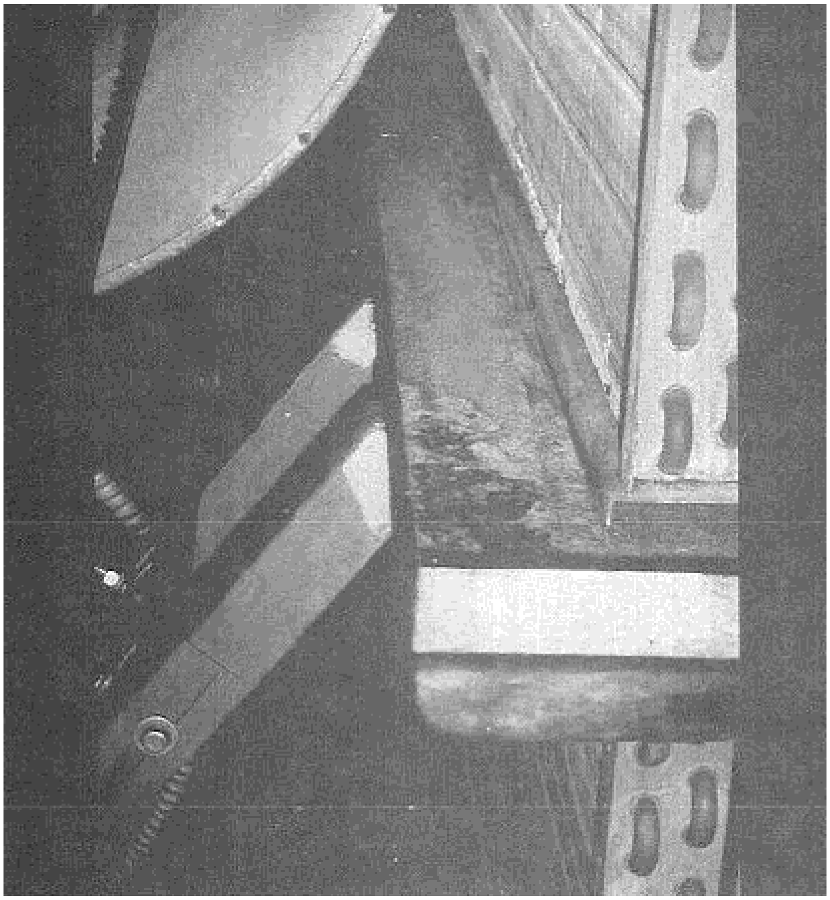
Filters should be selected for their ability to protect both the HVAC system components and general indoor air quality. In many buildings, the best choice is a medium efficiency, pleated filter because these filters have a higher removal efficiency than low efficiency filters, yet they will last without clogging for longer than high efficiency filters.



Pleated medium efficiency filters are often preferred over low efficiency filters because they offer added protection to both the HVAC equipment and to indoor air quality, yet they do not clog as easily as high efficiency filters. Medium efficiency filters do need routine maintenance, however, which the filter in this photo did not receive.

Choice of an appropriate filter and proper maintenance are important to keeping the ductwork clean. If dirt accumulates in ductwork and if the relative humidity reaches the dewpoint (so that condensation occurs), then the nutrients and moisture may support the growth of microbiologicals. Attention to air filters is particularly important in HVAC systems with acoustical duct liner, which is frequently used in air handler fan housings and supply ducts to reduce sound transmission and provide thermal insulation. Areas of duct lining that have become contaminated with microbiological growth must be replaced. (See later discussion of ducts and duct cleaning .) Sound reduction can also be accomplished with the use of special duct-mounted devices such as attenuators or with active electronic noise control.

Air handlers that are located in difficult-to-access places (e.g., in places which require ladders for access, have inconvenient access doors to unbolt, or are located on roofs with no roof hatch access) will be



Without proper installation and maintenance, rust and corrosion may accumulate in condensate pans under heating and cooling coils. The rust in the pan indi-cates that it was installed without a pitch or was pitched in the wrong direction, so that water did not drain out properly.

more likely to suffer from poor air filter maintenance and overall poor maintenance. Quick release and hinged access doors for maintenance are more desirable than bolted access panels.

Filters are available to remove gases and volatile organic contaminants from ventilation air; however, these systems are not generally used in normal occupancy buildings. In specially designed HVAC systems, permanganate oxidizers and activated charcoal may be used for gaseous removal filters. Some manufacturers offer "partial bypass" carbon filters and carbon impregnated filters to reduce volatile organics in the ventilation air of office environments. Gaseous filters must be regularly maintained (replaced or regenerated) in order for the system to continue to operate effectively.

Heating and Cooling Coils

Heating and cooling coils are placed in the airstream to regulate the temperature of the air delivered to the space. Malfunctions of the coil controls can result in thermal discomfort. Condensation on under-insulated pipes and leakage in piped systems will often create moist conditions conducive to the growth of molds, fungus, and bacteria.

During the cooling mode (air conditioning), the cooling coil provides dehumidification as water condenses from the airstream. Dehumidification can only take place if the chilled fluid is maintained at a cold enough temperature (generally below 45°F for water). Condensate collects in the drain pan under the cooling coil and exits via a deep seal trap. Standing water will accumulate if the drain pan system has not been designed to drain completely under all operating conditions (sloped toward the drain and properly trapped). Under these conditions, molds and bacteria will proliferate unless the pan is cleaned frequently.

It is important to verify that condensate lines have been properly trapped and are charged with liquid. An improperly trapped line can be a source of contamination, depending on where the line terminates. A properly installed trap could also be a source, if the water in the trap evaporates and allows air to flow through the trap into the conditioned air.

During the heating mode, problems can occur if the hot water temperature in the heating coil has been set too low in an attempt to reduce energy consumption. If enough outdoor air to provide sufficient ventilation is brought in, that air may not be heated sufficiently to maintain thermal comfort or, in order to adequately condition the outdoor air, the amount of outdoor air may be reduced so that there is insufficient outdoor air to meet ventilation needs.

Humidification and Dehumidification Equipment

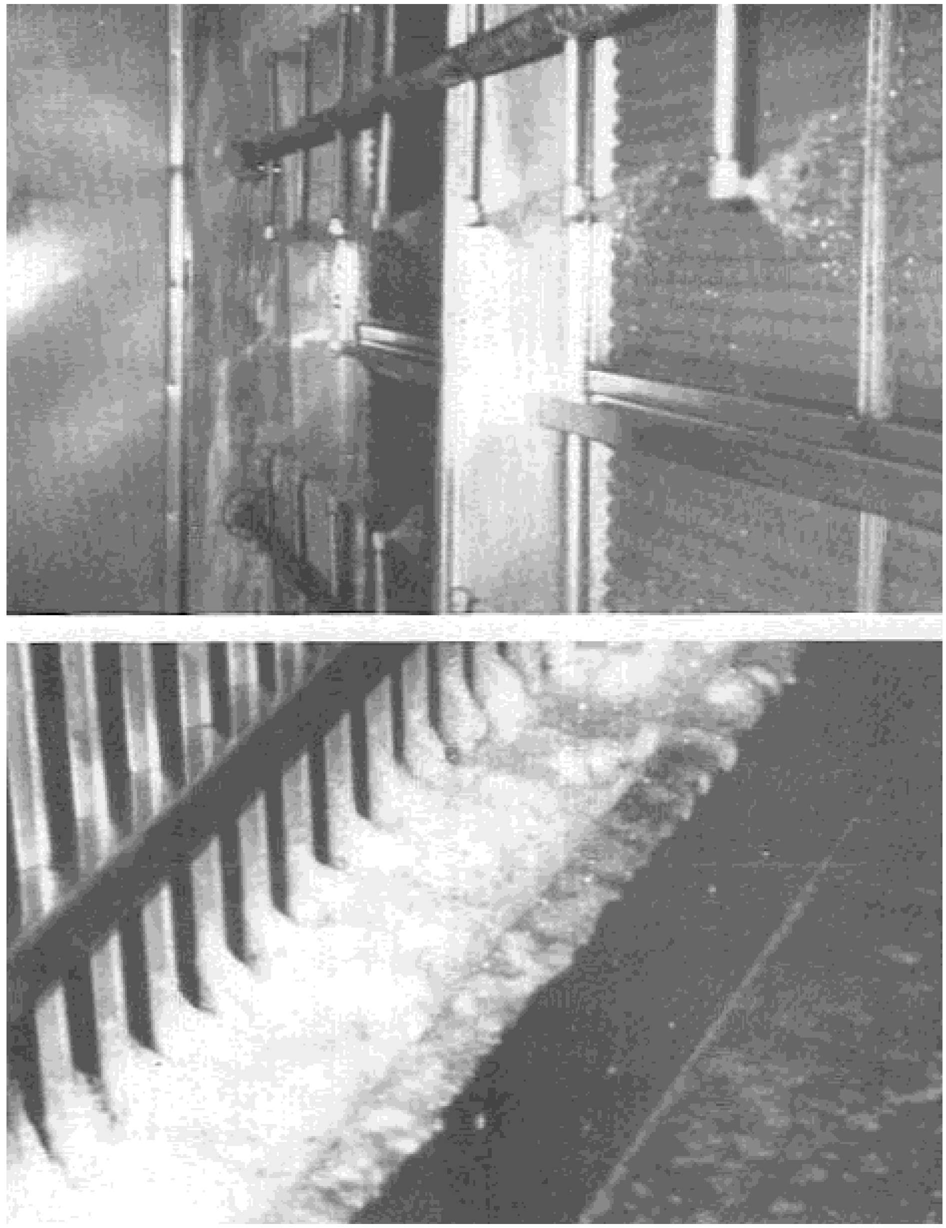
In some buildings (or zones within buildings), there are special needs that warrant the strict control of humidity (e.g., operating rooms, computer rooms). This control is most often accomplished by adding humidification or dehumidification equipment and controls. In office facilities, it is generally preferable to keep relative humidities above 20% or 30% during the heating season and below 60% during the cooling season. ASHRAE Standard 55-1981 provides guidance on acceptable temperature and humidity conditions. (See also the discussion of humidity levels in *Section 6*.)

The use of a properly designed and operated air conditioning system will generally keep relative humidities below 60% RH during the cooling season, in office facilities with normal densities and loads. (See the previous discussion of the cooling coil.)

Office buildings in cool climates that have high interior heat gains, thermally efficient envelopes (e.g., insulation), and economizer cooling may require humidification to maintain relative humidity within the comfort zone. When humidification is needed, it must be added in a manner that prevents the growth of microbiologicals within the ductwork and air handlers.

Steam humidifiers should utilize clean steam, rather than treated boiler water, so that occupants will not be exposed to chemicals. Systems using media other than clean steam must be rigorously maintained in accordance with the manufacturer's recommended procedures to reduce the likelihood of microbiological growth.

Mold growth problems are more likely if the humidistat setpoint located in the occupied space is above 45%. The high limit humidistat, typically located in the ductwork downstream of the point at



Above: Occupants of this building complained of an inter-mittant fish tank odor. An investigation showed that this water spray humidifi-cation system is regularly maintained. The coils are washed roughly every two weeks using fresh tap water, eliminating the need for any use of algacides. Below: Further investigation identified the fact that the maintenance practice was causing the odor problem. This picture of the downstream side of the coils was taken one day after the washing. A high pressure stream of water caused algae in the water to foam and float for several days, coinciding with the occupant complaints.

DUCT LEAKAGE

Leakage of air from ducts can cause or exacerbate air quality problems, in addition to wasting energy. In general, sealed duct systems specified with a leakage rate of less than 3% will have a superior life cycle cost analysis and reduce the likelihood of problems associated with leaky ductwork. Examples of excessive duct leakage leading to problems include:

- leakage of light troffer-type diffusers at the diffuser/light fixture interface when they are installed in a return plenum. Such leakage has been known to cause gross short-circuiting between supply and return, wasting much of the conditioned air. If the "room" thermostat is located in the return plenum, the room can be very uncomfortable while the temperature in the plenum is operating at the control setpoint.
- leakage of supply ductwork due to loose-fitting joints and connections or "blow outs" of improperly fabricated seams
- leakage of return ducts located in crawl spaces or below slabs, allowing soil gases and molds to enter the ductwork

which water vapor is added, is generally set at 70% to avoid condensation (with a potential for subsequent mold growth) in the ductwork. Adding water vapor to a building that was not designed for humidification can have a negative impact on the building structure and the occupants' health, if condensation occurs on cold surfaces or in wall or roof cavities.

Supply Fans

After passing through the coil section where heat is either added or extracted, air moves through the supply fan chamber and the distribution system. Air distribution systems commonly use ducts that are constructed to be relatively airtight. Elements of the building construction can also serve as part of the air distribution system (e.g., pressurized supply plenums or return air plenums located in the cavity space above the ceiling tiles and below the deck of the floor above). Proper coordination of fan selection and duct layout during the building design and construction phase and ongoing maintenance of mechanical components, filters, and controls are all necessary for effective air delivery.

Fan performance is expressed as the ability to move a given quantity of air (cubic feet per minute or cfm) at a given resistance or static pressure (measured in inches of water column). Airflow in ductwork is determined by the size of the duct opening, the resistance of the duct configuration, and the velocity of the air through the duct. The static pressure in a system is calculated using factors for duct length, speed of air movement and changes in the direction of air movement.

It is common to find some differences between the original design and the final installation, as ductwork must share limited space with structural members and other "hidden" elements of the building system (e.g., electrical conduit, plumbing pipes). Air distribution problems can occur, particularly at the end of duct runs, if departures from the original design increase the friction in the system to a point that approaches the limit of fan performance. Inappropriate use of long runs of flexible ducts with sharp bends also causes excessive friction. Poor system balancing (adjustment) is another common cause of air distribution problems.

Dampers are used as controls to restrict airflow. Damper positions may be relatively fixed (e.g., set manually during system testing and balancing) or may change in response to signals from the control system. Fire and smoke dampers can be triggered to respond to indicators such as high temperatures or signals from smoke detectors. If a damper is designed to modulate, it should be checked during inspections to see that it is at the proper setting. ASHRAE and the Associated Air Balance Council both provide guidance on proper intervals for testing and balancing.

Ducts

The same HVAC system that distributes conditioned air throughout a building air can distribute dust and other pollutants, including biological contaminants. Dirt or dust accumulation on any components of an air handling system — its cooling coils, plenums, ducts, and equipment housing — may lead to contamination of the air supply.

There is widespread agreement that building owners and managers should take great precautions to prevent dirt, high humidity, or moisture from entering the ductwork; there is less agreement at present about when measures to clean up are appropriate or how effective cleaning techniques are at making long-term improvements to the air supply or at reducing occupant complaints.

The presence of dust in ductwork does not necessarily indicate a current microbiological problem. A small amount of dust on duct surfaces is normal and to be expected. Special attention should be given to trying to find out if ducts are contaminated only where specific problems are present, such as: water damage or biological growth observed in ducts, debris in ducts that restricts airflow, or dust discharging from supply diffusers.

Problems with dust and other contamination in the ductwork are a function of filtration efficiency, regular HVAC system maintenance, the rate of airflow, and good housekeeping practices in the occupied space. Problems with biological pollutants can be prevented by minimizing dust and dirt build-up, promptly repairing leaks and water damage, preventing moisture accumulation in the components that are supposed to be dry, and cleaning the components such as the drip pans that collect and drain water.

In cases where sheet metal ductwork has become damaged or water-soaked, building owners will need to undertake clean-up or repair procedures. For example, in cases where the thermal liner or fiberboard has become water-soaked, building managers will need to replace the affected areas. These procedures should be scheduled and performed in a way that does not expose building occupants to increased levels of pollutants and should be carried out by experienced workers. Correcting theproblems that allowed the ductwork to become contaminated in the first place is important. Otherwise, the corrective action will only be temporary.

The porous surface of fibrous glass duct liner presents more surface area (which can trap dirt and subsequently collect water) than sheet metal ductwork. It is therefore particularly important to pay attention to the proper design, installation, filtration, humidity, and maintenance of ducts that contain porous materials. In addition, techniques developed for cleaning unlined metal ducts often are not suitable for use with fibrous glass thermal liner or fiberboard. Such ducts may require a special type of cleaning to maintain the integrity of the duct (i.e., no heavy brushing tools that might fray the inner lining) while removing dirt and debris.

More research on both the efficacy and the potential for unintended exposures to building occupants from various cleaning techniques is needed before firm guidance can be provided regarding duct cleaning.

Pay attention to worker safety when working with air handling systems including during duct cleaning. Any worker who may potentially breathe duct contaminants or biocides should wear suitable protective breathing apparatus. Workers who are doing the duct cleaning should be encouraged to also look for other types of problems, such as holes or gaps in the ducts that could allow contaminants to enter the ventilation airstream.

Building managers can obtain more information on the issue of HVAC contamination and cleaning from the professional standards developed by some trade associations (See *Guidelines of Care Developed by Professional and Trade Associations* in *Section 5* and refer to *Appendix G* for a list of organizations with expertise and materials on these issues.)

PRELIMINARY RECOMMENDATIONS ON DUCT CLEANING

1. Any duct cleaning should be scheduled during periods when the building is unoccupied to prevent exposure to chemicals and loosened particles.

The air handling unit should not be used during the cleaning or as an air movement device for the cleaning process. The National Air Duct Cleaning Association recommends that the system should be run to allow at least eight air changes in the occupied space when duct cleaning has been completed.

2. Negative air pressure that will draw pollutants to a vacuum collection system should be maintained at all times in the duct cleaning area to prevent migration of dust dirt, and contaminants into occupied areas.

Where possible, use vacuum equipment or fans during cleaning and sanitizing to make sure that cleaning vapors are exhausted to the outside and do not enter the occupied space.

3. If it is determined that the ductwork should be cleaned, careful attention must be given to protecting the ductwork.

When gaining access to sheet metal ducts for cleaning purposes, it is essential to seal the access hole properly in order to maintain the integrity of the HVAC system. Access doors are recommended if the system is to be cleaned periodically, and all access holes should be identified on the building's mechanical plans.

Particular attention is warranted when cutting fibrous glass ducts, and manufacturers' recommended procedures for sealing should be followed stringently. Use existing duct system openings where possible because it is difficult to repair the damage caused by cutting new access entries into the ductwork. Large, high volume vacuum equipment should only be used with extreme care because high negative pressure together with limited airflow can collapse ducts.

4. Duct cleaning performed with high velocity airflow (i.e., greater than 6,000 cfm) should include gentle, well-controlled brushing of duct surfaces or other methods to dislodge dust and other particles.

Duct cleaning that relies only on a high velocity airflow through the ducts is not likely to achieve satisfactory results because the flow rate at the duct surface remains too low to remove many particles.

5. Only HEPA filtered (high-efficiency particle arrestor) vacuuming equipment should be used if the vacuum collection unit is inside the occupied space.

Conventional vacuuming equipment may discharge extremely fine particulate matter back into the atmosphere, rather than collecting it. Duct cleaning equipment that draws the dust and dirt into a collection unit outside the building is also available. People should not be allowed to remain in the immediate vicinity of these collection units.

6. If biocides are to be used, then select only products registered by EPA for such use, use the products according to the manufacturer's directions, and pay careful attention to the method of application.

At present, EPA accepts claims and therefore registers antimicrobials for use only as sanitizers, not disinfectants or sterilizers in HVAC systems. (See *Appendix F* for definitions of antimicrobials.) There is some question about whether there are any application techniques that will deposit a sufficient amount of the biocide to kill bacteria, germs, or other biologicals that may be present. Materials such as deodorizers that temporarily eliminate odors caused by microorganisms provide only a fresh smell, and are not intended to provide real control of microbiological contaminants.

7. Use of sealants to cover interior ductwork surfaces is not recommended.

No application techniques have been demonstrated to provide a complete or long-term barrier to microbiological growth, nor have such materials been evaluated for their potential health effects on occupants. In addition, using sealants alters the surface burning characteristics of the duct material and may void the fire safety rating of the ductwork.

8. Careful cleaning and sanitizing of any parts of coils and drip pans can reduce microbiological pollutants.

Prior to using sanitizers, deodorizers, or any cleansing agents, carefully read the directions on the product label. Once cleaned, these components should be thoroughly rinsed and dried to prevent exposure of building occupants to the cleaning chemicals.

9. Water-damaged or contaminated porous materials in the ductwork or other air handling system components should be removed and replaced.

Even when such materials are thoroughly dried, there is no way to guarantee that all microbial growth has been eliminated.

10. After the duct system has been cleaned and restored to use, a preventive maintenance program will prevent the recurrence of problems.

Such a program should include particular attention to the use and maintenance of adequate filters, control of moisture in the HVAC system, and periodic inspection and cleaning of HVAC system components. (See discussion of *Preventive Maintenance* on page 36 in *Section 5*.)

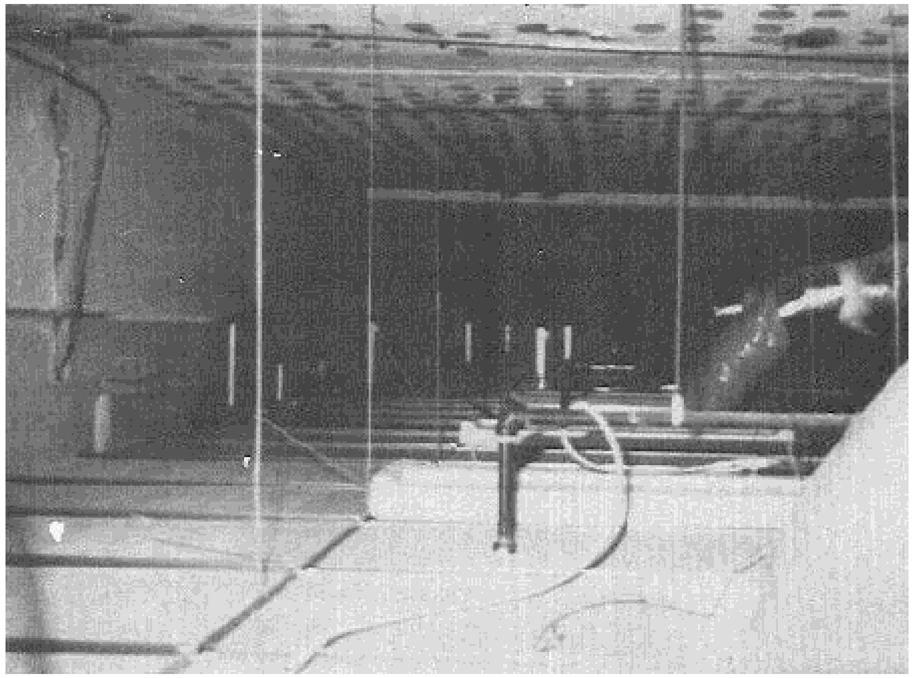
Terminal Devices

Thermal comfort and effective contaminant removal demand that air delivered into a conditioned space be properly distributed within that space. Terminal devices are the supply diffusers, return and exhaust grilles, and associated dampers and controls that are designed to distribute air within a space and collect it from that space. The number, design, and location (ceiling, wall, floor) of terminal devices are very important. They can cause a HVAC system with adequate capacity to produce unsatisfactory results, such as drafts, odor transport, stagnant areas, or short-circuiting.

Occupants who are uncomfortable because of distribution deficiencies (drafts, odor transport, stagnant air, or uneven temperatures) often try to compensate by adjusting or blocking the flow of air from supply outlets. Adjusting system flows without any knowledge of the proper design frequently disrupts the proper supply of air to adjacent areas. Distribution problems can also be produced if the arrangement of movable partitions, shelving, or other furnishings interferes with airflow. Such problems often occur if walls are moved or added without evaluating the expected impact on airflows.

Return Air Systems

In many modern buildings the above-ceiling space is utilized for the unducted passage of return air. This type of system approach often reduces initial HVAC system costs, but requires that the designer, maintenance personnel, and contractors obey strict guidelines related to life and safety codes (e.g., building codes) that must be followed for materials and devices that are located in the plenum. In addition, if a ceiling plenum is used for the collection of return air, openings into the ceiling plenum created by the removal of ceiling tiles will disrupt airflow patterns. It is particularly important to maintain the integrity of the ceiling and adjacent walls in areas that are designed to be exhausted, such as supply closets, bathrooms, and chemical storage areas.



Return air is frequently carried through non-ducted plenums. It is more difficult to control leakage of pollutants into or out of this type of return air system than a ducted system.

After return air enters either a ducted return air grille or a ceiling plenum, it is returned to the air handlers. Some systems utilize return fans in addition to supply fans in order to properly control the distribution of air. When a supply and return fan are utilized, especially in a VAV system, their operation must be coordinated in order to prevent under- or over-pressurization of the occupied space or overpressurization of the mixing plenum in the air handler.

Exhausts, Exhaust Fans, and Pressure Relief

Most buildings are required by law (e.g., building or plumbing codes) to provide for exhaust of areas where contaminant sources are strong, such as toilet facilities, janitorial closets, cooking facilities, and parking garages. Other areas where exhaust is frequently recommended but may not be legally required include: reprographics areas, graphic arts facilities, beauty salons, smoking lounges, shops, and any area where contaminants are known to originate.

For successful confinement and exhaust of identifiable sources, the exhausted area must be maintained at a lower overall pressure than surrounding areas. Any area that is designed to be exhausted must also be isolated (disconnected) from the return air system so that contaminants are not transported to another area of the building.

In order to exhaust air from the building, make-up air from outdoors must be brought into the HVAC system to keep the building from being run under negative pressure. This make-up air is typically drawn in at the mixed air plenum as described earlier and distributed within the building. For exhaust systems to function properly, the make-up air must have a clear path to the area that is being exhausted.

It is useful to compare the total cfm of powered exhaust to the minimum quantity of mechanically-introduced outdoor air. To prevent operating the building under negative pressures (and limit the amount of unconditioned air brought into the building by infiltration), the amount of make-up air drawn in at the air handler should always be slighter greater than the total amount of relief air, exhaust air, and air exfiltrating through the building shell. Excess make-up air is generally relieved at an exhaust or relief outlet in the HVAC system, especially in air economizer systems. In addition to reducing the effects of unwanted infiltration, designing and operating a building at slightly positive or neutral pressures will reduce the rate of entry of soil gases when the systems are operating. For a building to actually operate at a slight positive pressure, it must be tightly constructed (e.g., specified at less than one-half air change per hour at 0.25 pascals). Otherwise unwanted exfiltration will prevent the building from ever achieving a neutral or slightly positive pressure.

Self-Contained Units

In some designs, small decentralized units are used to provide cooling or heating to interior or perimeter zones. With the exception of induction units, units of this type seldom supply outdoor air. They are typically considered a low priority maintenance item. If self-contained units are overlooked during maintenance, it is not unusual for them to become a significant source of contaminants, especially for the occupants located nearby.

Controls

HVAC systems can be controlled manually or automatically. Most systems are controlled by some combination of manual and automatic controls. The control system can be used to switch fans on and off, regulate the temperature of air within the conditioned space, or modulate airflow and pressures by controlling fan speed and damper settings. Most large buildings use automatic controls, and many have very complex and sophisticated systems. Regular maintenance and calibration are required to keep controls in good operating order. All programmable timers and switches should have “battery backup” to reset the controls in the event of a power failure.

Local controls such as room thermostats must be properly located in order to maintain thermal comfort. Problems can result from:

- thermostats located outside of the occupied space (e.g., in return plenum)
- poorly designed temperature control zones (e.g., single zones that combine areas with very different heating or cooling loads)
- thermostat locations subject to drafts or to radiant heat gain or loss (e.g., exposed to direct sunlight)

- thermostat locations affected by heat from nearby equipment

To test whether or not a thermostat is functioning properly, try setting it to an extreme temperature. This experiment will show whether or not the system is responding to the signal in the thermostat, and also provides information about how the HVAC system may perform under extreme conditions.

Boilers

Like any other part of the HVAC system, a boiler must be adequately maintained to operate properly. However, it is particularly important that combustion equipment operate properly to avoid hazardous conditions such as explosions or carbon monoxide leaks, as well as to provide good energy efficiency. Codes in most parts of the country require boiler operators to be properly trained and licensed.

Both ASME and ASHRAE have made recommendations of how much combustion air is needed for fuel burning appliances.

Elements of boiler operation that are particularly important to indoor air quality and thermal comfort include:

- Operation of the boiler and distribution loops at a high enough temperature to supply adequate heat in cold weather.
- Maintenance of gaskets and breeching to prevent carbon monoxide from escaping into the building.
- Maintenance of fuel lines to prevent any leaks that could emit odors into the building.
- Provision of adequate outdoor air for combustion.
- Design of the boiler combustion exhaust to prevent re-entrainment, (especially from short boiler stacks, or into multi-story buildings that were added after the boiler plant was installed).

Modern office buildings tend to have much smaller capacity boilers than older buildings because of advances in energy efficiency. In some buildings, the primary heat source is waste heat recovered from the chiller (which operates year-round to cool the core of the building).

It is important to determine periodically whether the HVAC controls are correctly calibrated. In addition, time clocks must be checked to see if they are properly set and running. Power failures frequently cause time clocks to be out of adjustment.

Cooling Towers

Maintenance of a cooling tower ensures proper operation and keeps the cooling tower from becoming a niche for breeding pathogenic bacteria, such as *Legionella* organisms. Cooling tower water quality must be properly monitored and chemical treatments used as necessary to minimize conditions that could support the growth of significant amounts of pathogens. Proper maintenance may also entail physical cleaning (by individuals using proper protection) to prevent sediment accumulation and installing drift eliminators.

FIGURE B-2: Selected Ventilation Recommendations

Application		Occupancy (people/1000 ft^2)	Cfm/person	Cfm/ft^2
Food and Beverage Service	Dining rooms	70	20	
	Cafeteria, fast food	100	20	
	Bars, cocktail lounges	100	30	
	Kitchen (cooking)	20	15	
Offices	Office space	7	20	
	Reception areas	60	15	
	Conference rooms	50	20	
Public Spaces	Smoking lounge	70	60	
	Elevators			1.00
Retail Stores, Sales Floors, Showroom Floors	Basement and street	30		0.30
	Upper floors	20		0.20
	Malls and arcades	20		0.20
	Smoking lounge	70	60	
Sports and Amusement	Spectator areas	150	15	
	Game rooms	70	25	
	Playing floors	30	20	
	Ballrooms and discos	100	25	
Theaters	Lobbies	150	20	
	Auditorium	150	15	
Education	Classroom	50	15	
	Music rooms	50	15	
	Libraries	20	15	
	Auditoriums	150	15	
Hotels, Motels, Resorts, Dormitories	Bedrooms			30 cfm/room
	Living rooms			30 cfm/room
	Lobbies	30	15	
	Conference rooms	50	20	
	Assembly rooms	120	15	

SOURCE: ASHRAE Standard 62-1989, Ventilation for Acceptable Air Quality

Water Chillers

Water chillers are frequently found in large building air conditioning systems because of the superior performance they offer. A water chiller must be maintained in proper working condition to perform its function of removing the heat from the building. Chilled water supply temperatures should operate in the range of 45°F or colder in order to provide proper moisture removal during humid weather. Piping should be insulated to prevent condensation.

Other than thermal comfort, IAQ concerns associated with water chillers involve potential release of the working fluids from the chiller system. The rupture disk (safety release) of the system should be piped to the outdoors, and refrigerant leaks should be located and repaired. Waste oils and spent refrigerant should be disposed of properly.

ASHRAE STANDARDS AND GUIDELINES

Standard 62-1989, "Ventilation for Acceptable Air Quality"

ASHRAE 62-1989 is intended to assist professionals in the proper design of ventilation systems for buildings. The standard presents two procedures for ventilation design, a "Ventilation Rate" procedure and an "Air Quality" procedure.

With the Ventilation Rate procedure, acceptable air quality is achieved by specifying a given quantity and quality of outdoor air based upon occupant density and space usage. Examples of the tables listing the prescriptive amounts of outdoor air for the Ventilation Rate procedure are presented at the end of this section.

The Air Quality procedure is a performance specification that allows acceptable air quality to be achieved within a space by controlling for known and specifiable contaminants. This procedure is seldom used because source strength is usually not known.

Whichever procedure is utilized in the design, the standard states that the design criteria and assumptions shall be documented and made available to those responsible for the operation and maintenance of the system.

Important features of ASHRAE 62-1989 include:

- a definition of acceptable air quality
- a discussion of ventilation effectiveness
- the recommendation of the use of source control through isolation and local exhaust of contaminants
- recommendations for the use of heat recovery ventilation
- a guideline for allowable carbon dioxide levels
- appendices listing suggested possible guidelines for common indoor pollutants

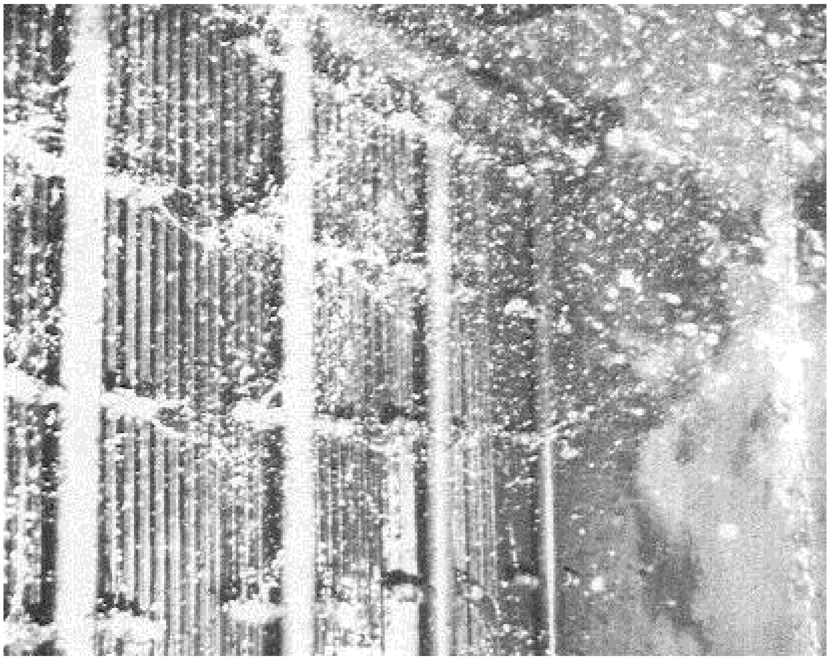
Standard 55-1981, "Thermal Environmental Conditions for Human Occupancy"

ASHRAE 55-1981 covers several environmental parameters including: temperature, radiation, humidity, and air movement.

The standard specifies thermal environmental conditions for the comfort of healthy people in normal indoor environments for winter and summer conditions. It also attempts to introduce limits on the temperature variations within a space. In addition to specifications for temperature and humidity, guidelines are given for air movement, temperature cycling, temperature drift, vertical temperature difference, radiant asymmetry, and floor temperatures. Adjustment factors are described for various activity levels of the occupants, and different clothing levels.

Important features of this standard include:

- a definition of acceptable thermal comfort



This air washer is used to remove particles and water-soluble gaseous contaminants and may also control temperature and humidity in the airstream. Such systems are subject to severe bacterial contamination.

- a discussion of the additional environmental parameters that must be considered
- recommendations for summer and winter comfort zones for both temperature and relative humidity
- a guideline for making adjustment for activity levels
- guidelines for making measurements

It should be noted that space temperatures above 76°F but within the summer comfort envelope have nevertheless been associated with IAQ complaints in offices.

Note: As of summer 1991, a revised Standard 55 was nearly ready.

Standard 52-76, "Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter"

This standard is intended to assist professionals in the evaluation of air cleaning systems for particle removal. Two test methods are described: the weight arrestance test and the atmospheric dust spot test. The standard discusses differences in results from the weight arrestance test and the atmospheric dust spot test. The atmospheric dust spot test is the test used to determine the "efficiency " of an air cleaner. The values obtained with these two tests are not comparable. For example, a filter with a weight arrestance of 90% may have an efficiency by the atmospheric dust spot test below 40%.

The weight arrestance test is generally used to evaluate low efficiency filters designed to remove the largest and heaviest particles; these filters are commonly used in residential furnaces and/or air-conditioning systems or as upstream filters for other air cleaning devices. For the test, a standard synthetic dust is fed into the air cleaner and the proportion (by weight) of the dust trapped on the filter is determined. Because the particles in the standard dust are relatively large, the weight arrestance test is of limited value in assessing the removal of smaller, respirable-size particles from indoor air.

The atmospheric dust spot test is usually used to rate medium efficiency air cleaners. The removal rate is based on the cleaner's ability to reduce soiling of a clean paper target, an ability dependent on the cleaner removing very fine particles from the air. However, it should be noted that this test addresses the overall efficiency of removal of a complex mixture of dust, and that removal efficiencies for different size particles may vary widely. Recent studies by EPA, comparing ASHRAE ratings to filter efficiencies for particles by size, have shown that efficiencies for particles in the size range of 0.1 to 1 microgram are much lower than the ASHRAE rating.

Important features of this ASHRAE standard include:

- definitions of arrestance and efficiency
- establishment of a uniform comparative testing procedure for evaluating the performance of air cleaning devices used in ventilation systems

- establishment of a uniform reporting method for performance
- methods for evaluating resistance to airflow and dust-holding capacity

No comparable guidelines or standards are currently available for use in assessing the ability of air cleaners to remove gaseous pollutants or radon and its progeny.

Guideline 1-1989, "Guideline for the Commissioning of HVAC Systems"

This guideline is intended to assist professionals by providing procedures and methods for documenting and verifying the performance of HVAC systems so that they operate in conformity with the design intent. The guideline presents a format for documenting the occupancy requirements, design assumptions, and the design intent for the HVAC system. It provides a format for testing the system for acceptance by the owner. In addition, the guideline addresses adjustments of the system to meet actual occupancy needs within the capacity of the system when changes in building use are made and recommissioning is warranted.

Important features of this guideline include:

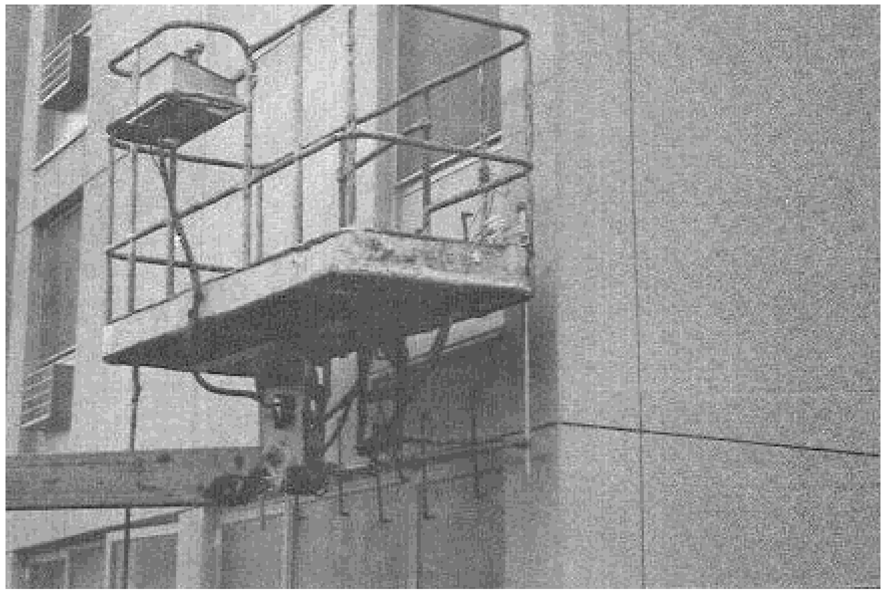
- definition of the commissioning process
- discussion of the process involved in a proper commissioning procedure
- sample specification and forms for logging information
- recommendation for the implementation of corrective measures as warranted
- guideline for operator training
- guidelines for periodic maintenance and recommissioning as needed

Appendix C: Moisture, Mold and Mildew

Molds and mildew are fungi that grow on the surfaces of objects, within pores, and in deteriorated materials. They can cause discoloration and odor problems, deteriorate building materials, and lead to allergic reactions in susceptible individuals, as well as other health problems.

The following conditions are necessary for mold growth to occur on surfaces:

- temperature range above 40°F and below 100°F
- mold spores
- nutrient base (most surfaces contain nutrients)
- moisture



There were complaints of visible water damage and musty odors in this senior citizen housing complex. Investigators confirmed that the problem was rain entry by using an array of hoses to spray the walls with water, while operating the building under negative pressure. The test showed that rain was entering at the joints of the exterior cladding, rather than at cracks around windows.

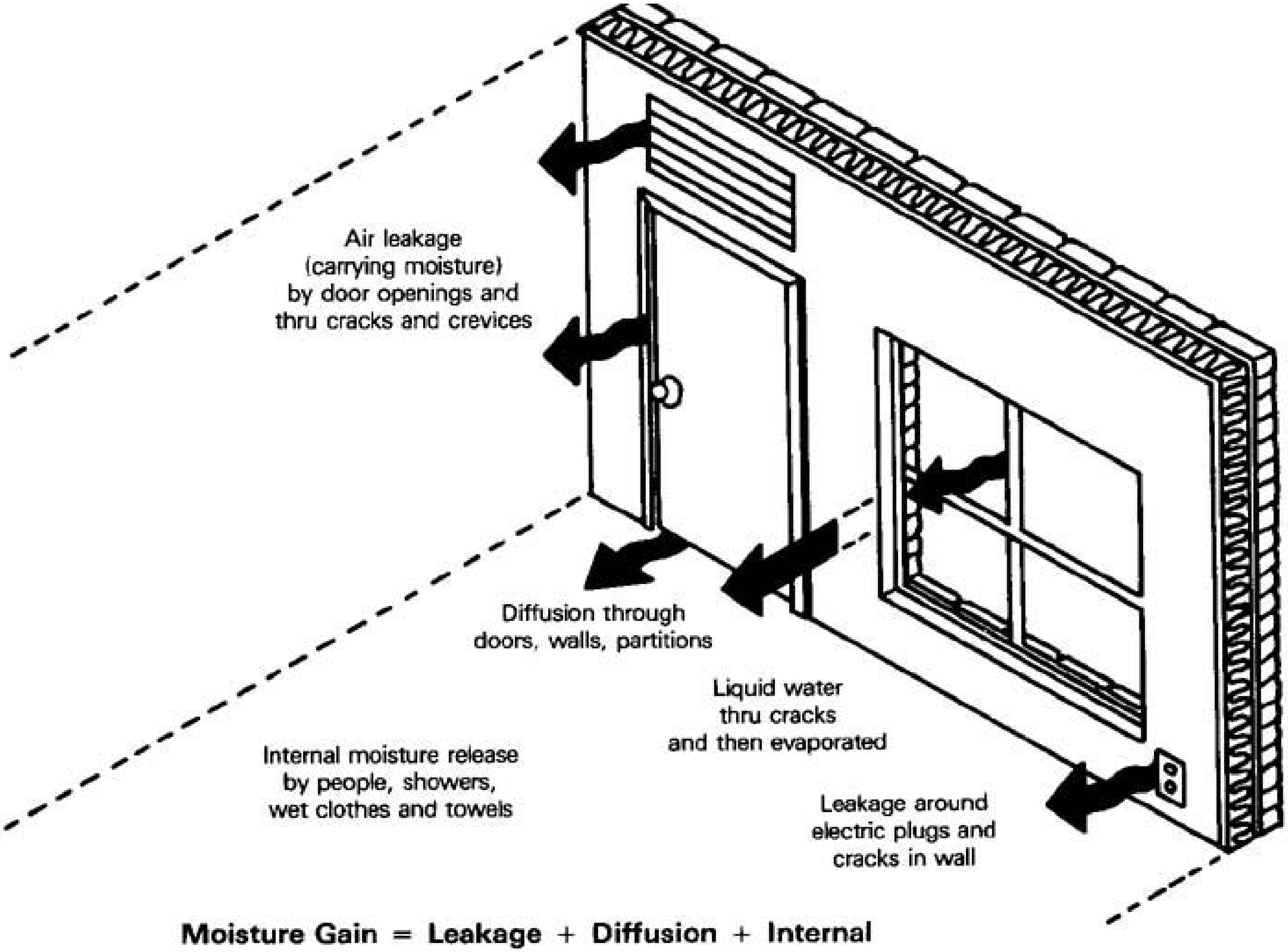
Human comfort constraints limit the use of temperature control. Spores are almost always present in outdoor and indoor air, and almost all commonly used construction materials and furnishings can provide nutrients to support mold growth. Dirt on surfaces provides additional nutrients. Cleaning and disinfecting with non-polluting cleaners and antimicrobial agents provides protection against mold growth. Other sections of this document have discussed the importance of building maintenance and proper sanitation in preventing IAQ problems. However, it is virtually impossible to eliminate all nutrients. Moisture control is thus an important strategy for reducing mold growth.

Mold growth does not require the presence of standing water; it can occur when high relative humidity or the hygroscopic properties (the tendency to absorb and retain moisture) of building surfaces allow sufficient moisture to accumulate. Relative humidity and the factors that govern it are often misunderstood. This appendix is intended to give building managers an understanding of the factors that govern relative humidity, and to describe common moisture problems and their solutions.

BACKGROUND ON RELATIVE HUMIDITY, VAPOR PRESSURE, AND CONDENSATION

Water enters buildings both as a liquid and as a gas (water vapor). Water, in its liquid form, is introduced intentionally in bathrooms, kitchens, and laundries and accidentally by way of leaks and spills. Some of that water evaporates and joins the water vapor that is exhaled by building occupants as they breathe or that is introduced by humidifiers. Water vapor also moves in and out of the building as part of the air that is mechanically introduced or that infiltrates and exfiltrates through openings in the building shell. A

FIGURE C-1: Moisture Gain in a Building



Courtesy of Dean Wallace Shakun, Clayton State College, Morrow, GA

lesser amount of water vapor diffuses into and out of the building through the building materials themselves. Figure C-1 illustrates locations of moisture entry.

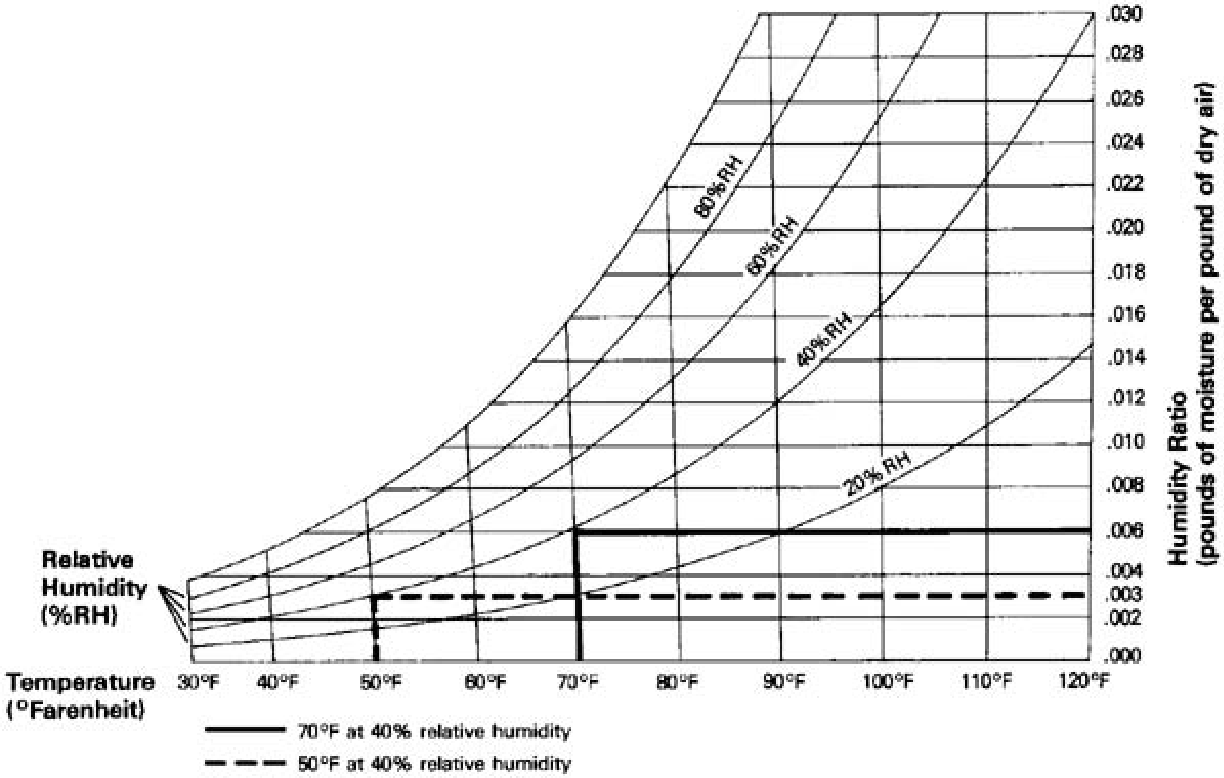
The ability of air to hold water vapor decreases as the air temperature is lowered. If a unit of air contains half of the water vapor it can hold, it is said to be at 50% relative humidity (RH). As the air cools, the relative humidity increases. If the air contains all of the water vapor it can hold, it is at 100% RH, and the water vapor condenses, changing from a gas to a liquid. It is possible to reach 100% RH without changing the amount of water vapor in the air (its "vapor pressure" or "absolute humidity"); All that is required is for the air temperature to drop to the "dew point."

Relative humidity and temperature often vary within a room, while the absolute humidity in the room air can usually be assumed to be uniform. Therefore, if one side of the room is warm and the other side cool, the cool side of the room has a higher RH than the warm side.

The highest RH in a room is always next to the coldest surface. This is referred as the "first condensing surface," as it will

FIGURE C-2: Relationship of Temperature, Relative Humidity, and Moisture in the Air

A relative humidity reading taken in a room will only give an accurate indication of the actual amount of moisture present if a temperature reading is taken at the same time. The chart below shows that air at 70°F and 40% RH contains approximately 0.006 pounds of moisture per pound of dry air (as indicated by the bold line), while air that is at 50°F and 40% RH contains approximately 0.003 pounds of moisture per pound of dry air (as indicated by the dashed line). Although both are at 40% RH, the 70°F air contains roughly twice as much moisture as the 50°F air.

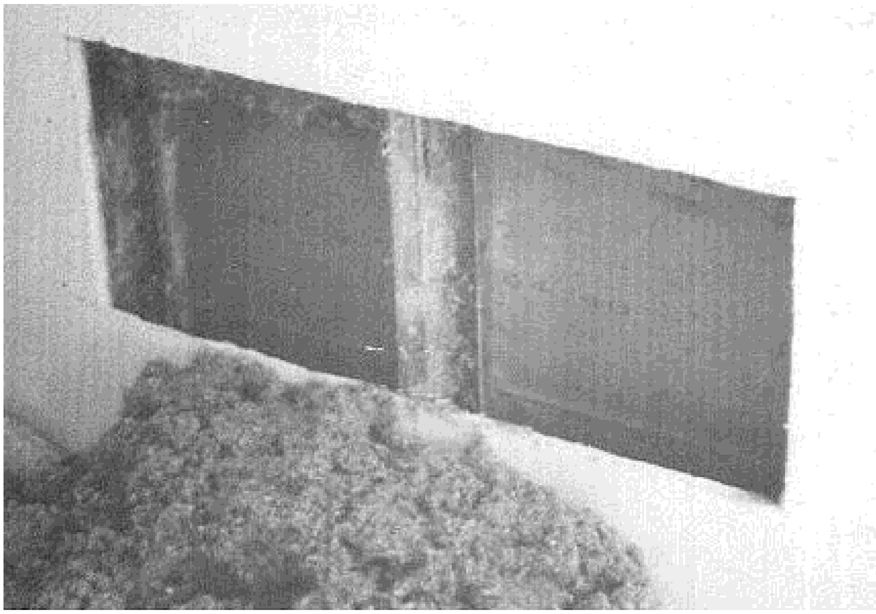


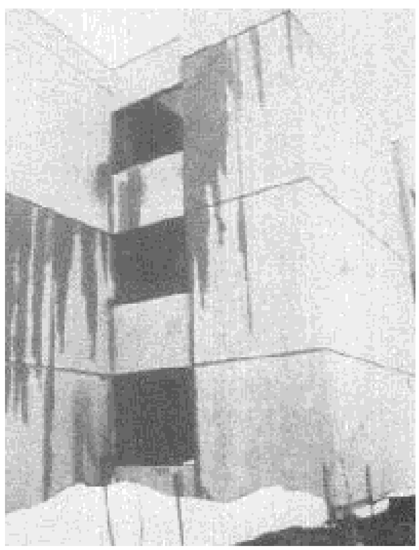
SOURCE: Adapted from Psychometric Chart from ASHRAE Fundamentals, 1981

be the location where condensation first occurs, if the relative humidity at the surface reaches 100%. It is important to understand this when trying to understand why mold is growing on one patch of wall or only along the wall-ceiling joint. It is likely that the surface of the wall is cooler than the room air because there is a void in the insulation or because wind is blowing through cracks in the exterior of the building.

TAKING STEPS TO REDUCE MOISTURE

Mold and mildew growth can be reduced where relative humidities near surfaces can be maintained below the dew point. This can be accomplished by reducing the moisture content (vapor pressure) of the air, increasing air movement at the surface, or increasing the air temperature (either the general space temperature or the temperature at building surfaces).





Above: *In this building, mold and mildew spots appeared on drywall joints on the interior walls. When the wall was cut open, mold growth was visible in the wall cavity and the structural steel showed corrosion. The problem was caused by construction moisture trapped between the interior finish and the exterior sheathing. The solution was to modify the exterior wall so that moisture could vent to the outdoors.* ***Below:*** *This is visual evidence of air movement through the building shell. The water vapor in the warm, humid indoor air has condensed and frozen on the exterior wall.*

Either surface temperature or vapor pressure can be the dominant factor in causing a mold problem. A surface temperature-related mold problem may not respond very well to increasing ventilation, whereas a vapor pressure-related mold problem may not respond well to increasing temperatures. Understanding which factor dominates will help in selecting an effective control strategy.

Consider an old, leaky, poorly insulated building. It is in a heating climate and shows evidence of mold and mildew. Since the building is leaky, its high natural air exchange rate dilutes interior airborne moisture levels, maintaining a low absolute humidity during the heating season. Providing mechanical ventilation in this building in an attempt to control interior mold and mildew probably will not be effective in this case. Increasing surface temperatures by insulating the exterior walls, and thereby reducing relative humidities next to the wall surfaces, would be a better strategy to control mold and mildew.

Reduction of **surface temperature-dominated mold and mildew** is best accomplished by increasing the surface temperature through either or both of the following approaches:

- Increase the temperature of the air near room surfaces either by raising the thermostat setting or by improving air circulation so that supply air is more effective at heating the room surface.
- Decrease the heat loss from room surfaces either by adding insulation or by closing cracks in the exterior wall to prevent wind-washing (air that enters a wall at one exterior location and exits another exterior location without penetrating into the building).

Vapor pressure-dominated mold and mildew can be reduced by one or more of the following strategies:

■ source control (e.g., direct venting of moisture-generating activities such as showers) to the exterior
■ dilution of moisture-laden indoor air with outdoor air that is at a lower absolute humidity
■ dehumidification

Note that dilution is only useful as a control strategy during heating periods, when cold outdoor air tends to contain less moisture. During cooling periods, outdoor air often contains as much moisture as indoor air.

IDENTIFYING AND CORRECTING COMMON PROBLEMS FROM MOLD AND MILDEW

Exterior Corners

Exterior corners are common locations for mold and mildew growth in heating climates, and in poorly insulated buildings in cooling climates. They tend to be closer to the outdoor temperature than other parts of the building surface for one or more of the following reasons:

■ poor air circulation (interior)
■ wind-washing (exterior)
■ low insulation levels
■ greater surface area of heat loss

Sometimes mold and mildew growth can be reduced by removing obstructions to airflow (e.g., rearranging furniture). Buildings with forced air heating systems and/or room ceiling fans tend to have fewer mold and mildew problems than buildings with less air movement, other factors being equal.

“Set Back” Thermostats

Set back thermostats are commonly used to reduce energy consumption during the heating season. Mold and mildew growth can occur when building temperatures are lowered during unoccupied periods. (Maintaining a room at too low a temperature can have the same effect as a set back thermostat.) Mold and mildew can often be controlled in heating climate locations by increasing interior temperatures during heating periods. Unfortunately, this also increases energy consumption and reduces relative humidity in the breathing zone, which can create discomfort.

Air Conditioned Spaces

The problems of mold and mildew can be as extensive in cooling climates as in heating climates. The same principles apply: either surfaces are too cold, moisture levels are too high, or both.

A common example of mold growth in cooling climates can be found in rooms where conditioned “cold” air blows against the interior surface of an exterior wall. This condition, which may be due to poor duct design, diffuser location, or diffuser performance, creates a cold spot at the interior finish surfaces. A mold problem can occur within the wall cavity as outdoor air comes in contact with the cavity side of the cooled interior surface. It is a particular problem in rooms decorated with low

HOW TO IDENTIFY THE CAUSE OF A MOLD AND MILDEW PROBLEM

Mold and mildew are commonly found on the exterior wall surfaces of corner rooms in heating climate locations. An exposed corner room is likely to be significantly colder than adjoining rooms, so that it has a higher relative humidity (RH) than other rooms at the same water vapor pressure. If mold and mildew growth are found in a corner room, then relative humidities next to the room surfaces are above 70%. However, is the RH above 70% at the surfaces because the room is too cold or because there is too much moisture present (high water vapor pressure)?

The amount of moisture in the room can be estimated by measuring both temperature and RH at the same location and at the same time. Suppose there are two cases. In the first case, assume that the RH is 30% and the temperature is 70°F in the middle of the room. The low RH at that temperature indicates that the water vapor pressure (or absolute humidity) is low. The high surface RH is probably due to room surfaces that are "too cold." Temperature is the dominating factor, and control strategies should involve increasing the temperature at cold room surfaces.

In the second case, assume that the RH is 50% and the temperature is 70°F in the middle of the room. The higher RH at that temperature indicates that the water vapor pressure is high and there is a relatively large amount of moisture in the air. The high surface RH is probably due to air that is "too moist." Humidity is the dominating factor, and control strategies should involve decreasing the moisture content of the indoor air.

maintenance interior finishes (e.g., impermeable wall coverings such as vinyl wallpaper) which can trap moisture between the interior finish and the gypsum board. Mold growth can be rampant when these interior finishes are coupled with cold spots and exterior moisture.

Possible solutions for this problem include:

- preventing hot, humid exterior air from contacting the cold interior finish (i.e., controlling the vapor pressure at the surface)
- eliminating the cold spots (i.e., elevating the temperature of the surface) by relocating ducts and diffusers
- ensuring that vapor barriers, facing sealants, and insulation are properly specified, installed, and maintained
- increasing the room temperature to avoid overcooling

In this case, increasing temperature decreases energy consumption, though it could cause comfort problems.

Thermal Bridges

Localized cooling of surfaces commonly occurs as a result of "thermal bridges," elements of the building structure that are highly conductive of heat (e.g., steel studs in exterior frame walls, uninsulated window lintels, and the edges of concrete floor slabs). Dust particles sometimes mark the locations of thermal bridges, because dust tends to adhere to cold spots.

The use of insulating sheathings significantly reduces the impact of thermal bridges in building envelopes.

Windows

In winter, windows are typically the coldest surfaces in a room. The interior surface of a window is often the first condensing surface in a room.

Condensation on window surfaces has historically been controlled by using storm windows or "insulated glass" (e.g., double-glazed windows or selective surface gas-filled windows) to raise interior surface temperatures. The advent of higher performance glazing systems has led to a greater incidence of moisture problems in heating climate building enclosures, because the buildings can now be operated at higher interior vapor pressures (moisture levels) without visible surface condensation on windows. In older building enclosures with less advanced glazing systems, visible condensation on the windows often alerted occupants to the need for ventilation to flush out interior moisture (so they opened the windows).

Concealed Condensation

The use of thermal insulation in wall cavities increases interior surface temperatures in heating climates, reducing the likelihood of interior surface mold, mildew and condensation. However, the use of thermal insulation also reduces the heat loss from the conditioned space into the wall cavities, decreasing the temperature in the wall cavities and therefore increasing the likelihood of concealed condensation. The first condensing surface in a wall cavity in a heating climate is typically the inner surface of the exterior sheathing, the "back side" of plywood or fiberboard. As the insulation value is increased in the wall cavities, so does the potential for hidden condensation.

Concealed condensation can be controlled by either or both of the following strategies:

- Reducing the entry of moisture into the wall cavities (e.g., by controlling infiltration and/or exfiltration of moisture-laden air)
- Elevating the temperature of the first condensing surface. In heating climate locations, this change can be made by installing exterior insulation (assuming that no significant wind-washing is occurring). In cooling climate locations, this change an be made by installing insulating sheathing to the interior of the wall framing and between the wall framing and the interior gypsum board.

Appendix D: Asbestos

"Asbestos" describes six naturally occurring fibrous minerals found in certain types of rock formations. When mined and processed, asbestos is typically separated into very thin fibers that are normally invisible to the naked eye. They may remain in the air for many hours if released from asbestos-containing material (ACM) and may be inhaled during this time. Three specific diseases — asbestosis (a fibrous scarring of the lungs), lung cancer, and mesothelioma (a cancer of the lining of the chest or abdominal cavity) — have been linked to asbestos exposure. It may be 20 years or more after exposure before symptoms of these diseases appear; however, high levels of exposure can result in respiratory diseases in a shorter period of time.

Most of the health problems resulting from asbestos exposure have been experienced by workers whose jobs exposed them to asbestos in the air over a prolonged period without the worker protection that is now required. Asbestos fibers can be found nearly everywhere in our environment (usually at very low levels). While the risk to occupants is likely to be small, health concerns remain, particularly for the custodial and maintenance workers in a building. Their jobs are likely to bring them into proximity to ACM and may sometimes require them to disturb the ACM in the performance of maintenance activities.

EPA estimates that "friable" (easily crumbled) ACM can be found in an estimated 700,000 public and commercial buildings. About 500,000 of those buildings are believed to contain at least some damaged asbestos. Significantly damaged ACM is found primarily in building areas not generally accessible to the public, such as boiler and mechanical rooms, where asbestos exposures generally would be limited to service and maintenance workers. However, if friable ACM is present in air plenums, it can be distributed throughout the building, thereby possibly exposing building occupants.

When is asbestos a problem? **Intact and undisturbed asbestos materials do not pose a health risk.** The mere presence of asbestos in a building does not mean that the health of building occupants is endangered. ACM which is in good condition, and is not damaged or disturbed, is not likely to release asbestos fibers into the air. When ACM is properly managed, release of asbestos fibers into the air is reduced, and the risk of asbestos-related disease is thereby correspondingly reduced.

There are a number of guidelines and regulations that govern asbestos exposure. Occupational standards for preventing asbestos-related diseases are recommended by NIOSH and promulgated by OSHA. NIOSH guidance contain Recommended Exposure Limits (RELs) and OSHA standards set Permissible Exposure Limits (PELs). The standards also contain many other measures, such as surveillance, medical screening, analytical methods, and methods of control. OSHA regulations and the EPA Worker Protection Rule also provide guidance on day-to-day activities that may bring workers in contact with ACM. EPA National Emission Standards for Hazardous Air Pollutants (NESHAP) define acceptable practices for renovation and demolition activities that involve asbestos-containing materials. In addition, many States have set exposure standards and other regulations concerning asbestos.

EPA and NIOSH recommend a practical approach that protects public health by emphasizing that ACM in buildings should be identified and appropriately managed, and that those workers who might disturb it should be properly trained and protected.

EPA AND NIOSH POSITIONS ON ASBESTOS

In an effort to calm unwarranted fears that a number of people seem to have about the mere presence of asbestos in their buildings and to discourage the decisions by some building owners to remove all ACM regardless of its condition, the EPA Administrator issued an *Advisory to the Public on Asbestos in Buildings* in 1991. This advisory summarized EPA's policies for asbestos control in the presentation of the following "five facts":

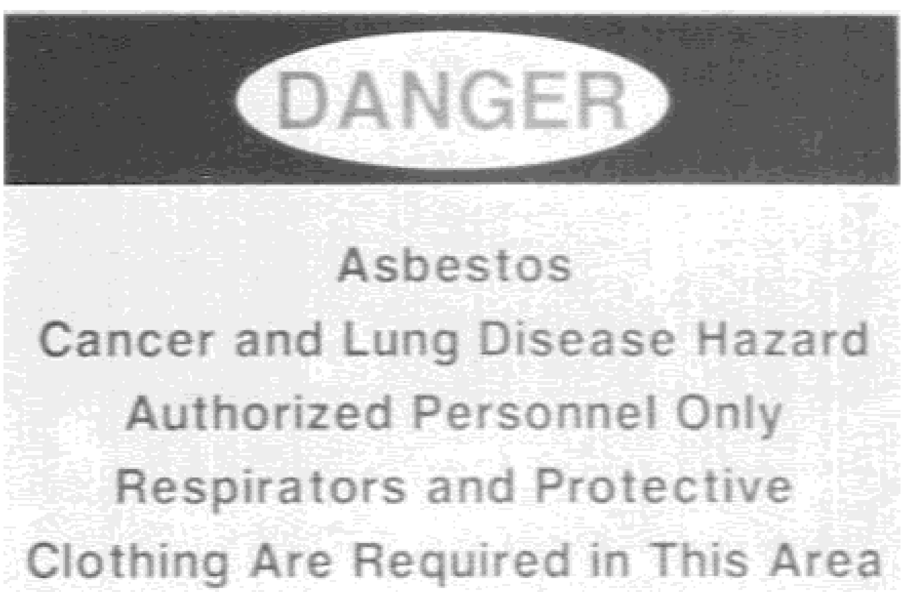
- Although asbestos is hazardous, the risk of asbestos-related disease depends upon exposure to airborne asbestos fibers.
- Based upon available data, the average airborne asbestos levels in buildings seem to be very low. Accordingly, the health risk to most building occupants also appears to be very low.
- Removal is often not a building owner's best course of action to reduce asbestos exposure. In fact, an improper removal can create a dangerous situation where none previously existed.
- EPA only requires asbestos removal in order to prevent significant public exposure to airborne asbestos fibers during building demolition or renovation activities.
- EPA does recommend a pro-active, in-place management program whenever asbestos-containing material is discovered.

NIOSH's position on asbestos exposure has been expressed in NIOSH policy statements and internal reports and at OSHA public hearings:

- NIOSH recommends the goal of eliminating asbestos exposure in the workplace. Where exposures cannot be eliminated, exposures should be limited to the lowest concentration possible.
- NIOSH contends that there is no safe airborne fiber concentration for asbestos. NIOSH therefore believes that any detectable concentration of asbestos in the workplace warrants further evaluation and, if necessary, the implementation of measures to reduce exposures.
- NIOSH contends that there is no scientific basis to support differentiating health risks between types of asbestos fibers for regulatory purposes.

Copies of the EPA and NIOSH policy statements and public advisories are available, respectively, from those agencies. See the last section in this appendix and the *Resources* section for information on how to obtain them.

OSHA requires that signs be posted around areas where work is being done that involves damaged asbestos-containing materials. These signs must communicate specific types of information.



PROGRAMS FOR MANAGING ASBESTOS IN-PLACE

In some cases, an asbestos operations and maintenance program is more appropriate than other asbestos control strategies, including removal. Proper asbestos management is neither to rip it all out in a panic nor to ignore the problem under the false presumption that asbestos is “risk free.” Health concerns remain, particularly for custodial and maintenance workers.

In-place management does not mean “do nothing.” It means having a program to ensure that the day-to-day management of the building is carried out in a manner that minimizes release of asbestos fibers into the air, and that ensures that when asbestos fibers are released, either accidentally or intentionally, proper control and clean-up procedures are implemented. Such a program may be all that is necessary to control the release of asbestos fibers until the asbestos-containing material in a building is scheduled to be disturbed by renovation or demolition activities.

The first responsibility of a building owner or manager is to identify asbestos-containing materials, through a building-wide inventory or on a case-by-case basis, before suspect materials are disturbed by renovations or other actions. The Asbestos Hazard Emergency Response Act (AHERA) program requires that in schools an inventory of asbestos materials be done by properly accredited individuals. Starting in late 1991 or 1992, there will also be a requirement that if an inventory of asbestos materials is done in public and commercial buildings, the inventory must be done by properly accredited individuals. In public and commercial buildings facing major renovations or demolition, inspections for the presence of ACM are required, according to the 1990 revision of the EPA Asbestos NESHAP. A carefully designed air monitoring program can be used as an adjunct to visual and physical evaluations of the asbestos-containing materials.

After the material is identified, the building management and staff can then institute controls to ensure that the day-to-day management of the building is carried out in a manner that prevents or minimizes the release of asbestos fibers into the air. These controls will ensure that when asbestos fibers are released, either accidentally or intentionally, proper management and clean-up procedures are implemented.

Another concern of EPA, NIOSH, and other Federal, State, and local agencies that are concerned with asbestos and public health is to ensure proper worker training and protection. In the course of their daily activities, maintenance and service workers in buildings may disturb materials and thereby elevate asbestos fiber levels and asbestos exposure, especially for themselves, if they are not properly trained and protected. For these persons, risk may be significantly higher than for other building occupants. Proper worker training and protection, as part of an active in-place management program, can reduce any unnecessary asbestos exposure for these workers and others. AHERA requires this training for school employees whose job activities may result in asbestos disturbances.

In addition to the steps outlined above, an in-place management program will usually include notification to workers and occupants of the existence of asbestos in their building, periodic surveillance of the material, and proper recordkeeping. EPA requires all of these activities for schools and strongly recommends that other building owners also establish comprehensive asbestos management programs. Without such programs, asbestos materials could be damaged or could deteriorate, which might result in elevated levels of airborne asbestos fibers. While the management costs of all the above activities will depend upon the amount, condition, and location of the materials, such a program need not be expensive. The verification code for this document is 433288.

WHERE TO GO FOR ADDITIONAL INFORMATION

For guidance on asbestos, building owners and managers are urged to become familiar with two EPA documents: *Managing Asbestos in Place* (published in 1990 and also known as the "Green Book") and *Guidance for Controlling Asbestos-Containing Materials in Buildings* (published in 1985 and also known as the "Purple Book").

To obtain copies of the guidance publications and other materials mentioned above, or to get additional information on technical issues, call or write:

Environmental Assistance Division
Office of Toxic Substances
U.S. EPA (TS-799)
401 M Street SW
Washington, DC 20460
Telephone (TSCA Information Hotline): 202-554-1404

National Institute for Occupational Safety and Health
Technical Information Branch
4676 Columbia Parkway
Cincinnati, OH 45226
Telephone: 1-800-35-NIOSH or 1-800-356-4674

Contact State air pollution control or health agencies for information on pertinent State activities and regulations. To find an asbestos contact in State agencies, consult the EPA Directory of State Indoor Air Contacts. For a more complete listing of publications concerning asbestos, refer to *Appendix G*.

Appendix E: Radon

Radon is a radioactive gas produced by the decay of radium. It occurs naturally in almost all soil and rock. Radon migrates through the soil and groundwater and can enter buildings through cracks or other openings in their foundations. Radon's decay products can cause lung cancer, and radon is second only to smoking as a cause of lung cancer in America.

Based on early data, the EPA concentrated its radon reduction efforts on one- and two- family homes. Citing results from a radon survey conducted jointly with 25 States, the EPA and the Surgeon General's office issued a National Health Advisory that called for testing most homes for the presence of radon. Extensive research and case studies in the field have demonstrated practical remediation methods that typically reduce the indoor radon concentrations below 4 pCi/L, the current EPA action level for all occupied buildings.

Now that EPA technical guidance is being successfully used to reduce human health risk in homes, the EPA is emphasizing the development of radon measurement, mitigation, and prevention techniques for schools and large buildings. Preliminary data from a nationwide survey of Federal buildings indicates that radon will probably not be as widespread a problem in large buildings as it is in homes. One of the major factors for this difference is that multi-story buildings have proportionally less space in direct contact with the earth when compared to homes.

Some of the control technologies utilized for homes are being studied for their appropriateness to other building types, including schools and large buildings. In addition, new methods and technologies are being developed to ensure a practical and cost-effective reduction of radon in these buildings. As a result, published documents on guidance and protocols for measurement and remediation of radon in large buildings are not currently available.

This publication provides an overview of radon issues, and should be used only as background information. For more information, refer to other sources of information that are specific to radon in indoor air.

BUILDING MEASUREMENT, DIAGNOSIS, AND REMEDIATION

Protocols specific to the measurement of radon and radon progeny in large buildings are tentatively scheduled to be published by EPA in early 1992. These large building measurement protocols can assist skilled building owner or facility personnel in making initial screening tests for the presence of radon. A new protocol specific to large buildings is necessary due to the major differences in building dynamics, HVAC systems, and occupancy patterns between large buildings and homes, and how these impact radon.

As part of its effort to develop widespread State and private sector capabilities, the EPA established a voluntary proficiency program (Radon Measurement Proficiency Program) for radon laboratories and commercial measurement firms. *A State Proficiency Report* (EPA 520/1-91-014), which gives information on specific radon measurement firms in your area, can be obtained from your State radon office or from your EPA Regional Office.

Three elements must be present for radon to be a problem: a radon source, a pathway that allows radon to enter the building, and a driving force that causes the radon to flow through the pathway and into the building. Preventing radon from entering the building is always desirable compared with mitigation after radon has entered. The reduction of pathways and driving forces are therefore usually the focus of attention during diagnostic and remediation efforts.

Due to the diversity and complexity of large buildings, and because the research and development of appropriate radon remediation technologies for these structures are in the early phases, generalized building diagnostic and remediation methodologies are not yet available. For assistance, please contact the appropriate organizations on the following list or a professional engineering firm or mitigation company with experience in this matter.

WHERE TO GO FOR ADDITIONAL INFORMATION

State Radon Offices
There are several ways to get the name of a contact person in your State radon office or information about that office. You can call the radon contact in the EPA Regional Office for your state or you can order the *Directory of State Indoor Air Contacts* from the EPA Public Information Center. (See list of IAQ and radon contacts and list of EPA publications in *Appendix G*.)

Regional Radon Training Centers
As part of its effort to develop State and private sector capabilities for radon reduction, the EPA has coordinated the formation of four Regional Radon Training Centers (RRTCs). The RRTCs provide a range of radon training and proficiency examination courses to the public for a fee.

Eastern Regional Radon Training Center
Rutgers, The State University
Livingston Campus, Building 4087
New Brunswick, NJ 08903-0231
908-932-2582

Mid-West Universities Radon Consortium
University of Minnesota
1985 Buford Avenue (240)
St. Paul, MN 55108-6136
612-624-8747

Western Regional Radon Training Center
Guggenheim Hall
Colorado State University
Fort Collins, CO 80523
1-800-462-7459/303-491-7742

Southern Regional Radon Training Center
Auburn University
Housing Research Center
Harbert Engineering Center
Auburn University, AL 36849-5337
205-844-6261

EPA Regional Offices
If you want additional information from EPA regarding radon, start with the EPA Regional Offices. Telephone numbers for radon information contacts are given in the list of EPA Regional Offices in *Appendix G* of this publication.

EPA Radon Division
If information is unavailable from the above sources, please contact the EPA Radon Division at:

Radon Division (ANR-464)
U.S. EPA
401 M Street, SW
Washington, DC 20460
202-260-9605

Appendix F: Glossary and Acronyms

ACGIH — American Conference of Governmental Industrial Hygienists.

ASHRAE — American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

ASTM — American Society for Testing and Materials.

Air Cleaning — An IAQ control strategy to remove various airborne particulates and/or gases from the air. The three types of air cleaning most commonly used are particulate filtration, electrostatic precipitation, and gas sorption.

Air Exchange Rate — Used in two ways: 1) the number of times that the outdoor air replaces the volume of air in a building per unit time, typically expressed as air changes per hour; 2) the number of times that the ventilation system replaces the air within a room or area within the building.

Antimicrobial — Agent that kills microbial growth. See "disinfectant," "sanitizer", and "sterilizer."

BRI — See "Building-Related Illness."

Biological Contaminants — Agents derived from or that are living organisms (e.g., viruses, bacteria, fungi, and mammal and bird antigens) that can be inhaled and can cause many types of health effects including allergic reactions, respiratory disorders, hypersensitivity diseases, and infectious diseases. Also referred to as "microbiologicals" or "microbials."

Breathing Zone — Area of a room in which occupants breathe as they stand, sit, or lie down.

Building Envelope — Elements of the building, including all external building materials, windows, and walls, that enclose the internal space.

Building-Related Illness — Diagnosable illness whose symptoms can be identified and whose cause can be directly attributed to airborne building pollutants (e.g., Legionnaire's disease, hypersensitivity pneumonitis).

CFM — Cubic feet per minute.

CO — Carbon monoxide.

CO_2 — Carbon dioxide.

Ceiling Plenum — Space below the flooring and above the suspended ceiling that accommodates the mechanical and electrical equipment and that is used as part of the air distribution system. The space is kept under negative pressure.

Commissioning — Start-up of a building that includes testing and adjusting HVAC, electrical, plumbing, and other systems to assure proper functioning and adherence to design criteria. Commissioning also includes the instruction of building representatives in the use of the building systems.

Conditioned Air — Air that has been heated, cooled, humidified, or dehumidified to maintain an interior space within the "comfort zone." (Sometimes referred to as "tempered" air.)

Constant Air Volume Systems — Air handling system that provides a constant air flow while varying the temperature to meet heating and cooling needs.

Dampers — Controls that vary airflow through an air outlet, inlet, or duct. A damper position may be immovable, manually adjustable, or part of an automated control system.

Diffusers and Grilles — Components of the ventilation system that distribute and diffuse air to promote air circulation in the occupied space. Diffusers supply air and grilles return air.

Disinfectants — One of three groups of antimicrobials registered by EPA for public health uses. EPA considers an antimicrobial to be a disinfectant when it destroys or irreversibly inactivates infectious or other undesirable organisms, but not necessarily their spores. EPA registers three types of disinfectant products based upon submitted efficacy data: limited, general or broad spectrum, and hospital disinfectant.

EPA — United States Environmental Protection Agency.

ETS — Environmental tobacco smoke.

Environmental Agents — Conditions other than indoor air contaminants that cause stress, comfort, and/or health problems (e.g., humidity extremes, drafts, lack of air circulation, noise, and overcrowding).

Ergonomics — Applied science that investigates the impact of people's physical environment on their health and comfort (e.g., determining the proper chair height for computer operators).

Exhaust Ventilation — Mechanical removal of air from a portion of a building (e.g., piece of equipment, room, or general area).

Gas Sorption — Devices used to reduce levels of airborne gaseous compounds by passing the air through materials that extract the gases. The performance of solid sorbents is dependent on the airflow rate, concentration of the pollutants, presence of other gases or vapors, and other factors.

HEPA — High efficiency particulate arrestance (filters).

HVAC — Heating, ventilation, and air-conditioning system.

Hypersensitivity Diseases — Diseases characterized by allergic responses to animal antigens. The hypersensitivity diseases most clearly associated with indoor air quality are asthma, rhinitis, and hypersensitivity pneumonitis. Hypersensitivity pneumonitis is a rare but serious disease that involves progressive lung damage as long as there is exposure to the causative agent.

IAQ — Indoor air quality.

IPM — Integrated pest management.

Indicator Compounds — Chemical compounds, such as carbon dioxide, whose presence at certain concentrations may be used to estimate certain building conditions (e.g., airflow, presence of sources).

MCS — See "Multiple Chemical Sensitivity."

MSDS — Material Safety Data Sheet.

Make-up Air — Air brought into a building from the outdoors through the ventilation system that has not been previously circulated through the system.

Microbiologicals — See "Biological Contaminants."

Multiple Chemical Sensitivity — A term used by some people to refer to a condition in which a person is considered to be sensitive to a number of chemicals at very low concentrations. There are a number of views about the existence, potential causes, and possible remedial actions regarding this phenomenon.

NIOSH — National Institute for Occupational Safety and Health.

NTIS — National Technical Information Service.

Negative Pressure — Condition that exists when less air is supplied to a space than is exhausted from the space, so the air pressure within that space is less than that in surrounding areas.

OSHA — Occupational Safety and Health Administration.

PELs — Permissible Exposure Limits (standards set by OSHA).

PM — Preventive Maintenance.

Plenum — Air compartment connected to a duct or ducts.

Positive Pressure — Condition that exists when more air is supplied to a space than is exhausted, so the air pressure within that space is greater than that in surrounding areas.

Psychosocial Factors — Psychological, organizational, and personal stressors that could produce symptoms similar to poor indoor air quality.

RELs — Recommended Exposure Limits (recommendations made by NIOSH).

Radiant Heat Transfer — Radiant heat transfer occurs when there is a large difference between the temperatures of two surfaces that are exposed to each other, but are not touching.

Re-entrainment —Situation that occurs when the air being exhausted from a building is immediately brought back into the system through the air intake and other openings in the building envelope.

SBS — See "Sick Building Syndrome."

Sanitizer — One of three groups of antimicrobials registered by EPA for public health uses. EPA considers an antimicrobial to be a sanitizer when it reduces but does not necessarily eliminate all the microorganisms on a treated surface. To be a registered sanitizer, the test results for a product must show a reduction of at least 99.9% in the number of each test microorganism over the parallel control.

Short-circuiting — Situation that occurs when the supply air flows to exhaust registers before entering the breathing zone. To avoid short-circuiting, the supply air must be delivered at a temperature and velocity that results in mixing throughout the space.

Sick Building Syndrome — Term sometimes used to describe situations in which building occupants experience acute health and/or comfort effects that appear to be linked to time spent in a particular building, but where no specific illness or cause can be identified. The complaints may be localized in a particular room or zone, or may be spread throughout the building.

Soil Gases — Gases that enter a building from the surrounding ground (e.g., radon, volatile organics, pesticides).

Stack Effect —Pressure-driven airflow produced by convection as heated air rises, creating a positive pressure area at the top of a building and a negative pressure area at the bottom of a building. The stack effect can overpower the mechanical system and disrupt ventilation and circulation in a building.

Static Pressure — Condition that exists when an equal amount of air is supplied to and exhausted from a space. At static pressure, equilibrium has been reached.

Sterilizer — One of three groups of antimicrobials registered by EPA for public health uses. EPA considers an antimicrobial to be a sterilizer when it destroys or eliminates all forms of bacteria, fungi, viruses, and their spores. Because spores are considered the most difficult form of a microorganism to destroy, EPA considers the term sporicide to be synonymous with "sterilizer."

TLVs — Threshold Limit Values (guidelines recommended by ACGIH).

TVOCs — Total volatile organic compounds.

Tracer Gases — Compounds, such a sulfur hexafluoride, which are used to identify suspected pollutant pathways and to quantify ventilation rates. Tracer gases may be detected qualitatively by their odor or quantitatively by air monitoring equipment.

VAV — Variable air volume system.

VOCs — See "Volatile Organic Compounds."

Variable Air Volume System — Air handling system that conditions the air to a constant temperature and varies the outside airflow to ensure thermal comfort.

Ventilation Air — Defined as the total air, which is a combination of the air brought into the system from the outdoors and the air that is being recirculated within the building. Sometimes, however, used in reference only to the air brought into the system from the outdoors.

Volatile Organic Compounds (VOCs) — Compounds that evaporate from the many housekeeping, maintenance, and building products made with organic chemicals. These compounds are released from products that are being used and that are in storage. In sufficient quantities, VOCs can cause eye, nose, and throat irritations, headaches, dizziness, visual disorders, memory impairment; some are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans. At present, not much is known about what health effects occur at the levels of VOCs typically found in public and commercial buildings.

WHO — World Health Organization.

Appendix G: Resources

FEDERAL AGENCIES WITH MAJOR INDOOR AIR RESPONSIBILITY FOR PUBLIC AND COMMERCIAL BUILDINGS

U.S. Environmental Protection Agency

Conducts a non-regulatory indoor air quality program that emphasizes research, information dissemination, technical guidance, and training. Issues regulations and carries out other activities that affect indoor air quality under the laws for pesticides, toxic substances, and drinking water.

Public Information Center
(PM-211B)
401 M Street, SW
Washington, DC 20460
202-382-2080
Distributes indoor air quality publications.

National Pesticides Telecommunications
Network National toll-free number:
1-800-858-PEST
In Texas: 806-743-3091
Provides information on pesticides.

TSCA Hotline Service
202-554-1404
Provides information on asbestos and other toxic substances.

Occupational Safety and Health Administration

Promulgates safety and health standards, facilitates training and consultation, and enforces regulations to ensure that workers are provided with safe and healthful working conditions. (For further information contact OSHA Regional Offices.)

National Institute for Occupational Safety and Health

Conducts research, recommends standards to the U.S. Department of Labor, and conducts training on various issues including indoor air quality to promote safe and healthful workplaces. Undertakes investigations at request of employees, employers, other federal agencies, and state and local agencies to identify and mitigate workplace problems.

Requests for Field Investigations
NIOSH
Hazard Evaluations and Technical
Assistance Branch (R-9)
4676 Columbia Parkway
Cincinnati, OH 45226
513-841-4382

Requests for Information:
1-800-35-NIOSH
or 1-800-356-4674

EPA Regional Offices

Address inquiries to the contacts in the EPA Regional Offices at the following addresses:

(CT,ME,MA,NH,RI,VT)
EPA Region 1
John F. Kennedy Federal Building
Boston, MA 02203
617-565-3232 (indoor air)
617-565-4502 (radon)
617-565-3744 (asbestos)
617-565-3265 (NESHAP)

(NJ,NY,PR,VI)
EPA Region 2
26 Federal Plaza
New York, NY 10278
212-264-4410 (indoor air)
212-264-4410 (radon)
212-264-6671 (asbestos)
212-264-6770 (NESHAP)

(DE,DC,MD,PA,VA,WV)
EPA Region 3
841 Chestnut Building
Philadelphia, PA 19107
215-597-8322 (indoor air)
215-597-4084 (radon)
215-597-3160 (asbestos)
215-597-1970 (NESHAP)

(AL,FL,GA,KY,MS,NC,SC,TN)
EPA Region 4
345 Courtland Street, NE
Atlanta, GA 30365
404-347-2864 (indoor air)
404-347-3907 (radon)
404-347-5014 (asbestos)
404-347-5014 (NESHAP)

(IL,IN,MI,MN,OH,WI)
EPA Region 5
230 South Dearborn Street
Chicago, IL 60604
Region 5 Environmental Hotline:
1-800-572-2515 (IL)
1-800-621-8431 (IN, MI, MN, OH, WI)
312-886-7930 (outside Region 5)

(AR,LA,NM,OK,TX)
EPA Region 6
1445 Ross Avenue
Dallas, TX 75202-2733
214-655-7223 (indoor air)
214-655-7223 (radon)
214-655-7223 (asbestos)
214-655-7223 (NESHAP)

(IA,KS,MO,NE)
EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
913-551-7020 (indoor air)
913-551-7020 (radon)
913-551-7020 (asbestos)
913-551-7020 (NESHAP)

(CO,MT,ND,SD,UT,WY)
EPA Region 8
999 18th Street Suite 500
Denver, CO 80202-2405
303-293-1440 (indoor air)
303-293-0988 (radon)
303-293-1442 (asbestos)
303-294-7611 (NESHAP)

(AZ,CA,HI,NV,AS,GU)
EPA Region 9
75 Hawthorne Street, A-1-1
San Francisco, CA 94105
415-744-1133 (indoor air)
415-744-1045 (radon)
415-744-1136 (asbestos)
415-744-1135 (NESHAP)

(AK,ID,OR,WA)
EPA Region 10
1200 Sixth Avenue
Seattle, WA 98101
206-553-2589 (indoor air)
206-553-7299 (radon)
206-553-4762 (asbestos)
206-553-1757 (NESHAP)

OSHA Regional Offices

(CT,ME,MA,NH,RI,VT)
OSHA Region 1
133 Portland Street, 1st Floor
Boston, MA 02114
617-565-7164

(NJ,NY,PR,VI)
OSHA Region 2
210 Varick Street, Room 670
New York, NY 10014
212-337-2376

(DE,DC,MD,PA,VA,WV)
OSHA Region 3
Gateway Building, Suite 2100
3535 Market Street
Philadelphia, PA 19104
215-596-1201

(AL,FL,GA,KY,MS,NC,SC,TN)
OSHA Region 4
1375 Peachtree Street, NE, Suite 587
Atlanta, GA 30367
404-347-3573

(IL,IN,MI,MN,OH,WI)
OSHA Region 5
230 South Dearborn Street, Room 3244
Chicago, IL 60604
312-353-2220

(AR,LA,NM,OK,TX)
OSHA Region 6
525 Griffin Street, Room 602
Dallas, TX 75202
214-767-4731

(IA,KS,MO,NE)
OSHA Region 7
911 Walnut Street, Room 406
Kansas City, MO 64106
816-426-5861

(CO,MT,ND,SD,UT,WY)
OSHA Region 8
Federal Building, Room 1576
1961 Stout Street
Denver, CO 80294
303-844-3061

(AZ,CA,HI,NV,AS,GU)
OSHA Region 9
71 Stevenson Street, 4th Floor
San Francisco, CA 94105
415-744-6570

(AK,ID,OR,WA)
OSHA Region 10
1111 Third Avenue, Suite 715
Seattle, WA 98101-3212
206-442-5930

OTHER FEDERAL AGENCIES WITH INDOOR AIR RESPONSIBILITIES

Bonneville Power Administration
P.O. Box 3621-RMRD
Portland, OR 97208
503-230-5475
Provides radon-resistant construction techniques, source control, and removal technology for indoor air pollutants.

Consumer Product Safety Commission
5401 Westbard Avenue
Bethesda, MD 20207
1-800-638-CPSC
Reviews complaints regarding the safety of consumer products and takes action to ensure product safety.

General Services Administration
18th and F Streets, NW
Washington, DC 20405
202-501-1464
Writes indoor air quality policy for Federal buildings. Provides proactive indoor air quality building assessments. Assesses complaints and provides remedial action.

U.S. Department of Energy
Office of Conservation and Renewable Energy
1000 Independence Avenue, SW, CE-43
Washington, DC 20585
202-586-9455
Quantifies the relationship among reduced infiltration, adequate ventilation, and acceptable indoor air quality.

U.S. Department of Health and Human Services
Office on Smoking and Health
National Center for Chronic Disease Prevention and Health Promotion
Centers for Disease Control
1600 Clifton Road, NE
Mail Stop K50
Atlanta, GA 30333
404-488-5705
Disseminates information about the health effects of passive smoking and strategies for eliminating exposure to environmental tobacco smoke.

Tennessee Valley Authority
Occupational Hygiene Department
328 Multipurpose Building
Muscle Shoals, AL 35660
205-386-2314
Provides building surveys and assessments associated with employee indoor air quality complaints.

STATE AND LOCAL AGENCIES

Your questions and concerns about indoor air problems can frequently be answered most readily by the government agencies in your State or locality. Responsibilities for indoor air quality issues are usually divided among many different agencies. You will often find that calling or writing the agencies responsible for health or air quality control is the best way to start getting information from your State or local government. The EPA and Public Health Foundation publication, ***Directory of State Indoor Air Contacts***, lists State agency contacts. (See publications list for information on ordering this publication.)

PRIVATE SECTOR CONTACTS

The private sector organizations that have information for the public on indoor air quality issues in commercial and public buildings include the following:

Building Management Associations

Association of Physical Plant Administrators of Universities and Colleges
1446 Duke Street
Alexandria, VA 22314-3492
703-684-1446

Building Owners and Managers Association International
1201 New York Ave., NW, Suite 300
Washington, DC 20005
202-408-2684

Institute of Real Estate Management
430 North Michigan Avenue
Chicago, IL 60611
312-661-1930

International Council of Shopping Centers
1199 North Fairfax Street, Suite 204
Alexandria, VA 22314
703-549-7404

International Facilities Management Association
Summit Tower, Suite 1710
11 Greenway Plaza
Houston, TX 77046
713-623-4362

National Apartment Association
1111 14th Street, NW, Suite 900
Washington, DC 20005
202-842-4050

National Association of Industrial and Office Parks
1215 Jefferson Davis Highway, Suite 100
Arlington, VA 22202
703-979-3400

Professional and Standard Setting Organizations

Air and Waste Management Association
P.O. Box 2861
Pittsburgh, PA 15230
412-232-3444

Air-Conditioning and Refrigeration Institute
1501 Wilson Blvd., Suite 600
Arlington, VA 22209
703-524-8800

American Conference of Governmental Industrial Hygienists
6500 Glenway Avenue, Building D-7
Cincinnati, OH 45211
513-661-7881

American Industrial Hygiene Association
P.O. Box 8390
345 White Pond Drive
Akron, OH 44320
216-873-2442

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103
215-299-5571

American Society of Heating, Refrigerating, and Air-Conditioning Engineers
1791 Tullie Circle, NE
Atlanta, GA 30329
404-636-8400

National Conference of States on Building Codes and Standards, Inc.
505 Huntmar Park Drive, Suite 210
Herndon, VA 22070
703-437-0100

Product Manufacturers

Adhesive and Sealant Council
1627 K Street, NW, Suite 1000
Washington, DC 20006-1707
202-452-1500

Asbestos Information Association
1745 Jefferson Davis Highway, Room 509
Arlington, VA 22202
703-979-1150

Business Council on Indoor Air Quality
1225 19th Street, Suite 300
Washington, DC 20036
(202) 775-5887

Carpet and Rug Institute
310 Holiday Avenue
Dalton, GA 30720
404-278-3176

Chemical Specialties Manufacturers Association
1913 I Street, NW
Washington, DC 20006
202-872-8110

Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
415-855-2902

Formaldehyde Institute, Inc.
1330 Connecticut Avenue, NW
Washington, DC 20036
202-822-6757

Foundation of Wall and Ceiling Industries
1600 Cameron Street
Alexandria, VA 22314-2705
703-548-0374

Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, IL 60631
312-399-8304

National Paint and Coatings Association
1500 Rhode Island Avenue, NW
Washington, DC 20005
202-462-6272

Thermal Insulation Manufacturers Association Technical Services
Air Handling Committee
1420 King Street
Alexandria, VA 22314
(703) 684-0474

Building Service Associations

Air-Conditioning and Refrigeration Institute
1501 Wilson Boulevard, 6th floor
Arlington, VA 22209
703-524-8800

Air-Conditioning Contractors of America
1513 16th Street, NW
Washington DC 20036
202-483-9370

American Consulting Engineers Council
1015 15th Street, NW, Suite 802
Washington, DC 20005
202-347-7474

Associated Air Balance Council
1518 K Street, NW
Washington, DC 20005
202-737-0202

Association of Energy Engineers
4025 Pleasantdale Rd., Suite 420
Atlanta, GA 30340
404-447-5083

Association of Specialists in Cleaning and Restoration International
10830 Annapolis Junction Road, Suite 312
Annapolis Junction, MD 20701
301-604-4411

National Air Duct Cleaners Association
1518 K Street, NW, Suite 503
Washington, DC 20005
202-737-2926

National Association of Power Engineers
3436 Haines Way, Suite 101
Falls Church, VA 22041
703-845-7055

National Energy Management Institute
601 North Fairfax Street, Suite 160

Alexandria, VA 22314
703-739-7100

National Environmental Balancing Bureau
1385 Piccard Drive
Rockville, MD 20850
301-977-3698

National Pest Control Association
8100 Oak Street
Dunn Loring, VA 22027
703-573-8330

Sheet Metal and Air Conditioning Contractors National Association
4201 LaFayette Center Drive
Chantilly, VA 22021
703-803-2980

Unions

AFL-CIO
Department of Occupational Safetyand Health
815 16th Street, NW
Washington, DC 20006
202-637-5000

American Federation of Government Employees
80 F Street, NW
Washington, DC 20001
202-737-8700

American Federation of State, County, and Municipal Employees
1625 L Street, NW
Washington, DC 20036
(202) 429-1215

American Federation of Teachers
555 New Jersey Avenue, NW
Washington, DC 20001
202-879-4400

Communication Workers of America
501 3rd Street, NW
Washington, DC 20001
202-434-1160

International Union of Operating Engineers
1125 17th Street, NW
Washington, DC 20036
202-429-9100

Service Employees International Union
1313 L Street, NW
Washington, DC 20005

Environmental/Health/ Consumer Organizations

American Academy of Allergy and Immunology
611 East Wells Street
Milwaukee, WI 53202
414-272-6071

American Lung Association
or your local lung association
1740 Broadway
New York, NY 10019

Consumer Federation of America
1424 16th Street, NW, Suite 604
Washington, DC 20036

National Center for Environmental Health Strategies
1100 Rural Avenue
Voorhees, NJ 08043
609-429-5358

National Environmental Health Association
720 South Colorado Blvd.
South Tower, Suite 970
Denver, CO 80222
303-756-9090

National Foundation for the Chemically Hypersensitive
P.O. Box 9
Wrightsville Beach, NC 28480
517-697-3989

Occupational Health Foundation
1126 16th Street, NW
Washington, DC 20036
202-842-7840

PUBLICATIONS

Items marked * are available from **EPA Public Information Center** (PM-211B), 401 M Street, SW, Washington, DC 20460. 202-382-2080.

Items marked ** are available from **TSCA Assistance Hotline** (TS-799), 401 M Street, SW, Washington, DC 20460. (202)554-1404.

Items marked*** are available from **NIOSH Publications Dissemination,** 4676 Columbia Parkway, Cincinnati, OH 45202. 513-533-8287.

General Information

Cone, James E. and Michael J. Hodgson, MD, MPH. ***Problem Buildings: Building-Associated Illness and the Sick Building Syndrome.*** 1989. From the series "Occupational Medicine: State of the Art Reviews." Hanley & Belfus, Inc., 210 South 13th Street, Philadelphia, PA 19107.

Godish, Thad. ***Indoor Air Pollution Control.*** 1989. Lewis Publishers, 121 South Main Street, Chelsea, MI 48118.

Rajhans, G.S., ***Report of the Interministerial Committee on Indoor Air Quality,*** 1988. Contact: G. Rajhans, Health and Safety Support Services Branch, Ministry of Labour, 400 University Avenue, 7th Floor, Toronto, Ontario, Canada M7A 1T7.

Sheet Metal and Air Conditioning Contractor's National Association, Inc. (SMACNA). ***Indoor Air Quality.*** 1988. 8224 Old Courthouse Road, Vienna, Virginia 22180.

U.S. Environmental Protection Agency. and the Public Health Foundation. ***Directory of State Indoor Air Contacts.*** Updated, 1991. *

U.S. Environmental Protection Agency. ***Designing for Good Indoor Air Quality: An Introduction for Design Professionals.*** (In progress).

U.S. Environmental Protection Agency. ***Project Summaries: Indoor Air Quality in Public Buildings.*** 1988. *Contains findings of research on IAQ in 10 new public and commercial buildings and on building material emissions.**

U.S. Environmental Protection Agency and the U.S. Consumer Product Safety Commission. ***The Inside Story: A Guide to Indoor Air Quality.*** 1988. *Addresses residential indoor air quality primarily, but contains a section on offices.* *

U.S. Environmental Protection Agency. ***Sick Building Syndrome.*** Indoor Air Quality Fact Sheet #4. Revised, 1991.*

U.S. Environmental Protection Agency. ***Ventilation and Air Quality in Offices.*** Indoor Air Quality Fact Sheet #3. Revised, 1990.*

World Health Organization. ***Air Quality Guidelines for Eiurope.*** 1987. WHO Regional Publications, European Series No. 23. Available from WHO Publications Center USA, 49 Sheridan Avenue, Albany, NY 12210.

Asbestos

Keyes, Dale L. and Jean Chesson. ***A Guide to Monitoring Airborne Asbestos in Buildings.*** 1989. Environmental Sciences, Inc., 105 E. Speedway Blvd., Tucson, Arizona 85705.

U.S. Department of Health and Human Services, Public Health Service, U.S. Centers for Disease Control, National Institute of Occupational Safety and Health. ***Testimony of NIOSH on the Occupational Safety and Health Administration's Proposed Rule on Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite.*** June 1984, May 1990, and January 1991. NIOSH Docket Office, C-34, 4676 Columbia Parkway, Cincinnati, OH 45226.

U.S. Environmental Protection Agency. ***A Guide to Respiratory Protection for the Asbestos Abatement Industry.*** 1986. EPA 560/OTS 86-001. **

U.S. Environmental Protection Agency. ***Abatement of Asbestos-Containing Pipe Insulation.*** 1986. Technical Bulletin No. 1986-2. **

U.S. Environmental Protection Agency. ***Asbestos Abatement Projects: Worker Protection.*** Final Rule 40 CFR. 763. February 1987. **

U.S. Environmental Protection Agency. ***Asbestos Ban and Phaseout Rule.*** 40 CFR 763.160 to 763.179. Federal Register, July 12, 1989. **

U.S. Environmental Protection Agency. ***Asbestos in Buildings: Guidance for Service and Maintenance Personnel*** (in English and Spanish). 1985. EPA 560/5-85-018. ("Custodial Pamphlet"). **

U.S. Environmental Protection Agency. ***Asbestos in Buildings: Simplified Sampling Scheme for Surfacing Materials.*** 1985. 560/5-85-030A. ("Pink Book"). **

U.S. Environmental Protection Agency. ***Guidance for Controlling Asbestos-Containing Materials in Buildings.*** 1985. EPA 560/5-85-024. ("Purple Book"). **

U.S. Environmental Protection Agency. ***Guidelines for Conducting the AHERA TEM Clearance Test to Determine Completion of an Asbestos Abatement Project,*** EPA 560/5-89-001. **

U.S. Environmental Protection Agency. ***Managing Asbestos In Place: A Building Owner's Guide to Operations and Maintenance Programs for Asbestos-Containing Materials,*** 1990. ("Green Book").**

U.S. Environmental Protection Agency. ***Measuring Airborne Asbestos Following An Abatement Action.*** 1985. EPA 600/4-85-049. ("Silver Book"). **

U.S. Environmental Protection Agency. ***National Emission Standards for Hazardous Air Pollutants.*** 40 Code of Federal Regulation 61. April 1984. **

U.S. Environmental Protection Agency. ***Transmission Electron Microscopy Asbestos Laboratories: Quality Assurance Guidelines.*** 1989. EPA 560/5-90-002.**

U.S. Department of Labor. OSHA Regulations. 29 Code of Federal Regulation 1910.1001. ***General Industry Asbestos Standard*** . 29 Code of Federal Regulation 1926.58. ***Construction Industry Asbestos Standard.*** June 1986; Amended September 1988. DOL-OSHA Docket, 200 Constitution Avenue, NW, Room N 2625, Washington, DC 20210

U.S. Department of Labor. OSHA Regulations. 29 Code of Federal Regulation 1910.134 ***Respiratory Protection Standard.*** June 1974. DOL-OSHA Docket, 200 Constitution Avenue, NW, Room N 2625, Washington, DC 20210

Biologicals

American Council of Governmental Industrial Hygienists. ***Guidelines for the Assessment of Bioaerosols in the Indoor Environment.*** 1989. 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211.

Morey, P., J. Feeley, and J. Otten. ***Biological Contaminants in Indoor Environments.*** 1990. American Society for Testing and Materials Publications, 1916 Race Street, Philadelphia, PA 19103.

Building Management, Investigation, and Remediation

Bazerghi, Hani and Catherine Arnoult. ***Practical Manual for Good Indoor Air Quality.*** 1989. Quebec Association for Energy Management. 1259 Berri Street, Suite 510, Montreal, Quebec, Canada, H2L 4C7.

Hansen, Shirley J., ***Managing Indoor Air Quality.*** 1991. Fairmont Press, 700 Indian

Trail, Lilburn, GA 30247.

U.S. Department of Health and Human Services. Public Health Service. Centers for Disease Control. National Institute for Occupational Safety and Health. ***Indoor Air Quality: Selected References.*** 1989.***

U.S. Department of Health and Human Services. Public Health Service. Centers for Disease Control. National Institute for Occupational Safety and Health. ***Guidance for Indoor Air Quality Investigations.*** 1987.***

Weekes, Donald M. and Richard B. Gammage. ***The Practitioner's Approach to Indoor Air Quality Investigations.*** Proceedings of the Indoor Air Quality International Symposium. 1989. American Industrial Hygiene Association, P.O. Box 8390, Akron Ohio 44320.

Environmental Tobacco Smoke

National Research Council. ***Environmental Tobacco Smoke: Measuring Exposures and Assessing Health Effects.*** 1986. National Academy Press. 2001 Wisconsin Avenue, NW, Washington, DC 20418.

U.S. Department of Health and Human Services. Public Health Service. Office on Smoking and Helath. ***The Health Consequences of Involuntary Smoking, A Report of the Surgeon General.*** 1986. 1600 Clifton Road, NE (Mail Stop K50) Atlanta, GA 30333.

U.S. Department of Health and Human Services, Public Health Service. Centers for Disease Control, National Institute for Occupational Safety and Health. ***Current Intelligence Bulletin 54: Environmental Tobacco Smoke in the Workplace—Lung Cancer and Other Health Effects.*** DHHS (NIOSH) Publication No. 91-108. 1991.***

U.S. Department of Health and Human Services, National Cancer Institute. Office of Cancer Communications. ***A series of one-page information sheets on all aspects of smoking in the workplace.*** For copies, call 1-800-4-CANCER.

U.S. Environmental Protection Agency. ***Environmental Tobacco Smoke.*** Indoor Air Quality Fact Sheet #5. 1989.*

U.S. Environmental Protection Agency. ***Environmental Tobacco Smoke: A Guide to the Development of Effective Smoking Policies.*** (In progress.) *

U.S. Environmental Protection Agency. ***Health Effects of Passive Smoking: Assessment of Lung Cancer in Adults and Respiratory Disorders in Children.***   (In progress.) *

PCBs

U.S. Department of Health And Human Services. Public Health Service. Centers for Disease Control.. National Institute of Occupational Safety and Health. ***Current Intelligence Bulletin 45: Polychlorinated Biphenyls—Potential Health Hazards from Electrical Equipment Fires or Failures*** . DHHS (NIOSH) Publication No. 86-111. 1977. Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

U.S. Department of Health and Human Services. Public Health Service. Centers for Disease Control. National Institute for Occupational Safety and Health. ***A Recommended Standard for Occupational Exposure to Polychlorinated Biphenyls*** DHHS (NIOSH) Publication No. 77-225. 1977. Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

U.S. Environmental Protection Agency. ***Transformers and the Risk of Fire: A Guide for Building Owners.***   1986. OPA/86-001. **

Radon

U.S. Environmental Protection Agency.

State Proficiency Report. 1991. EPA 520/1-94-014. Available from State radon offices. *List of laboratories that have demonstrated com- petence in radon measurement analysis.*

Standards and Guidelines

American Conference of Government Industrial Hygienists. ***Threshold Limit Values and Biological Exposure Indices.*** 1990-1991. 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211.

U.S. Department of Health and Human Services. Public Health Service. Centers for Disease Control. National Institute for Occupational Safety and Health . ***NIOSH Recommendations for Occupational Safety and Health. Compendium of Policy Documents and Statements.*** DHHS (NIOSH) Publications 91-109. 1991.***

U.S. Department of Labor. OSHA Rrgulations. 29 CFR Part 1910.1000. ***OSHA Standards for Air Contaminants.*** Available from the U.S. Government Printing Office, Washington, DC 20402. 202-783-3238. *Additional health standards for some specific air contaminants are also available in Subpart Z.*

Ventilation/Thermal Comfort

Brief descriptions of the ASHRAE standards listed below are included in *Appendix B.* ASHRAE materials are available from their Publication Sales Department, 1791 Tullie Circle, NE, Atlanta, GA 30329. 404-636-8400.

ASHRAE Guideline 1-1989. ***Guideline for the Commissioning of HVAC Systems.*** 1989.
ASHRAE Journal. ***October 1989 issue.*** *Several articles describing ASHRAE Standard 62-1989.*

ASHRAE Standard 52-76. ***Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter.*** 1976.

ASHRAE Standard 55-1981. ***Thermal Environmental Conditions for Human Occupancy.*** 1981.

ASHRAE Standard 62-1989. ***Ventilation for Acceptable Indoor Air Quality.*** 1989.

National Conference of States on Building Codes and Standards, Inc. ***The Ventilation Directory.*** 505 Huntmar Park Drive, Suite 210, Herndon, VA 22070. 703-481-2020. *Summarizes natural, mechanical, and exhaust ventilation requirements of the model codes, ASHRAE standards, and unique State codes.*

TRAINING

American Industrial Hygiene Association (AIHA). P.O. Box 8390, 345 White Pond Drive, Akron, OH 44320. 216-873-2442. *Sponsors indoor air quality courses in conjunction with meetings for AIHA members only.*

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). 1791 Tullie Circle NE, Atlanta, GA 30329. 404-636-8400. *Sponsors professional development seminars on indoor air quality.*

NIOSH Division of Training and Manpower Development and NIOSH-funded Educational Resource Centers. 4676 Columbia Parkway, Cincinnati, OH 45226. 513-8221. *Provide training to occupational safety and health professionals and paraprofessionals.*

OSHA Training Institute. 155 Times Drive, Des Plaines, Il 60018. 708-297-4913. *Provides courses to assist health and safety professionals in evaluating indoor air quality.*

Indoor Air Quality Forms

This section of the document is a collection of the forms that appear or are mentioned in the text. Consider making copies of the forms, blocking out the page information at the bottom of the copies, and then reproducing these copies for use in your building. Some or all of them may require adaptation to meet your specific needs. Blank formatted sheets are included for preparing your own *HVAC Checklist* and *Pollutant and Source Inventory*.

The forms appear in the following sequence:

Management Checklist: (4 pages): for keeping track of the elements of the IAQ profile and IAQ management plan.

Pollutant Pathway Record For IAQ Profiles: for identifying areas in which negative or positive pressures should be maintained.

Zone/Room Record: for recording information on a room-by-room basis on the topics of room use, ventilation, and occupant population.

Ventilation Worksheet: to be used in conjunction with the Zone/Room Record when calculating quantities of outdoor air that are being supplied to individual zones or rooms.

IAQ Complaint Form: to be filled out by the complainant or by a staff person who receives information from the complainant.

Incident Log: for keeping track of each IAQ complaint or problem and how it is handled.

Occupant Interview (2 pages): for recording the observations of building occupants in relation to their symptoms and conditions in the building .

Occupant Diary: for recording incidents of symptoms and associated observations as they occur.

Log of Activities and System Operation: for recording activities and equipment operating schedules as they occur.

HVAC Checklist - Short Form (4 pages): to be used as a short form for investigating an IAQ problem, or for periodic inspections of the HVAC system. Duplicate pages 2 through 4 for each large air handling unit.

HVAC Checklist - Long Form (14 pages, followed by one blank formatted sheet): to be used for detailed inspections of the HVAC system or as a long form for investigating an IAQ problem. Duplicate pages 1 through 11 for each large air handling unit.

Pollutant Pathway Form For Investigations: to be used in conjunction with a floor plan of the building.

Pollutant and Source Inventory (6 pages, followed by one blank formatted sheet): to be used as a general checklist of potential indoor and outdoor pollutant sources.

Chemical Inventory: for recording information about chemicals stored or used within the building.

Hypothesis Form: to be used for summarizing what has been learned during the building investigation, a tool to help the investigator collect his or her thoughts.

BLANK FORMS

Building Air Quality

Printed on Recycled Paper

IAQ Management Checklist

Building Name: ______________________ Date: ______________

Address: ______________________

Completed by (name/title): ______________________

Use this checklist to make sure that you have included all necessary elements in your IAQ profile and IAQ management plan. *Sections 4 and 5* discuss the development of the IAQ profile and IAQ management plan.

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
IAQ PROFILE			
Collect and Review Existing Records			
HVAC design data, operating instructions and manuals			
HVAC maintenance and calibration records, testing and balancing reports			
Inventory of locations where occupancy, equipment, or building use has changed			
Inventory of complaint locations			
Conduct a Walkthrough Inspection of the Building			
List of responsible staff and/or contractors, evidence oftraining, and job descriptions			
Identification of area where positive or negative pressure should be maintained			
Record of locations that need monitoring or correction			
Collect Detailed Information			
Inventory of HVAC system components needing repair, adjustment, or replacement			
Record of control settings and operating schedules			

IAQ Management Checklist

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
Plan showing airflow directions or pressure differentials in significant areas			
Inventory of significant pollutant sources and their locations			
MSDSs for supplies and hazardous substances that are stored or used in the building			
Zone/Room Record			
IAQ MANAGEMENT PLAN			
Select IAQ Manager			
Review IAQ Profile			
Assign Staff Responsibilities/ Train Staff			
Facilities Operation and Maintenance			
n confirm that equipment operating schedules are appropriate			
n confirm appropriate pressure relation-ships between building usage areas			
n compare ventilation quantities to design, codes, and ASHRAE 62-1989			
n schedule equipment inspections per preventive maintenance or recom-mended maintenance schedule			
n modify and use HVAC Checklist(s); update as equipment is added, re-moved, or replaced			
n schedule maintenance activities to avoid creating IAQ problems			

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
n review MSDSs for supplies; request additional information as needed			
n consider using alarms or other devices to signal need for HVAC maintenance (e.g., clogged filters)			
Housekeeping			
n evaluate cleaning schedules and procedures; modify if necessary			
n review MSDSs for products in use; buy different products if necessary			
n confirm proper use and storage of materials			
n review trash disposal procedures; modify if necessary			
Shipping and Receiving			
n review loading dock procedures (*Note:* If air intake is located nearby, take precautions to prevent intake of exhaust fumes.)			
n check pressure relationships around loading dock			
Pest Control			
n consider adopting IPM methods			
n obtain and review MSDSs; review handling and storage			
n review pest control schedules and procedures			
n review ventilation used during pesticide application			

IAQ Management Checklist

Item	Date begun or completed (as applicable)	Responsible person (name, telephone)	Location ("NA" if the item is not applicable to this building)
Occupant Relations			
n establish health and safety committee or joint tenant/ management IAQ task force			
n review procedures for responding to complaints; modify if necessary			
n review lease provisions; modify if necessary			
Renovation, Redecorating, Remodeling			
n discuss IAQ concerns with architects, engineers, contractors, and other professionals			
n obtain MSDSs; use materials and procedures that minimize IAQ problems			
n schedule work to minimize IAQ problems			
n arrange ventilation to isolate work areas			
n use installation procedures that minimize emissions from new furnishings			
Smoking			
n eliminate smoking in the building			
n if smoking areas are designated, provide adequate ventilation and maintain under negative pressure			
n work with occupants to develop appropriate non-smoking policies, including implementation of smoking cessation programs			

Pollutant Pathway Record For IAQ Profiles

This form should be used in combination with a floor plan such as a fire evacuation plan.

Building Name: ____ File Number: ________________________

Address: ____

Completed by:______________________________ Title: ________________________ Date: ______________

Sections 2, 4 and 6 discuss pollutant pathways and driving forces.

Building areas that contain contaminant sources (e.g., bathrooms, food preparation areas, smoking lounges, print rooms, and art rooms) should be maintained under negative pressure relative to surrounding areas. Building areas that need to be protected from the infiltration of contaminants (e.g., hallways in multi-family dwellings, computer rooms, and lobbies) should be maintained under positive pressure relative to the outdoors and relative to surrounding areas.

List the building areas in which pressure relationships should be controlled. As you inspect the building, put a Y or N in the “Needs Attention” column to show whether the desired air pressure relationship is present. Mark the floor plan with arrows, plus signs (+) and minus signs (-) to show the airflow patterns you observe, using chemical smoke or a micromanometer.

Building areas that appear isolated from each other may be connected by airflow passages such as air distribution zones, utility tunnels or chases, party walls, spaces above suspended ceilings (whether or not those spaces are serving as air plenums), elevator shafts, and crawlspaces. If you are aware of pathways connecting the room to identified pollutant sources (e.g., items of equipment, chemical storage areas, bathrooms), it may be helpful to record them in the “Comments” column, on the floor plan, or both.

Building Area (zone, room)	**Use**	**Intended Pressure**		**Needs Attention? (Y/N)**	**Comments**
		Positive (+)	**Negative (-)**		

Zone/Room Record

Building Name: ______________________ File Number: ______________________ Date: ______________

Address: ______________________ Completed by: ______________________ Title: ______________

This form is to be used differently depending on whether the goal is to prevent or to diagnose IAQ problems. During the development of a profile, this form should be used to record more general information about the entire building; during an investigation, the form should be used to record more detailed information about the complaint area and areas surrounding the complaint area or connected to it by pathways.

Use the last three columns when underventilation is suspected. Use the Ventilation Worksheet and Appendix A to estimate outdoor air quantities Compare results to the design specifications, applicable building codes, or ventilation guidelines such as ASHRAE 62-1989. (See Appendix A for some outdoor air quantities required by ASHRAE 62-1989.) Note: For VAV systems, minimum outdoor air under reduced flow conditions must be considered.

PROFILE AND DIAGNOSIS INFORMATION					DIAGNOSIS INFORMATION ONLY		
Building Area (Zone/Room)	Use**	Source of Outdoor Air*	Mechanical Exhaust? (Write "No" or estimate cfm airflow)	Comments	Peak Number of Occupants or Sq. Ft. Floor Area**	Total Air Supplied (in cfm)***	Outdoor Air Supplied per Person or per 150 Sq. Ft. Area (in cfm)****

* Sources might include air handling unit (e.g., AHU-4), operable windows, transfer from corridors.
** Underline the information in this column if corrent use or number of occupants is different from design specifications.
*** Mark the information with a P if it comes from the mechanical plans or an M if it comes from actual measurements, such as recent test and balance reports.
**** ASHRAE 62-1989 gives ventilation guidance per 150 sq. ft.

Ventilation Worksheet

Building Name: ____________________ File Number: ____________

Address: ______________________________

Completed by (name):____________________ Date: ____________

This worksheet is designed for use with the **Zone/Room Record.** Appendix A provides guidance on methods of estimating the amount of ventilation (outdoor) air being introduced by a particular air handling unit. Appendix B discusses the ventilation recommendations of ASHRAE Standard 62-1989, which was developed for the purpose of preventing indoor air quality problems. Formulas are given below for calculating outdoor air quantities using thermal or CO_2 information.

The equation for calculating outdoor air quantities using thermal measurements is:

$$\text{Outdoor air (in percent)} = \frac{T_{\text{return air}} - T_{\text{mixed air}}}{T_{\text{return air}} - T_{\text{outdoor air}}} \times 100$$

Where: T = temperature in degrees Fahrenheit

The equation for calculating outdoor quantities using carbon dioxide measurements is:

$$\text{Outdoor air (in percent)} = \frac{C_s - C_r}{C_0 - C_r} \times 100$$

Where: C_s= ppm of carbon dioxide in the supply air (if measured in a room), or
C_s= ppm of carbon dioxide in the mixed air (if measured at an air handler)
C_r= ppm of carbon dioxide in the return air
C_o= ppm of carbon dioxide in the outdoor air

Using the table below to estimate the ventilation rate in any room or zone. Note: ASHRAE 62-1989 generally states ventilation (outdoor air) requirements on an occupancy basis; for a few types of spaces, however, requirements are given on a floor area basis. Therefore, this table provides a process of calculating ventilation (outdoor air) on either an occupancy or floor area basis.

Zone/Room	Percent of Outdoor Air A	Total Air Supplied to Zone/Room (cfm) B	Peak Occupancy (number of people) or Floor Area (square feet) C	$D=\frac{B}{C}$ Total Air Supplied Per Person (or per square foot area) D	E = (Ax100) x D Outdoor Air Supplied Per Person (or per square foot area) E

Indoor Air Quality Complaint Form

This form can be filled out by the building occupant or by a member of the building staff.

Occupant Name: ____ Date: ________________________

Department/Location in Building: ____ Phone: ______________________

Completed by: ________________________________ Title: ______________________ Phone: __________________

This form should be used if your complaint may be related to indoor air quality. Indoor air quality problems include concerns with temperature control, ventilation, and air pollutants. Your observations can help to resolve the problem as quickly as possible. Please use the space below to describe the nature of the complaint and any potential causes.

We may need to contact you to discuss your complaint. What is the best time to reach you? _________________________

So that we can respond promptly, please return this form to: ____

IAQ Manager or Contact Person

____

Room, Building, Mail Code

OFFICE USE ONLY

File Number: _________________________ Received By: ________________________________ Date Received: __________

Incident Log

Building Name: ______________________________ Dates (from): ____________ (to): ____________

Address: ______________________________ Completed by (name): ______________________________

File Number	Date	Problem Location	Investigation Record (check the forms that were used)									Outcome/Comments (use more than one line if needed)	Log Entry By (initials)
			Complaint Form	Occupant Interview	Occupant Diary	Log of Activities	Zone/Room Record	HVAC Checklist	Pollutant Pathway	Source Inventory	Hypothesis Form		

Occupant Interview

Building Name: ______________________________________ File Number: ________________

Address: ____

Occupant Name: ____________________________ Work Location: ____________________________

Completed by:____________________________ Title: __________________ Date:___________

Sections 4 discusses collecting and interpreting information from occupants.

SYMPTOM PATTERNS

What kind of symptoms or discomfort are you experiencing?

Are you aware of other people with similar symptoms or concerns? Yes ___________ No ___________

If so, what are their names and locations? ____

____

Do you have any health conditions that may make you particularly susceptible to environmental problems?

- q contact lenses
- q allergies
- q chronic cardiovascular disease
- q chronic respiratory disease
- q chronic neurological problems
- q undergoing chemotherapy or radiation therapy
- q immune system suppressed by disease or other causes

TIMING PATTERNS

When did your symptoms start?

When are they generally worst?

Do they go away? If so, when?

Have you noticed any other events (such as weather events, temperature or humidity changes, or activities in the building) that tend to occur around the same time as your symptoms?

Occupant Interview

SPATIAL PATTERNS

Where are you when you experience symptoms or discomfort?

Where do you spend most of your time in the building?

ADDITIONAL INFORMATION

Do you have any observations about building conditions that might need attention or might help explain your symptoms (e.g., temperature, humidity, drafts, stagnant air, odors)?

Have you sought medical attention for your symptoms?

Do you have any other comments?

Occupant Diary

Occupant Name:___________________________ Title: ___________________________ Phone: _____________________

Location: ____ File Number: _____________________________

On the form below, please record each occasion when you experience a symptom of ill-health or discomfort that you think may be linked to an environmental condition in this building.

It is important that you record the time and date and your location within the building as accurately as possible, because that will help to identify conditions (e.g., equipment operation) that may be associated with your problem. Also, please try to describe the severity of your symptoms (e.g., mild, severe) and their duration (the length of time that they persist). Any other observations that you think may help in identifying the cause of the problem should be noted in the "Comments" column. Feel free to attach additional pages or use more than one line for each event if you need more room to record your observations.

Section 6 discusses collecting and interpreting occupant information.

Time/Date	Location	Symptom	Severity/Duration	Comments

Log of Activities and System Operations

Building Name: ________________________ Address: ___________________________ File Number:_________________

Completed by:___________________________________ Title: __________________________ Phone: ________________

On the form below, please record your observations of the HVAC system operation, maintenance activities, and any other information that you think might be helpful in identifying the cause of IAQ complaints in this building. Please report any other observations (e.g., weather, other associated events) think may be important as well.

Feel free to attach additional pages or use more than one line for each event.

Equipment and activities of particular interest:

Air Handler(s): ____

Exhaust Fan(s): ____

Other Equipment or Activities: ____

Date/Time	Day of Week	Equipment Item/Activity	Observations/Comments

HVAC Checklist - Short Form

Building Name: ______________________ Address: ______________________

Completed by: ______________________ Date: __________ File Number: __________

Sections 2, 4 and 6 and Appendix B discuss the relationships between the HVAC system and indoor air quality.

MECHANICAL ROOM

- Clean and dry? ______________ Stored refuse or chemicals? ______________
- Describe items in need of attention ______________________

MAJOR MECHANICAL EQUIPMENT

- Preventive maintenance (PM) plan in use? ______________________

Control System

- Type ______________________
- System operation ______________________
- Date of last calibration ______________________

Boilers

- Rated Btu input __________ Condition ______________________
- Combustion air: is there at least one square inch free area per 2,000 Btu input? ______________
- Fuel or combustion odors ______________________

Cooling Tower

- Clean? no leaks or overflow? ______________ Slime or algae growth? ______________
- Eliminator performance ______________________
- Biocide treatment working? (list type of biocide) ______________________
- Spill containment plan implemented? ______________ Dirt separator working? ______________

Chillers

- Refrigerant leaks? ______________________
- Evidence of condensation problems? ______________________
- Waste oil and refrigerant properly stored and disposed of? ______________________

HVAC Checklist - Short Form

Building Name: ______________________________ Address: ______________________________

Completed by: ______________________________ Date: __________ File Number: ______________

AIR HANDLING UNIT

- Unit identification ________________________ Area served ______________________________

Outdoor Air Intake, Mixing Plenum, and Damper

- Outdoor air intake location ______________________________
- Nearby contaminant sources? (describe) ______________________________
- Bird screen in place and unobstructed? ______________________________
- Design total cfm __________ outdoor air (O.A.) cfm ________ date last tested and balanced ______________
- Minimum % O.A. (damper setting) __________ Minimum cfm O.A. $\frac{\text{(total cfm x minimum \% O.A.)}}{100}$ = ______________
- Current O.A. damper setting (date, time, and HVAC operating mode) ______________________________
- Damper control sequence (describe) ______________________________
- Condition of dampers and controls (note date) ______________________________

Fans

- Control sequence ______________________________
- Condition (note date) ______________________________
- Indicated temperatures supply air ______ mixed air ______ return air ______ outdoor air ________
- Actual temperatures supply air ______ mixed air ______ return air ______ outdoor air ________

Coils

- Heating fluid discharge temperature ________ ΔT _____ cooling fluid discharge temperature ______ ΔT ______
- Controls (describe) ______________________________
- Condition (note date) ______________________________

Humidifier

- Type ______________________ if biocide is used, note type ______________________________
- Condition (no overflow, drains trapped, all nozzles working?) ______________________________
- No slime, visible growth, or mineral deposits? ______________________________

HVAC Checklist - Short Form

Building Name: ______________________ Address: ______________________

Completed by: ______________________ Date: __________ File Number: __________

DISTRIBUTION SYSTEM

Zone/ Room	System Type	Supply Air		Return Air		Power Exhaust		
		ducted/ unducted	cfm*	ducted/ unducted	cfm*	cfm*	control	serves (e.g. toilet)

Condition of distribution system and terminal equipment (note locations of problems)

- Adequate access for maintenance? ______________________
- Ducts and coils clean and obstructed? ______________________
- Air paths unobstructed? supply ______ return ______ transfer ______ exhaust ______ make-up ______
- Note locations of blocked air paths, diffusers, or grilles ______________________
- Any unintentional openings into plenums? ______________________
- Controls operating properly? ______________________
- Air volume correct? ______________________
- Drain pans clean? Any visible growth or odors? ______________________

Filters

Location	Type/Rating	Size	Date Last Changed	Condition (give date)

HVAC Checklist - Short Form

Building Name: ______________________ Address: ______________________

Completed by: ______________________ Date: __________ File Number: __________

OCCUPIED SPACE

Thermostat types ______________________

Zone/ Room	Thermostat Location	What Does Thermostat Control? (e.g., radiator, AHU-3)	Setpoints		Measured Temperature	Day/ Time
			Summer	Winter		

Humidistats/Dehumidistats type ______________________

Zone/ Room	Humidistat/ Dehumidistat Location	What Does It Control?	Setpoints (%RH)	Measured Temperature	Day/ Time

- Potential problems (note location) ______________________
- Thermal comfort or air circulation (drafts, obstructed airflow, stagnant air, overcrowding, poor thermostat location)

____

____

- Malfunctioning equipment ______________________
- Major sources of odors or contaminants (e.g., poor sanitation, incompatible uses of space)

____

HVAC Checklist - Long Form

Building: ________________________ File Number: ________________________

Completed by: ________________________ Title: ________________________ Date Checked: ____________

Appendix B discusses HVAC system components in relation to indoor air quality.

Component	OK	Needs Attention	Not Applicable	Comments
Outside Air Intake				
Location ________________________				
Open during occupied hours?				
Unobstructed?				
Standing water, bird droppings in vicinity?				
Odors from outdoors? (describe) ________________________				
Carryover of exhaust heat?				
Cooling tower within 25 feet?				
Exhaust outlet within 25 feet?				
Trash compactor within 25 feet?				
Near parking facility, busy road, loading dock?				
Bird Screen				
Unobstructed?				
General condition?				
Size of mesh? (½" minimum)				
Outside Air Dampers				
Operation acceptable?				
Seal when closed?				

HVAC Checklist - Long Form

Building: ____ File Number: __________________________

Completed by: ____________________________ Title: ________________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Actuators operational?				
Outdoor Air (O.A.) Quantity ***(Check against applicable codes and ASHRAE 62-1989.)***				
Minimum % O.A. ______________				
Measured % O.A. ______________ *Note day, time, HVAC operating mode under "Comments"*				
Maximum % O.A. ______________				
Is minimum O.A. a separate damper?				
For VAV systems: is O.A. increased as total system air-flow is reduced?				
Mixing Plenum				
Clean?				
Floor drain trapped?				
Airtightness				
■ of outside air dampers				
■ of return air dampers				
■ of exhaust air dampers				
All damper motors connected?				
All damper motors operational?				
Air mixers or opposed blades?				

HVAC Checklist - Long Form

Building: ____ File Number: _________________________

Completed by: ___________________________ Title: _______________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Mixed air temperature control setting _______ °F				
Freeze stat setting _____ °F				
Is mixing plenum under negative pressure? *Note: If it is under positive pressure, outdoor air may not be entering.*				
Filters				
Type ____________________				
Complete coverage? (i.e., no bypassing)				
Correct pressure drop? *(Compare to manufacturer's recommendations.)*				
Contaminants visible?				
Odor noticeable?				
Spray Humidifiers or Air Washers				
Humidifier type				
All nozzles working?				
Complete coil coverage?				
Pans clean, no overflow?				
Drains trapped?				
Biocide treatment working? *Note: Is MSDS on file?*_________				
Spill contaminant system in place?				

HVAC Checklist - Long Form

Building: ____ File Number: __________________________

Completed by: ____________________________ Title: ________________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Face and Bypass Dampers				
Damper operation correct?				
Damper motors operational?				
Cooling Coil				
Inspection access?				
Clean?				
Supply water temp. _____ ^{o}F				
Water carryover?				
Any indication of condensation problems?				
Condensate Drip Pans				
Accessible to inspect and clean?				
Clean, no residue?				
No standing water, no leaks?				
Noticeable odor?				
Visible growth (e.g., slime)?				
Drains and traps clear, working?				
Trapped to air gap?				
Water overflow?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ______________________ Title: ____________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Mist Eliminators				
Clean, straight, no carryover?				
Supply Fan Chambers				
Clean?				
No trash or storage?				
Floor drain traps are wet or sealed?				
No air leaks?				
Doors close tightly?				
Supply Fans				
Location ____________________				
Fan blades clean?				
Belt guards installed?				
Proper belt tension?				
Excess vibration?				
Corrosion problems?				
Controls operational, calibrated?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ________________________ Title: ____________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Control sequence conforms to design/specifications? (describe changes)				
No pneumatic leaks?				
Heating Coil				
Inspection access?				
Clean?				
Contol sequence conforms to design/specifications? (describe changes)				
Supply water temp. _____°F				
Discharge thermostat? (air temp. setting _______°F)				
Reheat Coils				
Clean?				
Obstructed?				
Operational?				
Steam Humidifier				
Humidifier type				
Treated boiler water				
Standing water?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ______________________ Title: ____________________ Date Checked: ________

Component	OK	Needs Attention	Not Applicable	Comments
Visible growth?				
Mineral deposits?				
Control setpoint ________ ^{o}F				
High limit setpoint ______ ^{o}F				
Duct liner within 12 feet? (If so, check for dirt, mold growth.)				
Supply Ductwork				
Clean?				
Sealed, no leaks, tight connections?				
Fire dampers open?				
Access doors closed?				
Lined ducts?				
Flex duct connected, no tears?				
Light troffer supply?				
Balanced within 3-5 years?				
Balanced after recent renovations?				
Short circuiting or other air distribution problems? Note location(s) ____________________ ____________________				
Pressurized Ceiling Supply Plenum				
No unintentional openings?				
All ceiling tiles in place?				

HVAC Checklist - Long Form

Building: ____ File Number: _____________________________

Completed by: _______________________________ Title: __________________________ Date Checked: ___________

Component	OK	Needs Attention	Not Applicable	Comments
Barrier paper correctly placed and in good condition?				
Proper layout for air distribution?				
Supply diffusers open?				
Supply diffusers balanced?				
Noticeable flow of air?				
Short circuiting or other air distribution problems? *Note location(s) in"Comments"*				
Terminal Equipment (supply)				
Housing interiors clean and unobstructed?				
Controls working?				
Delivering rated volume?				
Balanced within 3-5 years?				
Filters in place?				
Condensate pans clean, drain freely?				
VAV Box				
Minimum stops ________ %				
Minimum outside air ____ % *(from page 2 of this form)*				
Minimum airflow _________cfm				
Minimum outside air ______ cfm				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ________________________ Title: ____________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Supply setpoint _____°F (summer) _____°F (winter)				
Thermostats				
Type ____________________				
Properly located?				
Working?				
Setpoints _____°F (summer) _____°F (winter)				
Space temperature _____°F				
Humidity Sensor				
Humidistat setpoints ______ % RH				
Dehumudistat setpoints _____ % RH				
Actual RH _____ %				
Room Partitions				
Gap allowing airflow at top?				
Gap allowing airflow at bottom?				
Supply, return each room?				

HVAC Checklist - Long Form

Building: ____________________ File Number: ____________________

Completed by: ____________________ Title: ____________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Stairwells				
Doors close and latch?				
No openings allowing uncontrolled airflow?				
Clean, dry?				
No noticeable odors?				
Return Air Plenum				
Tiles in place?				
No unintentional openings?				
Return grilles?				
Balancing capability?				
Noticeable flow of air?				
Transfer grilles?				
Fire dampers open?				
Ducted Returns				
Balanced within 3-5 years?				
Unobstructed grilles?				
Unobstructed return air path?				
Return Fan Chambers				
Clean and no trash or storage?				
No standing water?				
Floor drain traps are wet or sealed?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ______________________ Title: __________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
No air leaks?				
Doors close tightly, kept closed?				
Return Fans				
Location ______________				
Fan blades clean?				
Belt guards installed?				
Proper belt tension?				
Excess vibration?				
Corrosion problems?				
Controls working, calibrated?				
Controls sequence conforms to design/specifications? (describe changes)				
Exhaust Fans				
Central?				
Distributed (locations) ________ ______________________				
Operational?				
Controls operational?				
Toilet exhaust only?				
Gravity relief?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ______________________ Title: __________________ Date Checked: __________

Component	OK	Needs Attention	Not Applicable	Comments
Total powered exhaust _____ cfm				
Make-up air sufficient?				
Toilet Exhausts				
Fans working occupied hours?				
Registers open, clear?				
Make-up air path adequate?				
Volume according to code?				
Floor drain traps wet or sealable?				
Bathrooms run slightly negative relative to building?				
Smoking Lounge Exhaust				
Room runs negative relative to building?				
Print Room Exhaust				
Room runs negative relative to building?				
Garage Ventilation				
Operates according to codes?				
Fans, controls, dampers all operate?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ______________________

Completed by: ______________________ Title: ____________________ Date Checked: ________

Component	OK	Needs Attention	Not Applicable	Comments
Garage slightly negative relative to building?				
Doors to building close tightly?				
Vestibule entrance to building from garage?				
Mechanical Rooms				
General condition?				
Controls operational?				
Pneumatic controls:				
■ compressor operational?				
■ air dryer operational?				
Electric contols?				
EMS (Energy Management System) or DDC (Direct Digital Control):				
■ operator on site?				
■ controlled off-site?				
■ are fans cycled "off" while building is occupied?				
■ is chiller reset to shed load?				
Preventive Maintenance				
Spare parts inventoried?				
Spare air filters?				
Control drawing posted?				

HVAC Checklist - Long Form

Building: ______________________________ File Number: ____________________

Completed by: ______________________ Title: __________________ Date Checked: ________

Component	OK	Needs Attention	Not Applicable	Comments
PM (Preventive Maintenance) schedule available?				
PM followed?				
Boilers				
Flues, breeching tight?				
Purge cycle working?				
Door gaskets tight?				
Fuel system tight, no leaks?				
Combustion air: at least 1 square inch free area per 2000 Btu input?				
Cooling Tower				
Sump clean?				
No leaks, no overflow?				
Eliminators working, no carryover?				
No slime or algae?				
Biocide treatment working?				
Dirt separator working?				
Chillers				
No refrigerant leaks?				
Purge cycle normal?				
Waste oil, refrigerant properly disposed of and spare refrigerant properly stored?				
Condensation problems?				

HVAC Checklist - Long Form

Page ___ of ___

Building: ____ File Number: ______________________________

Completed by: ________________________________ Title: ___________________________ Date Checked: ___________

Component	OK	Needs Attention	Not Applicable	Comments

Pollutant Pathway Form For Investigations

Building Name: ____ File Number : ____________________________

Address: ____ Completed by: _________________________________

This form should be used in combination with a floor plan such as a fire evacuation plan.

Building areas that appear isolated from each other may be connected by airflow passages such as air distribution zones, utility tunnels or chases, party walls, spaces above suspended ceilings (whether or not those spaces are serving as air plenums), elevator shafts, and crawl spaces.

Describe the complaint area in the space below and mark it on your floor plan. Then list rooms or zones connected to the complaint area by airflow pathways. Use the form to record the direction of air flow between the complaint area and the connected rooms/zones, including the date and time. (Airflow patterns generally change overtime). Mark the floor plan with arrows or plus (+) and minus (-) signs to map out the airflow patterns you observe, using chemical smoke or a micromanometer. The "comments" column can be used to note pollutant sources that merit further attention.

Rooms or zones included in the complaint area: ____

____

Sections 2, 4 and 6 discuss pollutant pathways and driving forces.

Rooms or Zones Connected to the Complaint Area By Pathways	**Use**	**Pressure Relative to Complaint Area**		**Comments (e.g., potential pollutant sources)**
		+/-	**date/time**	

Pollutant and Source Inventory

Building Name: ____ Address: ____________________________________

Completed by: _____________________________________ Date: _______________ File Number: ___________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Sections 2, 4 and 6 discuss pollutant sources. Appendix A provides guidance on common measurements.

Source Category	**Checked**	**Needs Attention**	**Location**	Comments
SOURCES OUTSIDE BUILDING				
Contaminated Ambient Air				
Pollen, dust				
Industrial contaminants				
General vehicular contaminants				
Emissions from Nearby Sources				
Vehicle exhaust (parking areas, loading docks, roads)				
Dumpsters				
Re-entrained exhaust				
Debris near outside air intake				
Soil Gas				
Radon				
Leaking underground tanks				
Sewage smells				
Pesticides				

Pollutant and Source Inventory

Building Name: ____ Address: ____________________________________

Completed by: _____________________________________ Date: _______________ File Number: ___________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
Moisture or Standing Water				
Rooftop				
Crawlspace				
EQUIPMENT				
HVAC System Equipment				
Combustion gases				
Dust, dirt, or microbial growth in ducts				
Microbial growth in drip pans, chillers, humidifiers				
Leaks of treated boiler water				
Non HVAC System Equipment				
Office equipment				
Supplies for equipment				
Labratory equipment				

Pollutant and Source Inventory

Building Name: ________________________________ Address: ____________________________

Completed by: ____________________________ Date: ____________ File Number: ______________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
HUMAN ACTIVITIES				
Personal Activities				
Smoking				
Cosmetics (odors)				
Housekeeping Activities				
Cleaning materials				
Cleaning procedures (e.g., dust from sweeping, vacuuming)				
Stored supplies				
Stored refuse				
Maintenance Activities				
Use of materials with volatile compunds (e.g., paint, caulk, adhesives)				
Stored supplies with volatile compounds				
Use of pesticides				

Pollutant and Source Inventory

Building Name: ______________________________________ Address: _______________________________

Completed by: _______________________________ Date: _____________ File Number: ________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
BUILDING COMPONENTS/FURNISHINGS				
Locations Associated with Dust or Fibers				
Dust-catching area (e.g., open shelving)				
Deteriorated furnishings				
Asbestos-containing materials				
Unsanitary Conditions/Water Damage				
Microbial growth in or on soiled or water-damaged furnishings				

Pollutant and Source Inventory

Building Name: ____ Address: ________________________________

Completed by: ____________________________________ Date: _______________ File Number: ___________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
Chemicals Released From Building Components or Furnishings				
Volatile compounds				
OTHER SOURCES				
Accidental Events				
Spills (e.g., water, chemicals, beverages)				
Water leaks or flooding				
Fire damage				

Pollutant and Source Inventory

Building Name: ____ Address: _________________________________

Completed by: _________________________________ Date: ______________ File Number: _________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Source Category	Checked	Needs Attention	Location	Comments
Special Use/Mixed Use Areas				
Smoking lounges				
Food preparation areas				
Underground or attached parking garages				
Laboratories				
Print shops, art rooms				
Exercise rooms				
Beauty salons				
Redecorating/Repair/Remodeling				
Emissions from new furnishings				
Dust, fibers from demolition				
Odors, volatile compounds				

Pollutant and Source Inventory

Page___of ___

Building Name: ____ Address: ____________________________________

Completed by: _____________________________________ Date: _______________ File Number: ___________________

Using the list of potential source categories below, record any indications of contamination or suspected pollutants that may require further investigation or treatment. Sources of contamination may be constant or intermittent or may be linked to single, unrepeated events. For intermittent sources, try to indicate the time of peak activity or contaminant production, including correlations with weather (e.g., wind direction).

Sections 2, 4 and 6 discuss pollutant sources. Appendix A provides guidance on common measurements.

Source Category	Checked	Needs Attention	Location	Comments

Chemical Inventory

Building Name: ______________________________ File Number: ____________________

Address: ____

Completed by: ______________________________ Phone: ______________________

The inventory should include chemicals stored or used in the building for cleaning, maintenance, operations, and pest control. If you have an MSDS (Material Safety Data Sheet) for the chemical, put a check mark in the right-hand column. If not, ask the chemical supplier to provide the MSDS, if one is available.

Sections 2 and 6 discuss pollutant sources. Section 4 discusses MSDSs.

Date	Chemical/Brand Name	Use	Storage Location(s)	MSDS on file?

Hypothesis Form

Building Name: ____ File Number: ___________________________

Address: ____

Completed by: ____

Complaint Area (may be revised as the investigation progresses):

____

____

____

____

Complaints (e.g., summarize patterns of timing, location, number of people affected):

____

____

HVAC: Does the ventilation system appear to provide adequate outdoor air, efficiently distributed to meet occupant needs in the complaint area? If not, what problems do you see?

____

____

Is there any apparent pattern connecting the location and timing of complaints with the HVAC system layout, condition or operating schedule?

____

____

Pathways: What pathways and driving forces connect the complaint area to locations of potential sources?

____

Are the flows opposite to those intended in the design? ____

Sources: What potential sources have been identified in the complaint area or in locations associated with the complaint area (connected by pathways)?

____

Is the pattern of complaints consistent with any of these sources? ____

Hypothesis Form

Hypothesis: Using the information you have gathered, what is your best explanation for the problem?

Hypothesis testing: How can this hypothesis be tested?

If measurements have been taken, are the measurement results consistent with this hypothesis?

Results of Hypothesis Testing:

Additional Information Needed:

Index