

COMPREHENSIVE REVIEW TESTS

(BY PART)

The fourteen topic-specific practice tests you have just completed were designed to assess your knowledge of individual chapters, isolating each subject area so you could identify strengths and weaknesses within specific disciplines. Those tests built your foundation one system at a time, ensuring you developed solid command of each MEP domain before moving forward.

The four comprehensive review tests in this section raise the challenge by integrating multiple chapters within each of the four major parts. Rather than focusing on a single system, these tests require you to draw connections across related topics and apply your knowledge the way real construction projects demand. An HVAC question may require you to connect heating fundamentals with building automation strategies. An electrical question may blend power distribution concepts with lighting design and energy sustainability. Plumbing questions may cross boundaries between water supply, drainage, and code compliance. Fire protection questions may integrate sprinkler design with fire alarm sequencing and code enforcement.

Each comprehensive review test contains 50 questions drawn from all chapters within its respective part. The questions are randomized across topics, meaning you will shift between subjects just as you would encounter them in the field or on a certification examination. This format tests not only your recall of individual facts but your ability to think across systems and recognize how different components interact within a unified discipline.

Approach these tests as a realistic measure of your readiness. If you score well, you have strong command of the integrated content. If specific areas reveal gaps, return to the relevant topic-specific tests and chapter content to reinforce those concepts before advancing to the full-length simulated examinations in the final section.

FULL-LENGTH PRACTICE TESTS

Practice Test 15: Comprehensive Hvac Systems Review – Chapters 1-4

Questions 1–50

1. What is the primary function of a condensing boiler that distinguishes it from a conventional boiler?
 - A. Operating at lower water temperatures to protect cast iron heat exchangers
 - B. Using electric resistance elements instead of gas burners
 - C. Recovering latent heat from exhaust flue gases by condensing water vapor, achieving efficiencies of 90 to 98 percent
 - D. Producing steam instead of hot water for distribution

2. A BAS operator notices that a VAV box is hunting between heating and cooling. What is the most likely cause?
 - A. The heating and cooling deadband is too narrow, causing the system to oscillate between modes
 - B. The supply air temperature is too low for the zone's heating demand
 - C. The VAV box actuator has been manually overridden to full open
 - D. The zone occupancy sensor has been removed from the system

3. What is the primary purpose of ASHRAE Standard 62.1 in commercial HVAC design?
 - A. Establishing maximum noise levels for mechanical equipment
 - B. Setting minimum energy efficiency requirements for HVAC systems

- C. Defining fire damper installation requirements in duct systems
- D. Establishing minimum outdoor air ventilation rates to maintain acceptable indoor air quality

4. A chiller plant operates with a constant condenser water temperature year-round. What energy-saving strategy would reduce chiller energy consumption during cooler weather?

- A. Increasing the chilled water supply temperature setpoint
- B. Lowering the condenser water temperature when ambient wet-bulb conditions allow, reducing compressor lift
- C. Shutting down all cooling tower fans to save fan energy
- D. Bypassing the condenser water through the chiller at maximum flow

5. What is the primary function of an air-side economizer on a rooftop unit?

- A. Recovering heat from the exhaust air stream to preheat outdoor air
- B. Filtering outdoor air to remove particulates before entering the building
- C. Using outdoor air for free cooling when ambient conditions are favorable, reducing compressor operation
- D. Providing dehumidification during humid summer conditions

6. During commissioning, a hot water heating system fails to maintain setpoint at remote terminal units. What should the commissioning team investigate first?

- A. System water balance, pump operation, and control valve function at the remote terminals
- B. The chiller plant operating schedule
- C. The fire alarm integration with the boiler system
- D. The rooftop unit refrigerant charge

7. What information does an ASHRAE Level II energy audit provide that a Level I walkthrough assessment does not?

- A. A basic list of no-cost operational improvements
- B. A general overview of the building's energy consumption profile
- C. A brief visual inspection of mechanical equipment condition
- D. Detailed energy calculations, engineering analysis, and cost-benefit evaluation of specific energy conservation measures

8. A building's energy dashboard shows that HVAC energy consumption spikes every Monday morning. What is the most likely operational cause?

- A. The cooling tower is running in free cooling mode over the weekend
- B. The system is recovering from weekend setback, simultaneously heating and cooling the building to occupied setpoints
- C. The fire alarm system is conducting its weekly test
- D. The building automation system performs a software backup every Monday

9. What is the primary advantage of a variable refrigerant flow system compared to a conventional rooftop unit serving multiple zones?

- A. Lower first cost for all building sizes and applications
- B. Simpler installation requiring no refrigerant piping
- C. Individual zone temperature control with simultaneous heating and cooling capability and heat recovery between zones
- D. Higher airflow capacity for large open-plan spaces

10. What is the primary purpose of the testing, adjusting, and balancing process for HVAC systems?

- A. Verifying that all air and water systems deliver design flow rates to each zone and terminal device
- B. Selecting the HVAC equipment manufacturers for the project
- C. Calculating the building's annual energy consumption estimate
- D. Establishing the preventive maintenance schedule for HVAC equipment

11. A building owner reports that occupants on the south-facing floors are consistently too warm in the afternoon while north-facing floors are comfortable. What HVAC system adjustment should be evaluated?

- A. Increasing the boiler supply water temperature setpoint
- B. Verifying proper operation of perimeter zone VAV boxes, solar-loaded zone setpoints, and automated blind or shading controls
- C. Replacing all interior zone thermostats with manual models
- D. Reducing the outdoor air ventilation rate to the south zones

12. What is the primary purpose of an enthalpy wheel in an energy recovery ventilation system?

- A. Filtering particulates from the exhaust air stream
- B. Boosting the supply fan static pressure
- C. Providing supplemental cooling during peak summer conditions
- D. Transferring both sensible heat and moisture between the exhaust and outdoor air streams to reduce the energy required to condition ventilation air

13. What does the coefficient of performance measure for a heat pump system?

- A. The ratio of heating or cooling output to energy input, indicating the system's efficiency
- B. The maximum refrigerant charge permitted in the system

- C. The compressor's operating speed in revolutions per minute
- D. The system's total airflow capacity in cubic feet per minute

14. A commissioning agent discovers that a chilled water pump VFD is running at a constant speed rather than modulating. What is the impact on energy performance?

- A. No impact because VFDs do not affect pump energy consumption
- B. Reduced energy consumption because constant speed is more efficient
- C. Increased energy consumption because the pump runs at full speed regardless of demand, eliminating significant part-load savings
- D. Improved chiller performance because constant flow stabilizes the evaporator

15. What distinguishes a dedicated outdoor air system from a conventional mixed-air AHU?

- A. DOAS units only provide heating with no cooling capability
- B. DOAS handles 100 percent outdoor air ventilation independently, allowing separate zone systems to handle sensible loads without ventilation responsibilities
- C. DOAS units recirculate 100 percent of return air with no outdoor air intake
- D. DOAS units are limited to single-zone applications only

16. What is the primary function of a cooling tower in a water-cooled chiller system?

- A. Storing chilled water for distribution to air handling units
- B. Filtering the condenser water to remove mineral deposits
- C. Providing emergency cooling water during chiller maintenance
- D. Rejecting heat absorbed by the chiller's condenser to the atmosphere through evaporative cooling

17. During retro-commissioning of an existing building, which measures typically provide the shortest payback period?

- A. Complete replacement of all HVAC equipment with new units
- B. Installing a new building automation system from a different manufacturer
- C. Correcting control sequences, scheduling errors, and setpoint adjustments that restore designed operating efficiency
- D. Adding a central chilled water plant to replace all packaged units

18. What is the primary purpose of duct leakage testing during HVAC commissioning?

- A. Verifying that ductwork is sealed within acceptable limits to prevent energy waste, comfort problems, and indoor air quality issues from uncontrolled air leakage
- B. Measuring the airflow velocity at each supply diffuser
- C. Confirming that fire dampers close on fire alarm activation
- D. Testing the structural integrity of duct hangers and supports

19. A building's BAS trend data shows the outdoor air damper on a large AHU remains at minimum position even when outdoor conditions are ideal for economizer operation. What should be investigated?

- A. The chiller plant's condenser water temperature setpoint
- B. The economizer control sequence, outdoor air sensor calibration, and damper actuator operation
- C. The fire alarm system's HVAC shutdown programming
- D. The boiler system's outdoor air reset schedule

20. What primary advantage do geothermal heat pump systems provide compared to air-source systems?

- A. Lower installation cost in all applications

- B. Simpler maintenance with no underground components
- C. Higher airflow rates at each terminal unit
- D. More stable source temperatures year-round, resulting in higher efficiency and lower operating costs

21. What is the primary purpose of ASHRAE Standard 90.1 in commercial building design?

- A. Establishing minimum energy efficiency requirements for building systems including HVAC, lighting, and building envelope
- B. Setting indoor air quality ventilation rates for occupied spaces
- C. Defining fire protection system requirements for commercial buildings
- D. Establishing plumbing fixture flow rate maximums

22. A cooling tower's approach temperature has increased significantly over the past year. What does this indicate?

- A. The chiller's compressor is operating more efficiently than design
- B. The condenser water pump is delivering higher flow than required
- C. The tower's heat rejection capacity has degraded, likely from fouling, scale buildup, or mechanical deterioration of fill media
- D. The building's cooling load has decreased below the tower's minimum capacity

23. What is the primary function of a fire smoke damper in an HVAC duct system?

- A. Regulating airflow volume for zone temperature control
- B. Preventing the passage of both fire and smoke through duct penetrations of rated assemblies by closing on both heat exposure and fire alarm signal
- C. Filtering particulates from the return air stream
- D. Maintaining duct static pressure at the design setpoint

24. During functional performance testing, a commissioning agent finds that the chilled water system's differential pressure setpoint is located at the pump discharge rather than at the most remote coil. What is the consequence?

- A. Improved energy performance because the pump can run at lower speed
- B. Better control accuracy at the remote terminal units
- C. Reduced wear on the control valves at nearby terminal units
- D. Excessive pump energy consumption because the pump maintains higher pressure than needed at remote coils to overcome system friction

25. What is the primary benefit of demand-controlled ventilation using CO2 sensors?

- A. Reducing outdoor air volume during partial occupancy, saving energy while maintaining adequate ventilation based on actual occupant count
- B. Eliminating the need for mechanical cooling in the building
- C. Providing fire detection capability through air quality monitoring
- D. Increasing the supply air temperature during peak cooling conditions

26. What is the primary purpose of a hydronic system's expansion tank?

- A. Storing additional hot water for peak heating demand
- B. Filtering sediment and debris from the circulating water
- C. Absorbing the volume change that occurs when water is heated or cooled, maintaining stable system pressure
- D. Providing makeup water to compensate for system leaks

27. A BAS operator receives an alarm indicating high supply air temperature from a cooling-only AHU. The chilled water valve shows 100 percent open. What should be investigated next?

- A. The outdoor air damper position and minimum ventilation setpoint
- B. Chilled water supply temperature, flow rate, and coil condition to determine if the coil is receiving adequate chilled water
- C. The fire alarm panel for active alarms affecting the AHU
- D. The heating hot water valve position on the same unit

28. What does the integrated part-load value measure for a chiller?

- A. The chiller's maximum cooling capacity at full load design conditions
- B. The chiller's refrigerant charge requirement at startup
- C. The chiller's electrical demand during morning warmup
- D. The chiller's weighted average efficiency across multiple part-load operating points, reflecting typical annual operating conditions

29. What is the primary function of an outdoor air reset control strategy for a hot water boiler system?

- A. Reducing the hot water supply temperature as outdoor temperature rises, improving efficiency and comfort by matching supply temperature to actual heating demand
- B. Increasing the boiler firing rate as outdoor temperature increases
- C. Maintaining a constant hot water temperature regardless of outdoor conditions
- D. Shutting down the boiler when outdoor temperature drops below freezing

30. A newly commissioned building shows significantly higher energy consumption than the design energy model predicted. What should the commissioning team evaluate first?

- A. The building's architectural finish materials and paint colors

- B. The landscaping irrigation schedule and water features
- C. Operating schedules, setpoints, control sequences, and simultaneous heating and cooling to identify operational deviations from design assumptions
- D. The number of occupants in the building compared to the parking lot capacity

31. What is the primary purpose of smoke control system integration with the BAS?

- A. Providing general ventilation to stairwells during normal operation
- B. Controlling the building's normal HVAC scheduling and setpoints
- C. Monitoring outdoor air quality for pollutant levels
- D. Enabling the BAS to activate smoke control fans, dampers, and pressurization sequences upon fire alarm system command

32. A facility manager notices that the HVAC system is simultaneously heating and cooling the same zone. What is the most common cause of this energy waste?

- A. The zone is served by a properly operating heat recovery VRF system
- B. Improperly configured control sequences, overlapping setpoints, or a faulty changeover between heating and cooling modes
- C. The commissioning authority requested simultaneous operation for testing
- D. The zone thermostat was recently calibrated correctly

33. What is the primary purpose of the commissioning plan document?

- A. Defining the scope, schedule, procedures, roles, and responsibilities for the entire commissioning process before testing begins
- B. Recording the final commissioning test results for closeout
- C. Establishing the HVAC contractor's warranty obligations
- D. Calculating the building's expected annual energy cost

34. A building experiences poor indoor air quality complaints in a conference room that becomes heavily occupied during meetings. What HVAC system enhancement would address this?

- A. Reducing the room's supply air temperature by 10 degrees
- B. Installing an exhaust fan in the adjacent corridor
- C. Implementing demand-controlled ventilation with a CO₂ sensor to increase outdoor air during high-occupancy periods
- D. Replacing the room's light fixtures with higher-output models

35. What is the primary purpose of point-to-point verification during BAS commissioning?

- A. Testing the fire alarm system's connection to the BAS
- B. Confirming that each field sensor, actuator, and controlled device is correctly wired, addressed, and communicates accurately with the BAS controller
- C. Measuring the building's total electrical demand at peak load
- D. Verifying the BAS operator workstation's screen resolution

36. What information does a building's Energy Use Intensity provide?

- A. The total electrical demand in kilowatts during peak cooling
- B. The building's annual water consumption per occupant
- C. The chiller plant's coefficient of performance at design conditions
- D. The building's total annual energy consumption per square foot, enabling comparison with benchmarks and similar buildings

37. A rooftop unit's compressor is short-cycling on and off rapidly. What is the most likely cause?

- A. A refrigerant charge problem, dirty condenser coil, or thermostat differential set too narrow

- B. The unit's economizer damper is stuck in the fully open position
- C. The fire alarm system is sending repeated shutdown signals
- D. The unit's supply fan belt is slipping and needs adjustment

38. What is the primary benefit of commissioning HVAC systems before building occupancy?

- A. Reducing the HVAC contractor's warranty period
- B. Allowing construction activities to continue without disruption
- C. Identifying and correcting deficiencies before occupants arrive, ensuring comfort, efficiency, and proper operation from day one
- D. Eliminating the need for ongoing preventive maintenance

39. What is the primary purpose of a measurement and verification plan for HVAC energy conservation measures?

- A. Calculating the HVAC system's initial installation cost
- B. Scheduling the HVAC contractor's preventive maintenance visits
- C. Establishing the building's fire protection system testing schedule
- D. Quantifying actual energy savings achieved by the implemented measures compared to the baseline to verify that projected savings are realized

40. A chilled water plant with multiple chillers is operating all chillers simultaneously at low load. What operational improvement would reduce energy consumption?

- A. Increasing the chilled water supply temperature above design setpoint
- B. Implementing optimal chiller staging to match the number of operating chillers to the actual building load
- C. Running all condenser water pumps at full speed regardless of load
- D. Disabling the cooling tower fans to reduce total plant energy

41. What is the primary purpose of seasonal commissioning verification?

- A. Repainting the mechanical room walls before each season change
- B. Testing HVAC system performance during both heating and cooling seasons to verify proper changeover operation and seasonal control sequences
- C. Replacing all air filters at the beginning of each season
- D. Adjusting the building's lease rates based on seasonal utility costs

42. A facility manager wants to reduce the building's peak electrical demand charges. What HVAC strategy is most effective?

- A. Running all equipment continuously at full capacity 24 hours a day
- B. Increasing the chilled water supply temperature during unoccupied periods
- C. Implementing ice or chilled water thermal energy storage to shift cooling production from peak to off-peak periods
- D. Disabling the BAS scheduling system to allow manual equipment control

43. What is the primary function of a building automation system's trending capability?

- A. Providing real-time video surveillance of mechanical rooms
- B. Generating monthly tenant billing statements
- C. Printing equipment warranty certificates
- D. Recording and storing time-series data from system sensors and controllers for performance analysis, troubleshooting, and optimization

44. What is the primary purpose of the HVAC system closeout documentation package?

- A. Providing the building operations team with as-built drawings, equipment manuals, control sequences, test reports, and maintenance procedures needed for ongoing system operation

- B. Satisfying the architect's interior design documentation requirements
- C. Providing marketing materials for the building's leasing brochure
- D. Calculating the building's property tax assessment value

45. A building's hot water heating system uses constant-speed pumping. What upgrade would provide the greatest energy savings?

- A. Increasing the boiler supply water temperature to maximum
- B. Adding additional constant-speed pumps in parallel
- C. Converting to variable-speed pumping with VFDs controlled by system differential pressure
- D. Replacing the expansion tank with a larger model

46. What is the primary purpose of LEED enhanced commissioning compared to fundamental commissioning?

- A. Eliminating the need for functional performance testing
- B. Extending the commissioning scope to include design review, construction observation, seasonal testing, and post-occupancy verification
- C. Reducing the total commissioning cost by simplifying procedures
- D. Limiting commissioning to the fire protection systems only

47. A VAV system's static pressure sensor is located at the supply fan discharge instead of two-thirds down the duct. What is the energy impact?

- A. Reduced fan energy because the fan operates at lower speed
- B. Improved airflow distribution to all terminal units
- C. No measurable impact on fan energy consumption
- D. Increased fan energy because the fan maintains higher pressure than needed at downstream VAV boxes to overcome duct friction

48. What is the primary benefit of predictive maintenance using BAS data analytics for HVAC systems?

- A. Identifying equipment degradation trends before failure occurs, enabling proactive repair and avoiding unplanned downtime
- B. Eliminating the need for all routine preventive maintenance
- C. Automatically repairing mechanical equipment without human intervention
- D. Replacing the building's energy management system entirely

49. During retro-commissioning, trend data reveals that an economizer on a major AHU has not operated for an entire cooling season. What is the estimated energy waste impact?

- A. No impact because economizers only affect heating season performance
- B. Significant energy waste because the chiller ran unnecessarily during hours when outdoor air could have provided free cooling
- C. Minimal impact because economizer savings are less than one percent of total energy
- D. Improved indoor air quality because the outdoor air damper remained closed

50. What is the primary purpose of the owner's project requirements document in the HVAC commissioning process?

- A. Specifying the HVAC contractor's insurance requirements
- B. Establishing the construction project's general conditions
- C. Defining the fire protection system's performance criteria
- D. Establishing the building owner's expectations for system performance, efficiency, comfort, and operational requirements that the commissioned systems must satisfy

ANSWER KEY 15: DETAILED EXPLANATIONS — PRACTICE TEST 15 COMPREHENSIVE HVAC SYSTEMS REVIEW

Questions 1–50

1. **C. Recovering latent heat from exhaust flue gases by condensing water vapor, achieving efficiencies of 90 to 98 percent** — Condensing boilers extract additional heat from flue gases by cooling them below the dew point, causing water vapor in the combustion products to condense and release latent heat. This recovered energy boosts efficiency significantly beyond the 80 to 85 percent typical of conventional non-condensing boilers.
2. **A. The heating and cooling deadband is too narrow, causing the system to oscillate between modes** — When the temperature gap between heating and cooling setpoints is insufficient, the system satisfies one mode and immediately triggers the opposite. A properly configured deadband, typically 2 to 4 degrees, provides a neutral zone where neither heating nor cooling operates, preventing wasteful oscillation.
3. **D. Establishing minimum outdoor air ventilation rates to maintain acceptable indoor air quality** — ASHRAE 62.1 specifies the minimum quantity of outdoor air that must be delivered to occupied spaces based on occupancy density and floor area. These rates ensure adequate dilution of indoor contaminants including CO₂, volatile organic compounds, and other pollutants generated by occupants and building materials.
4. **B. Lowering the condenser water temperature when ambient wet-bulb conditions allow, reducing compressor lift** — Chiller efficiency improves when the temperature difference between the evaporator and condenser decreases. Lower ambient wet-bulb temperatures enable cooling towers to produce cooler condenser water, reducing the compressor's lift and energy consumption while maintaining the same cooling output.
5. **C. Using outdoor air for free cooling when ambient conditions are favorable, reducing compressor operation** — Air-side economizers open the outdoor air damper to bring in cool outdoor air when its temperature or enthalpy is below the return air condition. This provides free cooling that partially or fully replaces mechanical refrigeration, significantly reducing compressor energy during mild weather.

6. **A. System water balance, pump operation, and control valve function at the remote terminals** — When remote terminal units cannot maintain setpoint, the most likely causes involve inadequate hot water flow. The investigation should verify that pumps deliver design flow, the system is properly balanced to distribute water to remote terminals, and control valves operate through their full stroke.
7. **D. Detailed energy calculations, engineering analysis, and cost-benefit evaluation of specific energy conservation measures** — A Level II audit goes beyond the Level I walkthrough by providing detailed engineering calculations for each identified energy conservation measure, including estimated savings, implementation costs, simple payback periods, and prioritized recommendations supported by quantitative analysis.
8. **B. The system is recovering from weekend setback, simultaneously heating and cooling the building to occupied setpoints** — When the building returns from unoccupied setback temperatures Monday morning, heating and cooling systems work simultaneously at maximum capacity to bring all zones to occupied setpoints. This recovery period creates a peak demand spike that can be reduced through optimal start programming.
9. **C. Individual zone temperature control with simultaneous heating and cooling capability and heat recovery between zones** — VRF systems provide independent temperature control at each indoor unit with the ability to simultaneously heat some zones while cooling others. Heat recovery VRF systems capture rejected heat from cooling zones and redirect it to zones requiring heating, significantly improving energy efficiency.
10. **A. Verifying that all air and water systems deliver design flow rates to each zone and terminal device** — TAB verifies that every supply air diffuser, return air grille, VAV box, fan coil, hydronic terminal, and air handler delivers the airflow or water flow specified in the design documents. Proper balancing ensures that every space receives its designed heating, cooling, and ventilation capacity.
11. **B. Verifying proper operation of perimeter zone VAV boxes, solar-loaded zone setpoints, and automated blind or shading controls** — South-facing zones experience significant afternoon solar heat gain that increases cooling demand beyond typical interior conditions. The investigation should verify that perimeter VAV boxes can deliver adequate cooling, zone setpoints account for solar loads, and any automated shading systems operate correctly.
12. **D. Transferring both sensible heat and moisture between the exhaust and outdoor air streams to reduce the energy required to condition ventilation air** — Enthalpy wheels rotate between the exhaust and outdoor air streams, transferring both heat and moisture. In winter, the wheel recovers heat and humidity from warm exhaust air. In summer, it pre-cools and dehumidifies hot humid outdoor air, reducing the load on the cooling and heating systems.
13. **A. The ratio of heating or cooling output to energy input, indicating the system's efficiency** — COP expresses how many units of heating or cooling the system delivers for each unit of energy

consumed. A COP of 3.0 means the system produces three units of thermal energy for every one unit of electrical energy input. Higher COP values indicate greater efficiency.

14. **C. Increased energy consumption because the pump runs at full speed regardless of demand, eliminating significant part-load savings** — VFDs on chilled water pumps reduce speed and energy consumption as building load decreases. Pump energy varies with the cube of speed, so even small speed reductions yield large energy savings. A VFD running at constant speed wastes the substantial part-load savings VFDs are designed to provide.
15. **B. DOAS handles 100 percent outdoor air ventilation independently, allowing separate zone systems to handle sensible loads without ventilation responsibilities** — DOAS decouples ventilation from zone conditioning, allowing the outdoor air to be treated, dehumidified, and delivered independently. Zone systems such as fan coils or radiant panels handle only sensible heating and cooling, enabling more precise humidity control and improved energy performance.
16. **D. Rejecting heat absorbed by the chiller's condenser to the atmosphere through evaporative cooling** — Cooling towers cool the condenser water by exposing it to ambient air and evaporating a small portion. This evaporative process rejects the heat absorbed from the building plus the compressor's heat of compression to the atmosphere, allowing the chiller to continue its refrigeration cycle.
17. **C. Correcting control sequences, scheduling errors, and setpoint adjustments that restore designed operating efficiency** — Retro-commissioning identifies low-cost and no-cost operational improvements that have drifted from the original design intent. Correcting schedules, setpoints, and control sequences requires minimal capital investment but restores efficiency that has degraded over time, typically achieving payback periods under two years.
18. **A. Verifying that ductwork is sealed within acceptable limits to prevent energy waste, comfort problems, and indoor air quality issues** — Duct leakage wastes conditioned air into unconditioned spaces, increases fan energy to compensate for lost airflow, creates comfort problems from insufficient supply air, and can introduce contaminants from ceiling plenums or mechanical spaces into occupied areas through return air leaks.
19. **B. The economizer control sequence, outdoor air sensor calibration, and damper actuator operation** — When the economizer fails to engage during favorable conditions, the fault likely lies in the control logic enabling economizer operation, the outdoor air temperature or enthalpy sensor providing inaccurate readings, or the damper actuator failing to respond to the control signal.
20. **D. More stable source temperatures year-round, resulting in higher efficiency and lower operating costs** — Ground temperatures remain relatively constant at 50 to 60 degrees Fahrenheit regardless of season, providing a more favorable heat source in winter and heat sink in summer compared to outdoor air temperatures that fluctuate widely. This stability enables higher COP values and lower energy consumption throughout the year.

21. **A. Establishing minimum energy efficiency requirements for building systems including HVAC, lighting, and building envelope** — ASHRAE 90.1 is the primary energy standard for commercial buildings, setting mandatory and prescriptive requirements for HVAC equipment efficiency, system controls, insulation, lighting power density, and building envelope performance. Most building codes reference 90.1 as the enforceable energy standard.
22. **C. The tower's heat rejection capacity has degraded, likely from fouling, scale buildup, or mechanical deterioration of fill media** — Approach temperature is the difference between the leaving condenser water temperature and the ambient wet-bulb temperature. An increasing approach indicates the tower cannot cool water as effectively as designed, typically caused by scale deposits, biological fouling, clogged nozzles, or degraded fill media reducing heat transfer.
23. **B. Preventing the passage of both fire and smoke through duct penetrations of rated assemblies by closing on both heat exposure and fire alarm signal** — Combination fire smoke dampers serve a dual function, closing on heat from a fusible link to maintain fire ratings and closing on a fire alarm signal to prevent smoke migration. This eliminates the need for separate fire and smoke dampers at penetrations requiring both functions.
24. **D. Excessive pump energy consumption because the pump maintains higher pressure than needed at remote coils to overcome system friction** — When the differential pressure sensor is at the pump discharge, the pump maintains a high pressure that includes all system friction losses. A sensor at the remote coil allows the pump to reduce speed as valves close, maintaining only the pressure needed at the coil and saving significant energy.
25. **A. Reducing outdoor air volume during partial occupancy, saving energy while maintaining adequate ventilation based on actual occupant count** — DCV uses CO₂ sensors as a proxy for occupancy to modulate the outdoor air volume. When spaces are partially occupied, less outdoor air is needed to maintain acceptable CO₂ levels. Reducing outdoor air volume reduces the energy required to heat, cool, and dehumidify ventilation air.
26. **C. Absorbing the volume change that occurs when water is heated or cooled, maintaining stable system pressure** — Water expands when heated and contracts when cooled. In a closed hydronic system, the expansion tank provides a compressible air cushion that absorbs these volume changes, preventing excessive pressure buildup during heating and maintaining positive pressure during cooling.
27. **B. Chilled water supply temperature, flow rate, and coil condition to determine if the coil is receiving adequate chilled water** — With the valve fully open and the supply air temperature still high, the coil is not receiving sufficient cooling. The investigation should verify chilled water supply temperature at the coil, water flow rate through the coil, and coil condition including cleanliness of fins and absence of air locks.
28. **D. The chiller's weighted average efficiency across multiple part-load operating points, reflecting typical annual operating conditions** — IPLV weights the chiller's efficiency at 100,

75, 50, and 25 percent load at varying condenser water temperatures that reflect typical annual conditions. Since chillers operate at part load most of the year, IPLV provides a more realistic efficiency comparison than full-load rating alone.

29. **A. Reducing the hot water supply temperature as outdoor temperature rises, improving efficiency and comfort** — Outdoor air reset reduces the boiler supply temperature proportionally as outdoor temperature increases and heating demand decreases. Lower supply temperatures improve condensing boiler efficiency, reduce distribution losses, prevent overheating at terminal units, and improve occupant comfort.
30. **C. Operating schedules, setpoints, control sequences, and simultaneous heating and cooling to identify operational deviations from design assumptions** — The most common causes of higher-than-modeled energy consumption are operational rather than equipment deficiencies. Schedules running equipment beyond occupied hours, setpoints not matching design, improperly configured control sequences, and simultaneous heating and cooling waste significant energy.
31. **D. Enabling the BAS to activate smoke control fans, dampers, and pressurization sequences upon fire alarm system command** — The BAS receives smoke control commands from the fire alarm system and executes pre-programmed sequences that start smoke exhaust fans, activate pressurization fans, and position smoke dampers to contain and exhaust smoke from the fire area while maintaining tenable conditions in egress paths.
32. **B. Improperly configured control sequences, overlapping setpoints, or a faulty changeover between heating and cooling modes** — Simultaneous heating and cooling in the same zone is one of the most common energy waste conditions in commercial buildings. It typically results from setpoints with insufficient deadband, malfunctioning changeover controls, or conflicting heating and cooling sequences fighting each other.
33. **A. Defining the scope, schedule, procedures, roles, and responsibilities for the entire commissioning process before testing begins** — The commissioning plan establishes the roadmap for the entire commissioning effort. It identifies every system to be commissioned, defines the testing procedures, assigns responsibilities to each party, establishes the schedule, and sets quality standards before any testing activities commence.
34. **C. Implementing demand-controlled ventilation with a CO₂ sensor to increase outdoor air during high-occupancy periods** — A CO₂ sensor monitors the conference room's air quality and signals the HVAC system to increase outdoor air when occupancy drives CO₂ levels above the setpoint. This provides adequate ventilation during heavily occupied meetings while avoiding excessive outdoor air when the room is lightly occupied or empty.
35. **B. Confirming that each field sensor, actuator, and controlled device is correctly wired, addressed, and communicates accurately with the BAS controller** — Point-to-point verification tests every individual connection between field devices and the BAS. Each sensor is

checked for correct reading, each actuator is verified to respond to commands in the correct direction and range, and each device address is confirmed to match the programming.

36. **D. The building's total annual energy consumption per square foot, enabling comparison with benchmarks and similar buildings** — EUI normalizes energy consumption by building area, expressed as kBtu per square foot per year. This metric enables meaningful comparison between buildings of different sizes and allows benchmarking against ENERGY STAR Portfolio Manager databases and industry averages for similar building types.
37. **A. A refrigerant charge problem, dirty condenser coil, or thermostat differential set too narrow** — Short-cycling results from conditions that cause the compressor to reach its safety limits quickly. Low refrigerant causes low suction pressure trips, a dirty condenser causes high head pressure trips, and a narrow thermostat differential causes the setpoint to be reached too quickly before restarting.
38. **C. Identifying and correcting deficiencies before occupants arrive, ensuring comfort, efficiency, and proper operation from day one** — Pre-occupancy commissioning catches and resolves installation errors, control programming mistakes, and integration failures before they affect occupants. This prevents the discomfort, complaints, and energy waste that occur when problems are discovered only after the building is occupied and operational.
39. **D. Quantifying actual energy savings achieved by the implemented measures compared to the baseline to verify projected savings are realized** — M&V plans establish a pre-retrofit baseline and define the methodology for measuring post-retrofit energy consumption. Comparing actual performance against the baseline quantifies real savings, verifies that investments deliver their projected returns, and identifies measures that may need adjustment.
40. **B. Implementing optimal chiller staging to match the number of operating chillers to the actual building load** — Running multiple chillers at low load is less efficient than running fewer chillers at higher load percentages closer to their peak efficiency point. Optimal staging sequences chillers on and off based on actual building load, minimizing total plant energy while maintaining adequate cooling capacity.
41. **B. Testing HVAC system performance during both heating and cooling seasons to verify proper changeover operation and seasonal control sequences** — Many HVAC deficiencies only manifest during specific seasons. Heating system problems are invisible during summer commissioning, and economizer failures only appear during mild weather. Seasonal verification ensures all control sequences operate correctly during their respective operating conditions.
42. **C. Implementing ice or chilled water thermal energy storage to shift cooling production from peak to off-peak periods** — Thermal storage produces and stores cooling capacity during off-peak nighttime hours when electricity rates are lower, then discharges the stored cooling during peak afternoon hours. This shifts the chiller's electrical demand from peak to off-peak periods, reducing demand charges significantly.

43. **D. Recording and storing time-series data from system sensors and controllers for performance analysis, troubleshooting, and optimization** — BAS trending captures data points at regular intervals, creating historical records of system operation. This data enables identification of performance degradation, diagnosis of comfort complaints, verification of control sequence operation, and energy optimization through analysis of actual operating patterns.
44. **A. Providing the building operations team with as-built drawings, equipment manuals, control sequences, test reports, and maintenance procedures** — The closeout package transfers all knowledge necessary for ongoing system management from the construction team to the operations team. Without accurate as-built drawings, control sequence documentation, and maintenance procedures, the operations team cannot maintain designed performance.
45. **C. Converting to variable-speed pumping with VFDs controlled by system differential pressure** — Variable-speed pumping reduces pump speed as control valves close at terminal units, reducing flow demand. Since pump energy varies with the cube of speed, even modest speed reductions yield significant energy savings. Differential pressure control at the most remote terminal ensures adequate flow while minimizing pump energy.
46. **B. Extending the commissioning scope to include design review, construction observation, seasonal testing, and post-occupancy verification** — LEED enhanced commissioning requires the commissioning authority's involvement earlier in the project during design review, continued oversight during construction, seasonal testing to verify heating and cooling performance, and post-occupancy verification to confirm systems perform under actual operating conditions.
47. **D. Increased fan energy because the fan maintains higher pressure than needed at downstream VAV boxes to overcome duct friction** — A sensor at the fan discharge causes the fan to maintain a static pressure that includes all downstream duct friction losses. A sensor located two-thirds down the duct allows the fan to reduce speed as VAV boxes close, maintaining only the pressure needed at the sensor location.
48. **A. Identifying equipment degradation trends before failure occurs, enabling proactive repair and avoiding unplanned downtime** — Predictive maintenance uses BAS trend data and analytics to detect gradual changes in equipment performance such as increasing vibration, rising temperatures, or declining efficiency that indicate developing problems. Identifying these trends enables scheduled repairs before catastrophic failure and unplanned system outages.
49. **B. Significant energy waste because the chiller ran unnecessarily during hours when outdoor air could have provided free cooling** — A non-functioning economizer forces the chiller to operate during all cooling hours, including mild weather when outdoor air temperature is cool enough to satisfy the cooling load without mechanical refrigeration. Depending on climate, economizer savings can represent 20 to 40 percent of annual cooling energy.
50. **D. Establishing the building owner's expectations for system performance, efficiency, comfort, and operational requirements that the commissioned systems must satisfy** — The

OPR is the foundational document that defines what the building owner expects from the HVAC systems. It establishes performance criteria, comfort standards, energy goals, and operational preferences that guide the entire design, construction, and commissioning process and serve as the benchmark for verifying system performance.