BOC Exam Resource Guide

Section D - Maintain Indoor Environmental Quality to Standards

Introduction

Section D of the exam covers the critical work functions for **Maintaining Indoor Environmental Quality to Standards.** This resource guide is targeted to the content of the exam questions in this section of the exam. It is organized by topic area as noted in the Table of Contents. Each section provides the source of the citation, a link to where it can be found online, and a set of study questions about the content in the citation, followed by a paragraph or two of the material specific to the exam question. The study questions serve as guidance for independent study as candidates prepare for the exam. In addition to the study questions, the reading list provides practice questions and answers from the early versions of the certification exam. The study questions and practice questions are also covered in the BOC Exam Prep Webinar Series (http://www.theboc.info/certifications/exam/preparing-for-exam/). Additional resources are provided in the form of PDF documents which provide further discussion and useful illustrations, tables and figures. We recommend exam candidates familiarize themselves with the content and be prepared to answer the questions posed in each section.

Study Questions: These questions provide guidance for independent study of the topics in the Resource Guide. Study questions do not represent actual questions on the certification exam. Study questions appear under each citation in this document.

Practice Questions: These are questions that appeared on earlier versions of the certification exam and which have been retired from circulation. Practice questions are provided on the last page of this document.

Section D - Exam Blueprint Skill Areas and Number of Questions

Measure and monitor IEQ parameters (6 questions)

- Conduct an assessment of indoor air quality.
- Maintain an inventory of pollutant sources in the building.

Troubleshoot IEQ issues (5 questions)

- Manage the integrity of the building envelope.
- Operate building systems to meet indoor environmental quality standards.
- Investigate indoor environmental quality

Assist in developing & implementing an IEQ plan (4 questions)

- Manage consumables
- Manage environmental requirements (permits, etc.)
- Respond to IEQ complaints
- Implement lighting strategies to maintain indoor environmental quality.

Table of Contents

READING LIST

1. Pollutant Types

Carbon Monoxide

https://www7.nau.edu/itep/main/eeop/AirQlty/aq_iaqMsmts

https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_CarbonMonoxide.pdf

GOAL: Be familiar with the units of measure for common IAQ pollutants and the tools for collecting measurements.

STUDY QUESTIONS:

What is the unit of measure for CO2? ____

How is it measured? ____

What are normal levels of CO2 in a commercial building? __________________________

What standards exist for CO2 levels? ____

Indoor Air Quality Measurements: Facility Managers and Residents can find it challenging to determine if their buildings have exceptional, fair, or even poor indoor air quality (IAQ). Measuring and testing indoor air quality is an imperfect science with many variables, and the path to establishing whether or not a building has healthy indoor air is rarely clear cut. The most important tools for evaluating indoor air quality are your nose, eyes, and ears; however, there are additional measurements that can help assess indoor air quality in buildings.

While investigating any indoor air quality situation, be aware of the entire picture. Many parameters that may be contributing to an overall problem must be considered and checked. Also keep in mind that it is not uncommon to find multi-layered problems; finding and solving one issue may not get to the root cause. Think of an investigation as peeling an onion; as each layer is removed, another is exposed. Be sure to understand the exact time and place that problems are suspected, since many indoor air quality problems are transitory. Use common sense along with the proper tools and keep investigating and correcting problems until complaints stop.

Measurement Guidelines: The measurement guidelines outlined in the links below will provide a basic introduction to various measurements that may help assess indoor air quality. In addition to these guidelines, you may need to refer to the operator's manual for details on operation of the instrument. We do not recommend specific instruments. You should select an instrument based on your goals and approach. For example, I look for instruments that are low cost and measure one parameter. I am generally working with large groups of students and want to get everyone involved in making the measurements.

Resources:

Carbon Dioxide
http://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_CarbonDioxide.pdf

https://www.buildingenclosureonline.com/blogs/14-the-be-blog/post/91554-carbon-dioxide-levels-and-indoor-environmental-quality

https://www.co2meter.com/blogs/news/ashrae-co2-standards-classrooms

https://www.dhs.wisconsin.gov/chemical/carbondioxide.htm

Carbon Monoxide
http://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_CarbonMonoxide.pdf

Radon
http://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_Radon.pdf

https://www.who.int/news-room/fact-sheets/detail/radon-and-health

Thermal Comfort (Temperature / Relative Humidity)
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_ThermalComfort.pdf

https://www.buildingsiot.com/blog/thermal-comfort-temperature-and-humidity-control-in-buildings-bd

Surface Temperature
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_SurfaceTemperature.pdf

Ventilation (Air Flow)
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_AirMovementAirFlow.pdf

Particles
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_Particles.pdf

Volatile Organic Compounds
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_VolatileOrganicCompounds.pdf

Ozone
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_Ozone.pdf

Moisture Control / Mold
https://www7.nau.edu/itep/main/eeop/docs/airqlty/AkIAQ_MoistureControlMold.pdf

Particulates

https://www.cleatech.com/what-is-a-particle-counter/

https://www.pmeasuring.com/application_note/beginner-guide-to-particle-technology-3/

Basic Guide to Particulate Counters & Particle Counting, 2011© Particle Measuring Systems, Inc.

Editor's Note: This reference is specific to clean rooms and other specific conditions not typically found in commercial office buildings. Real time particle counters can be useful to verify filter performance and for limited forensic evaluations but aren't very useful for identifying surface contaminants. A common issue in IEQ is addressing potential health concerns, dust or bioaerosol related, by building occupants, particularly with sensitive individuals (e.g., allergic, asthmatic). It is customary to collect surface samples (e.g. tape lift) and sometimes air samples (e.g., spore trap) for particulate ID to understand what is in the environment that might trigger health concerns.

GOAL: Be familiar with surface particulate testing and the tools for collecting measurements.

STUDY QUESTIONS:

When might it be necessary to conduct a surface particulate contamination test?

____

What measurement tools would be used? ___________________________________

How clean is it? Surface particulate contamination testing provides valuable information about the cleanliness of critical components. Particle Measuring Systems (PMS) can be used to gauge performance of your cleaning system and reduce uncertainty about the final assembly.

The current trend in Environmental Monitoring Systems (EMS) is to focus on data integrity by using an industrial automated solution instead of the older PC based approaches. PC-based Environmental Monitoring Systems were common in the late 1990 and early 2000s and were the preferred solution because they cost less upfront and have reduced installation times compared to Automated Control Systems.

However, over the last ten years the reliability and complexity in requirements of an EMS has increased while the costs of industrial automated solutions has decreased. The requirements of the industry for a more robust and reliable EMS solution, that protects data integrity, is driving facilities to prefer an Industrial Automated Control Solution.

Learn about different options and considerations to protect your data integrity in an environmental monitoring system.

Carbon monoxide detector

http://positive-energy.com/monoxer-iii-19-8104/

Note: Search for "Monoxer III" once at the link.

A useful tool for CO safety checks on combustion stack gas and ambient air levels, Analyzing indoor air quality and safety, Furnace and boiler servicing or replacement. Measures and displays levels of CO 0-2,000 ppm. Good tools measure in increments of 1 ppm.

https://www.jjstech.com/0019-8104.html

GOAL: Understand safety issues associated with carbon monoxide in buildings and the methods used to control and monitor for it.

STUDY QUESTIONS:

What are common sources of CO in a commercial building?

What safety checks should be in place for measuring CO?

If initial testing does not confirm the presence of carbon monoxide, what might be the reasons?

What is carbon monoxide and who is at risk?

Carbon monoxide (CO) is a colorless, odorless deadly gas. Because you can't see, taste, or smell it, carbon monoxide can kill you before you know it's there.

Everyone is at risk for carbon monoxide poisoning. Experts believe, however, that individuals with greater oxygen requirements such as unborn babies, infants, children, senior citizens, and people with coronary or respiratory problems are at greater risk.

Why is carbon monoxide so dangerous?

The great danger of carbon monoxide is its attraction to hemoglobin in the bloodstream. When breathed in, carbon monoxide replaces the oxygen which cells need to function. When CO is present in the air, it rapidly accumulates in the blood, causing symptoms similar to the flu, such as headaches, fatigue, nausea, dizzy spells, confusion, and irritability. As levels increase, vomiting, loss of consciousness, and eventually brain damage or death can result.

Where does carbon monoxide come from?

Carbon monoxide is a by-product of combustion, present whenever fuel is burned. It is produced by common home appliances, such as gas or oil furnaces, gas refrigerators, gas clothes dryers, gas ranges, gas water heaters or space heaters, fireplaces, charcoal grills, and wood burning stoves. Fumes from automobiles and gas-powered lawn mowers also contain carbon monoxide and can enter a home through walls or doorways if an engine is left running in an attached garage.

All of these sources can contribute to a CO problem in the home. If a home is vented properly and is free from appliance malfunctions, air pressure fluctuations or airway blockages, carbon monoxide will most likely be safely vented to the outside. But in today's "energy efficient" homes this is frequently not the case. Tightly constructed/sealed homes can trap CO-polluted air in a home year-round. Furnace heat exchangers can crack, vents can become blocked, inadequate air supply for combustion appliances can cause conditions known as backdrafting or reverse stacking, which force contaminated air back into the home. Exhaust fans on range hoods, clothes dryers and bathroom fans can also pull combustion products into the home.

Mold

http://www.fsec.ucf.edu/en/consumer/buildings/basics/moldgrowth.htm Page 1., Consumer, Mold Growth, page authors Philip Fairey, Subrato Chandra and Neil Moyer of Florida Solar Energy Center (FSEC), University of Central Florida,2007-2014

GOAL: Understand the impact of fungi growth in buildings and how to prevent problems associated with it.

STUDY QUESTIONS:

What are the four critical requirements for mold growth in a commercial building?

Molds and mildew are fungi. There are 4 critical requirements for mold growth – available mold spores, available mold food, appropriate temperatures and considerable moisture. The removal of any one of these items will prohibit mold growth.

Radon

https://www.epa.gov/radon/radon-schools

https://www.who.int/news-room/fact-sheets/detail/radon-and-health

Radon is a known human carcinogen. Prolonged exposure to elevated radon concentrations causes an increased risk of lung cancer. Like other environmental pollutants, there is some uncertainty about the magnitude of radon health risks. There are two general ways to test for radon:

1. A short-term test is the quickest way to test for radon. In this test, the testing device remains in an area (e.g., schoolroom) for a period of 2 to 90 days depending on the device. Because radon levels tend to vary from day to day and from season to season, a short-term test is less likely than a long- term test to give an average radon level for a school year.
2. A long-term test remains in place for more than 90 days. A long-term test (e.g., a test conducted over the school year) will give a result that is more likely to represent the school year average radon level in a schoolroom than a short-term test. Short-term measurements are most often made with activated charcoal devices, alpha track detectors, electret-ion chambers, continuous monitors, and charcoal liquid scintillation detectors. Alpha track detectors and electret-ion chambers are used for long-term tests. Some general information about radon detectors is given in Appendix D. More detailed information can be found in the document entitled Indoor Radon and Radon Decay Product Measurement Device Protocols (EPA-402-R-92-004). In order to assure adequate test results, only devices that are used for a measurement period of at least 48 continuous hours should be used when testing for radon in school buildings.

Volatile Organic Compounds

https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds

last updated 11/8/2012, EPA Volatile Organic Compounds (VOCs), Technical Overview, General Definitions & Classifications

GOAL: Understand what VOCs are and why they are found in buildings.

STUDY QUESTIONS:

What are the sources of VOCs in a commercial building?

How are they measured?

When would it be appropriate to test for VOC's?

General Definition and Classifications

Volatile organic compounds (VOCs) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates and ammonium carbonate, which participates in atmospheric photochemical reactions, except those designated by EPA as having negligible photochemical reactivity2.

Volatile organic compounds, or VOCs are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure3. This is the general definition of VOCs that is used in the scientific literature, and is consistent with the definition used for indoor air quality. Since the volatility4 of a compound is generally higher the lower its boiling point temperature, the volatility of organic compounds are sometimes defined and classified by their boiling points.

For example, the European Union uses the boiling point, rather than its volatility in its definition of VOCs.

A VOC is any organic compound having an initial boiling point less than or equal to 250° C measured at a standard atmospheric pressure of 101.3 kPa.5, 6, 7 VOCs are sometimes categorized by the ease they will be emitted. For example, the World Health Organization (WHO) categorizes indoor organic pollutants as:

- Very volatile organic compounds (VVOCs)
- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)

The higher the volatility (lower the boiling point), the more likely the compound will be emitted from a product or surface into the air. Very volatile organic compounds are so volatile that they are difficult to measure and are found almost entirely as gases in the air rather than in materials or on surfaces. The least volatile compounds found in air constitute a far smaller fraction of the total present indoors while the majority will be in solids or liquids that contain them or on surfaces including dust, furnishings and building materials.

2. IEQ Standards & Guidelines

2011 ASHRAE Handbook – HVAC Applications, Review Sections 3.2 and 3.6

Review Table 3. Recommended Design Criteria for Ventilation and Filtration of Office Buildings

GOAL: Understand the basics of ventilation and filtration and their purpose.

STUDY QUESTIONS:

What is the difference between ventilation and filtration for office spaces?

____

What standards exist for ventilation and filtration for office spaces?

____

What space types in office buildings might require special considerations for ventilation?

____

Table 3 Typical Recommended Design Criteria for Ventilation and Filtration for Office Buildings

Category	Ventilation and Exhaust[a,b]				Minimum Filtration Efficiency, MERV[c]
	Combined Outdoor Air (Default Value) cfm per Person	Occupant Density,[f] per 1000 ft^2	Outdoor Air cfm/ft^2	Outdoor Air cfm per Unit	
Office areas	17	5			6 to 8
Reception areas	7	30			6 to 8
Main entry lobbies	11	10			6 to 8
Telephone/data entry	6	60			6 to 8
Cafeteria	9	100			6 to 8
Kitchen[d,e]			0.7 (exhaust)		NA
Toilets				70 (exhaust)	NA
Storage[g]			0.12		1 to 4

Notes:

[a]Based on ASHRAE *Standard* 62.1-2010, Tables 6-1 and 6-4. For systems serving multiple zones, apply multiple-zone calculations procedure. If DCV is considered, see the section on Demand Control Ventilation (DCV).

[b]This table should not be used as the only source for design criteria. Governing local codes, design guidelines, ANSI/ASHRAE *Standard* 62.1-2010 and user's manual, (ASHRAE 2010) must be consulted.

[c]MERV = minimum efficiency reporting values, based on ASHRAE *Standard* 52.2-2007.

[d]See Chapter 33 for additional information on kitchen ventilation. For kitchenette use 0.3 cfm/ft^2

[e]Consult local codes for kitchen exhaust requirements.

[f]Use default occupancy density when actual occupant density is not known.

[g]This recommendation for storage might not be sufficient when the materials stored have harmful emissions.

Office Building Areas with Special Considerations

Office building areas with special ventilation and cooling requirements include elevator machine rooms, electrical and telephone closets, electrical switchgear, plumbing rooms, refrigeration rooms, and mechanical equipment rooms. The high heat loads in some of these rooms may require air-conditioning units for spot cooling. In larger buildings with intermediate elevator, mechanical, and electrical machine rooms, it is desirable to have these rooms on the same level or possibly on two levels. This may simplify horizontal ductwork, piping, and conduit distribution systems and allow more effective ventilation and maintenance of these equipment rooms. An air-conditioning system cannot prevent occupants at the perimeter from feeling direct sunlight. Venetian blinds and drapes are often provided but seldom used. External shading devices (screens, overhangs, etc.) or reflective glass are preferable. Tall buildings in cold climates experience severe stack effect. The extra amount of heat provided by the air-conditioning system in attempts to overcome this problem can be substantial. The following features help combat infiltration from stack effect:

- Revolving doors or vestibules at exterior entrances
- Pressurized lobbies or lower floors
- Tight gaskets on stairwell doors leading to the roof
- Automatic dampers on elevator shaft vents
- Tight construction of the exterior skin
- Tight closure and seals on all dampers opening to the exterior

IPMVP Standard

International Performance Measurement & Verification Protocol & Concepts & Practices for Improved Indoor Environmental Quality, Vol. II, DIANE Publishing

The M&V protocol establishes parameters for measuring indoor environmental conditions based on seasonal variability. Parameters that don't vary much include are light levels and air flow rates. Higher variability is with indoor temperatures and humidity, carbon dioxide and monoxide concentrations, and outdoor air intake. Building occupants' perceptions are also relevant in establishing IEQ conditions.

GOAL: Become familiar with the pros and cons of various energy conservation methodologies.

STUDY QUESTIONS:

What is the potential impact on IAQ of using an outside air economizer for free cooling?

What precautions or mitigations might be taken to reduce IAQ impacts of this energy conservation measure?

Energy Conservation Measures (ECM's) that influence indoor environmental quality

Review Section 6, Linkages between energy conservation measures & IEQ (see attached PDF file of Table 2), International Performance Measurement & Verification Protocol: Concepts & Practices for Improved Indoor Environmental Quality, Vol. II, DIANE Publishing

Section 6 lists common energy conservation measures for commercial buildings, describes their potential influence on IEQ, and identifies precautionary actions or mitigations that can help to assure acceptable IEQ. The primary information is provided in Table 2. For many energy conservation measures, the cited references provide additional information on the IEQ impacts or on the related precautions and mitigations. The measures marked with "_" in Table 2 deserve special consideration because they will often simultaneously improve IEQ and save energy. Because of the growing interest in IEQ, energy efficiency proposals that are expected to protect or improve IEQ will have a competitive advantage relative to proposals that ignore IEQ. The last column of Table 2 links each energy conservation measure to the most directly relevant IEQ measurement and verification (M&V) alternatives provided subsequently in Table 4. (PDF attached)

IEQ Impacts

Backflow and the harmful effects
https://valleyfire.com/the-dangers-of-backflow-solutions-for-public-safety/

QUESTIONS: What is backflow and what are the harmful effects? When would a backflow prevention device be appropriate to install and monitor in a commercial building? What inspection or testing of these conditions is advised?

Backflow takes place when the flow of contaminated liquid reverses and mixes with clean or "potable" water. This generally occurs in or between the public water system and a consumer's potable water system. Backflow can make water unusable or unsafe to consume. The reversal of contaminated liquids can place pollutants, pesticides, and other harmful agents in the water supply and the aquifer. A Backflow prevention device is used to protect water supplies and the aquifer from contamination.

Within distribution systems there exist points called cross-connections where non-potable water can be connected to potable sources. These cross-connections can provide a pathway for backflow of non-potable water into potable sources. Backflow can occur either because of reduced pressure in the distribution system (termed back-siphonage) or the presence of increased pressure from a non-potable source (termed backpressure). Back-siphonage may be caused by a variety of circumstances, such as main breaks, flushing, pump failure, or emergency firefighting water drawdown. Backpressure may occur when heating/cooling, waste disposal, or industrial manufacturing systems are connected to potable supplies and the pressure in the external system exceeds the pressure in the distribution system. Both situations act to change the direction of water, which normally flows from the distribution system to the customer, so that non-potable and potentially contaminated water from industrial, commercial, or residential sites flows back into the distribution system through a cross-connection. During incidents of backflow, these chemical and biological contaminants have caused illness and deaths, with contamination affecting a number of service connections. The number of incidents actually reported is believed to be a small percentage of the total number of backflow incidents in the United States.

The risk posed by backflow can be mitigated through preventive and corrective measures. For example, preventative measures include the installation of backflow prevention devices and assemblies and formal programs to seek out and correct cross-connections within the distribution system and, in some cases, within individual service connections. Corrective measures include activities such as flushing and cleaning the distribution system after a detected incident. These may help mitigate any further adverse health effects from any contaminants that may remain in the distribution system.

Carbon Dioxide Impacts on Occupants

http://newscenter.lbl.gov/2012/10/17/elevated-indoor-carbon-dioxide-impairs-decision-making-performance/; 10/17/2012 (updated 2/18/2015) by Julie Chao, Elevated Indoor Carbon Dioxide Impairs Decision-Making Performance, posted to News Center Berkeley Lab

STUDY QUESTIONS:

What is the maximum level of CO2 acceptable in indoor environments? Levels above this maximum can affect occupants in what ways?

Poor IEQ Impacts on Occupants

Elevated Indoor Carbon Dioxide Impairs Decision-Making Performance Overturning decades of conventional wisdom, researchers at the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) have found that moderately high indoor concentrations of carbon dioxide (CO_2) can significantly impair people's decision-making performance. The results were unexpected and may have particular implications for schools and other spaces with high occupant density.

On nine scales of decision-making performance, test subjects showed significant reductions on six of the scales at CO_2 levels of 1,000 parts per million (ppm) and large reductions on seven of the scales at 2,500 ppm. The most dramatic declines in performance, in which subjects were rated as "dysfunctional," were for taking initiative and thinking strategically. "Previous studies have looked at 10,000 ppm, 20,000 ppm; that's the level at which scientists thought effects started," said Berkeley Lab scientist Mark Mendell, also a co-author of the study. "That's why these findings are so startling."

IEQ Strategies

Demand Control Ventilation

https://svach.lbl.gov/demand-controlled-ventilation/

GOAL: Become familiar with the pros and cons of various energy conservation methodologies.

STUDY QUESTIONS:

What is demand control ventilation?

When might ventilation rates controlled by CO2 sensors be inadequate for ensuring good IAQ?

Demand Control Ventilation (DCV) is an approach to ventilation that modulates the amount of outside air supplied to a building based on actual occupancy, saving energy and potentially improving humidity control as well. There is one limitation of DCV that end users need to be aware of: ventilation control based on CO2 levels is an important tool that can help control occupant-related pollutants and satisfy occupant-based ventilation standards, but relying on CO2 sensors alone to indicate or control the ventilation rate will not always guarantee good IAQ, particularly in buildings that have significant non-human sources of air pollutants. A thorough IAQ strategy should also include a complete audit of potential pollutant sources in the building, such as vapors from copiers, building materials, furniture, cleaning solutions or, in a retail or warehouse setting, the products on the shelves.

CMMS Systems

https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19634.pdf
Operations & Maintenance Best Practices, A Guide to Achieving Operational Efficiency, August 2010.

https://www.ifm.com/lt/en/shared/technologies/real-time-maintenance/rtm

https://www.ibm.com/products/maximo/maintenance-management

STUDY QUESTIONS:

What is real-time maintenance management?

What is the difference between a standard filter change PM schedule and a need-based filter change?

How might integration of a CMMS system with an EMCS be used to achieve a real-time filter maintenance program?

One of the greatest benefits of the CMMS is the elimination of paperwork and manual tracking activities, thus enabling the building staff to become more productive. It should be noted that the functionality of a CMMS lies in its ability to collect and store information in an easily retrievable format. A CMMS does not make decisions, rather it provides the O&M manager with the best information to affect the operational efficiency of a facility.

Benefits to implement a CMMS include the following:

- Detection of impending problems before a failure occurs resulting in fewer failures and customer complaints.
- Achieving a higher level of planned maintenance activities that enables a more efficient use of staff resources.
- Affecting inventory control enabling better spare parts forecasting to eliminate shortages and minimize existing inventory.
- Maintaining optimal equipment performance that reduces downtime and results in longer equipment life.

CMMS systems automate most of the logistical functions performed by maintenance staff and management. CMMS systems come with many options and have many advantages over manual maintenance tracking systems. CMMS systems can be used to track and manage maintenance tasks associated with a facility’s IEQ management program including IEQ maintenance procedures, work orders, and product inventory.

CMMS and EMCS (Energy Management and Control System) Integration

As technology improves and both of these systems develop capabilities, opportunities for integration exist. A good example is with air filtration systems. Traditionally, air filters are changed as part of a time-based PM activity – filters may get changed every 3 months, needed or not. Newer filtration systems made use of pressure sensors to calculate a need based filter change out. Many of these systems communicate back though an existing EMCS and notify the system monitor of differential pressure limit/alarm and the need for a filter change.

The opportunity and capability now exists to "port" this same differential pressure limit from the EMCS directly to the CMMS. This development affords a level of real-time maintenance management, whereby the filter change notification becomes an automatically generated work order scheduled based on need. In addition, this particular filter item is removed from inventory and a re-order paced if necessary. While this example highlight a simple air filter integration capability, the same logic applies to many other systems and equipment for which time-based maintenance can be replaced with need-based maintenance.

Green Cleaning & Integrated Pest Management

http://www.leeduser.com/credit/EBOM-2009/IEQc3.6 LEEDuser, US Green Building Council (USGBC), EBOM-2009 IEQc3.6 Green Cleaning & Indoor Integrated Pest Management

STUDY QUESTIONS:

What is IPM?

What is indoor IPM?

Is there a LEED credit for indoor IPM?

Intent

To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants, which adversely affect air quality, human health, building finishes, building systems and the environment.

Requirements

Develop, implement and maintain an indoor integrated pest management (IPM) plan, defined as managing indoor pests in a way that protects human health and the surrounding environment and that improves economic returns through the most effective, least-risk option. IPM calls for using least-toxic chemical pesticides, minimum use of chemicals, use only in targeted locations and use only for targeted species. IPM requires routine inspection and monitoring. The plan must include the following elements, integrated with any outdoor IPM plan used for the site as appropriate:

- Integrated methods, site or pest inspections, pest population monitoring, evaluation of the need for pest control and 1 or more pest control methods, including sanitation, structural repairs, mechanical and living biological controls, other nonchemical methods, and if nontoxic options are unreasonable and have been exhausted, a least toxic pesticide.
- Specification of the circumstances under which an emergency application of pesticides in a building or on surrounding grounds being maintained by building management can be conducted without complying with the earlier provisions.
- A communications strategy directed to building occupants that addresses universal notification, which requires advance notice of not less than 72 hours before a pesticide under normal conditions and 24 hours after application of a pesticide in emergencies, other than a least-toxic pesticide, is applied in a building or on surrounding grounds that the building management maintains.

EBOM-2009 IEQc3.6: *Green Cleaning—Indoor Integrated Pest Management*

Implementation of an indoor integrated pest management program qualifies as a credit under the LEED EBOM standard. To comply with the credit, performance requirements are to provide pesticide application logs for the most recent 25% of recertification performance period and to "demonstrate that the IPM plan was implemented and maintained 100% of the time."

Ventilation Strategies

VAV Operation

https://www.pnnl.gov/projects/om-best-practices/variable-air-volume-systems

https://www.computrols.com/static-pressure-control-vav-hvac/

STUDY QUESTIONS:

Ventilation and indoor air quality work hand in glove. Name some examples of VAV control practices building operators can take to manage ventilation rates for energy efficiency and good IAQ?

Ventilation and indoor air quality. VAV box control and supply air pressure reset often have the largest impact on system efficiency. Design engineers are encouraged to pay particular attention to these two issues. Here are some of the key recommendations for operation of VAV systems to achieve cost-effective energy savings which can be implemented using current technology.

- Reduce design system static pressure
- Employ demand-based static pressure reset
- Use low-pressure plenum returns/relief fans

- Employ demand-based, supply temperature reset to reduce reheat energy and extend economizer effectiveness
- Design fan systems to turn down and stage efficiently
- Size terminal units to balance energy impacts of pressure drop and minimum airflow control
- Set terminal unit minimums as low as required for ventilation and use intelligent VAV box control schemes to prevent stratification
- Employ demand-based ventilation controls for high-density occupancies
- Design conference rooms to provide ventilation without excessive fan energy or reheat

Ventilation Flow Rate

http://www.ncbi.nlm.nih.gov/pubmed/21470313; Abstract – Indoor Air by Fisk WJ, Black D, Brunner G.; 2011 John Wiley & Sons A/S

Note: The above link will take you to the article and allow you to read about a paragraph of it for free. Full access to the document requires payment. The pertinent information for BOC exam prep is provided below.

GOAL: Understand ventilation principles as they relate to building and occupant needs.

STUDY QUESTIONS:

What unit of measure is used for ventilation flow rates?

____

How is it measured?

____

What standards exist for flow rates in commercial buildings?

____

Why might air flow rates differ for different space uses?

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Owners, designers, and operators of office buildings have an opportunity to improve IEQ, health, work performance, and comfort of building occupants and to obtain economic benefits by improving IEQ. These benefits can be achieved with simultaneous energy savings or with only small increases in energy costs. The scenarios include increasing ventilation rates when they are below 10 or 15 l/s per person, adding outdoor air economizers and controls when absent, eliminating winter indoor temperatures >23°C, and reducing dampness and mold problems. The estimated benefits of the scenarios analyzed are substantial in magnitude, including increased work performance, reduced Sick Building Syndrome symptoms, reduced absence, and improved thermal comfort for millions of office workers. The combined potential annual economic benefit of a set of non-overlapping scenarios is approximately $20 billion. While the quantitative estimates have a high uncertainty, the opportunity for substantial benefits is clear. Some IEQ improvement measures will save energy while improving health or productivity, and implementing these measures should be the highest priority.

Basic concept of ventilation flow rate

The ventilation flow rate can be referred to as either an absolute ventilation flow rate in liters/second, or an air-change rate relative to the volume of the space. For example, in an airborne infection isolation room, we need a 12 ACH air-change rate (CDC, 2005), while in an office, we need a 10 l/s per person ventilation rate.

3. IEQ Management

Commissioning and Retro-Commissioning

https://cx.lbl.gov/definition.html

https://www.newmanconsultinggroup.us/commissioning

STUDY QUESTIONS:

What is building retro-commissioning?

What is the difference between retro-commissioning and monitoring-based commissioning?

How might a retro-commissioning project improve IAQ?

Building commissioning is a method of risk reduction for new construction and major renovation projects to ensure that building systems meet their design intent, operate and interact optimally and provide the owner what he or she expects. This systematic process typically includes building HVAC, controls, lighting, hot water, security, fire, life and safety systems.

Successful Cx results in optimal energy efficiency, indoor environmental quality, reduced change orders during construction, extended systems life and reduced operation and maintenance costs, often paying for itself before construction is completed. To be most effective, building commissioning begins in the planning phase and continues through design, construction, startup, acceptance, training and the warranty period, and continues throughout a building's life cycle.

The commissioning process can be applied to existing buildings that have never been commissioned to restore them to optimal performance. Retro-commissioning (RCx) is a systematic, documented process that identifies low-cost operational and maintenance improvements in existing buildings and brings the buildings up to the design intentions of its current usage.

RCx typically focuses on energy-using equipment such as mechanical equipment, lighting and related controls and usually optimizes existing system performance, rather than relying on major equipment replacement, typically resulting in improved indoor air quality, comfort, controls, energy and resource efficiency.

Monitoring-based Commissioning

7/10/2013 Monitoring-based Commissioning, Siemens Whitepaper, Jim Butler, Craig Engelbrecht, Jim Lee & Jim Sinopoli

https://www.downloads.siemens.com/download-center/Download.aspx?pos=download&fct=getasset&id1=A6V10702463

According to a report by the Lawrence-Berkeley National Laboratory, "Monitoring based commissioning (MBCx) combines ongoing building energy system monitoring with standard retro-commissioning (RCx) practices with the aim of providing substantial, persistent, energy savings*." What we are really talking about is a sophisticated package of software applications that combines building data from a wide variety of sources to better manage building performance and efficiency. MBCx involves the implementation of improvement measures along with ongoing service and insights necessary for full transparency, measurement, and reporting. That is, what facility engineers have done manually for decades can now be completed more efficiently, more comprehensively, and more accurately by combining building and energy system data with an engineering team's expertise through the

MBCx process. When MBCx is built into a continuous building improvement process, it allows combined technologies involved in data mining to identify faults or issues in building systems with the necessary human analysis to determine how to address those faults or issues. Truly advanced MBCx solutions will also help identify and prioritize resolution paths; for example, if there is simultaneous heating and cooling in air handler 5, facility engineers should investigate a leaking chilled water valve to avoid a potential costly expenditure.

General IEQ Building Walk-through Checklists

https://19january2017snapshot.epa.gov/iaq-schools/walk-through-inspection-checklist-indoor-air-quality-tools-schools_.html

https://sftool.gov/explore/green-building/section/30/ieq/system-overview#facility-wide/hvac-natural-ventilation

GOAL: Understand the need for good communication, information gathering, recordkeeping, and follow-up when investigation of building occupant health concerns.

STUDY QUESTIONS:

What information is important to collect and record when investigating an IEQ complaint?

What are important areas inside the building to be inspected for IEQ?

What equipment is important to inspect?

IEQ Management Guidance

The Centers for Disease Control recommends the following actions be taken when health problems are believed to be caused by exposure to dampness or mold in the workplace:

A. Always respond when occupant health concerns are reported.
B. Establish clear procedures for recording and responding to IEQ complaints to ensure an adequate and timely response.
   a. Log all complaints or problem reports.
   b. Collect information about each complaint. This information should include, but not be limited to: what symptoms are people reporting; What conditions in the facility are suspected of causing problems; Where and when were the problems noticed and/or reported?
   c. Ensure confidentiality.
   d. Develop and communicate a response plan.
   e. Identify appropriate resources for response.
   f. Apply remedial action.
   g. Provide timely feedback to building occupants regarding the complaint and response actions until complete.
   h. Follow-up to ensure that remedial action has been effective.

C. Regularly inspect building areas for evidence of dampness; initiate prompt steps within 48 hours to identify and correct the causes of any dampness problems found.
D. Conduct regularly scheduled heating, ventilating, air-conditioning (HVAC) system inspections and walkthroughs. Use the Walkthrough Inspection Checklist or Teacher's Classroom Checklist to document findings. Problem areas should be entered into the work order system for scheduling and correction.
E. Prevent high indoor humidity through the proper design and operation of HVAC systems.
F. Dry any porous building materials that have become wet from leaks or flooding within 48 hours.
G. Clean and repair or replace any building materials that are moisture-damaged or show evidence of visible mold growth.
H. Encourage occupants who have developed persistent or worsening respiratory symptoms while working in the building to see a health care provider.
I. Follow health care provider recommendations for relocation of occupants diagnosed with building-related respiratory disease.
J. Establish an indoor environmental quality (IEQ) team consisting of a coordinator and representatives of the building employees, employers, and building management who would oversee implementation of an IEQ program.

Indoor Environmental Quality Checklist, University of Pennsylvania:
https://ehrs.upenn.edu/sites/default/files/inline-files/Indoor%20Environmental%20Quality%20Checklist.pdf

INDOOR ENVIRONMENTAL QUALITY QUARTERLY BUILDING INSPECTION CHECKLIST

- Interview of Building occupants (preferably Plant Manager) to determine if complaints have been filed concerning IEQ, and to identify known problem areas (water leaks, HVAC, repairs, unusual odors, etc.)
- Inspect air filter change schedule. Check HVAC units for proper installation. Check A/C for cleanliness.
- Check for quantity of air and quality of air dampers.
- Inspect coils, ensure condensate drain pans are clean.
- Check for standing water, inside or outside the building, especially around A/C units.
- Thorough walk-through of Building to determine if there are areas of the building connected to ventilation shaft where moisture can collect and stand for periods of time.
- Inspect chemical storage rooms for chemicals that should be discarded or have damaged containers.

- Inspect wooden cabinets with water supplies, i.e. chemistry labs and home economic labs, for leaks or leaks that have been repaired.
- Inspect drains to determine if water is being carried off properly. Check outdoor storm drains for stoppages by leaves, grass, etc. Check floor drains to ensure proper drainage.

4. Practice Questions and Answers

The practice questions below are retired exam questions from early versions of the certification exam. Candidates should review the questions and answers, and be prepared to answer questions of similar content.

1. Unintended increase in humidity of delivered conditioned air could be caused by

   a. cooling coil control valve failed shut
   b. electric heat failed on
   c. excessive air velocity at the cooling coil
   d. improper fire damper position

2. In typical office settings to avoid complaints of “drafts”, which of the following factors is not a concern about the air moving past the building occupants?

   a. The temperature of the air
   b. The turbulence of the air
   c. The CO_2 content of the air
   d. The velocity of the air

3. Dirt visible on ceiling surfaces adjacent to slot diffusers is typically caused by

   a. clogged filters
   b. fan speed set too low
   c. dirty distribution ducts
   d. dirt entrained in the air of the space being conditioned

4. Maintaining gaskets on roof access doors ensuring a tight building envelope, and pressurizing lower lobbies in tall buildings are ways to minimize:

   a. mold growth
   b. temperature complaints
   c. window condensation
   d. stack effect

5. Based on measured Carbon Dioxide levels in a classroom at a university building, the space appears to be under-ventilated. The CO_2 levels are around 1500 ppm. The facility has one main

air-handler with an integrated economizer and a supply fan controlling to a fixed duct-static pressure set-point. Each zone in the facility has a VAV box with a re-heat coil.

When trouble-shooting this ventilation issue, which activity should be included in your task list?

a. Make sure the VAV box serving the classroom provides the minimum amount of airflow during all operational modes: min heating, max heating, min cooling and max cooling.
b. Make sure the building static pressure sensor is calibrated and that the supply fan changes speed to meet the building static pressure sensor set-point.
c. Make sure the control valve on the hot water loop connected to the VAV box is not leaking when the zone is in a re-heat mode.
d. Make sure the air-side economizer is working properly and that the required amount of outside air is introduced into the facility when the OSA dampers are fully open.

Practice Question Answers:

1. a   2. c   3. d   4. d   5. a

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