HIGH PERFORMANCE
Building Operations Professional

EXAM STUDY GUIDE (2024)

Certification Exam Overview with Sample Quiz

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Building Efficiency for a Sustainable Tomorrow

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HPBOP Exam Study Guide

Overview of the High-Performance Building Operations Professional Certification Exam with Sample Quiz & Explanations

March 24, 2024

HPBOP Exam Study Guide

High Performance Building Operations Professional (HPBOP)

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Dedication

HPBOP Test Writing & Standards Setting Committees

Test Writing and Standards Setting Committees were formed to develop the *Pilot Exam* for the HPBOP national certification. Committee members included technical experts in high performance building operations and represented a range of different stakeholder groups including community colleges/higher education, hospitality, labor, facility management, building automation systems educators, energy management consulting & service providers, and a global property management firm. Their duties involved 1) creation and review of test items/questions and 2) assessment of items to establish an exam performance standard.

BEST Center wishes to acknowledge all who served diligently on the Test Writing and Standards Setting Committees. Without their support, our collective mission to enhance the high-performance building operations workforce could not have been realized. Our deepest thanks go to:

- **Wayne Aldredge**, Director of Sustainability and Regional Engineering Manager, Servi-Tek Facility Solutions, CA
- **Michael Bobker**, Executive Director, Building Performance Lab, City University of New York, NY
- **Robert Clark**, HVAC Faculty and Department Coordinator, College of DuPage, IL
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- **Dennis Dawe**, Global Account Operations Director, CBRE, IN
- **Paul Ehrlich**, Principal, Building Intelligence Group, MN
- **Laurie Gilmer**, President and COO, Facility Engineering Associates, and National Board Member of IFMA
- **Hadley Hartshorn**, Mechanical Engineer, Lawrence Livermore National Lab, retired, CA
- **Robert Nirenberg**, Principal of EduControls, LLC, and BEST Center Co-PI, Omaha, NE
- **Carlos Santamaria**, Principal, Optimal Building, CA
- **Rodney Schauf**, Director of Engineering, Marriott International, Inc., WA
- **Ted Wilinski**, HVAC/BAS Faculty Lead and BEST Center Co-PI, Milwaukee Area Technical College, WI
- **Paul Wingco**, Principal, Wingco Clean Energy Resources, CA

Introduction

About BEST Center

Established in 2012, BEST (Building Efficiency for a Sustainable Tomorrow) is a national Resource Center funded by the National Science Foundation. Its mission is to serve and support the professional development of building science instructors and the collection, dissemination, and adoption of responsive, timely, and exceptional education and training programs for advanced building systems technicians. The need for this work is urgent. Multiple factors have converged to highlight the importance of building technicians:

- The COVID-19 pandemic stressed the critical role of technicians to ensure occupant safety and comfort.
- Because buildings are major users of energy, the role of technicians in implementing and maintaining energy conservation and efficiency measures is of crucial importance for climate change mitigation.
- New and emerging technology applications—more effective use of Building Automation Systems (BAS), increasing adoption of ASHRAE Guideline 36 for control sequences, and application of automated tools for data management and fault detection and diagnosis—reinforce the importance of building technicians who can understand and apply these tools.
- The growing trends toward on-site renewable energy generation, the introduction of EV charging to the building load profile, and the need for grid interactive flexible load management are expanding the knowledge and skill requirements for building technicians.
- As more and more cities adopt enforceable Building Performance Standards for energy efficiency and conservation, the technician role in preserving energy savings is growing in importance.

Today's building technicians must be prepared to manage the complex building automation, data analytics, and energy management systems of the high-performance, "sustainable" buildings of the future.

Over the last decade, BEST has galvanized and led improvements in building systems education by providing professional development and industry-validated curriculum resources to a national network of more than 70 community and technical colleges as well as labor and industry partners. BEST has worked closely with industry practitioners and stakeholders to map and codify knowledge and skills standards for a national certification for High Performance Building Operations Professionals (HPBOP). BEST will make curriculum guidance available to community and technical colleges, apprenticeship programs, and other training providers to prepare new entrants as well as industry incumbents for HPBOP certification. To learn more, visit BESTctr.org.

Purpose of HPBOP

The HPBOP certification creates a national certification for the following purposes:

- Validates the skills and knowledge of high-performance building technicians.
- Elevates the status of building technicians to a technical professional level.
- Gives recognition to possession of the knowledge and skills to use the advanced technologies available in building operations.
- Recognizes the new workforce requirements challenging today's building technicians.
- Promotes the documentation of building operations for ease of sharing technical information within the organization.
- Integrates continuous quality improvement principles and practices into building operations.
- Emphasizes a systems approach to whole building operations and maintenance.
- Creates a national standard of excellence for high performance building technicians.
- Stimulates and supports education and training opportunities to advance building technicians' knowledge and skills to the new standard.

Value of the Certification

The HPBOP certification acknowledges the professional status for building technicians and confirms the essential status of building technician work. Employing technical professionals possessing the certification creates value for building owners such that they can be assured that buildings are being operated at a high performing level and assures facility managers that their frontline technical workforce can operate and maintain buildings to a high standard of performance. For technicians the certification represents a formal recognition of knowledge and skills.

About the Certification

The certification has been developed in accordance with International Organization for Standardization (ISO) Standard 17024. The knowledge and skill standards were developed and validated nationally by a large network of building technicians and engineers. The certification creates a valid, verifiable, and portable representation of the certification holder's achievement.

About the Exam Study Guide

The purpose of this guide is to provide information about the BEST Center HPBOP certification written exam. No information or material in this guide creates a contract between BEST Center and an individual user or organization. BEST Center will do its best to apply the principles and provisions contained within this document as written but reserves the right to change and update those principles and provisions without actual notice. However, BEST will make reasonable efforts to notify users of any changes.

Please refer to the *HPBOP Candidate Guidebook* for details about eligibility requirements, applying for the certification, the exam procedure, and re-certification. To obtain a copy of the *Candidate Guidebook*, see https://hpbop.org/eligibility/

HPBOP Certification Exam

Overview

The HPBOP certification examination is an online, proctored, closed book/closed notes multiple choice exam. The content outline for the exam is developed from the original HPBOP DACUM (Designing a Curriculum). The DACUM describes major duties, or areas of responsibility, and tasks required for operating and maintaining a high-performance building. Some tasks captured in the DACUM were omitted from the exam because they were deemed by the Scheme Committee as the primary responsibility of facility owners or managers, not technical personnel; for example, setting ***sustainability policies*** for the operation of a building is deemed an owner/manager responsibility. Duty G, Perform Administrative Tasks, and Duty H, Participate in Professional Development Activities, were also omitted from the examination by the Scheme Committee. The DACUM can be reviewed below.

The cognitive levels tested on the HPBOP examination include the following:

1. Recall: The ability to remember or recognize specific information.
2. Application: The ability to apply knowledge to a described situation or set of conditions.
3. Analysis: The ability to assess information about a problem, compare possible solutions, and synthesize the most likely best solution for the circumstances.

Exam Preparation

The HPBOP Certification exam does not require participation in any additional specific preparatory activity. Nor does it require purchasing any publication or membership. However, candidates who choose to participate in related preparatory education and training activities are encouraged to do so. A review of the exam contents follows and may help inform those seeking to participate in preparatory education and training activities. Similarly, review of various publications such as the most recent version of ASHRAE Guideline 1.4, ASHRAE Guideline 32, ASHRAE Standard 90.1, or other related publications may be useful.

Exam Content Overview

(See also Appendix B of the *Candidate Guidebook*)

Introduction

In addition to the operation of its individual pieces of equipment or components, a building can also be assessed as a whole system by reviewing characteristics such as annual energy use, indoor environmental quality mea–surements, and—using tools already available—the building's carbon footprint. Across the U.S. an increasing number of cities are adopting or are planning to adopt municipal codes requiring conformance with Building Performance Standards (BPS) and reporting on various measures including energy use, water consumption, and IEQ; some cities such as Boston and New York are already imposing financial sanctions on buildings not meeting the established Building Performance Standards. Such sanctions effectively incentivize implementing strategies and practices to improve building performance so as not to incur fees. In the future it is anticipated that this trend will continue and expand to many more cities and states as detailed implementation plans are worked out. The HPBOP certification anticipates this trend by focusing on the duties and tasks as well as knowledge and skills associated with assessing, improving, and maintaining higher building performance.

The HPBOP DACUM outlines the logical progression of duties and tasks required to develop and maintain the operation of a high-performance building. In addition, the DACUM outlines the general knowledge and skills and the use of tools, equipment, supplies, and materials, required for an HPBOP as well as the future trends shaping knowledge and skills of the future. The following sections review the basic duties and tasks in which the high-performance technical professional will engage or participate. Items in the DACUM that were deemed by the Scheme Committee as managerial or ownership functions or clearly outsourced are not included below and are not part of the exam.

Overview of Duty A: *Analyze Building Operations*

To analyze building operations, the HPBOP assesses the operational performance of individual components and equipment using instrumentation, looks at operational trends, and assesses overall building system performance. Through the process of reviewing building documentation, investigating equipment performance, and reviewing utility use and cost, the HPBOP prepares an analysis for performance assessment and goal setting. the HPBOP might conduct a Level I site audit, benchmark building performance, and help develop building performance goals. Over time, auditing and benchmarking the facility to update goals to improve performance are all part of the process of maintaining a high-performance building.

The HPBOP must be knowledgeable of the procedures and processes to complete the various tasks involved in analyzing building operations. Facility management practices and procedures will determine what specific roles the HPBOP will play in guiding and informing the assessment and goal setting process.

Duty A Tasks:

- **Review**
  - Building documentation (e.g., SOPs, BMS, MEP)
  - Capital improvement plan
- **Perform (**ASHRAE) Level I site assessment
- **Interview** facility operators to determine current operations
- **Determine** equipment performance (e.g., temperature, pressure, schedules)
- **Benchmark** building performance
- **Develop** building performance goals (e.g., energy, IEQ, water)
- **Identify** environmental requirements (e.g., temperature, lighting, ventilation)
- **Trend**:
  - Service calls
  - Utility usage and cost
  - Building occupancy/production

Overview of Duty B: *Maintain Building Operating Efficiency*

This duty identifies and describes the ongoing tasks required of the HPBOP to maintain and operate efficiently various building systems including air distribution, heating, and cooling as well as ensuring the accuracy and reliability of the interactions between these systems and sensors and building controls. There is an assumption that the organization supports a proactive approach to maintenance which builds a solid preventive maintenance planning process to support predictive maintenance processes and establishment of key performance indicators.

Tasks within this duty area require four types of activity: (1) calibration of sensors; (2) visual inspection of equipment, valves, damper positions, motor operation, etc.; (3) optimizing pumps, operating schedules, and set points; and (4) management of repairs, outside vendor support, and maintenance plans. The HPBOP must have knowledge and skill relevant to each of these areas of activity to perform or coordinate implementation. Typical activities include looking for aberrant operating conditions, for example, locating and correcting units in override mode, checking calibration of equipment and controls, checking sensor outputs in the BAS system against data logger data, checking air and water flows, knowing when to bring in a TAB specialist, and checking and adjusting setpoints as necessary to help optimize performance. Because maintenance is a team effort, frequent team meetings are important for data gathering and coordination of effort.

The HPBOP must be knowledgeable of the procedures and processes to complete the various tasks involved in maintaining efficient building operations. Facility management practices and procedures will determine what roles the HPBOP will play in the process--in particular, identifying tasks which may be outsourced, how are key performance indicators established, and the determination of cost-benefit analysis.

Duty B Tasks

- **Identify** BAS discrepancies
- **Check** for equipment override conditions
- **Calibrate** equipment controls
- **Coordinate** repair of deficient equipment
- **TAB** air distribution systems (e.g., economizers, VAV, air handlers)
- **Calibrate** central cooling systems (e.g., temperature resets, flow, pressure)
- **Calibrate** central heating systems (e.g., temperature resets, flow, pressure)
- **Calibrate** evaporative cooling systems (e.g., cooling towers, filtration, free cooling)
- **Optimize** pump performance
- **Review** VFD settings
- **Optimize** equipment operating schedules
- **Optimize** operating set points
- **Develop** key performance indicators (e.g., reset schedule, KW/sq. ft., peak load)

Overview of Duty C: *Audit Building Operational Performance*

This area of responsibility uses analytical tools such as Energy Star to assess building energy performance and also assesses performance of major building systems including lighting, indoor air quality, occupant comfort, combustion equipment, and waste systems. In addition, this duty requires review of sequence of equipment operations, occupancy schedules, alarm histories, maintenance and repair logs, water treatment procedures, as well as an overall facilities condition assessment. Using this information, operations can be improved with better energy performance, better occupant comfort, and identification of needed corrections, repairs, and system improvements.

Performance of these activities requires thorough knowledge of data collection and analytic procedures, use of Energy Star analytics, ability to analyze and correct sequences of operation, ability to interpret results of audits of building systems, and ability to prepare analyses to inform improvement plans and activities.

Duty C Tasks:

- **Review** maintenance and repair log
- **Perform** utility bill audit (e.g., electric, gas, water)
- **Perform** disaggregation of utilities (e.g., electric, gas, water)
- **Perform** facility condition assessment
- **Perform** Energy Star® review
- **Review** building occupancy plan
- **Quantify** scope 1 greenhouse gas emissions
- **Review** waste audit (e.g., hazardous, landfill, recycling)
- **Perform** lighting audit
- **Audit** equipment sequence of operations
- **Review** building occupant comfort survey results
- **Review** system alarm history
- **Facilitate** testing of combustion equipment efficiencies
- **Perform** water treatment audit
- **Determine** need for energy consultant

Overview of Duty D: ***Create High Performance Building Plans***

This area of responsibility involves engaging in analysis of the performance of various building systems to inform system improvement plans, participate in the development of long-term operational policies, and improve energy and resource conservation overall.

To engage in these activities, the HPBOP must have knowledge in capital improvement planning, maintenance and repair planning, procedure for ROI analysis, commissioning processes, optimization of sequences of operation, load shedding strategies, utility rebate programs, building occupancy planning, onsite alternative energy strategies, tenant engagement programs, control system improvement strategies, water conservation strategies, development of systems manuals and operational documentation, and development of energy management and efficiency planning in preparation for implementation. In a number of the tasks listed in this duty, the HPBOP participates meaningfully in the planning process but does not determine the final outcome.

Duty D Tasks:

- **Obtain** payback analysis
- **Participate** in the development of formal energy policy
- **Determine** load shedding opportunities
- **Participate** in the development of a zero-waste plan
- **Optimize** SOPs (Standard Operating Procedures)
- **Update** maintenance & repair plan
- **Optimize** equipment sequence of operations
- **Develop** commissioning plan
- **Participate** in the development of building occupancy policy
- **Identify** alternative energy opportunities
- **Participate** in the development of zero net energy plan
- **Develop** control system plan (e.g., enhanced data points, trends, data analysis)
- **Participate** in development of system integration plan
- **Participate** in development of tenant engagement programs
- **Participate** in development of water conservation plan
- **Review** predictive maintenance plan

Duty E Overview: ***Implement Continuous Improvement***

This area of responsibility involves the translation of various planning efforts and documents into actual implementation of conservation and efficiency improvement measures. The scope of activity ranges from straightforward implementation of an inspection program and adjustment of occupancy schedules to broad optimization of control systems, and implementation of commissioning and M&V plans.

To complete these activities successfully, the HPBOP must be knowledgeable in BMS and BAS systems, effectiveness of various load shedding measures, use of data loggers and other data collection and tracking systems for improvement verification, use and improvement of building documentation, prioritization of commissioning and M&V procedures, and vendor management procedures. Furthermore, the HPBOP and the organization itself must be committed to continuous quality improvement (CQI) of facility operations and to CQI forming an integral part of organizational culture.

The degree to which the HPBOP performs these activities depends on the organization, job description, and the HPBOP's skill set. Some of the items that fall under this duty may be conducted by outside vendors under the direction of the HPBOP.

Duty E Tasks:

- **Review** engineering budget (e.g., operating, capital)
- **Perform** routine inspections (e.g., equipment, systems, controls)
- **Implement** energy savings plan
- **Implement** load shedding measures
- **Implement** zero waste plan
- **Implement** commissioning plan
- **Adjust** equipment settings per occupancy plan
- **Implement** zero net energy plan
- **Implement** system integration plan
- **Optimize** control system (e.g., enhance data points, trends, data analysis)
- **Implement** predictive maintenance plan

Duty F Overview: *Manage Building Systems*

This area of responsibility involves ongoing tracking of the performance of various system improvements, energy consumption, and operational systems. Within the context of Continuous Quality Improvement (CQI) the activities in this area of responsibility correspond to the stages of ***checking*** results of planning and implementation and then ***acting*** to make system corrections. Some activities required to manage building systems are straightforward such as tracking utility costs and service calls and comparing these to plans. Other activities require skills of interpretation and evaluation of system performance data and critical thinking to “look in the right places” for data inputs and to set priorities on corrective actions.

To be successful in managing building systems, the HPBOP must be able to capture and interpret ongoing building performance data using the BAS system, data logging tools, and the CMMS, and be able to read and interpret blueprints, TAB reports, M&V reports, manufacturer’s equipment specifications, O&M manuals, and planning documents. In maintaining a high-performance building, these activities are continuous and ongoing, and the HPBOP must be able to translate evaluative results into corrective actions. These corrective actions not only fix immediate problems but also continuously improve overall system performance including improved occupant comfort and safety and conservation of energy and other resources. Tasks completed in Duty F provide feedback and inform tasks to be completed in Duty B and closely linked.

Duty F Tasks

- **Track** utility costs & consumption
- **Track** equipment performance
- **Track** service calls
- **Determine** need for systems balance
- **Track** maintenance and repairs
- **Track** predictive maintenance
- **Review** measurement & verification reports

Sample Quiz

The following questions provide a sample of the types of items that you might encounter during the certification exam. They correspond to the duties A-F and tasks outlined in the HPBOP DACUM (see at the end of this Exam Study Guidebook) and later verified via a Job Task Analysis and the Scheme Committee. This guide does NOT provide comprehensive exam preparation since knowledge and skills are gained over years of education and work experience. However, you will find assorted questions that assess your familiarity with definitions and concepts, problems requiring math calculations, and scenario-based reasoning skills.

List of Abbreviations:

AHU	air handling unit
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BAS	building automation systems
Btu	British thermal unit
CFM	cubic feet per minute
DD	degree day
DDC	direct digital control
EUI	energy use intensity (or index)
FLA	full load ampere
kVA	kilovolt-ampere
kVAR	kilovolt-ampere reactive
kW	kilowatt
kWh	kilowatt-hour
OA	outside air
PF	power factor
ROI	return on investment
RTU	rooftop unit
TH	therm
VAV	variable air volume
VFD	variable frequency drive
WC	water column
ZNE	zero net energy

1. On electric billing information, which are the energy units?
    a) kW
    b) kWh
    c) kVA
    d) kVAR

2. When developing a zero net energy (ZNE) plan, the most likely first step is to:
    a) Determine how much solar energy is required to meet existing needs.
    b) Purchase renewable energy to meet current demand.
    c) Set an energy use reduction target.
    d) Determine how to generate all required energy onsite.

3. You have a facility with 323,250 square feet that used 137,819 therms last year. How many kBtu of natural gas were used per square foot last year?
    a) 42.6
    b) 42,600
    c) 0.426
    d) 426

4. You have a 323,250 square feet facility that used 3.3 million kWh last year. How many kBtu of electricity did the building use per square foot last year?
    a) 10.2
    b) 10,200
    c) 34.8
    d) 34,800

5. Which ASHRAE standard or guideline provides the minimum requirements for energy-efficient design of most sites and buildings, except low-rise residential buildings?
    a) ASHRAE Guideline 32
    b) ASHRAE Standard 180
    c) ASHRAE Standard 62.1
    d) ASHRAE Standard 90.1

6. When presenting lighting options, which financial method is most likely to encourage investment?
    a) Simple payback
    b) ROI (Return on Investment)
    c) Least implementation cost
    d) Lowest operating cost

7. What is benchmarking in relation to building energy usage?
   a) A benchtop tool for measuring the performance of mechanical and electrical equipment
   b) A comparison of current energy performance with past data or buildings of similar size and occupancy
   c) A series of functional tests used to determine relative energy efficiency
   d) A comparison between current energy usage and the baseline established by the Energy Policy and Conservation Act (1975)

8. Which is the better power factor to have?
   a) .5
   b) .25
   c) .8
   d) .7

9. When checking the building automation system (BAS) graphics for an air handling unit (AHU), you find that the supply duct static pressure is at .4” water column (WC) with a setpoint of 1.2” WC, and the BAS graphics indicate that fan speed is being commanded to 100%. You physically check the AHU and find no obstructions to flow, but the variable frequency drive (VFD) is only operating at 30Hz. What settings in the VFD should you check first?
   a) Determine if the BAS signal type matches the actual BAS setting.
   b) Determine if the minimum frequency matches the motor requirements.
   c) Determine if the drive is in the hand, off, or auto position.
   d) Determine if the maximum current setting matches the FLA on the motor nameplate.

10. Where would you look for the appropriate quantity of outside air during occupied mode for your specific air handling unit?
   a) Nameplate on the fan
   b) The most recent design documents
   c) ASHRAE Standard 202
   d) Local fire codes

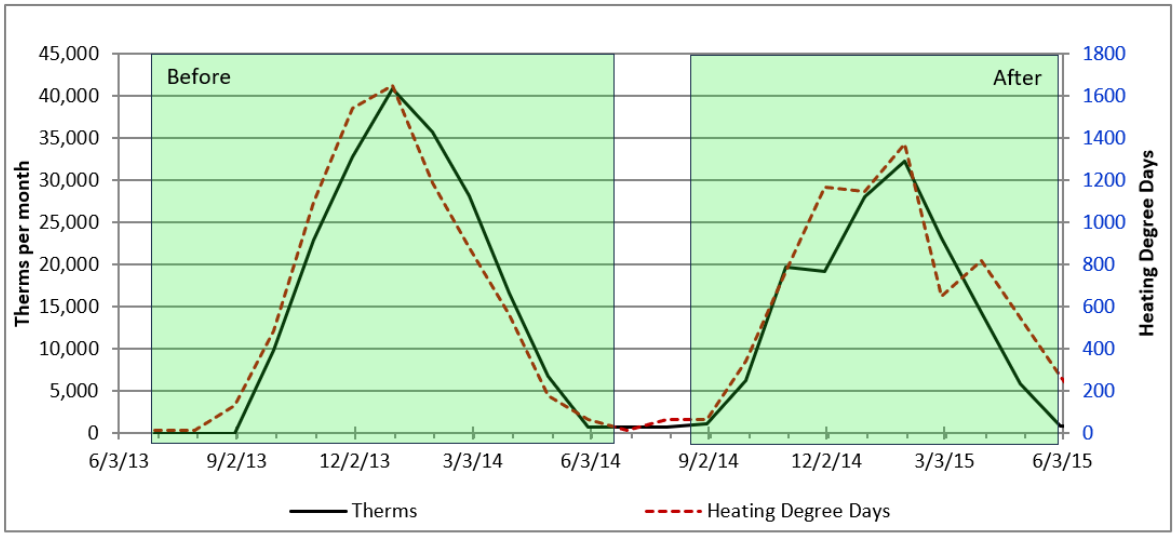
11. Developing a zero waste plan often starts with:
   a) Contracting with firms to recycle your waste
   b) Eliminating waste receptacles
   c) Stopping the purchase of materials that end up as waste
   d) Conducting a waste audit

<u>SCENARIO for questions 12 & 13</u>: You are working on an older office building that your company recently purchased. The building's control system consists of (1) pneumatics which control the zones and (2) recently installed DDC on the major systems such as the central plant and air handling units.

12. Re-setting system hot water temperature saves energy. You are tasked to change the hot water system from a static setpoint of 180°F to a dynamic setpoint. Given the current capabilities of the system, what strategy should you use?
    a) Reset the hot water supply setpoint based on outside air temperature.
    b) Reset the hot water supply setpoint based on zone setpoint error.
    c) Reset the hot water supply setpoint based on AHU supply setpoint error.
    d) Reset the hot water supply setpoint based on minimum and maximum AHU valve positions.

13. The hot water system pumps were originally constant volume, but variable frequency drives have been added. Given the capabilities of the system, what strategy could be used to take advantage of the new VFDs for maximizing energy savings?
    a) None. The old system was designed for constant volume and must remain so.
    b) Modulate the pump speed based on outside air temperature.
    c) Modulate the pump speed based on minimum and maximum hot water valve positions for the zone controls and AHUs.
    d) Modulate the pump speed based on system differential pressure with respect to minimum required water flow through the boilers and close as many bypass legs of 3-way valves as practical.

14. While performing an alarm log audit, you notice that the "Room Temperature Over-Range" alarm has been activated almost every day for the month of December. The alarm typically activates 1 to 3 hours after the zone goes into occupied mode and clears after the zone becomes unoccupied. You find a note attached to one of the alarm instances stating that the room temperature was verified and the space was overly warm. You also note that this zone is served by a single VAV air terminal unit with hot water reheat. Your next step should be to:
    a) Increase the over-range threshold since this is just a nuisance alarm.
    b) Increase the maximum CFM setpoint for the VAV.
    c) Review the trend log data for this VAV, zone, and AHU.
    d) Decrease the zone setpoint for this space.



	th/yr	Htg DD	th/DD
Before	194,476	7,808	24.9
After	152,240	7,232	21.1

15. The graph and table above show the natural gas use for a facility in the upper Midwest that had old standard efficiency boilers replaced with condensing boilers. The above graph shows the year before and after the project was completed. There were no other changes to the facility in this two-year period. What can you conclude about the boiler replacement's true impact from June 2014-June 2015?

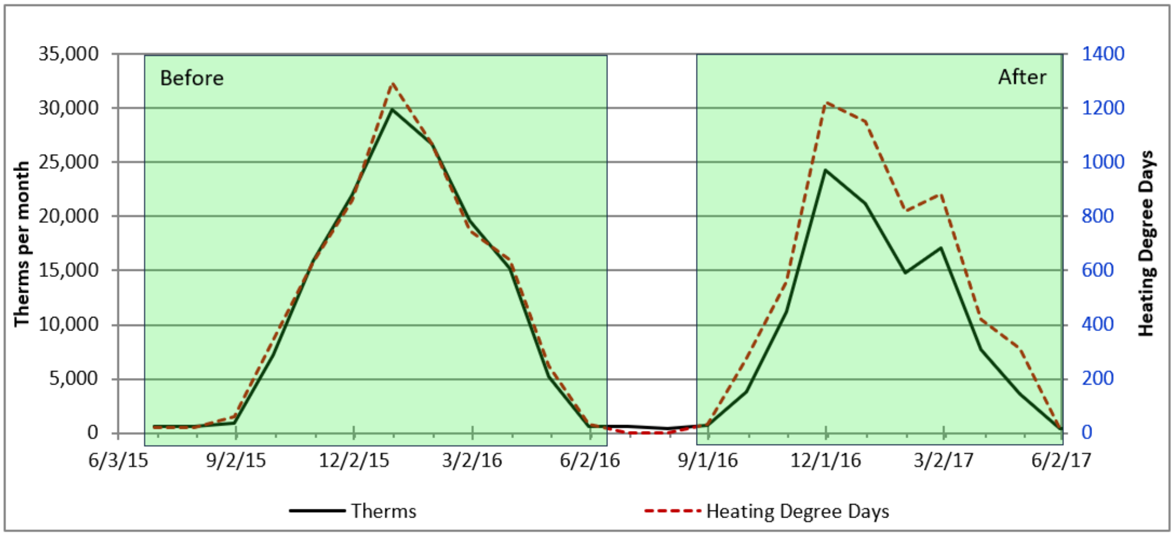
    a) Natural gas use decreased the year after the boiler project.
    b) Natural gas use increased the year after the boiler project.
    c) Natural gas use appears to have been unimpacted the year after the boiler project.
    d) Boiler operation and natural gas use are not related.

16. When adjusting the occupancy schedules for a building with multiple usage areas and occupancies, each with its own dedicated air handling unit (AHU) or rooftop unit (RTU), you should:

    a) Set all occupancy schedules' start times to match the earliest start time for any area of the building and set all end times to match the latest end time for any area of the building.
    b) Set all occupancy schedules' start times to match the latest start time for any area of the building and set all end times to match the earliest end time for any area of the building.
    c) Set all start times to 8AM and all end times to 6PM.
    d) Set each occupancy schedule to match each individual area's schedule while accounting for warm up / cool down time.

17. What range would you expect the % of control signal to be to meet the design requirement of 25% outside air (assuming 0% means zero outside air)? Assume the AHU damper is typical, with non-linear response.

    a) 0-20%
    b) 20-25%
    c) 25-40%
    d) 40-60%



18. The graph above shows the natural gas use for a facility in the upper Midwest. Operations staff made a strong effort to reduce the operating times of equipment and to keep heating setpoints at 68^{o}F when occupied and 60^{o}F when unoccupied. There were no other changes to the facility during the period. What do the graphs show as the true impact of the organization's energy efficiency effort?

    a) Natural gas use decreased the year after staff implemented the changes.
    b) Natural gas use increased the year after staff implemented the changes.
    c) Natural gas use appears to have been unimpacted the year after staff implemented the changes.
    d) Heating setpoints and natural gas use are not related.

19. In reviewing hot and chilled water pumping systems at your facility, you note that on several constant flow pumping stations the balancing valves are 100% open. Over time these pumping systems have been repaired for leaking gaskets, failed motors, and other maintenance issues. What is the best course of action to take?

    a) Nothing is required since it is common for the valves to be 100% open.
    b) Water flow rates and pressures should be measured and restored to design flow rates by adjusting the balancing valve positions accordingly.
    c) The balancing valves should be adjusted to the 80% open position.
    d) The balancing valves are no longer needed and should be removed to reduce pumping losses.

20. A 323,250 sf facility used 137,819 therms and 3.3 million kWh last year. What is the EUI (Energy Use Intensity) in kBtu/sf/yr for this facility?

    a) 34.8
    b) 42.6
    c) 52.8
    d) 77.5

Sample Quiz: Answers and Explanations

1. The answer is **b.** kW, kVA, kVAR are all demand or power units. Power used over time is energy. Therefore, kWh is the unit for electrical energy.

2. The answer is **c.** Before knowing what renewable energy quantity is needed, the facility should be using as little energy as possible. This reduces the amount of any renewable source needed, minimizing cost and size of installation. Observe your facility's energy management plan and practice *efficiency first*.

3. The answer is **a**. Derived from the Greek word meaning "heat," a *therm* is used by utility companies to measure gas use. It is a unit of heat equivalent to 100,000 British thermal units (Btu). 1 kBtu is equivalent to 1,000 Btu, and the energy used in commercial buildings is often expressed in kBtu. To assess building efficiency, we must convert therms to kBtu.

   Solution:
   First, convert therms to kBtu using the standard formula 1 therm = 100,000 Btu = 100kBtu:
   137,819 therms/yr X 100 kBtu/therm = 13,781,900 kBtu/yr

   Next, divide kBtu per year by the facility square footage:
   13,781,900 kBtu/yr ÷ 323,250 sf = **42.6 kBtu/sf/yr**

4. The answer is **c**. Information regarding electrical energy use is provided by utilities in kWh (kilowatt-hours), and kWh must then be converted to kBtu. These energy conversions can also be done via building performance benchmarking tools such as Energy Star Portfolio Manager.

   Solution:
   First, convert kWh to kBtu using the standard formula 1 kWh = 3,412 Btu = 3.412 kBtu:
   3,300,000 kWh/yr X 3.412 kBtu/kWh = 11,259,600 kBtu/yr

   Next, divide kBtu per year by the facility square footage:
   11,259,600 kBtu/yr ÷ 323,250 sf = **34.8 kBtu/sf/yr**

5. The answer is **d**. The HVAC industry uses multiple guidelines and standards, and many are developed by ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers)**.** Being aware of these standards and which ones apply to a given situation is important. Below are some ASHRAE documents which are often referenced, and among them, Standard 90.1 is the energy standard for buildings.

   Relevant ASHRAE technical documents (link: ASHRAE Standards & Guidelines)
   - *Guideline 32-2018 -- Management for Sustainable High-Performance Operations and Maintenance*
   - *Standard 180-2018 -- Standard Practice for Inspection & Maintenance of Commercial Building HVAC Systems*
   - *Standard 211-2018 -- Standard for Commercial Building Energy Audits*
   - *Standard 90.1-2022 -- Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings*
   - *Standard 62.1-2022 -- Ventilation and Acceptable Indoor Air Quality*

6. The answer is **b.** Let's start with two common methods for analyzing any project's financial feasibility; refer to the link: How to Calculate ROI and Payback

   Simple payback (answer **a**) refers to how soon an investment can be recouped, so the emphasis is on time in years or months. The shorter the payback period, the more attractive an investment becomes. However, it doesn't account for what happens after the break-even point is reached. A typical calculation is:

   Payback period = cost of investment ÷ average annual savings (or incoming cash flow)

   Example of simple payback:
   For a lighting project which costs $10,000 and delivers an average annual savings of $2000,

   $10,000 project cost ÷ $2000 per year = **5-year payback period**

   On the other hand, *return on investment or ROI* (answer **b**) examines how well an investment performs; it focuses on return (or profit) in addition to the cost of investment. Many people in finance think in terms of ROI by calculating the following:

   Net savings = total savings - project cost
   ROI = net savings ÷ project cost = % profit or return

   Example of ROI:
   Using the same lighting project analyzed above, a total savings of $12,000 is achieved in year six. To determine the ROI by year six,

   $12,000 in total savings - $10,000 project cost = $2000 net savings
   $2000 net savings ÷ $10,000 project cost = **20% profit or ROI**

   Least implementation cost (answer **c**) can lead to poor quality projects that don't last or meet occupant needs. Lowest operating cost (answer **d**) alone might eventually become costly or not meet needs. To encourage investment in energy savings, ROI is typically the best choice.

7. The answer is **b**. This is the definition found on the Department of Energy's Better Buildings website (link: Benchmarking and Building Performance Standards). Annual energy benchmarking is a key measure of building energy efficiency and is increasingly required by cities like San Francisco and New York City to track and publish building performance.

8. The answer is **c.** The closer the power factor is to 1, the better. Lower power factors require more amperage to perform the same task. Higher amperage can lead to circuits and electrical panels being overloaded. The utility must provide the amps regardless of power factor, and thus, a lower power factor can load up distribution and transmission systems and cause increased energy use. However, a higher power factor (closer to 1) results in lower amperage on the system, lower cost, and more efficient use of resources - both infrastructure and energy. Most utilities also use power factor to adjust monthly charges. For instance, some adjust the demand with the power factor (PF) to a reference PF of 0.85.

9. The answer is **c.** The key clues that should lead you to consider an override (i.e., the drive position in hand/local control) are (1) the system's inability to maintain setpoint and (2) sending a 100% signal with the drive at 30Hz. The other answers are good things to check and/or set when replacing the motor or drive.

   The following video explains variable air volume (VAV) systems and covers duct static pressure specifically in the last few minutes (link: VAV Systems).

10. The answer is **b.** Minimum outside air (OA) can be determined by multiple factors depending on the intended use of the spaces which the air handling unit serves. The most common practice is to base cfm of outside air flow needed on the type of activity, floor area, and quantity of people occupying those spaces. These design criteria are specified by building codes which in turn are based often on ASHRAE Standard 62.1-2022 -- Ventilation and Acceptable Indoor Air Quality. The engineers who designed the HVAC system would calculate and specify OA in the design documents; however, always reference the most recent set of design documents for an area and system since remodels will often change the use and functional requirements of spaces and thereby change the amount of fresh air required.

11. The answer is **d.** Before contracting with a firm for recycling, you must know what waste you have and how much of it is generated at your facility. If you eliminate waste receptacles, you will end up with a mess and still have the waste. Not purchasing materials that end up as waste is impossible to do. First, find out what types of waste you have and the amount generated over a given period of time; then items such as contracting with recycling firms can be done. As the saying goes, "You can't manage what you don't measure."

12. The answer is **a.** This is not an uncommon scenario in older buildings that get updated control systems and/or boiler replacements.

    While newer sequences using system data have proven to be more energy and cost efficient, we only have access to the data from the large systems at this time due to the remaining pneumatic zone controls. This eliminates the viability of answer **b**.

    While the AHU data is accessible, answer **c** is unlikely to be characteristic of the actual building load and is therefore not a good set of metrics to use to determine one of the most critical setpoints for many buildings. Using AHU data would work in buildings where the AHU doubles as zone control, such as a building using only single-zone AHUs or multi-zone units where the zone controls were enhanced as part of the AHU upgrade; however, this is not the case in the example.

    Answer **d** is incorrect because the AHU valve positions do not typically provide data that represent the entire building, like the AHU supply setpoint error.

13. The answer is **d.** This is not an uncommon scenario as older buildings get updated control systems and/or boiler replacements. Answer **d** is correct because using a differential pressure sensor is a very common method of estimating system load for hydronic systems, but additional changes will be required to take best advantage of the new system variability. Constant volume systems typically have a large quantity of return paths for water, but with a variable flow system most of these returns are no longer beneficial. Those at the end of piping runs should typically remain open to ensure readily available hot water when a zone or unit requires it. However, if 3-way coil control valves are accessible and isolation valves are present for the bypass lines, close as many of them as practical while still maintaining minimum flow through the boilers to decrease unnecessary water flow. Whenever a system change of this magnitude is undertaken, it must be done very mindfully after the original system and its capabilities have been researched--rushing into a project like this will often cause more issues than it solves!

    While there is some logic to answer **a**, leaving the system alone and running it at constant volume will do nothing for energy savings (often one of the driving factors of system upgrades and updates).

    Answer **b** is incorrect because it does not maximize energy savings.

    Answer **c** doesn't work because in this case we have no access to the zone data since it is still part of the pneumatic system, and the AHUs alone are not a good representation of building load.

14. The answer is **c.** This scenario describes a hot water valve that is locked open because it is physically stuck or overridden within the control system. However, as written, you are not given enough information to determine the exact issue, and so the next step should be to seek additional data and determine if this is a zone-specific problem or an area problem. The valve positions and supply air temperature readings would be the most revealing pieces of data to examine.

15. The answer is **a.** Standard efficiency boilers are in the mid 80%, older ones even less. The efficiency of condensing boilers depends on return water temperatures and can range from upper 80% to upper 90%. Assuming the new system was designed, installed, and controlled properly, we should see a reduction in natural gas use over the full operating range during the year. Based on the graphs, it might be unclear if the project resulted in any real savings; however, the numerical data in the table clearly show that the therm per heating degree day actually decreased by 15%. In fact, it might be advantageous or necessary to review different pieces of relevant information in order to arrive at a sound conclusion.

16. The answer is **d.** Lack of proper system scheduling is typically one of the easiest energy efficiency measures to implement for a building and often results in huge ROI due to low implementation costs. However, to be most effective the schedules need to closely match the occupancy and usage of the different spaces in the building and should be tailored to each major area whenever possible. Warm up and cool down sequencing can be implemented in different ways and should be taken into consideration when setting up and adjusting schedules to take advantage of night setbacks while not disrupting occupant needs.

17. The answer is **a.** For most dampers, the percentage of control signal sent to a damper actuator does not necessarily equal the same percentage of airflow going through the damper, i.e., 25% control signal = 25% open damper ≠ 25% airflow. Dampers that do have a direct, linear relationship between percentage of control signal to change in air movement are often expensive and not regularly used. Typical (lower cost) dampers tend not to seal well and allow a significantly larger amount of airflow compared to percentage of damper movement, especially when opening from zero to 20% of control signal.

18. The answer is **a.** The graphs clearly show that gas use (therms) tracks heating degree days very closely in the "before" case. In the "after" case, therm usage tracks well below the heating degree days. This shows a clear reduction in use thanks to staff efforts to optimize setpoints and scheduling.

19. <u>The answer is **b.**</u> The design flow rates should be restored by re-balancing the system because the original valve position is unknown. Although common pump maintenance procedures use the balancing valve to isolate a pump, the need for flow re-balancing is often overlooked. Instead, the valve is simply closed -- without any record of its original position--and then re-opened to 100% when maintenance is complete. If optimizing energy efficiency is a priority, you might consider evaluating the pump's operating parameters and trimming the pump impeller to match the system's needs instead of partially closing the balance valve to control flow.

Answer **a** (valves 100% open) can lead to an over-pressurized system which forces heat exchanger valves to remain open and spaces to become uncomfortably overheated. The amount of water pumped is also greater than what the design requires. As a result, higher flow rates and pressure will place a greater load on the pump motor, increase energy use, and likely create more maintenance issues.

Answer **c** (valves 80% open) does not mention if this option was determined via flow re-balancing; as stated, this solution is arbitrary and might lead to the same problems described above.

Answer **d** (eliminating the balancing valves) will reduce pressure loss, but potentially cause the same problems described in answer **a**.

20. <u>The answer is **d**</u>. The building Energy Use Intensity (alternatively described as Energy Use Index) can be expressed in kBtu per square foot per year. Using a common metric, a building can be compared to peers with respect to energy efficiency (cross-sectional benchmarking) or compared over time against its own performance (longitudinal benchmarking).

Solution:
First, convert therms to kBtu using 100 kBtu per therm (th):
137,819 th/yr x 100 kbtu/th = 13,781,900 kBtu/yr

Then convert kWh to kBtu using the formula 3.412 kBtu = 1 kWh:
3,300,000 kWh/yr x 3.412 kBtu/kWh = 11,259,600 kBtu/yr

Add the two together:
13,781,900 kBtu/yr + 11,259,600 kBtu/yr = 25,041,500 kBtu/yr

Divide by the facility square footage:
25,041,500 kBtu/yr ÷ 323,250 sf = **77.5 kBtu/sf/yr**

DACUM Research Chart for High Performance Building Operations Professional

Produced for

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DACUM Research Chart for High Performance Building Operations Profession

DUTIES	TASKS			
A. Analyze Building Operations	A.1 Review building documentation (e.g., SOPs, BMS, MEP)	A.2 Perform Level I site assessment	A.3 Interview facility operators	A.4 Determine equipment performance (e.g., temperature, pressure, schedules)
	A.10 Trend building occupancy/production	A.11 Review capital improvement plan		
B. Maintain Building Operating Efficiency	B.1 Identify BAS discrepancies	B.2 Check for equipment override conditions	B.3 Calibrate equipment controls	B.4 Coordinate repair of deficient equipment
	B.10 Review VFD settings	B.11 Manage preventive maintenance plan	B.12 Manage predictive maintenance plan	B.13 Optimize equipment operating schedules
C. Audit Building Operational Performance*	C.1 Review maintenance and repair log	C.2 Perform utility bill audit (e.g., electric, gas, water)	C.3 Perform disaggregation of utilities (e.g., electric, gas, water)	C.4 Perform facility condition assessment
	C.10 Perform lighting audit	C.11 Perform indoor air quality audit	C.12 Audit equipment sequence of operations	C.13 Audit building/ equipment operating procedures
	C.19 Perform life cycle analysis			
D. Create High Performance Building Plans	D.1 Obtain payback analysis	D.2 Update capital improvement plan	D.3 Prioritize audit recommendations	D.4 Participate in the development of formal energy policy
	D.10 Optimize equipment sequence of operations	D.11 Develop operational & performance metrics	D.12 Identify utility rebates	D.13 Develop commissioning plan
	D.19 Participate in the development of tenant engagement programs	D.20 Participate in the development of water conservation plan	D.21 Review predictive maintenance plan	D.22 Develop measurement & verification policy

* Audit reports include recommendations for improvement

*Changes made from Task Analysis are shown in red.

A.5 Benchmark building performance	A.6 Develop building performance goals (e.g., energy, IEQ, water)	A.7 Identify environmental requirements (e.g., temperature, lighting, ventilation)	A.8 Trend service calls	A.9 Trend utility usage and cost
B.5 TAB air distribution systems (e.g., economizers, VAV, air handlers)	B.6 Calibrate central cooling systems (e.g., temperature resets, flow, pressure)	B.7 Calibrate central heating systems (e.g., temperature resets, flow, pressure)	B.8 Calibrate evaporative cooling systems (e.g., cooling towers, filtration, free cooling)	B.9 Optimize pump performance
B.14 Optimize operating set points	B.15 Develop key performance indicators (e.g., reset schedule, KW/sq. ft., peak load)	B.16 Conduct regular building performance meetings		
C.5 Perform Energy Star® review	C.6 Perform green building certification review	C.7 Review building occupancy plan	C.8 Quantify scope1 greenhouse gas emissions	C.9 Review waste audit (e.g., hazardous, landfill, recycling)
C.14 Review building occupant comfort survey results	C.15 Review system alarm history	C.16 Facilitate Testing of combustion equipment efficiencies	C.17 Perform water treatment audit	C.18 Determine need for energy consultant
D.5 Develop energy savings plan	D.6 Determine load shedding opportunities	D.7 Participate in the development of zero waste plan	D.8 Optimize SOPs	D.9 Update maintenance & repair plan
D.14 Participate in the development of building occupancy policy	D.15 Identify alternative energy opportunities	D.16 Participate in the development of zero net energy plan	D.17 Develop control system plan (e.g., enhanced data points, trends, data analysis)	D.18 Participate in the development of system integration plan
D.23 Develop proposals for management				

DACUM Research Chart for High Performance Building Operations Profession

DUTIES	TASKS			
E. Implement Continuous Improvement	E.1 Present facility improvement plan to management	E.2 Manage vendor contracts (e.g., RFP, proposals, awards)	E.3 Review engineering budget (e.g., operating, capital)	E.4 Perform routine inspections (e.g., equipment, systems, controls)
	E.10 Implement zero net energy plan	E.11 Implement system integration plan	E.12 Optimize control system (e.g., enhance data points, trends, data analysis)	E.13 Implement predictive maintenance plan
F. Manage Building Systems	F.1 Track utility costs & consumption	F.2 Evaluate energy savings	F.3 Track equipment performance	F.4 Track service calls
G. Perform Administrative Tasks	G.1 Review test equipment and tools	G.2 Manage operating budget	G.3 Prepare monthly reports for management (e.g., energy, labor, activity)	G.4 Manage building energy efficiency standards
	G.10 Assess vendor's high performance qualifications			
H. Participate in Professional Development Activities	H.1 Develop staff succession plan	H.2 Conduct staff evaluations	H.3 Conduct high performance job training	H.4 Facilitate problem solving meetings
	H.10 Participate in conferences and trade shows	H.11 Participate in code update training (e.g., energy efficiency, building codes, local ordinances)	H.12 Share best practices (e.g., peer-to-peer, online, conferences	H.13 Obtain professional certifications (e.g., CXA, LEED, BOC)

E.5 Implement energy savings plan	E.6 Implement load shedding measures	E.7 Implement zero waste plan	E.8 Implement commissioning plan	E.9 Adjust equipment settings per occupancy plan
E.14 Review measurement & verification plan				
F.5 Determine need for systems balance	F.6 Track maintenance and repairs	F.7 Track predictive maintenance	F.8 Review measurement & verification reports	F.9 Monitor staff performance (e.g., service calls, preventive maintenance, rounds)
G.5 Research new technology	G.6 Establish staff performance goals	G.7 Develop green procurement policy	G.8 Facilitate energy efficiency meetings (e.g., staff, management, vendors)	G.9 Develop staff training program
H.5 Identify staff professional development activities	H.6 Develop vendor shadowing program	H.7 Develop staff training on new equipment technologies	H.8 Create employee engagement programs	H.9 Participate in professional organizations
H.14 Participate in continuing education classes				

General Knowledge and Skills

Knowledge:
Root cause analysis
Basic algebra
Basic geometry
Fluid dynamics
Thermodynamics
Mechanical systems
Lighting systems
Building construction
Systems thinking
HVAC cycle
DDC controls
Basic finance
Real estate finance
Insurance & liability
Codes and standards
Air & water balance
Psychrometrics
Plumbing systems
Electrical systems
Design intent
Building loads
Building science
Engineering ethics
Sustainability principles
Environmental impact
Available certifications

Skills:
Communication
Tool operation
Report writing
Blueprint reading
System diagrams
Single line diagrams
Flow charting
Troubleshooting
Analytical
Leadership
Negotiation
Prioritizing
Selling
Presentation
Conflict resolution
Mentoring
Managerial
Problem solving

Acronyms

VFD	Variable Frequency Drive
PPE	Personal Protective Equipment
LED	Light Emitting Diode
RFP	Request for Proposal
SOP	Standard Operating Procedure
BMS	Building Management System
PM	Preventive Maintenance
MEP	Mechanical Electrical Plumbing
IEQ	Indoor Environmental Quality
BAS	Building Automation System
DDC	Direct Digital Controls
CXA	Certified Commissioning Authority
LEED	Leadership in Energy & Environmental Design
BOC	Building Operator Certification

Behaviors

Team player
Accountable
Confident
Multitasker
Analytical
Persistent
Punctual
Trainable
Passionate
Open minded
Physically fit
Innovative
Knowledgeable
Able to follow directions
Inquisitive
Precise
Safety oriented
Mechanically inclined
Self starter
Forward thinking
Solution driven

Tools, Equipment, Supplies and Materials

Light meter
pH meter
Tachometer
Computer
Calculator
Basic hand tools
Digital camera
Infrared camera
PPE
Ladders
Basic office supplies
Megger
Multimeter
Cell phone
Internet/Intranet
Flash drives
Flashlights
Carbon dioxide meter
Anemometer
Manometer
Power meter
Temperature meter
Flow hood
Oxygen sensor
Data logger
Combustion analyzer
Building automation system
Lockout/tagout tags
Man lifts
Particulate counter
Water quality testing equipment
Software:
* HOBO
* Universal Translator
* Microsoft Office
* Microsoft Project
* DOE programs
* Visio
* Energy Plus

Network access to:
* BAS
* Tenant interface
* PM program
* Work order program
* Energy dashboard
* Google Docs
* File sharing

Vibration analysis
Ultrasonic microphone
Ultrasonic meter

Future Trends and Concerns

Trend toward:
* zero net energy
* zero waste
* on site energy generation
* use of direct digital controls
* carbon footprint reduction
* lighting controls
* big data/Internet of things
* building certifications
* variable refrigerant flow
* water conservation
* increased occupancy density
* consolidating data centers
* sub metering
* electric vehicle charging stations
* onsite energy shortage
* micro grids
* utility demand response
* smart meters
* wireless systems
* carbon dioxide monitoring
* electronic data gathering
* integration of systems

Proliferation of data centers
Cloud data storage
Workforce shortages
LED lighting