G|PRO

OPERATIONS AND MAINTENANCE ESSENTIALS

TEST YOURSELF QUESTIONS: Answer Key

CHAPTER 1: Operations and Maintenance in Green Building

1. **Why does sustainability in building operations and management matter?**
   Since buildings consume more than 40% of energy and 12% of water, achieving more sustainable building operations can contribute toward significant environmental improvements. When properly operated for efficiency, well-maintained buildings can have 20-50% lower operating costs while drastically reducing environmental impact. In addition to energy savings, indoor air quality (IAQ) is a primary sustainability concern for building occupants, operators, and engineers - given the profound impact it can have on human health *(see pages 2-4).*

2. **Why use a "whole-building" approach when thinking about operation of a building's facilities?**
   When thinking about operation of a building's facilities, use a "whole-building" approach rather than addressing each system individually. This approach fits both as an underlying sustainability concept and as a basic principle of building operations science. We use this approach to explore energy and water usage in buildings and to determine how to make our buildings operate more efficiently *(see page 2)*.

3. **Give an example of how the operation of one facility system in a building affects another of the building's systems.**
   Consider the fact that if you change out all your lighting from incandescent to fluorescent you will save money on your electric bill, but you will also see the heating bill go up slightly, and the air-conditioning bill go down. The power going to the lights, which is released as heat to the space the lights are in, will have been reduced dramatically. This increases the heating load and decreases the cooling load *(see page 4)*.

CHAPTER 2: Building Performance Metrics

1. **When would you measure water by cubic feet rather than by gallons?**
   The term cubic feet (cf) or hundred cubic feet (ccf or HCF) is used when measuring larger amounts of water *(see page 6)*.

2. **Why is it important to measure energy and water consumption?**
   Keeping track of water and energy consumption is an important component in achieving sustainability in your building operations, as it allows you to identify areas for improvement and benchmark progress (see page 6).

3. **What is benchmarking and how does it help manage energy and water consumption?**
   Benchmarking is establishing a baseline of energy or water use over at least a full-year period, for comparison with future annual patterns of use and to average behavior for similar buildings. Benchmarking helps manage energy and water consumption by using metrics to track, monitor,

and assess energy and water use. The process of benchmarking identifies potential savings and prioritizes necessary improvements *(see page 12)*.

4. **Why pay close attention to water and energy bills? What is an example of something that could cause a jump in your building's fuel bill?**
   Paying careful attention to water and energy bills and learning how to make sense of the data helps you identify problems that need immediate attention and improvements. An example of something that could cause a jump in your building's fuel bill is equipment or control failure, since a pump can be running full time when it is only needed a few hours per day *(see page 11)*.

CHAPTER 3: The Building Envelope

1. **What is the purpose of the building envelope and why is it important that it works effectively?**
   A properly functioning envelope is essential to thermal comfort and the efficient operation of building systems. If the envelope does not limit heat flow, control air infiltration, and manage moisture sufficiently, the building can have serious problems that affect the health of building occupants, require other building systems to work harder, increase energy consumption, and even reduce the life of the building *(see page 16)*.

2. **What are the three types of heat transfer and how does the building envelope control them?**
   The three types of heat transfer are conduction, convection, and radiation.
   - **Conduction:** Heat is transferred through direct material contact. Building insulation increases the thermal resistance of the envelope and reduces conductive losses.
   - **Convection:** Heat is transferred through air (or water) movement. Tight building construction, weather seals, and vapor barriers work to reduce air infiltration and convective heat losses.
   - **Radiation:** Heat is transferred through direct line-of-sight electromagnetic waves (light or infra-red). Wall, glass, and roof coatings or shade on the building can influence the reflection and absorption of solar heat radiation.

   (see pages 16-17)

3. **Explain the stack effect and two methods used to control it.**
   The stack effect occurs when the warm air within a building rises to the top and escapes through openings at the roof, pulling in new, cooler air from openings at the bottom. The impact of stack effect can be controlled by compartmentalizing interior spaces and coordinating use of HVAC ventilating systems and operable windows *(see page 21)*.

4. **Describe three things building managers can do to maintain air integrity in a building.**
   Three things building managers can do to maintain air integrity in a building are:
   1. Ensure careful sealing at wall penetrations and at the entire perimeter of the window openings during any window replacement or other façade repair.
   2. Request that tenants notify the building manager or engineer if the temperature is too hot in winter, rather than openings windows in an attempt to prevent overheating of apartments.
   3. If the building has attached parking facilities, make sure there is adequate air sealing to eliminate the possibility of carbon monoxide exhaust infiltration into the living spaces.

   (see page 21)

5. **Describe how to prevent condensation of water in walls.**

   You can prevent condensation of water in walls through proper wall insulation, well-sealed insulated windows, and vapor barriers. In effective construction, vapor barriers are installed to prevent moisture from entering the wall cavity and reaching the insulation. The most important step is to ensure that there is only one vapor barrier in a wall, and it should face toward the side that is warm in winter, so that moisture on either side of it can dry out *(see page 22)*.

6. **Describe three things you could see in your building that would indicate the building envelope is not functioning correctly.**

   Indications of an improperly functioning building envelope are:

   1. Patterns of complaints concerning discomfort, suggesting a hidden problem.
   2. Increased demand on heating or cooling systems.
   3. Water leaks and mold buildup.

   (see page 23)

CHAPTER 4: Water Use

1. **How is using a single-dial water meter different from using a compound water meter?**

   On a single dial water meter, the consumption is read on one gauge. On a compound meter, both gauges need to be added together *(see page 25)*.

2. **What are two ways to check for water leaks in boilers?**

   If you have a leak in the mechanical water system, you will see higher-than-expected water use. To check this, attach a water meter to the low water cutoff and automatic feeder combination, and track usage through your logging process. Another way to determine a leak here is by turning off the water feed valve, then marking the gauge glass with a grease pencil and checking the level 12 hours later. If the water level has dropped by a large amount, there is most likely a leak *(see page 27)*.

3. **Name three causes of water use spikes.**

   Leaks, outdated or malfunctioning equipment or appliances, and occupant usage can all contribute to water use spikes *(see page 26)*.

4. **Describe four ways tenants can reduce water consumption.**

   Some ways tenants can reduce water consumption are by reporting leaks and signs of corrosion, using low-flow fixtures, purchasing newer ENERGY STAR and WaterSense appliances that use less water, turning off water when brushing teeth, scrubbing pots in the sink, and washing clothes and dishes only when there is a full load *(see pages 26-27)*.

CHAPTER 5: Heating and Cooling

1. **What does combustion efficiency measure, and how do you measure it?**

   Combustion efficiency measures how much energy is lost "up the stack" by a piece of fuel-burning equipment. Any energy that goes up the stack will not be available for useful heat in the building. So, if 20% of the input fuel's energy is lost in the flue gas outlet, the equipment has 80% combustion efficiency. Combustion efficiency is measured with a handheld instrument that analyzes flue gases while the boiler is firing *(see page 31)*.

2. **What can building operators do to maintain equipment and prevent typical boiler malfunctions?**

   To maintain equipment and prevent typical boiler malfunctions, building operators can:

   - Clean the burner—if it is dirty, fuel and air won't be delivered in the right ratio.
   - Pay attention to the color of the flame. For gas, it should be blue and steady and never orange. For oil, a fluctuating yellow flame is normal.
   - Clean nozzles of oil burners a minimum of once a week to ensure proper atomization of the fuel.
   - Change filters and clean coils per manufacturer's specifications.

   (see page 32)

3. **How do you monitor chiller efficiency?**

   The best method to monitor chiller efficiency is to monitor energy input (electricity or heat) into the chiller and compare it to Cooling Degree Days (CDD). You can also monitor efficiency by tracking supply and return water temperatures, determining how much energy should be required to generate a ton of cooling compared to actual use, and using BMS to set chiller schedules *(see page 33)*.

4. **Give three examples of problems that can arise with HVAC distribution and ways to manage those problems.**

   Three examples of problems with HVAC distribution are:

   - When hot or cold water or air moves through a pipe or duct, it will lose or gain heat quickly if insulation is inadequate. Check for and repair all loose or missing insulation. On older systems, be sure to have samples checked for asbestos before proceeding.
   - When uninsulated pipes and ducts pass through unconditioned spaces, 10-40% of the heat can be lost by the time it reaches the intended location. Make sure all pipes are properly insulated.
   - Holes and gaps in ducts will leak hot air and cause substantial losses. This will cause the equipment to work harder to deliver conditioned air. Make sure all ducts are properly sealed.

   (see page 34)

CHAPTER 6: Lighting

1. **Give 2 pro and 2 cons for each of the following types of lamps: incandescent, fluorescent, metal halide, and LED.**
   - **Incandescent:**
     - Pros: CRI of 100 produces full spectrum light, inexpensive
     - Cons: Low efficacy, short lifespan
   - **Fluorescent:**
     - Pros: Higher efficacy, longer lifespan than incandescent
     - Cons: Lower CRI, contain mercury
   - **Metal Halide:**
     - Pros: Higher efficacy, longer lifespan than fluorescent
     - Cons: Low CRI, contain mercury
   - **LED:**
     - Pros: Higher efficacy than incandescent, longest lifespan

- Cons: High initial cost, require precise heat management

(*see pages 44-49)*

2. **What is CRI and what does it measure?**

   CRI stands for Color Rendering Index and is a scale that represents a lamp's ability to render color on a scale of 0-100, based on an actual test of its ability to display eight specific color samples accurately *(see page 43).*

3. **How does lighting affect a building's HVAC system?**

   With electricity being the most expensive fuel, the financial savings from lighting upgrades are substantial. Additional benefits include a reduction in HVAC costs due to less heat being generated by the lighting system *(see page 51).*

4. **Why is it important to consider lamp disposal?**

   All fluorescent lamps, CFLs, tubes, and other shapes contain small amounts of mercury, a toxin. They should be disposed of through a registered recycling service. This will reduce the amount of mercury released into the environment *(see page 46).*

5. **How can sensors and timers increase lighting efficiency?**

   Sensors automatically turn lights off when spaces are unoccupied and can save up to 70% on energy costs for lighting. Programmable timers are another easy and effective way to curb usage costs. They can be set to power lights on and off depending on the room's or building's occupancy schedule *(see pages 50-51).*

CHAPTER 7: Indoor Air Quality

1. **Describe the trade-off that occurs between IAQ and HVAC energy consumption.**

   Ensuring proper IAQ requires a trade-off in building management practices. On the one hand, excessive ventilation results in unnecessary heat losses and thereby higher greenhouse gas emissions, while inadequate ventilation can result in poor air quality and a higher risk of condensation and mold. Striking the right balance is key *(see page 52).*

2. **What are some products that contain pollutants that can cause sick building syndrome?**

   Paints, lacquers, paint strippers, cleaning supplies, pesticides, adhesives, caulk, solvents, carpets and furnishings are some examples of products that contain pollutants that can cause sick building syndrome *(see page 53)*.

3. **Describe one or two problems that occur when relative humidity is too high, and one or two that occur when it is too low.**

   - If indoor relative humidity (RH) is greater than 80% for more than a couple of weeks, mold growth on interior surfaces is likely. If indoor air is consistently greater than 55% RH, dust mites may colonize carpets and furniture.
   - At consistent RH conditions of less than 25-30%, dry skin conditions such as eczema or psoriasis are aggravated. Eye, nose, and throat irritation are more likely.

   (see page 54)

4. **Name three causes of poor IAQ and what building managers can do to ensure they don't occur in their building.**

   - **Volatile Organic Compounds:** Limit the use of VOCs

- **Dust:** Maintain a tight envelope, prevent airflows within the building, develop an integrated cleaning program and use a HEPA (high-efficiency particulate air) vacuum. These actions will help control dust and other indoor air pollutants.
- **Lack of Exchange Air:** Provide adequate air flow (outside air that must be provided by natural or mechanical ventilation systems) in a room/building.

(see pages 53-57)

5. **What is ASHRAE? Describe how ASHRAE's standard for a building's indoor air quality works.**
   The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) maintains a standard for ventilation, ASHRAE 62.1, which is often incorporated into state and local building codes. This standard specifies the amount of outside air that must be provided by natural or mechanical ventilation systems to various areas of the building to maintain acceptable IAQ. These standards inform design engineers of the criteria they must meet *(see page 54).*

6. **What are three ways to maintain a building's IAQ during construction?**
   Three ways to maintain a building's IAQ during construction are:
   - **Testing:** Before performing any demolition, check for lead-based paints and asbestos.
   - **Timing:** When possible, perform work at times when the occupants are not in the building.
   - **Barriers:** Install temporary barriers to seal the work areas from the occupied areas.

   (see page 58)

CHAPTER 8: Dealing with Waste

1. **Describe three strategies for good waste management.**
   Three strategies for good waste management are:
   - Purchasing concentrated cleaning supplies in bulk will reduce the quantity of containers purchased and packaging discarded.
   - Use washable, reusable cleaning cloths, drop cloths, and dust curtains instead of throw-away towels or other disposable products.
   - Purchase durable, reusable O&M tools and supplies instead of disposables, such as heavy duty paint brushes and trays, reusable vacuum bags, and hand tools with rechargeable batteries.

   (see pages 61-62)

2. **List three or more ways recycling reduces environmental impact.**
   Recycling reduces environmental impact by reducing the need for land filling and incineration, preventing pollution caused by the manufacturing of products from virgin materials, decreasing emissions of greenhouse gases that contribute to global climate change, and conserving natural resources *(see page 63).*

3. **What are some ways to communicate your waste program to building tenants?**
   Communicate with tenants through memos and meetings with facilities management and cleaning staff. Management can also post signs descripting the waste management program in tenant spaces and on loading docks *(see Case Study on page 61).*

4. **How can reuse of waste be incorporated in a construction job?**

   Reuse refers to deconstructing some object (a building, apartment components, etc.) and then using salvaged material over again rather than tossing it in the dumpster. Items that can be reused include lumber, carpeting, old gypsum wallboard, and other material that can be used again *(see page 63).*

5. **How is recycling good for the economy?**

   Recycling is good for the economy because it protects and expands U.S. manufacturing jobs and increases U.S. competitiveness *(see page 57).*

CHAPTER 9: Commissioning and Energy Audits

1. **What is a commissioning manual and how is it different from standard equipment manuals?**

   A commissioning manual contains the required operation protocols. It is different from standard equipment manuals because equipment manuals deal with specific systems which did not embody a whole-building approach and resulted in fragmented facilities management practices. Operating manuals have detailed best practices tailored to the building and its systems *(see pages 66-67).*

2. **What are retro-commissioning and recommissioning, and why are they important for building systems' efficiency?**

   - **Retro-commissioning (retro-Cx)** is a process meant for buildings that were never commissioned. The commissioning agent uses a whole-building approach to review all systems and identify new operation strategies that will help the equipment and systems function at optimal levels.
   - If a building has been previously commissioned, **recommissioning** occurs to ensure that its systems are still operating as they were designed. It is a recurring process to tune-up equipment.

   (see page 67)

3. **Explain how managing staging and sequencing of combustion and chilling equipment can increase efficiency.**

   The term sequencing refers to activating or bringing online parallel units in a system and, conversely, deactivating or taking parallel units offline when appropriate. Sequencing is the control strategy, while staging refers to the practice of starting the boilers or chillers in a staggered manner. In this way, when the first-stage equipment has sufficient excess capacity, one or more second-stage pieces of equipment can go offline while still meeting the energy needs or load of the building *(see page 69)*.

4. **How do energy audits lead to better building efficiency?**

   Energy audits allow you to assess how energy is used in your building and to identify opportunities for increased efficiency. These opportunities may involve changing operating practices to reduce energy consumption or retrofitting the building to make the building more energy efficient *(see page 71).*

5. **Why is it important to use a “whole-building” approach when implementing energy audit recommendations?**

   It is important to use a “whole-building” approach when implementing energy audit recommendations because all systems affect one another, and if not scrutinized carefully, can result in lower-than-expected energy savings *(see page 73).*