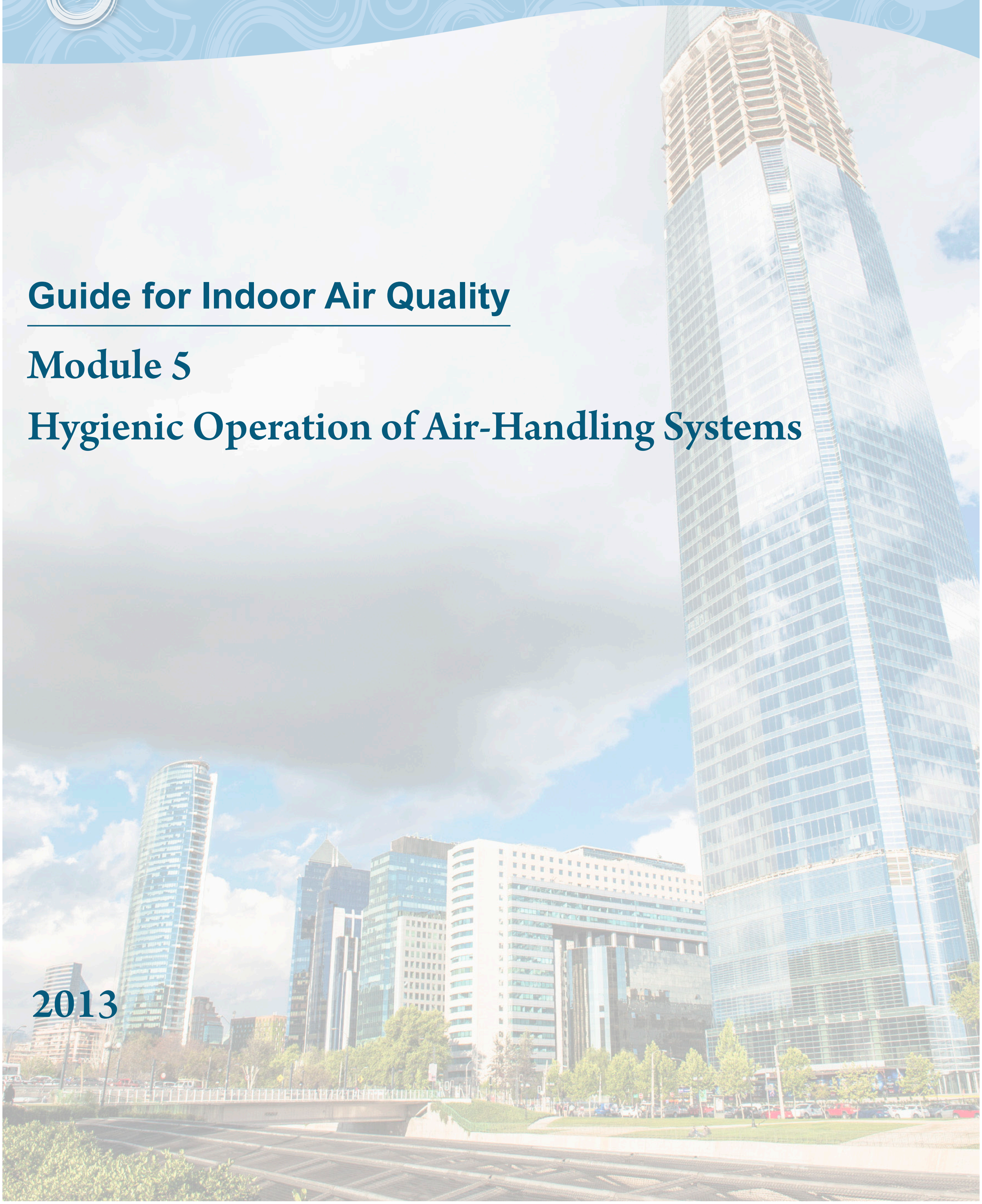
CCIAQB | Canadian Committee on Indoor Air Quality and Buildings

Guide for Indoor Air Quality

Module 5

Hygienic Operation of Air-Handling Systems

2013



Canadian Committee on Indoor Air Quality and Buildings (CCIAQB)

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Indoor air quality is a very complex issue and there is currently a significant gap between knowledge of the effects of indoor air quality on the health of occupants and the effectiveness of various air quality technologies and solutions. User discretion is advised.

Preamble

The objective of the CCIAQB is, ultimately, to improve indoor air quality for all Canadians in every type of building. The CCIAQB has decided that its initial focus should be on buildings where many Canadians spend time outside their home, working, learning, shopping, being entertained, etc. For the most part, these buildings have relatively complex heating, ventilating and air conditioning systems that are operated and managed by knowledgeable persons. The table below gives examples of buildings that are covered using the classification found in the National Building Code of Canada (NBC). Documents produced by the CCIAQB are primarily intended for the use of building operators and facility managers, but the information contained in the guides can be helpful to anyone seeking a general understanding of indoor air quality issues.

The Committee welcomes feedback on the documents as well as ideas for the development of new materials. Contact the CCIAQB Secretary at info@IAQforum.ca or register on the website at www.IAQforum.ca

NBC Classification	Examples
Group A, Division 1	Theatres, movie theatres and other facilities for the performing arts
Group A, Division 2	Art galleries, museums, libraries, educational facilities (schools, colleges and universities), gymnasia, air and rail terminals
Group A, Division 3	Arenas and swimming pools
Group C	Apartments, hotels, college residences
Group D	Offices, including medical and dental offices
Group E	Department stores, supermarkets, shops, retail space

Guide for Indoor Air Quality
Module 5: Hygienic Operation of Air-Handling Systems

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1. Purpose of This Module

The purpose of this Module is to help building operators and managers operate air-handling systems in order to maintain acceptable indoor air quality.

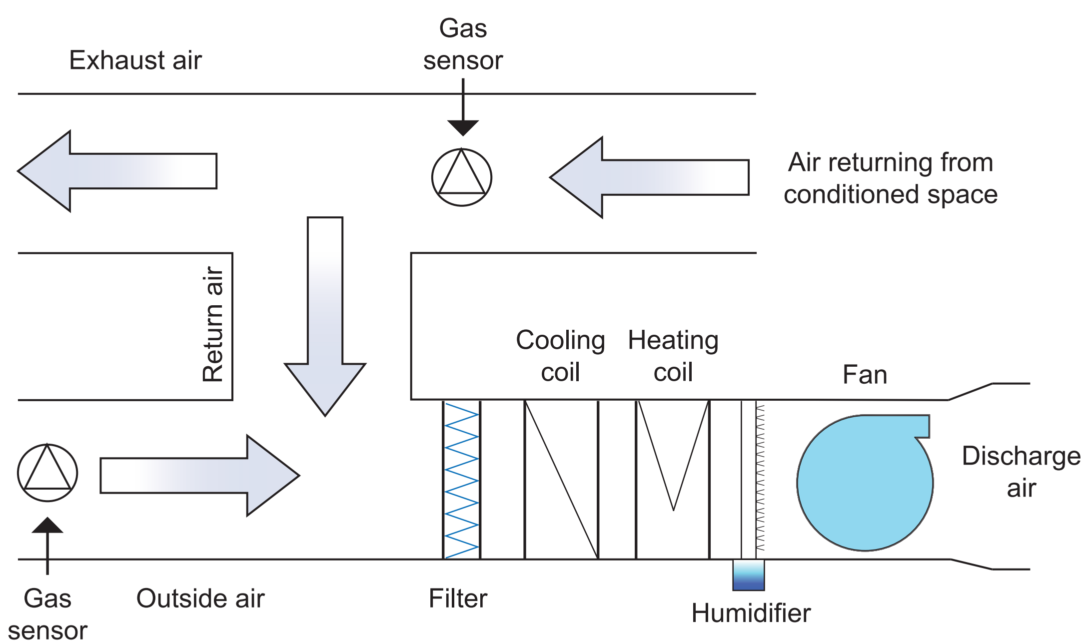
This document is part of a series of modules forming the CCIAQB *Guide for Indoor Air Quality* available at www.IAQForum.ca. For definitions and acronyms, refer to *Module 1 – Introduction to Indoor Air Quality (IAQ)*.

2. Background

An adequate supply of fresh air is a basic requirement to dilute internally generated contaminants such as odours, moisture, chemicals, and particles. Before being introduced into a building, incoming air may be filtered, dehumidified or otherwise altered to improve its condition. The purpose of an air-handling system is to provide thermal comfort and acceptable indoor air quality within an occupied space. Air-handling systems are known to be the cause of many office indoor air quality (IAQ) problems.

A typical air-handling system includes the air intake, mixing plenum, filters, heating and cooling coils, humidifier, and fan (see Figure 5-1)). Although commonly referred to as heating, ventilating, and air-conditioning (HVAC) systems, not all systems perform all these functions. In a typical system, outdoor air (ventilation) is brought into the system through adjustable dampers and then mixed with return air, from within the building. This mixed supply air is then filtered, heated or cooled, humidified or de-humidified, and distributed to various zones within a building. In some system design configurations, the supply air is conditioned by compartmental or terminal air-handling units located on individual floors.

Figure 5-1 Typical air-handling system



Salary costs typically exceed building operating and energy expenses. It is therefore crucial, when planning operational and maintenance energy-saving measures, to consider their impact on IAQ and employee productivity.

Standard 62.1-2010, *Ventilation for Acceptable Indoor Air Quality* of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) provides key IAQ performance indicators including temperature, relative humidity, ventilation, air motion, carbon monoxide, formaldehyde, total volatile organic compounds (TVOCs), particulates, microbials, humidifier water quality, and cooling tower water quality.

ASHRAE guidelines define the process of commissioning as "verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirements." Equipment specifications, record-keeping, as well as testing, adjusting, and balancing the air-handling system are an integral part of building commissioning. In additiopn, whenever use of a building or the interior layout changes, the HVAC system should be re-commissioned and the system re-balanced (Canadian Standard Association (CSA), Z-204-94, *Guideline for Managing Indoor Air Quality in Office Buildings*).

A key issue is ensuring that there is continuity of information regarding the operation and use of air handing systems. Clear, concise and thorough descriptions of what the system should do are essential to ensure the system is operated and maintained correctly throughout its service life.

3. Operation, Inspection, and Maintenance of HVAC System Components

3.1. Outdoor Air Intakes

Intake dampers control the amount of outdoor air that is introduced to the ventilation air. Outdoor air is mixed with return air, conditioned in the air-handling system, and then supplied to the indoor environment.

The outdoor air supply should be free of contaminants. ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Indoor Air Quality* provides minimum separation distances between various contaminant sources and outdoor air intakes. Inspection items for outdoor intakes are listed in Checklist 5-1.

For some residential condominiums, the air-handling system provides ventilation to the hallway areas and this air migrates to each condo through a gap under the front door. This is effective when

Photo 1 - Roofs can be crowded spaces with air intakes next to vent stacks

Photo 2 - Ballast near this air intake makes removal of bird droppings difficult the individual units are under negative air pressure with respect to the hallway. The other routes for ventilation are through the building envelope or through windows and doors.

Problems can arise when condo units, usually located on the mid-floors of the building at the neutral pressure plane, experience little or no air infiltration. In this case, the recommended solution is to increase the exhaust to increase negative air pressure. Another issue is intermittent operation of an air-handling system. The system should be operating continuously to pressurize the hallways for ventilation, as well as for fire and smoke control.

Checklist 5-1 Checking and maintaining outdoor intakes
1. Is the outdoor air intake sufficiently isolated from exterior pollutant sources?
2. Is there a screen across the outdoor air intake to trap debris and eliminate the entry of birds?
3. Can the dampers open and close freely?
4. Is the linkage fully operational?
5. Is there a minimum outdoor damper set-point?
6. If rain and snow can potentially enter the outdoor air intake, is there proper drainage?
7. If a floor drain connected to a sewer line is present, is a self-priming trap installed to avoid odours?
8. Are the dampers and intake clean and free of debris?
9. Is there damaged insulation within the air intake?
10. Is the enclosure dry and free of visible mould growth?
11. Has the CO2 sensor been calibrated?
12. Is the regulated ventilation rate being provided to each work station?

3.2. Mixing Plenums and Mechanical Rooms

In a typical office building, outdoor air is mixed with return air in the mechanical room or in the air-handling unit mixing plenum. The mechanical room should be free of pollutants and odours. Chemicals and cleaning compounds should be properly stored well away from areas used for the air-handling system. Refuse materials and flammable materials should not be present in the mechanical room. Standing water and dry drain traps can result in odours and biological contamination being entrained into an air-handling unit.

Depending on design, the entire length of an air-handling system up to the supply fan may be under negative air pressure. Air from the mechanical room will infiltrate the air-handling unit through poorly sealed and uncaulked sheet metal joints, access doors, and testing ports. Work activity such as welding, pipe fitting or painting should only take place when the work is isolated from the air-handling system.

Pipe, duct, and air-handling system insulation that is soiled and possibly contaminated with mould is a particular concern in the mechanical room. Insulation can become saturated with water from leaking pipes, regulators, and valves. Condensation on un-insulated or improperly insulated pipes, air ducts, valves and elbows will wet surrounding surfaces. It is important to repair leaks and insulate cold surfaces to avoid condensation in the mechanical room. Evidence of surface mould growth must be remediated in accordance with established guidelines.

Areas of ducting with exterior insulation may show dark or discoloured patches. These may be the result of dust particle deposition resulting from air leakage or from moisture damage and/or mould growth. Discoloured insulation should be replaced.

Checklist 5-2 Checking and maintaining mixing plenums / mechanical rooms
Mixing Plenum Inspection 1. Are the mixing plenum dampers, linkages, and controls operational? 2. Are metal joint seams sealed and access doors airtight? 3. Are the outdoor air and the return air damper seals intact and airtight? 4. Is the mixing plenum clean, dry, and free of debris? 5. Is the interior insulation undamaged? 6. Is there any evidence of current or past water damage or mould growth? 7. Are there odours within the mixing plenum? 8. Is there evidence of poor air mixing?
Mechanical Room Inspection 1. Are chemicals and other materials properly stored? 2. Are work activities generating pollutants and odours? 3. Is there standing water? 4. Are there dry or unprimed drain traps? 5. Are cold surfaces, pipes, and ducts properly insulated? 6. Is there any evidence of water leaks, or condensate damage on materials? 7. Is there evidence of soiled or stained insulation or mould growth? 8. Are the mechanical room and air-handling unit free of asbestos containing materials; or is the asbestos encapsulated and signage present? 9. Are exhaust shafts and ducts properly sealed with no apparent odours?
Maintenance 1. Inspect mixing plenum monthly. 2. Clean twice a year and when debris is evident. 3. Seal areas where there is air leakage. 4. Clean and disinfect floor areas around drains and water leaks twice a year. 5. Check drainage traps and add water as required.

Photo 3 - This mechanical room which doubles as a return air plenum shows evidence of moisture entry from the adjacent outdoor air intake. It is also contaminated with organic matter.

There are often fixed mixing vanes in the mixing plenum to ensure that the return and incoming air are properly mixed. Areas of warm and cold air (temperature stratification) and a non-uniform dust collection pattern on filters are evidence of poor mixing.

The interior walls of the mixing plenum may be covered with acoustic and thermal insulation. This material should: be non-porous; not absorb humidity; not release odours; and, not provide a nutrient substrate for bioaerosols. Ensure that the inner surface is intact and well-sealed to prevent moisture entry and surface erosion.

Inspection items and maintenance recommendations for mixing plenums and mechanical rooms are listed in Checklist 5-2 (previous page).

3.3. Filters

Although internally generated sources may have a significant impact on in-situ air pollution, filters play an important role in reducing the airborne particulate level in supply air. They remove dust, debris, and bioaerosols from the incoming outdoor air as well as from the recirculating return air. Airborne particulates are generated indoors by occupants, work activities, space refits, and equipment use. Construction, traffic, and the natural environment generate airborne particulates in the outdoor air.

n addition to improving IAQ, filters also keep the HVAC system components clean and operating more efficiently. Unclean heating and cooling coils reduce the thermal transfer efficiency of the air-handling system and decrease airflow, making it difficult to achieve comfortable conditions indoors.

Fibreglass panel, pleated, or bag filters are commonly used in air-handling systems. In small systems, a single filter is usually used, while in large systems, pre-filters and secondary bag filters are common. Pre-filters are often lower-efficiency panel- or roll-type media, while secondary filters may be panels, bag, box or other types. Other filtration systems—notably washable filters, electrostatically-charged filter media, electronic air cleaners, carbon, and HEPA filters—are not be addressed in this guide.

Filters are often placed in a holder or rack in the supply air stream after the mixing plenum and before the other system components. There should be no gaps between the filters and the rack. A small opening will allow a large volume of supply air to bypass the filters.

Filter racks should be located away from outdoor air dampers to avoid rain and snow infiltration. To avoid wet filters, filters must not be placed after the cooling coil or humidifier. Moisture will degrade and matt the filter media and allow mould to grow on the surface.

The collection efficiency of a filter is dependent on particle size. Large particulates (between 4 and 10 µm) are more easily collected, while highly respirable particles (between 0.3 and 1 µm) have a lower collection efficiency value. Filter rating is defined by ASHRAE Standard 52, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size, using the "minimum efficiency reporting value" or MERV. Filters are tested and rated using particulates in the respirable range, between 0.3 to 10 micrometers (µm) in diameter.

The MERV scale ranges from 1 to 16, and measures a filter's ability to remove particles from .30 to 10 microns in size. Table 5-1 MERV rating chart shows MERV scales and related filter capabilities.

In general, as a filter accumulates particulates, the spaces between the filter fibres decrease and the filter becomes more capable of capturing particulates. However, the resistance to air flow increases, as indicated by pressure drop across the filter. For each filter type, the manufacturer specifies an initial and final pressure drop, indicating when the filter should be changed. By replacing filters too early, the maximum efficiency rating of the filter will not be reached and smaller particulates will flow through the filter.

Pressure drop across a filter bank is measured using a pressure gauge. In older systems, an inclined manometer may be present and should be checked and maintained. Manometers need to be properly installed in a level position, require the addition of fluid, and are more difficult to calibrate and read than other types of modern pressure measuring devices. Small air-handling systems with a pleated filter do not usually have a pressure gauge. If the gauge is across the pre-filter and final filter, then the maximum pressure drop is the sum of the two specified pressure drops. The pressure drop gauge should be calibrated each time filters are replaced.

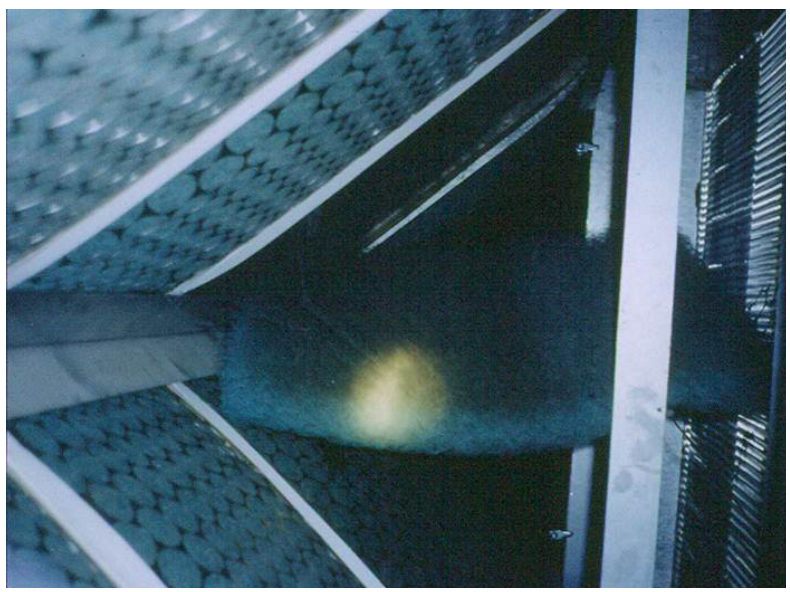


Photo 4 - Filters that are not properly sized or that become too dirty can displace from frames.

Higher-efficiency filters may need to be replaced more frequently as more particulates are collected by these filters. The use of a mid-range efficiency (MERV 6–8) panel or pleated pre-filter in combination with a bag filter extends the life of a bag filter. Less-expensive pre-filters will collect large particulates and can be changed 2 to 4 times a year. Bag filters are usually changed annually.

In an office environment, the effectiveness of activated charcoal filters for odour control can be limited. These filters are more expensive, have a high pressure drop, and an unknown lifecycle. Careful consideration should be given before installing activated charcoal filters. Source control of odours within the workplace is the recommended option. Checklist 5-3 lists inspection items and maintenance recommendations for filters.

Table 5-1 MERV rating chart

MERV Rating	Dust Spot Efficiency	Typical Controlled Contaminant	Applications	Air Filter Type
1	<20%	>10.0 micron particle size Pollen, dust mites, sanding dust, spray paint dust, textile fibers, carpet fibers	Minimal filtration Residential window A/C units	Throwaway - Disposable fiberglass or synthetic panel filter Washable - Aluminum mesh Electrostatic - Self charging woven panel filter
2	<20%			
3	<20%			
4	<20%			
5	<20%	3.0-10.0 micron particle size Mold spores, hair spray, fabric protector, dusting aids, cement dust, pudding mix	Commercial buildings Better residential Industrial workplace Paint booth inlet	Pleated Filters - Disposable, extended surface area, thick with cotton-polyester blend media, cardboard frame Cartridge Filters - Graded density viscous coated cube or pocket filters, synthetic media Throwaway - Disposable synthetic panel filter
6	<20%			
7	25-30%			
8	30-35%			
9	40-45%	1.0-3.0 micron particle size Legionella, humidifier dust, lead dust, milled flour, auto emissions, welding fumes	Better commercial Superior residential Hospital laboratories Welding booth inlet	Bag Filter - Non-supported micro-fine fiberglass or synthetic media, typically 6" - 36" deep, 6 - 12 pockets Box Filter - Rigid style cartridge filters typically 4" - 12" deep may use lofted or paper media
10	50-55%			
11	60-65%			
12	70-75%			
13	89-90%	0.30-1.0 micron particle size All bacteria, most tobacco smoke, proplet nuceli (sneeze)	Superior commercial General surgery Hospital rooms Smoking lounge	Bag Filter - Non-supported micro-fine fiberglass or synthetic media, typically 6" - 36" deep, 6 - 12 pockets Box Filter - Rigid style cartridge filters typically 4" - 12" deep may use lofted or paper media
14	90-95%			
15	>95%			
16	>95%			

Source: U.S. Environmental Protection Agency (http://www.epa.gov/iaq/)

* Dust spot efficiency measures a filter's ability to remove large particles, those that tend to soil building interiors.

Checklist 5-3 Checking and maintaining filters
Inspection 1. Are filters properly racked and in place? 2. Is there any space between the filters and the enclosure? 3. Is there a calibrated pressure drop indicator across the filter? 4. Is the pressure drop below the maximum recommended value? 5. Is there excess debris on the filter? 6. Are filters dry with no evidence of past moisture damage? 7. Are bag filters fully extended in a horizontal position during operation? 8. Is there a record of when filters were changed?
Maintenance 1. Inspect filters monthly to ensure that they are all placed in the rack and that no excess debris is visible on the filters or in the mixing plenum. 2. Check monthly to ensure that filters are dry. 3. If filters have an odour, the source must be found and the filter should be replaced. Filters contaminated with bioaerosols (mould) can off-gas compounds. 4. Change filters when the pressure drop approaches the manufacturer's specified maximum, or at the recommended time interval. 5. Change filters when the system is shut down. 6. When pre-filters are changed, inspect the bag filters. 7. Verify that the pressure drop gauges are calibrated every time filters are changed.

3.4. Cooling / Heating Coils

Fin and tube coils in an air-handling unit add or remove heat from the supply air. This can be done with one coil, where the temperature of the liquid in the coil is changed between the heating and cooling season, or by separate coils dedicated to either heating or cooling. Over time, coils accumulate particulates and debris that reduce the thermal transfer efficiency of the unit and reduce supply air flow. One measure of coil capacity is the temperature of the coolant entering and leaving the coil.

When the design cooling load is calculated, it must consider heat that will be generated by occupants, equipment, lights, and solar gain. Changing the occupant density or adding office equipment will impact the ability of the air-handling system to provide acceptable thermal comfort.

The cooling coil may also lower the relative humidity of the supply air. Depending on the coil surface temperature, the cooling coil may cause condensation, which will remove some moisture from the air stream. Many coils do not run cool enough to do this, either by design or due to operations and maintenance issues. If warm air is cooled below the dew point, condensation on the coils will occur, which must be collected and drained in a condensate pan under the cooling coil.

Depending on the amount of condensation on the cooling coil and the supply air velocity, water droplets can become aerosolized in the supply air stream, wetting the system enclosure and components further inline. To avoid this situation, a set of baffles or a drift eliminator is usually installed after the coil. With an ineffective drift eliminator and high air velocity, water droplets can migrate into the fan enclosure and into the supply air ducts. Generally, the maximum air velocity through the coil should be between 2.3–2.8 m/s (450–550 fpm).

To minimize the potential for mould growth, it is important to keep coils clean. Also, the interior insulation within the air-handling unit and in the supply duct must be intact, clean, and non-porous. If water pools within an air-handling unit, drainage is advised.

Metal floors in the enclosure that are wet throughout the cooling process should be disinfected periodically during system downtime. The cleaning sequence is to first vacuum the coil to remove loose debris, wet the coil with water, apply an appropriate foaming agent and let it stand for 10 to 15 minutes, then pressure wash and rinse the coil. The foaming agent penetrates the coil surface to remove dirt and grime from the fins and tubes. It should be non-corrosive, non-toxic, and not have a strong odour. The manufacturer's instructions must be followed and the product's material safety data sheet (MSDS) must be available. The pressure washer should be set to a low setting so that the cooling coil fins are not damaged. After the coils have been cleaned, the condensate pans and floor should also be cleaned.

Bent fins can be straightened using a fin comb. A light deposit of scale and lime on the cooling coil, due to minerals in the water, can be removed with an appropriate, non-corrosive product.

Both sides of a coil, or the space between tandem coils, must be accessible for cleaning. When access is not provided, an opening should be cut into the air handler so that the coil can be properly cleaned and disinfected.

Inspection items and maintenance recommendations for cooling / heating coils are listed in Checklist 5-4.

Checklist 5-4 Checking and maintaining cooling / heating coils

Inspection

1. Are the heating and cooling coils clean?
2. Are the fins intact and undamaged?
3. Is there any evidence of leaking heating or cooling fluid?
4. Is there an abnormal amount of scale or lime on the cooling coil?
5. Are the incoming and outgoing temperatures within the design range?
6. Is the drift eliminator clean?
7. Is the insulation within the air-handling system clean, non-porous, and intact?
8. Are there wet porous materials in the air-handling system after the cooling coil?
9. Is there stagnant water on the floor of the enclosure?

Maintenance

1. Clean and disinfect cooling coils during the spring season.
2. Inspect coils in the fall and vacuum if debris is evident.

3.5. Condensate Pans

Condensate from the cooling coil is collected in a pan under the coil. Horizontal channels across the coils also collect and drain water to the pan. To avoid bioaerosols (mould and bacteria) contamination, the condensate pan must be drained and clean.

The pan should be sloped towards the drain pipe, which should be located at the lowest point of the pan. However, during fan operation, complete drainage will not occur due to suction within the air-handling system. A solution to this problem is to install a water trap in the drain pipe which will siphon the water out of the pan. Vertical space is needed to construct a trap between the pan and the floor drain that will overcome the static pressure of the fan. As the condensate pan is usually at floor level, this drainage system is usually not in place. However, if the system is shut down in the evening, the pan will drain without a trap. ASHRAE 62.1, Section 5.11 addresses drain pan design and operation.

Some condensate drains are routed to floor drains or other sanitary pipes. Depending on the drain pan location, the pressure in the ducting can be positive (outflow of air through the drain), neutral or negative (inflow of air through the drain), so it is important to ensure that condensate drains are fitted with traps to allow liquid to flow but prevent the movement of air. The height of the trap must be selected based on the system static pressure at the drain. Note that plumbing codes typically prohibit direct connections to the building plumbing system. Check applicable codes and standards.

The condensate pan in large air-handling systems should be cleaned once a month during the cooling season. If there is not a proper access door to the cooling coil and condensate pan, one should be provided. For effective cleaning and disinfection, the pan interior should be smooth and not rusted or pitted. Pans that are structurally sound and slightly rusted should be cleaned, treated with a rust converter, and coated to provide a smooth surface. Damaged pans should be replaced.

During downtime, the pan should be wire-brushed with an appropriate disinfectant (3–6% hydrogen peroxide bleach solution (not chlorine) or similar non-toxic product), then rinsed and drained. Steam can also be used to clean a condensate pan. Wet metal wall and floor sections within the air-handling unit, including the fan compartment, should also be cleaned and disinfected each month.

In the winter, when condensate is not being collected, the condensate pan should be completely dry. If there is a concern that supply air will flow underneath the heating or cooling coil, then a cover should be installed across the condensate pan. The cover should be removed during the summer air conditioning period. It is not good practice to fill the condensate pan with water during the winter, as stagnant water can become contaminated.

Terminal or compartmental heat pumps and fan coil units on each floor, situated in the ceiling space or along the building perimeter, also have condensate pans. As the cold condensate makes the metal pan cold, surrounding air in the ceiling or office will condense on the outside of the pan. It is therefore necessary to insulate the outside of these condensate pans and drain pipes. Having insulation inside the pan is not good design practice, as the interior is difficult to clean. Insulation inside the pan increases the potential for water stagnation, odour generation, and microbial contamination. The condensate pan in terminal units should be sloped towards the drain pipe and the inlet kept free of debris.

Perimeter induction units placed under windows in an office area are usually designed to operate with a low cooling capacity, with little condensation on the coil. The condensate in the pan should evaporate over the evening hours, so no drainage is provided. If the operating design has been altered, or if the pan has been damaged, condensate may overflow and wet the floor in an office or drip down into walls and ceilings below.

Checklist 5-5 lists Inspection items and maintenance recommendations for condensate pans.

Checklist 5-5 Checking and maintaining condensate pans
Inspection 1. Is the entire surface of the condensate pan accessible for cleaning? 2. Is the interior surface of the pan clean and smooth? 3. Is the surface of the pan slimy? 4. Is the condensate pan sloped towards the drain? 5. Is the drain at the lowest point of the pan so that water will not stagnate? 6. Is the pan drain pipe properly sloped, trapped and routed to a drain? 7. Is the drain inlet clean to allow the free flow of water? 8. Does the pan drain overnight when the system is shut down? 9. Are the channels clean and does the water drain into the condensate pan? 10. Does the drain pipe overflow in the mechanical room and wet the floor? 11. On smaller compartmental units, is the condensate pan insulated on the inside? 12. Are pipes and drain lines insulated with no evidence of water damage? 13. Is there evidence of water damage on ceiling tiles, floors or on carpets?
Maintenance 1. Inspect and clean the condensate pan in compartmental or terminal units once a year. 2. Clean condensate channels in the spring, when the cooling coil is cleaned. 3. Inspect the pan for rust and corrosion; repair if surface is pitted. 4. Replace the pan if it leaks or is structurally unsound.

3.6. Humidifiers

In most Canadian climate zones and occupancies, the indoor relative humidity level should generally be above 25% during the winter heating season, and below 60% during the summer cooling period. In winter, humidity is added to the supply air using a steam humidifier, water spray, or wet media system. In summer, the incoming outdoor air may be dehumidified as it passes through the cooling coils.

The ability to provide a comfortable relative humidity level in the work environment is dictated by the building and the air-handling system design. In locations with temperate winters, there may not be a need to humidify the supply air. On cold days, humidity levels must be controlled to avoid condensation on interior surfaces.

The condensation on cold surfaces should be minimized, not by lowering relative humidity, but by other measures such insulating cold building components. In air-handling systems with automated controls, relative humidity can be controlled by a sensor in the return air stream. For smaller systems, sensors can be placed in the work area. Relative humidity sensors must be calibrated on a regular basis and at least once a year.

Photo 5 - The bottom of this fan cabinet rusted through because of a humidifier leak.

In winter, some water spray humidification systems use a pump to spray water from a reservoir onto an inactive cooling coil. The reservoir, located under the cooling coil, also serves as the condensate pan during the summer when the coil is inactive and providing cooling. Spray nozzles and the reservoir require regular maintenance. Chemicals may be added to the reservoir to control corrosion, suspended particulates, minerals, and microbial growth. A float valve regulates the addition of potable water to the reservoir as water is evaporated. A small amount of water drainage (bleeding off or purging) is also necessary to reduce contaminant concentrations. Water in the reservoir should be clear, not foaming (too many chemical additives) and the surface should not be slimy (indicating biological growth).

Water quality should be tested regularly. Mould and bacteria concentrations can be monitored using a dipstick or dipslide. Concentrations are compared to a density chart to determine the number of colonies in the water. The amount of dissolved solids is measured using a conductivity meter. The conductivity of the water in the reservoir should be less than seven times the conductivity of potable water. If greater than seven times, more potable water should be added to the reservoir.

There are also water spray systems that use nozzles and compressed air to create a fine mist or fog. These systems can be used within a specific location to provide direct humidification for specialized operations.

Due to maintenance and water testing costs and the potential for microbial contamination, steam humidifiers are preferred over water spray systems. Spray humidifiers are usually converted to steam systems when air-handling units are upgraded.

Steam humidifiers inject steam through a manifold into the supply air. Although some existing systems may take steam directly from the building's heating boiler, this is not appropriate because the anti-corrosion chemicals (amines) added to the boiler water may become vapourized and distributed in the supply air. Systems should have dedicated, potable water (no chemicals added) steam supplies.

While IAQ measurements of these chemicals seldom exceed the regulated exposure threshold for health, possible irritating effects and odours may be present during the initial start-up of the system. The U.S.

Environmental Protection Agency (EPA), Building Air Quality: A Guide for Building Owners and Facility Managers, 1991, ASHRAE 62.1, and the CSA 6.2, stipulate that water used for humidification should not contain chemicals.

Boiler steam can be used in a closed-loop, steam-to-steam converter to heat up potable water for humidification. In this instance, boiler water chemicals are not aerosolized. A separate steam generator, using a gas or oil burner and a heat exchanger, can convert potable or specifically treated water to humidification steam.

Steam can also be generated using electrical power and electrodes in a cylinder or canister, following manufacturers' installation and maintenance instructions. The use of potable water results in the deposition of minerals (scale) and particulates within these systems, so regular maintenance and replacement of components is required. Depending on water quality, softeners and filters can extend the life of the electrodes and canister. Operation times can range between 1,200 and 2,000 hours at full capacity for city water, to 500 or less hours for well water. Electric steam generators can have alarms (error code or flashing light) to indicate when components require replacement.

A humidifier using a wetted media, usually a metallic or water resistant mesh, can be found in certain small building installations. The mesh and reservoir require regular cleaning and maintenance.

Inspection items and maintenance recommendations for humidifiers are listed in Checklist 5-6.

3.7. Fans

Filtered and conditioned supply air is distributed by a fan to a series of central and branch ducts. Proper fan selection and duct layout and ongoing routine maintenance are important requirements for proper air distribution.

Fans are usually specified based on their ability to move a given quantity of air against a specified pressure, usually expressed in litres per second (cubic feet per minute). Fan performance is typically indicated by a curve, with a series of flow and pressure points. Balancing between supply, return, and exhaust air volumes is usually designed to place the overall building under a slight positive air pressure, typically 12.5 Pa (0.05 in.) relative to the outdoors. The intent is to have indoor air gently exhausted through the building envelope, rather than have unconditioned and unfiltered outdoor air infiltrating the work area.

Within buildings, various areas may be designed to have negative or positive pressure relative to adjacent areas in order to provide a pressure gradient to control the direction of air flow. Building height, wind velocity and direction, stack effect, and seasonal temperature variations affect building pressure levels which can vary between positive, neutral, and negative along the height of the building. Building pressure also affects the operation of entrance and elevator doors.

The fan chamber and fan components should be clean and dry. The fan belts should be properly tensioned and not frayed. The fan housing and blades should be in good condition. Excess fan noise and vibration should not be evident. The fan chamber, as well as the entire air-handling system, should be airtight.

For safety reasons and for easy access to the pressurized chamber, the fan is usually shut off for inspection. If a fan is exposed (not located inside a plenum), there must be a guard around the drive belts.

Inspection items and maintenance recommendations for fans are listed in Checklist 5-7.

Checklist 5-6 Checking and maintaining humidifiers

Inspection

1. Is the relative humidity maintained between 25% and 60% over the work day?
2. Is there any evidence of condensation or water damage within the facility due to high relative humidity levels?
3. Are the relative humidity sensors calibrated annually?
4. In a water spray system, is the spray pattern uniform across the cooling coil?
5. Are the water and reservoir surfaces clean?
6. Is there a build-up of scale on the cooling coil?
7. Are water quality tests and treatment done on a scheduled basis?
8. Are results of water testing recorded and available on site?
9. Are water droplets wetting air-handling system surfaces or components?
10. In a steam system, is heater boiler steam injected directly into the air supply?
11. Are the heat exchanger coils, water canisters, electrodes, and other components in good operating condition?
12. Is the water level in the canister too high, indicating corroded electrodes?
13. Are there excessive deposits in the canister?
14. Is the steam completely vapourized in the supply air stream?
15. Are surfaces and components in the air-handling system free of stains, mineral deposits or other evidence of past wetting?

Maintenance

1. For water-spray systems, inspect and test water in the reservoir on a weekly or monthly basis, depending on equipment age, chemical treatment, and past test results.
2. Clean water reservoir monthly when water is present.
3. Drain, clean, and repair reservoir in the spring, before the air conditioning period.
4. Repair and clean water spray nozzles in the fall, before the heating season.
5. Clean and disinfect any wetted non-porous (metal) surfaces in the air-handling system monthly. Do this during downtime.
6. Inspect the air-handling system monthly. Seal any unbonded insulation. Remove and replace saturated insulation with water-resistant material.
7. Calibrate relative humidity sensors at least once a year.
8. Inspect electrodes and canister monthly. Replace when required.
9. Clean drain valve when the canister is replaced.
10. Flush out minerals in the canister and clean strainer monthly.

Checklist 5-7 Checking and maintaining fans
Inspection 1. Is the fan chamber clean and dry? 2. Is debris from the fan belt evident? 3. Are fan belts loose or frayed? 4. Are the fan blades clean and undamaged? 5. Is excessive noise and vibration transmitted to the floor below? 6. Is there any evidence of air leakage? Are seams caulked and do assess doors have gaskets?
Maintenance 1. Disinfect wet metal floors each month. 2. Clean floors in the spring and fall. Clean wall surfaces if required. 3. Lubricate and maintain the fan assembly once a year. 4. Clean the fan chamber, fan blades, and housing annually. 5. Inspect fan chamber and fan components monthly.

3.8. Supply Ducts

Supply air from the air-handling system is conveyed through a series of central and branch ducts to other compartmental or terminal air-handling units, or to ceiling, floor or wall diffusers. Compartmental units—such as reheat or air conditioning units, heat pumps or variable air volume (VAV) boxes—may be located on individual floors, within the ceiling, and along an office perimeter.

The "as built" mechanical system drawings should indicate the location of supply air ducts and system components. A balancing report, as part of the commissioning documentation, can also quantify the actual airflow velocity measurements in metres per second (m/s), or the airflow volume in litres per second (L/s), to the various components and supply diffusers. Duct sections, usually made of sheet metal, have many seams and connections that must be as airtight as possible. Branch ducts and supply diffusers are usually linked by flexible material or metal sections. Air supply ducts can also be made of fibreglass board. The U.S. EPA states that ducts with a leakage rate of less than 3% will have a superior lifecycle cost. Measurement of duct leakage is a complex procedure and depends on many variables, including building type, floor area, fan operation, pressure differentials, and accessibility.

Thermal and acoustic insulation is usually applied on the outside of the duct. However, it is not uncommon to have insulation lining inside the duct.

To ensure the distribution system does not add any contaminants to the IAQ, the physical integrity of ductwork, its connections, and the condition of the interior surface must be properly maintained. A leaking duct will reduce design airflow to the workspace. The air will also pressurize a return ceiling plenum. This can cause debris and fibres from the ceiling tiles and acoustic insulation to infiltrate the work area through gaps in the ceiling or through the return air grills. Supply air leakage into a return air plenum reduces the effective ventilation of the occupied space and can cause a variety of IAQ and temperature control issues.

The interior lining of a duct, especially the section close to the air supply fan, should be inspected for dirt accumulation, current or past water damage, and for torn, unbonded, or friable insulation. The high velocity airstream at the beginning of the supply duct can erode insulation bonding. The presence of moisture and condensation can also result in microbial contamination of the interior surface.

ASHRAE Standard 62.1, Section 5.5.1 Resistance to Mold Growth, states that all airstream surfaces in equipment and ducts shall be resistant to mould growth. ASHRAE also notes that, even with this resistance, any airstream surface that is continuously wetted is still subject to microbial growth."

ASHRAE Standard 62.1, Section 5.5.2 Resistance to Erosion, states that "Airstream surface materials shall be evaluated in accordance with the Erosion Test in UL 181 and shall not break away, crack, peel, flake off, or show evidence of delamination or continued erosion under test conditions."

All duct interior surfaces should be dry. Fibreglass duct board and fibreglass insulation that has been water damaged should be replaced - it cannot be remediated or disinfected. When fibreglass becomes compressed (matted), it loses its insulation effectiveness. Duct cleaning and maintenance activities must be conducted carefully to prevent damaging the relatively delicate surfaces of interior insulation components.

Along central and branch lines, ducts should be inspected for leaking seams and the accumulation of debris. A light coating of dust on the interior surface is normal. A thick layer of dust, clumped dust, or hanging dust and fibres warrants cleaning. Lined ducts should be smooth inside (not worn) and the original colour should be apparent.

As airborne bioaerosols, fibres, and debris in the air distribution system may be downstream of a system's filters, these contaminants will be distributed to the occupied areas of a building. Since various mould spores are common constituents of normal outdoor and indoor air, dust found inside ducts will also naturally contain mould spores, principally Cladosporium, Penicillium, and other phylloplane species (refer to ASHRAE Standard 62.1).

Photo 6 - Air duct after cleaning

Condensation can occur on cold surfaces where insulation is missing or defective. This problem can become apparent in the summer air conditioning period when return air in the ceiling plenum is humid. If in sufficient quantity to drip, condensation on the cold duct will discolour the ceiling tiles. If condensation is not in sufficient quantity to drip, mouldy ducts and pipes may go undetected. Uninsulated cold water pipes and condensate pans in the ceiling will also result in soiled ceiling tiles. Refer to ASHRAE Standard 62.1 for more information.

Duct cleaning is a specialized activity and a certified and experienced contractor should be used. Cleaning interior metal duct surfaces is easier and more effective than cleaning insulated surfaces. Flexible metal ducts are usually replaced when dirty. Other important considerations are the need for engineering controls to isolate the cleaning area from other areas and from the occupied space, the need to deactivate and reactivate system controls and smoke and fire detection equipment, and the proper use of cleaning agents, antimicrobials, and other chemicals.

Building operators and other facilities personnel should be wary of the use of any type of cleaning products or systems for ductwork. Products can be absorbed into the insulation or be inadvertently distributed throughout the facility to building occupants. Refer to Module 3, Custodial Activities, Maintenance, Repair and Renovation. The National Research Council (NRC) has conducted an evaluation of the effectiveness of duct cleaning. A report entitled "*Testing Effectiveness of Duct Cleaning and Its Impact on Airborne Particles, Mold and Biocide Levels in Commercial Office Buildings*" is available at http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20374769&article=0&fd=pdf.

Further information on duct cleaning can also be found on the Canada Mortgage and Housing Corporation (CMHC) (http://www.cmhc-schl.gc.ca/) and the Canadian Centre for Occupational Health and Safety (CCOHS) (http://www.ccohs.ca/) websites.

Check items and maintenance recommendations for supply ducts are listed in Checklist 5-8.

Checklist 5-8 Checking and maintaining supply ducts
Inspection 1. Are there properly constructed and sealed access ports to inspect air supply ducts? 2. Is there any evidence of wet or past wet interior metal or lined duct surfaces? 3. Is there any evidence of duct lining that is eroded, broken, or unbonded? 4. Is there any evidence of duct leakage through openings, connections, or seams? 5. Is there any evidence of condensation or water damage from improperly insulated ducts? 6. Is there evidence of debris, visible mould, or dust in the supply ducts?
Maintenance 1. Inspect duct interior at representative locations 2. Clean ducts on an as-needed basis. 3. Repair duct seams and openings when detected. 4. Provide immediate attention to moisture intrusion and visible mould contamination within the duct.

3.9. Compartmental or Terminal Air-handling Units

In some buildings, compartmental or terminal units are situated on each floor to provide additional air conditioning and ventilation by distributing air from the central air-handling unit. Each terminal component should have similar operating, maintenance, and cleaning requirements to those in the central air-handling unit.

Compartmental or terminal air-handling units can be located in a mechanical room, return air plenums, or along the perimeter of each floor. The design specifications of terminal air-handling units may be different, but the air supplied to the occupied space must be within acceptable IAQ guidelines. Terminal units must not add pollutants or contaminants to the air supply.

Terminal units have different designs and functions. Units that are fan-powered are called fan-coil units. Those with nozzles are called induction units. Systems with a pipe-and-fin arrangement are called convection units. Fin-type units, as well as electric baseboard heaters, are meant to heat space by radiation. All these terminal units are usually installed around a floor perimeter, blanketing walls and windows with warm air during the winter and cool air during the summer.

Heat pumps are also terminal air-handling units that provide ventilation and thermal comfort control. These units can be placed in the central mechanical room, the mechanical room on each floor, or in a ceiling plenum. The advantage of using heat pumps is that each unit can be set to either cool or heat the supply air. Supply of outdoor air must be assured. If the outdoor air source or duct is placed near a terminal unit, it is unlikely that the design ventilation rate will be met. Airflow will follow the path of least resistance and only return air in the ceiling plenum will be supplied. The solution is to attach the outdoor air duct to a mixing box in front of these units.

Unit ventilators are small stand-alone air-handling systems often used in small buildings and usually placed along an exterior wall and having outdoor air dampers.

Diffusers, slots, or grills are located at the end of the supply air system to circulate air around the work area, provide thermal comfort, dilute and remove pollutants, and reduce condensation on cold (window) surfaces. Dust and staining around diffusers may be due to particulates in the supply air or from particulates generated in the work area. Dust on diffusers or grills can simply be removed; heavily soiled ceiling tiles should be replaced.

The Canadian Standards Association (CSA) publication Z204-94, Guidelines for Managing Indoor Air Quality in Office Buildings: Occupational Health and Safety, recommends an air velocity range at desk level between 0.05 and 0.15 m/s. Ideal airflow should gently encircle a workstation. Direct drafts are not advised for occupant comfort.

Inspection items and maintenance recommendations for air-handling units are listed in Checklist 5-9.

3.10. Return Air Plenums / Return Air Risers

In typical office environments, the space above the ceiling tiles often serves as the return air plenum. Fans in the mechanical room draw air from the workplace up through slots or grills in the ceiling and then through air shafts or risers on each floor. The return air is mixed with the incoming outdoor air, conditioned by the air-handling unit, and redistributed within the building. On floors with compartmental air-handling units, the return air is drawn into the mechanical room and mixed with an outdoor air supply on each floor. Other return air systems may be partially or fully ducted.

There should be free flow of return air within the plenum. To improve acoustic privacy between offices, walls are sometimes constructed above the ceiling up to the concrete slab. This will restrict the return airflow and affect the air balance and supply air distribution pattern for the entire floor. The solution is to construct a Z-duct through the barrier. Note that fibreglass batt insulation does not provide an effective acoustic barrier and should not be placed above the ceiling tiles.

Fire dampers are required where return air plenum or return air duct pass through firewalls. During normal operation, these dampers are always open and will shut when there is a fire alarm or fire.

Checklist 5-9 Checking and maintaining compartmental or terminal air-handling units
Inspection
Are all terminal units identified on a drawing?
Are terminal units properly supplied with outdoor air?
Do VAV boxes have a properly set minimum open position?
Are components accessible for inspection, cleaning and maintenance?
Are components (including filters, screens, fins, coils, pans, nozzles, grates) clean?
Is the acoustic/thermal insulation clean, bonded, and intact?
Is there evidence of water/refrigerant leakage or damage?
Is the airflow too high or too noisy?
Is airflow impeded by the placement of files, plants or books?
Have occupants obstructed or directed airflow?
Are cleaning and maintenance records kept for each terminal unit?
Maintenance
Inspect terminal units once a year.
Inspect and maintain heat pumps and fan-coil units every six months.
Clean or replace perimeter unit filters, vacuum coils and nozzles once a year.
Clean perimeter condensate pans and floor under unit once a year.
Clean ceiling diffusers when visually dirty; replace soiled ceiling tiles.
Attend to and correct obstructed airflow; rebalance the system if necessary.

Where there are strong indoor pollutant sources, air from these locations should be separately exhausted outside, not recirculated within the entire building. Pollutants and odours from laboratories, fume hoods, infectious areas, workshops, kitchens and washrooms must not become part of the building's supply air. In multi-use buildings with different tenants, odours such as those generated by a restaurant, can adversely affect the air quality in the entire building.

As return air flows with a low velocity through the ceiling plenum, dust and debris from occupants and activities within the work area can be deposited on ceiling tiles and other horizontal surfaces such as pipes, ducts, electrical conduits and light fixtures. Moisture in the ceiling space from condensation on cold metal surfaces, pipe or roof leaks, increases the potential for microbial contamination.

Leaking air supply ducts can cause the migration of particulates and mould spores from the ceiling to the work area through gaps around structural columns and missing ceiling tiles. Missing tiles will also unbalance the return air system and change the supply airflow velocity and direction along the entire floor.

Fibreglass batt insulation is sometimes placed over ceiling tiles to act as an acoustic barrier. Fibreglass, a skin and mucous membrane irritant, can adversely affect building occupants. To reduce noise transmission, it is more effective to use rigid acoustic ceiling tiles which should not contain asbestos or unbonded fibreglass.

If return grills are too close to supply air diffusers, supply air can be entrained into the return air plenum (short-circuiting). This will result in a reduction of ventilation, thermal comfort, and air circulation within the occupied space.

Ceiling tiles get dirty over time and are typically replaced after 25 years of service. Whatever their age, stained tiles should be replaced to avoid a perception that a building is leaky or has mould problems; and to create a baseline of clean conditions, so that if stains reoccur, it indicates a current leakage concern. Replacement should be done during the evenings and on weekends, with the office furnishings and contents covered, and the air-handling unit on. The operation of the ventilation and return air system will reduce airborne particulate concentrations in the occupied area when ceiling tiles are removed. All horizontal surfaces above the ceiling, such as light fixtures, pipes, ducts, as well as the ceiling support system (T-bars) should also be cleaned when tiles are replaced. See Checklist 5-10 for inspections and maintenance recommendations for plenums and risers.

Checklist 5-10 Checking and maintaining return air plenum / return air riser

Inspection

1. Is there free flow of return air in the ceiling plenum?
2. Are fire dampers open and operable?
3. Are strong pollutant sources separately exhausted and not returned to the air-handling unit air supply?
4. Are there gaps in the ceiling or missing tiles?
5. Are return grills or slots too close to supply air diffusers?
6. Are ceiling tiles clean?
7. Are there any sources of moisture or water in the ceiling plenum?
8. Is there loose fibreglass, asbestos, or accumulated debris on top of the ceiling tiles?
9. Are ceiling tiles asbestos free?
10. Is there any evidence of supply air leaks within the ceiling plenum?
11. Is there unencumbered return airflow up the risers?

Maintenance

1. Seal gaps and replace missing ceiling tiles.
2. Replace soiled or stained ceiling tiles and correct the cause of damage.
3. Eliminate odour by controlling its source. This can be done by removal, relocation, substitution, isolation, exhaust or changing time of use.
4. Ensure that fire dampers are open and operational after a fire alarm or fire.

3.11. Controls and Building Automation Systems

Air-handling unit control systems range from simple to complex and building operators need to understand how their system operates. Control systems regulate the operation of air-handling systems and the provision of thermal comfort (temperature and relative humidity), ventilation, and airflow to various building zones. For example, carbon monoxide sensors in the garage may control the ventilation and exhaust strategies in this area. Some areas such as occupied workspace, computer, special activity rooms, conference and training rooms, and garages have unique air quality requirements.

Most building automation control systems are described in a building's maintenance manuals and facility mechanical drawings as a 'sequence of operations.' A sequence of operation is a clear description of how a system is configured and is intended to be operated. Having an adequate system schematic and sequence of operation is essential to understanding, operating and maintaining an air-handling system.

Sensors in an air-handling system and work area monitor and control comfort and IAQ parameters. They should provide information to the building operator or possibly, to an automated control system. This information establishes a sequence of air-handling unit operations including when the system is turned on and off, and how it responds to changes in outdoor temperature, indoor occupancy, and pollutant levels.

Sensors controlling IAQ and comfort parameters should be placed in zones with similar thermal and ventilation requirements. These sensors and thermostats should not be placed close to windows, in direct air streams, or in hidden locations. Cooling, heating, and ventilation demands change throughout the day depending on outdoor weather conditions, wind velocity and direction, building orientation, occupancy level, equipment use, and other variables. Likewise, the perimeter and interior areas within a building have different needs. Due to heat gains from lights, equipment, and occupants within the interior, cooling is often required throughout the year. The perimeter zone will usually require summer cooling and winter heating.

Occupied conference and training rooms also have unique thermal and ventilation requirements. These areas should have separate controls. One effective strategy is to use demand-controlled ventilation, where the amount of ventilation and cooling provided is a function of the actual number of people present in the area being controlled. CO2 sensors are typically used for demand-controlled ventilation (since they reflect current occupancy load) and may be integrated with temperature sensors.

Control systems require scheduled maintenance and calibration. Sensors can fail at any time, which would cause inaccurate readings. This, in turn, would result in improper air-handling system operation and performance.

Automated computer control systems, using digital signals from sensors and algorithms can control the operations of an air-handling unit, resulting in the quick response time, graphical display of the operating parameters, and effective record-tracking. Contractors are often engaged to monitor and maintain the control system and a trained building operator can manage day-to-day operations.

When investigating indoor environmental complaints, operation and performance of the control system should be verified. It is possible that operating controls are set improperly or that the system is not operating properly. For example, the system may be shut down too early or started too late; sensor ranges may not be properly set for daytime and nighttime operation; sensors may not be calibrated or may be in the wrong location, or; the function of the workplace space may have been altered.

Check items and maintenance recommendations for controls are listed in Checklist 5-11.

Checklist 5-11 Checking and maintaining controls and building automation systems
Checks 1. Are areas within the building too hot, too cool, too stuffy, or too odourous? 2. Are the control sensors set to appropriate operating ranges? 3. Are control system documents in place and are the system's operating algorithms understood? 4. Are sensors placed in the appropriate location for zone control? 5. Do control sensors reflect actual conditions or do they need to be recalibrated? 6. Are all sensor locations documented and are all sensors accessible? 7. Is the control clock set properly?
Maintenance 1. The manual or automated control system, and the operation and performance of the air-handling units, should be checked annually. 2. Sensors should be verified and calibrated according to the manufacturer's specifications. Usually, relative humidity sensors are checked twice a year; all other sensors are checked once a year.

4. IAQ Testing and Key Performance Indicators

One of the tools that can be used to verify the design, operation, and performance of an air-handling system is to measure the basic IAQ indicators of temperature, relative humidity, and ventilation (refer to ASHRAE Standard 62.1-2010). The majority of IAQ workplace complaints are based on inadequate thermal comfort (hot or cold), stuffiness or lack of air movement, or the presence of unpleasant odours.

Temperature and relative humidity can be accurately measured using a psychrometer. A fan-powered unit will provide accurate readings in less than five minutes. While portable electronic measurement equipment is readily available, temperature and relative humidity sensors may require a considerable length of time to stabilize in a location (over 30 minutes) and therefore should not be used to "spot measure" workplace locations. Test equipment also requires regular accuracy verification and calibration.

Measurement of the ventilation rate can be estimated by indirect methods, either by using temperature differences between the outdoor, indoor, and supply air, or by measuring indoor carbon dioxide (CO2) levels.

Carbon dioxide concentrations can be measured by using a hand pump and a direct-reading colorimetric tube, an electronic diffusion sensor, or a non-dispersive infrared analyser. Each method has different accuracies and methodologies.

A qualified IAQ consultant should be retained to investigate when other specific IAQ pollutants are suspected, such as airborne particulates due to construction, poor housekeeping, improper filtration, mould due to water damage, volatile organic compounds (VOCs) due to construction or renovation activities, or due to new building components. Refer to Module 2: VOC Sampling Strategies and Methods for further information.

Using a pragmatic approach, visible surface or airborne dust, wet or soiled areas, mould growth and odours in the work environment should be remediated. If mould is visible, there is no need to sample to quantify and identify the genus. The cause of contamination should be corrected and the area must be restored. The Canadian Construction Association, Mould Guidelines for the Canadian Construction Industry, defines three levels of mould remediation and provides procedures to clean and disinfect a contaminated air-handling unit.

Mould (fungi) spores and bacteria are part of the natural environment and are commonly present outdoors, indoors, and on all surfaces. Although there are no established airborne exposure limits/guidelines, some microbial air sampling guidelines have been published. If there are building occupant concerns about mould, sampling should be done by qualified specialists with recognized professional training and experience. If sampling will be required, clear objectives and criteria for the interpretation of results should be established. As a rule, indoor mould growth on water-damaged materials and other components needs to be remediated.

Following established water damage restoration procedures will minimize the potential for uncontrolled release of mould contamination during clean-up and minimize the potential for the recurrence of mould growth.

A comprehensive indoor environmental assessment should include both the measurement of IAQ parameters and an evaluation of the air-handling unit's design, operation, and performance.

Measured IAQ parameters in the workplace can be compared to key performance indicators (refer to ASHRAE Standard 62.1-2010).

5. Sources of Additional Information

1. Testing Effectiveness of Duct Cleaning and Its Impact on Airborne Particles, Mold and Biocide Levels in Commercial Office Buildings, NRC Construction, 2012: http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc55230.pdf

2. ASHRAE Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality

3. Canadian Construction Association, 82-2004, Mould Guidelines for the Canadian Construction Industry: www.cca-acc.com/documents/cca82/cca82.pdf

4. 2011 ASHRAE Handbook—HVAC Applications: http://www.ashrae.org/resources--publications/Description-of-the-2011-ASHRAE-Handbook-HVAC-Applications

5. EPA, Building Air Quality: A Guide for Building Owners and Facility Managers, 1991: http://www.epa.gov/iaq/largebldgs/pdf_files/iaq.pdf