

# **PRACTICE EXAM 11: STATIONARY ENGINEER APPRENTICE SIMULATION (100 QUESTIONS)**

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*This independently created practice exam contains 100 multiple-choice questions covering boiler operation, refrigeration, air conditioning, air handling, electrical systems and controls, pumps and rotating equipment, water treatment, and combustion fundamentals. Select the single best answer for each question. An answer key with detailed explanations follows the exam.*

1. During a boiler startup, why is a furnace pre-purge performed before the burner is allowed to light?
  - A. To raise boiler-water conductivity before firing begins
  - B. To clear accumulated combustible gases from the furnace and passes
  - C. To increase steam pressure before the main flame is established
  - D. To force the safety valve open before ignition
  
2. A burner flame signal disappears during normal firing. What should the flame-safeguard system do?
  - A. Keep the fuel valves open until steam pressure begins to fall
  - B. Open the boiler blowdown valve to restore the flame signal
  - C. Close the fuel supply promptly and place the burner in a safe shutdown sequence
  - D. Increase combustion-air flow while continuing unrestricted fuel flow
  
3. Plant meters show 62 million Btu/h entering a boiler as fuel and 49.6 million Btu/h leaving as useful steam energy. What percentage of the input becomes useful output in this simplified balance?
  - A. 80%
  - B. 70%
  - C. 75%
  - D. 90%

4. What is the main purpose of blowing through or testing a boiler gauge-glass connection according to the operating procedure?

- A. To cool the glass by introducing combustion air
- B. To add treatment chemical directly through the glass connection
- C. To increase boiler pressure by venting the water column
- D. To verify the glass and its steam-and-water connections are communicating properly

5. What condition most directly promotes boiler-water carryover into the steam outlet?

- A. Reduced combustion-air temperature at the burner inlet
- B. Low stack temperature with normal water chemistry
- C. Excessively high boiler water level or severe foaming
- D. A clean fireside surface with normal firing rate

6. Why is condensate commonly returned to the boiler plant when its quality is acceptable?

- A. It always eliminates the need for water treatment and deaeration
- B. It reduces makeup-water and heating requirements because the returned water is already warm
- C. It increases dissolved oxygen so feedwater pumps operate more quietly
- D. It guarantees boiler pressure remains constant without firing control

7. A boiler evaporates 9,600 lb of water during an 8-hour operating period. What is the average evaporation rate?

- A. 1,000 lb/h
- B. 1,400 lb/h
- C. 800 lb/h
- D. 1,200 lb/h

**8.** What is the function of a steam trap on a steam-heating or process return system?

- A. Discharge condensate and air while limiting the loss of useful steam
- B. Increase steam pressure by throttling the boiler outlet
- C. Mix feedwater directly with flue gas before it enters the boiler
- D. Maintain burner flame by supplying a continuous pilot-air stream

**9.** A steam line develops repeated water hammer shortly after startup. Which operating condition should be investigated first?

- A. Excess oxygen in combustion air with dry steam piping
- B. Low feedwater hardness at the boiler makeup connection
- C. Condensate collecting in piping because drainage or trapping is inadequate
- D. Excessive lubrication of the forced-draft fan bearings

**10.** Why is an economizer normally placed in the hot flue-gas path downstream of the boiler heating surfaces?

- A. To separate steam from boiler water in the main drum
- B. To reduce burner fuel pressure before the gas train
- C. To increase dissolved oxygen in feedwater before deaeration
- D. To recover remaining flue-gas heat for incoming feedwater

**11.** What is the main purpose of a boiler feedwater check valve at the boiler connection?

- A. Prevent reverse flow from the boiler toward the feedwater system
- B. Continuously throttle steam pressure to the building header
- C. Vent dissolved oxygen from the feedwater storage tank
- D. Regulate the burner air-fuel ratio during load changes

**12.** A boiler cycles rapidly between burner on and burner off while steam demand is steady. Which condition should be checked first?

- A. A correctly sized burner operating through a wide modulation range
- B. A pressure-control differential or firing-control setup that is too narrow or unstable
- C. A properly vented deaerator with stable feedwater temperature
- D. A clean gauge glass showing normal water level

**13.** What does a boiler draft gauge or differential-pressure indication primarily tell the operator?

- A. The dissolved-solids concentration in boiler water
- B. The shaft alignment of the feedwater pump and motor
- C. The pressure relationship that drives air and combustion products through the furnace system
- D. The electrical insulation resistance of the burner motor

**14.** A boiler produces 14,500 lb/h of steam for 3.2 hours at a steady rate. How much steam is produced?

- A. 41,700 lb
- B. 52,200 lb
- C. 45,300 lb
- D. 46,400 lb

**15.** A boiler room uses 1,250 gallons of treated makeup water during a 10-hour shift. What is the average makeup rate?

- A. 125 gph
- B. 100 gph
- C. 150 gph
- D. 175 gph

**16.** Why should a boiler operator avoid using the safety valve as a routine pressure-control device?

- A. Because opening it permanently lowers boiler-water hardness to zero
- B. Because it is designed to control feedwater flow instead of pressure
- C. Because it supplies combustion air whenever the burner modulates
- D. Because a safety valve should remain available for overpressure protection rather than normal regulation

**17.** A compressor suction line is not insulated in a warm mechanical room. What is a likely effect?

- A. The liquid line will automatically become more subcooled
- B. The suction vapor can gain unwanted heat before reaching the compressor
- C. Condenser water flow will increase without a control command
- D. The expansion device will raise evaporator pressure by itself

**18.** What is the primary purpose of a refrigerant filter-drier in a liquid line?

- A. Remove moisture and particulate contamination from circulating refrigerant
- B. Increase compressor displacement by heating suction vapor
- C. Store all system refrigerant during every normal operating cycle
- D. Raise condenser pressure to improve liquid flow through the valve

**19.** What symptom is commonly associated with noncondensable gas trapped in a refrigeration condenser?

- A. Lower-than-normal head pressure with a cold condenser
- B. Higher-than-expected condensing pressure for the actual load and cooling conditions
- C. Zero compressor discharge temperature under normal operation
- D. A guaranteed loss of all evaporator superheat

**20.** Why is a crankcase heater used on many refrigeration compressors during off cycles?

- A. To raise evaporator pressure by boiling refrigerant in the coil
- B. To cool the compressor shell below suction-line temperature
- C. To keep refrigerant from migrating and condensing excessively in the compressor oil
- D. To replace the need for an oil-level check during service

**21.** A thermostatic expansion valve is hunting widely around the desired superheat. What does hunting mean?

- A. The compressor runs backward each time the thermostat cycles
- B. The condenser fan remains at one fixed speed under every load
- C. The valve repeatedly overfeeds and underfeeds instead of settling near stable control
- D. The liquid receiver permanently fills with vapor instead of liquid

**22.** What does an abnormally high compressor discharge temperature often indicate?

- A. The evaporator is completely flooded with no vapor formation
- B. The compressor is operating with excessive compression ratio, superheat, or inadequate cooling
- C. The condenser has no heat to reject under load
- D. The compressor is moving only subcooled liquid through its discharge line

**23.** A suction temperature is 52°F and the saturation temperature corresponding to suction pressure is 40°F. What is the evaporator-outlet superheat?

- A. 8°F
- B. 40°F
- C. 92°F
- D. 12°F

**24.** A liquid line measures 88°F while saturation temperature at the measured condensing pressure is 102°F. What is the liquid subcooling?

- A. 14°F
- B. 10°F
- C. 190°F
- D. 22°F

**25.** What is the purpose of a condenser fan-cycle control on some air-cooled systems?

- A. Force the compressor to run continuously regardless of refrigeration demand
- B. Lower evaporator airflow by cycling the indoor fan on pressure
- C. Replace the liquid-line metering device during low load
- D. Maintain suitable condensing pressure as outdoor temperature and load change

**26.** A compressor is running, suction pressure is low, and superheat is high. Which condition is most consistent with these readings?

- A. An overfed evaporator returning liquid refrigerant
- B. A starved evaporator caused by restricted or insufficient refrigerant feed
- C. A condenser that is rejecting too little heat because of fouling
- D. A receiver that contains excessive subcooled liquid only

**27.** What is the main purpose of a hot-gas bypass control when one is used?

- A. Maintain evaporator load or suction pressure during very low system demand
- B. Recover oil from a receiver by increasing liquid-line pressure
- C. Increase condenser subcooling by shutting off all discharge gas
- D. Replace the compressor motor overload protection

**28.** What is a common reason to verify evaporator airflow before adding refrigerant to a comfort-cooling system?

- A. Low airflow always proves the condenser is overcharged

- B. Airflow has no effect on refrigerant pressure or coil temperature
- C. Low airflow can imitate a low-suction refrigeration problem even when charge is adequate
- D. Increasing refrigerant charge automatically repairs a dirty air filter

**29.** What does a liquid-line solenoid valve commonly do in a pump-down control arrangement?

- A. Increase suction-line pressure by bypassing the compressor
- B. Separate oil droplets from the compressor discharge gas
- C. Measure superheat at the evaporator outlet
- D. Stop liquid refrigerant flow when the controlled load is satisfied

**30.** A chiller removes 525 kW of heat while the compressor input is 150 kW. What is the simplified refrigeration COP?

- A. 3.5
- B. 3.0
- C. 2.5
- D. 4.0

**31.** Why is oil return through a refrigeration system important?

- A. Oil must replace refrigerant whenever system load decreases
- B. The compressor needs adequate lubricant while excessive oil in heat exchangers can reduce performance
- C. Oil is the primary fluid that absorbs heat in the evaporator
- D. Oil raises room humidity so the cooling coil can dehumidify

**32.** A system has normal suction pressure but unusually high head pressure. Which check is most appropriate early in troubleshooting?

- A. Whether the evaporator drain pan contains enough standing water

- B. Whether the thermostat anticipator is calibrated for a boiler
- C. Condenser heat rejection, including airflow or water flow and surface cleanliness
- D. Whether the compressor suction accumulator is completely full of liquid

**33.** Why is a chilled-water control valve often modulated instead of operated only fully open or fully closed?

- A. To match coil water flow more closely to changing cooling demand
- B. To force the cooling tower fan to remain off at all times
- C. To maintain constant boiler steam pressure through the HVAC loop
- D. To eliminate the need for any room or discharge-air temperature sensor

**34.** What is the purpose of a condensate trap on the drain connection of an air-handling unit operating under negative pressure?

- A. Prevent refrigerant vapor from leaving through the drain line
- B. Allow condensate drainage while blocking reverse air through the drain
- C. Increase chilled-water pressure before water enters the cooling coil
- D. Maintain fan bearing lubrication through the condensate drain pan

**35.** A zone is cool enough but remains uncomfortably humid. Which operating change generally supports better dehumidification?

- A. Raise coil temperature above dew point so no condensate forms
- B. Increase supply-air leakage to the ceiling plenum
- C. Disable the condensate drain so water stays on the coil
- D. Maintain adequate cooling-coil run time and keep the coil surface below the air dew point

**36.** A chilled-water coil receives 180 gpm with a 14°F water-temperature rise. Using  $Q = 500 \times \text{gpm} \times \Delta T$ , what is the approximate heat transfer?

- A. 1,080,000 Btu/h
- B. 900,000 Btu/h
- C. 1,260,000 Btu/h
- D. 1,400,000 Btu/h

**37.** What is the main purpose of a building chilled-water differential-pressure sensor used with variable-speed pumps?

- A. Determine refrigerant superheat leaving the evaporator
- B. Measure boiler-water conductivity at the cooling coil
- C. Control the room thermostat deadband directly
- D. Provide feedback so pump speed can maintain adequate distribution pressure

**38.** Why is a minimum outdoor-air position sometimes maintained on an air-handling unit even when an economizer is not providing free cooling?

- A. To raise condenser pressure during cold weather
- B. To provide the intended ventilation airflow for occupied spaces
- C. To guarantee the supply fan operates at full speed
- D. To replace exhaust-air paths with refrigerant piping

**39.** A heat pump in heating mode periodically switches operation so the outdoor coil warms and melts frost. What sequence is occurring?

- A. Boiler warm-up
- B. Air-side economizer cooling
- C. Defrost operation
- D. Cooling-tower blowdown

**40.** A room is intended to remain slightly positive relative to a corridor. Which airflow relationship generally supports that condition?

- A. Supply airflow to the room slightly exceeds the air leaving through return and exhaust paths
- B. Exhaust airflow greatly exceeds supply airflow under all conditions
- C. Return airflow equals zero while the door is sealed airtight
- D. Supply airflow is shut off whenever the door opens

**41.** What does cooling-tower approach describe?

- A. The difference between leaving condenser-water temperature and entering-air wet-bulb temperature
- B. The difference between boiler pressure and chilled-water pressure
- C. The compressor discharge temperature minus suction-line temperature
- D. The supply-air dry-bulb temperature minus return-air dry-bulb temperature

**42.** Why is a chilled-water expansion tank connected to a closed hydronic loop?

- A. To remove all dissolved minerals from chilled water continuously
- B. To provide space for water-volume changes and establish system pressure at its connection point
- C. To separate refrigerant oil from compressor discharge vapor
- D. To meter outdoor air into the building during occupied hours

**43.** A supply-air sensor reads 58°F while a reliable reference at the same location reads 64°F. What is the best first response?

- A. Increase chilled-water flow until both values become equal
- B. Add refrigerant to the system because the sensor must be sensing low charge
- C. Verify sensor calibration, wiring, and location before changing the cooling sequence
- D. Reduce outdoor-air ventilation until the displayed value rises

**44.** What is a common reason to reset supply-air temperature upward during periods of low cooling load?

- A. Increase boiler firing rate by warming return air

- B. Force every VAV box to full cooling flow
- C. Eliminate all need for outdoor-air ventilation
- D. Reduce unnecessary overcooling and reheat while maintaining comfort and humidity requirements

**45.** Using  $Q = 1.08 \times \text{cfm} \times \Delta T$  for sensible air heat transfer, what is Q at 8,000 cfm and a 16°F temperature difference?

- A. 102,400 Btu/h
- B. 156,800 Btu/h
- C. 138,240 Btu/h
- D. 128,000 Btu/h

**46.** What is the main function of a three-way mixing valve in a hydronic temperature-control application?

- A. Combine two water streams in controlled proportions to produce a desired mixed temperature
- B. Increase compressor discharge pressure by restricting condenser flow
- C. Measure room humidity without a sensing element
- D. Act as an electrical disconnect for a circulation pump

**47.** A mixing box receives 1,500 cfm of outdoor air at 92°F and 4,500 cfm of return air at 72°F. Ignoring heat gains, what is the mixed-air temperature?

- A. 82°F
- B. 87°F
- C. 72°F
- D. 77°F

**48.** A VAV system has many boxes nearly full open while duct static pressure is below setpoint. What should the supply-fan control normally do?

- A. Reduce fan speed further to force the boxes closed
- B. Increase fan speed, within limits, to restore required duct pressure
- C. Close the outdoor-air damper regardless of ventilation needs
- D. Shut the chilled-water plant off immediately

**49.** A belt-driven supply fan shows black rubber dust near the sheaves and reduced airflow. What should be suspected?

- A. A clogged chilled-water strainer
- B. Excessive boiler blowdown
- C. Belt slip, wear, or sheave misalignment
- D. A refrigerant receiver overfilled with oil

**50.** Why should a fan wheel be inspected for dirt accumulation on its blades?

- A. Dirt automatically increases motor insulation resistance
- B. Dirt guarantees the fan will deliver more static pressure
- C. Dirt converts a forward-curved wheel into an axial fan
- D. Dirt can alter balance and reduce aerodynamic performance

**51.** What is the purpose of a flexible connector between an air handler and connected ductwork?

- A. Transmit fan vibration directly into the duct system
- B. Reduce vibration transmission and accommodate small movement at the connection
- C. Increase duct static pressure by permanently blocking leakage
- D. Act as a fire damper whenever the fan starts

**52.** A filter differential pressure rises from 0.35 inch water column to 0.95 inch. By how much did it increase?

- A. 0.60 inch water column

- B. 0.45 inch water column
- C. 0.30 inch water column
- D. 1.30 inches water column

**53.** What does a pitot-tube traverse of a duct primarily help determine?

- A. Refrigerant moisture content in the liquid line
- B. Air velocity distribution and average airflow through the duct
- C. Boiler-water pH at the feedwater pump
- D. Motor winding temperature without electrical contact

**54.** What is the likely effect of closing a balancing damper too far in one branch duct?

- A. The branch airflow increases because the opening is smaller
- B. Refrigerant subcooling always increases at the condenser
- C. The branch airflow decreases and resistance through that path increases
- D. The fan motor automatically changes from three-phase to single-phase

**55.** A fan delivers 7,500 cfm at 1,000 rpm. Using the proportional airflow-speed law, what flow is expected at 1,200 rpm under similar conditions?

- A. 9,000 cfm
- B. 8,250 cfm
- C. 7,200 cfm
- D. 10,800 cfm

**56.** According to the fan affinity relationships, if fan speed increases by 10% under similar conditions, approximately how does fan static pressure change?

- A. It increases by about 10% because pressure varies directly with speed
- B. It increases by about 33% because pressure varies with the cube of speed

- C. It remains exactly unchanged regardless of speed
- D. It increases by about 21% because pressure varies with the square of speed

**57.** Why is a smoke detector sometimes located in an air-handling system return or supply duct?

- A. Measure refrigerant superheat in the air-handling system automatically
- B. Balance chilled-water flow through the cooling coil during operation
- C. Lubricate smoke-damper bearings when the fire alarm activates
- D. Signal the fire-safety sequence when smoke is detected in moving air

**58.** What is the purpose of a fan discharge transition with gradual rather than abrupt changes in duct area?

- A. Reduce turbulence and unnecessary pressure loss as air enters the duct system
- B. Increase refrigerant pressure by compressing the air mechanically
- C. Create deliberate fan imbalance for better mixing
- D. Eliminate the need for any downstream balancing dampers

**59.** A supply fan bearing temperature rises steadily while vibration also increases. What is the best interpretation?

- A. The readings prove the air filter has become cleaner
- B. The fan is guaranteed to be operating at peak efficiency
- C. The trend suggests a developing mechanical problem that should be investigated
- D. The bearing must be cooled by increasing refrigerant charge

**60.** A rectangular duct carries 6,300 cfm through an area of 3.5 ft<sup>2</sup>. What is the average air velocity?

- A. 1,400 ft/min
- B. 1,800 ft/min
- C. 2,200 ft/min

D. 1,575 ft/min

**61.** What is the main reason to verify fan rotation after motor wiring or VFD work?

- A. Backward rotation always increases airflow above design
- B. Rotation direction affects only motor noise and not fan performance
- C. A reversed fan automatically corrects itself after several minutes
- D. A centrifugal fan can run backward yet deliver greatly reduced airflow and pressure

**62.** Why is return-air temperature useful when diagnosing a cooling air handler?

- A. It directly measures refrigerant charge in pounds
- B. It helps establish the entering air condition and temperature change produced through the unit
- C. It identifies boiler-water hardness without a chemical test
- D. It proves every supply diffuser receives identical airflow

**63.** What is a common effect of an excessively dirty cooling coil on the air side?

- A. Higher pressure drop with reduced airflow and poorer heat transfer
- B. Lower pressure drop and improved heat transfer
- C. Automatic increase in fan motor insulation resistance
- D. Elimination of condensate because the coil becomes warmer than all air

**64.** A VFD command drops a supply fan from 50 Hz to 40 Hz. Assuming speed is proportional to frequency, what percentage of the original speed remains?

- A. 70%
- B. 60%
- C. 80%
- D. 90%

**65.** A 208-volt resistive heater has a resistance of 26 ohms. What current does it draw?

- A. 6 A
- B. 10 A
- C. 12 A
- D. 8 A

**66.** A single-phase 240-volt resistive load draws 15 amperes. Ignoring power factor, what power does it use?

- A. 3.6 kW
- B. 2.4 kW
- C. 4.8 kW
- D. 6.0 kW

**67.** What is the purpose of the normally closed STOP pushbutton in a typical three-wire motor-control circuit?

- A. Bypass overload protection whenever the motor is heavily loaded
- B. Provide a closed control path during normal operation that opens when STOP is pressed
- C. Reverse the phase sequence each time the motor is stopped
- D. Increase control voltage during motor acceleration

**68.** A control transformer is rated 480 volts primary and 120 volts secondary. What is its main purpose in a motor-control panel?

- A. Increase motor horsepower by changing shaft speed
- B. Convert AC control power into compressed air
- C. Provide a lower AC voltage suitable for control devices
- D. Measure current without a meter or sensing device

**69.** A motor contactor coil is energized, but the motor receives no line voltage. Which fault is most consistent?

- A. A room thermostat setpoint that is too low
- B. Excess boiler-water alkalinity
- C. A possible open power contact or upstream power-circuit problem
- D. A dirty condensate drain trap

**70.** What is the primary purpose of an equipment grounding conductor?

- A. Carry normal load current during every operating cycle
- B. Provide a low-impedance fault-current path for exposed conductive equipment parts
- C. Raise branch-circuit voltage during motor starting
- D. Replace the circuit breaker whenever a short circuit occurs

**71.** A valve positioner uses a linear 4-20 mA command for 0-100% travel. If the control signal is 16 mA, what commanded position does that represent?

- A. 75%
- B. 62.5%
- C. 50%
- D. 80%

**72.** What does a motor overload relay primarily protect against?

- A. Every possible short circuit without any fuse or breaker
- B. Loss of building ventilation caused by a dirty filter
- C. High refrigerant head pressure in the condenser
- D. Sustained overcurrent conditions that can overheat the motor

**73.** What is the purpose of an interposing relay in a control system?

- A. Increase refrigerant pressure before gas enters the condenser coil
- B. Provide electrical isolation or additional contacts between a controller output and the controlled circuit
- C. Measure duct airflow without using any separate pressure sensor
- D. Lubricate a motor bearing whenever the starter coil energizes

**74.** A three-phase motor runs backward after maintenance. What common wiring change reverses its direction?

- A. Increase the overload setting on all three phases
- B. Disconnect the equipment grounding conductor
- C. Lower the control-transformer secondary voltage
- D. Interchange any two phase conductors supplying the motor

**75.** A centrifugal pump makes a crackling sound and discharge pressure fluctuates. What hydraulic condition should be suspected?

- A. Cavitation caused by vapor formation and collapse in the pump
- B. Perfectly stable operation at the best efficiency point
- C. An electrical ground fault in the lighting circuit
- D. Excessive boiler-water alkalinity

**76.** Why should a centrifugal pump suction valve normally be fully open during operation unless the system is specifically designed otherwise?

- A. A closed suction valve always increases pump capacity
- B. Suction throttling raises available NPSH by reducing pressure loss
- C. Restricting suction can lower inlet pressure and increase cavitation risk
- D. The suction valve controls motor phase rotation

**77.** What is the main purpose of an impeller wear ring in many centrifugal pumps?

- A. Increase motor voltage during pump startup
- B. Remove dissolved oxygen from pumped water
- C. Control chilled-water chemical concentration
- D. Provide a renewable close-clearance surface that limits internal leakage

**78.** Two identical centrifugal pumps operate in parallel on the same system. What is the general purpose of parallel operation?

- A. Double the head at zero change in system flow under all conditions
- B. Increase available flow capacity at a given system head compared with one pump
- C. Eliminate the need for check valves on pump discharges
- D. Guarantee both pumps always share flow equally regardless of condition

**79.** Pressure taps at the suction and discharge of a pump are at the same elevation. The readings are 12 psi and 58 psi, respectively. What pressure rise is the pump producing?

- A. 40 psi
- B. 34 psi
- C. 46 psi
- D. 70 psi

**80.** A water pump develops a 42 psi pressure rise. Using 2.31 feet of water head for each psi, what equivalent head does the pump develop?

- A. 97.0 ft
- B. 90.5 ft
- C. 84.0 ft
- D. 105.4 ft

**81.** Why is a discharge check valve commonly installed on a pump connected to a common header?

- A. Increase suction pressure by opening to atmosphere
- B. Prevent reverse flow through the stopped pump
- C. Lubricate the pump shaft while the motor is off
- D. Balance electrical current between parallel motors

**82.** A pump delivers 640 gpm at 1,800 rpm. Its VFD reduces speed to 1,575 rpm. Assuming flow changes directly with speed, what new flow is expected?

- A. 560 gpm
- B. 600 gpm
- C. 700 gpm
- D. 490 gpm

**83.** What symptom can result from a badly clogged suction strainer on a centrifugal pump?

- A. Higher available NPSH with quieter operation
- B. Guaranteed increase in discharge flow at the same speed
- C. Reduced suction pressure, lower flow, and increased cavitation tendency
- D. Automatic correction of motor-to-pump misalignment

**84.** Why is coupling alignment checked after a pump or motor is moved?

- A. Alignment changes water chemistry in the pump casing
- B. Misalignment improves efficiency by increasing shaft friction
- C. Alignment is needed only for electrical continuity
- D. Misalignment can increase bearing, seal, and coupling loads

**85.** A boiler-water sample shows a sudden conductivity increase while makeup-water conductivity is unchanged. What should be investigated?

- A. A guaranteed drop in boiler-water solids
- B. A fan belt that has become too loose
- C. A possible increase in dissolved-solids concentration or insufficient blowdown
- D. A motor starter auxiliary contact that is open

**86.** What is the purpose of testing hardness downstream of a sodium-cycle softener?

- A. Measure compressor oil viscosity in the refrigeration system
- B. Determine fan static pressure without a manometer
- C. Set the burner fuel pressure during low fire
- D. Detect hardness breakthrough indicating the resin may need regeneration or service

**87.** A water sample has pH 6.2. Under the usual pH interpretation, how is it classified?

- A. Acidic
- B. Neutral
- C. Alkaline
- D. Exactly saturated with dissolved oxygen

**88.** Why can scale on a heat-transfer surface increase fuel or energy use?

- A. Scale always increases metal thermal conductivity
- B. Scale adds thermal resistance between the hot and cold fluids
- C. Scale eliminates the temperature difference needed for heat transfer
- D. Scale converts dissolved oxygen into harmless nitrogen

**89.** A cooling-tower basin sample measures 2,250  $\mu\text{S}/\text{cm}$  conductivity while incoming makeup water measures 500  $\mu\text{S}/\text{cm}$ . Using their ratio as a simple estimate, what concentration ratio is indicated?

- A. 4.0 cycles
- B. 3.5 cycles

- C. 4.5 cycles
- D. 5.0 cycles

**90.** Why is a cooling-tower bleed or blowdown stream used?

- A. Add hardness to improve evaporation efficiency
- B. Remove concentrated water so dissolved solids do not continue building without limit
- C. Return all evaporated water directly to the tower basin
- D. Eliminate the need for makeup water during hot weather

**91.** After a deaerator removes most dissolved gases, which job is performed by an oxygen-scavenging chemical added to the boiler feedwater program?

- A. React with residual dissolved oxygen that remains after mechanical deaeration
- B. Increase dissolved oxygen to passivate every metal surface
- C. Raise feedwater hardness before it enters the boiler
- D. Remove suspended dust from combustion air

**92.** Why is consistent sample cooling important before testing some hot boiler-water samples?

- A. It raises the sample pressure so conductivity becomes zero
- B. It removes all treatment chemical before the test begins
- C. It guarantees hardness cannot be detected in the sample
- D. It improves safety and helps measurements be compared under consistent test conditions

**93.** What is a likely consequence of uncontrolled biological growth in a cooling-water system?

- A. Guaranteed improvement in heat-transfer coefficient
- B. Permanent elimination of scale formation
- C. Biofilm, fouling, restricted flow, and possible under-deposit corrosion
- D. Automatic reduction of makeup-water demand to zero

**94.** Why is burner fuel pressure checked both before and after a gas pressure regulator when troubleshooting unstable firing?

- A. To determine whether the regulator is receiving adequate inlet pressure and maintaining the intended outlet pressure
- B. To measure boiler-water level without using the gauge glass
- C. To calculate chilled-water flow through a cooling coil
- D. To determine fan bearing clearance from gas pressure readings

**95.** What does excess air mean in combustion?

- A. Air supplied below the amount needed to burn the fuel
- B. Air supplied above the theoretical amount required for complete combustion
- C. Steam intentionally mixed with flue gas to raise oxygen content
- D. The portion of burner fuel that leaves through the stack unburned

**96.** A combustion analyzer shows rising carbon monoxide while burner load is unchanged. What should this trend prompt?

- A. Immediate increase of boiler-water hardness
- B. Reduction of feedwater pump lubrication
- C. Assumption that combustion is automatically complete
- D. Investigation of combustion quality, fuel-air mixing, and burner condition

**97.** Why is an ignition trial limited in time by a burner management sequence?

- A. To increase steam pressure before the flame appears
- B. To allow the safety valve to cycle during every startup
- C. To prevent unlimited accumulation of unburned fuel if flame is not established
- D. To cool the furnace by shutting off combustion air permanently

**98.** What is the purpose of proving combustion airflow before allowing a burner to fire?

- A. Increase boiler-water solids concentration before startup
- B. Guarantee steam traps remain closed during firing
- C. Replace the need for flame detection after ignition
- D. Confirm that the required air path and fan condition exist before fuel admission

**99.** A gas meter indicates a burner is consuming 95 standard cubic feet per hour. If the fuel contains 1,020 Btu per standard cubic foot, what fuel-energy input is entering the burner each hour?

- A. 91,800 Btu/h
- B. 96,900 Btu/h
- C. 102,000 Btu/h
- D. 193,800 Btu/h

**100.** What is a likely effect of operating a burner with substantially more excess air than needed?

- A. Greater stack heat loss because extra air is heated and exhausted
- B. Guaranteed zero oxygen in the flue gas
- C. Automatic elimination of all carbon monoxide under every condition
- D. Higher boiler-water level without added feedwater

## Practice Exam 11: Answer Key and Explanations

**1. B** — A pre-purge moves a required volume of air through the furnace and gas passages before ignition so any residual combustible mixture is diluted and removed. It is a combustion-safety step, not a water-treatment, pressure-building, or safety-valve operation. Burner permissives normally require the purge sequence to complete before fuel is admitted.

**2. C** — Loss of proven flame means continued fuel flow could create an unburned combustible mixture. The flame safeguard is intended to deenergize the fuel safety valves and initiate the required shutdown

or recycle sequence. Blowdown does not restore flame, and adding air while leaving fuel unrestricted does not provide the positive fuel isolation needed.

**3. A** — Simplified efficiency is useful heat output divided by fuel heat input. Dividing 49.6 by 62 gives 0.80, or 80 percent. The other percentages do not match the stated energy balance. This calculation does not identify individual stack, radiation, or blowdown losses; it only compares the two energy rates supplied. Use operating trends to confirm the diagnosis.

**4. D** — A gauge glass can display a false level if either the steam or water connection becomes restricted. The prescribed blow-through or functional check helps demonstrate that the passages are open and that the indicated level responds properly. It is not used to raise pressure, cool the glass with air, or serve as a chemical-feed connection.

**5. C** — Carryover occurs when droplets or foam leave the boiler with the steam. An excessively high water level reduces steam-separation space, while foaming can entrain water and dissolved solids. Clean heating surfaces and normal combustion-air conditions do not directly create this moisture transport. Water level and chemistry should therefore be checked when wet steam is suspected.

**6. B** — Usable condensate contains recovered heat and is already treated water from the steam system, so returning it can reduce cold makeup demand and the energy needed to heat replacement water. It does not eliminate treatment or deaeration, and it should not be used if contaminated. Pressure control still depends on firing and steam demand.

**7. D** — Average evaporation rate equals total mass evaporated divided by elapsed time. Dividing 9,600 pounds by 8 hours gives 1,200 pounds per hour. The other choices result from using incorrect divisors or arithmetic. The calculation assumes the stated total is spread evenly over the full eight-hour period rather than describing short-term peaks.

**8. A** — A steam trap removes condensate and noncondensable gases from steam equipment while retaining live steam as much as its design permits. A failed-open trap can waste steam, while a failed-closed trap can cause waterlogging and poor heat transfer. Traps are not boiler pressure regulators, feedwater mixers, or combustion-air devices. Use operating trends to confirm the diagnosis.

**9. C** — Water hammer can occur when high-velocity steam drives condensate slugs through piping or when trapped condensate flashes and collapses. Poor drainage, failed traps, improper warm-up, or incorrect piping slope are therefore important checks. Combustion oxygen, feedwater hardness, and fan lubrication do not directly explain liquid accumulation in a steam distribution line.

**10. D** — An economizer captures sensible heat that would otherwise leave with the flue gas and transfers it to feedwater. Raising feedwater temperature can reduce the fuel required to produce steam. The device is not a deaerator, drum separator, or fuel-pressure regulator. Fouling, corrosion, and gas-side pressure drop still require operating attention.

**11. A** — The check valve permits feedwater to move toward the boiler while resisting reverse flow if feed pressure falls. This protects the feed system from boiler-side backflow and works with other stop

and control valves. It does not regulate steam pressure, remove dissolved gases, or control the burner fuel-air relationship. Use operating trends to confirm the diagnosis.

**12. B** — Rapid cycling under a steady load can result when the firing control cannot modulate smoothly or when the pressure-control differential is set too narrowly. The burner repeatedly reaches cutoff and restarts instead of matching load. Stable water level and deaerator operation do not directly explain this repeated pressure-control behavior. Use operating trends to confirm the diagnosis.

**13. C** — Draft is a pressure relationship in the furnace and gas path that helps move combustion air to the flame and products of combustion toward the stack. Draft readings can reveal fan, damper, leakage, or blockage problems. They do not measure water chemistry, shaft alignment, or electrical insulation, which require different instruments and procedures.

**14. D** — Total steam production equals the stated mass-flow rate multiplied by time. Multiplying 14,500 pounds per hour by 3.2 hours gives 46,400 pounds. The hours cancel, leaving pounds. The other choices reflect incorrect multiplication or rounding. This is an integrated production quantity, not the instantaneous rate shown on a steam-flow indicator.

**15. A** — Average makeup rate is total volume divided by operating time. Dividing 1,250 gallons by 10 hours gives 125 gallons per hour. A rising makeup trend can indicate leaks, excessive blowdown, steam losses, or poor condensate return, so the calculated rate is also useful as an operating baseline rather than only an arithmetic exercise.

**16. D** — The safety valve is a final protective device intended to relieve excessive pressure if normal controls fail or cannot limit pressure. Routine lifting wastes energy and can damage seating surfaces or indicate a control problem. Normal pressure should be maintained by firing and load controls, leaving the safety valve available for its protective function.

**17. B** — A cold suction line exposed to warm surroundings can absorb heat, increasing suction-gas superheat before the compressor. Insulation reduces this unwanted heat gain and also helps prevent surface condensation. The missing insulation does not automatically increase liquid subcooling, condenser-water flow, or evaporator pressure through the expansion device. Use operating trends to confirm the diagnosis.

**18. A** — A filter-drier captures solid contamination and contains desiccant that removes limited moisture from the refrigerant circuit. This helps protect small metering passages and reduces chemical problems associated with moisture. It is not a compressor-capacity device, receiver substitute, or means of intentionally raising condensing pressure during normal operation. Use operating trends to confirm the diagnosis.

**19. B** — Noncondensable gas occupies condenser volume and adds partial pressure without condensing like refrigerant. The result can be elevated head pressure and reduced condenser effectiveness even when airflow or water flow is adequate. The symptom must be distinguished from overcharge, fouling, or poor heat rejection using temperature and pressure measurements. Use operating trends to confirm the diagnosis.

**20. C** — A crankcase heater keeps the compressor oil and shell warmer during off periods, discouraging refrigerant migration and condensation in the crankcase. Excess dissolved refrigerant can dilute oil and foam during startup. The heater does not control evaporator pressure, refrigerate the compressor shell, or eliminate the need to verify lubrication condition.

**21. C** — Hunting is an unstable oscillation in which the expansion valve alternately opens and closes too much, causing superheat and evaporator feeding to swing. Causes can include oversized valves, poor bulb installation, rapid load changes, or incorrect adjustment. It is not reverse compressor rotation, fixed condenser fan speed, or a receiver filled permanently with vapor.

**22. B** — High discharge temperature can result when the compressor must raise vapor through a large pressure ratio or when suction vapor enters excessively superheated. Inadequate compressor cooling can contribute as well. The condition should be evaluated with suction pressure, discharge pressure, superheat, load, and manufacturer limits rather than from shell temperature alone.

**23. D** — Superheat equals actual vapor temperature minus the saturation temperature at the same pressure. Subtracting 40°F from 52°F gives 12°F. Using the pressure-derived saturation temperature is essential because superheat describes how far the vapor is above saturation, not simply the measured suction temperature by itself. Use operating trends to confirm the diagnosis.

**24. A** — Subcooling equals the saturation temperature corresponding to liquid-side pressure minus the actual liquid temperature. Subtracting 88°F from 102°F gives 14°F. This shows the liquid is below its saturation temperature at that pressure. Reversing or adding the temperatures would not represent subcooling and would produce physically misleading results. Use operating trends to confirm the diagnosis.

**25. D** — Cycling or modulating condenser fans can keep head pressure from falling too low during cool outdoor conditions while still providing adequate heat rejection. The control acts on condenser airflow, not on indoor evaporator airflow or the metering device. It also does not require continuous compressor operation when the refrigeration load is satisfied.

**26. B** — Low suction pressure combined with high superheat indicates the evaporator is receiving too little refrigerant for the available load. A restriction, underfeeding expansion device, low charge, or liquid-line problem may cause this pattern. A flooded evaporator would generally show low superheat, so the measurements should guide troubleshooting toward starvation rather than overfeeding.

**27. A** — Hot-gas bypass routes some discharge gas to the low side under low-load conditions to prevent suction pressure or evaporator temperature from falling excessively. It is a capacity-control method with energy penalties, not an oil-recovery shortcut, condenser subcooling device, or electrical overload protector. Its operation should match the system design and control sequence.

**28. C** — Insufficient airflow reduces heat transfer into the evaporator, which can lower suction pressure and coil temperature and may resemble an undercharge. Adding refrigerant without checking airflow can therefore create an actual overcharge while leaving the original restriction. Filter condition, fan operation, dampers, and coil cleanliness should be verified before judging charge from pressure alone.

**29. D** — In a pump-down sequence, the liquid-line solenoid closes when cooling is no longer required. The compressor then removes refrigerant from the low side until the low-pressure control stops it. The solenoid is therefore a flow-control device, not a suction bypass, oil separator, or superheat sensor. Use operating trends to confirm the diagnosis.

**30. A** — Coefficient of performance for this simplified refrigeration calculation equals cooling effect divided by compressor power input. Dividing 525 kW by 150 kW gives 3.5. Because the units are the same, they cancel. The result does not include auxiliary pumps or fans unless their power is specifically included in the stated input.

**31. B** — Compressor oil must circulate or be separated and returned in a way that maintains lubrication. Oil trapped in evaporators or piping can reduce heat transfer and starve the compressor crankcase. The oil is not the refrigeration working fluid and does not replace refrigerant or intentionally alter room humidity. Use operating trends to confirm the diagnosis.

**32. C** — High head pressure often points toward inadequate condenser heat rejection, so airflow, water flow, fouling, fan operation, water temperature, and noncondensables are logical early checks. Normal suction pressure does not rule out a high-side problem. Condensate-pan water and unrelated thermostat settings do not directly control refrigeration condensing pressure. Use operating trends to confirm the diagnosis.

**33. A** — A modulating chilled-water valve varies coil water flow to match changing load and maintain the controlled air or space temperature more smoothly. Full-open/full-closed operation can cause wider temperature swings and unnecessary cycling. The valve does not directly control cooling-tower fans or boiler pressure, and its modulation still requires valid sensor feedback.

**34. B** — A properly sized trap provides a water seal that overcomes the negative pressure at the drain pan so condensate can leave without the fan pulling air backward through the drain. An incorrect or dry trap can cause drainage problems and overflow. It is unrelated to refrigerant containment, chilled-water pressure, or bearing lubrication.

**35. D** — Moisture is removed when humid air contacts a cooling surface below its dew point and condensate drains away. Adequate run time allows this latent process to continue after sensible temperature approaches setpoint. Raising coil temperature above dew point or preventing drainage reduces dehumidification, while supply leakage does not solve the moisture-removal mechanism.

**36. C** — Using the supplied hydronic relationship, multiply 500 by 180 gpm and by the 14°F temperature rise. The result is 1,260,000 Btu per hour. The formula already contains the customary water density and heat-capacity approximation, so no additional conversion is needed for this problem. Flow and temperature difference both directly affect calculated capacity.

**37. D** — A differential-pressure sensor provides feedback about the pressure available across the chilled-water distribution system. A variable-speed pump can respond by increasing or decreasing speed to maintain the required pressure as control valves move. The sensor does not measure water chemistry or refrigerant superheat, and it does not replace zone temperature control.

**38. B** — An economizer may modulate outdoor air for cooling, but a separate minimum position can maintain the ventilation quantity required by the building operating strategy during occupancy. The minimum is not intended to raise refrigeration head pressure or force full fan speed. Actual outdoor airflow should be confirmed because damper position alone does not prove delivered ventilation.

**39. C** — An air-source heat pump can accumulate frost on the outdoor coil during heating. A defrost sequence temporarily changes refrigerant operation, often using reverse-cycle heat, to warm the outdoor coil and melt frost. This is distinct from cooling-tower water treatment, boiler warm-up, or an air-side economizer that uses favorable outdoor air for cooling.

**40. A** — Positive room pressure is supported when conditioned supply entering the space slightly exceeds the air intentionally removed by return and exhaust paths, allowing the small excess to leave through transfer paths and leakage. Excessive exhaust instead tends to create negative pressure. Actual pressure should be measured because door position and leakage can affect the result.

**41. A** — Cooling-tower approach compares the temperature of water leaving the tower with the entering-air wet-bulb temperature. A smaller approach generally indicates the tower is bringing water closer to the thermodynamic limit set by the entering air, subject to design and load. The other temperature differences describe unrelated HVAC or refrigeration conditions.

**42. B** — Water volume changes as loop temperature changes. The expansion tank provides a compressible space that accepts or supplies this volume and helps stabilize hydronic pressure. Its connection point also influences the system pressure reference. The tank is not a water softener, refrigerant oil separator, or ventilation damper and should not be treated as one.

**43. C** — A six-degree disagreement at the same sensing location suggests an instrumentation problem should be resolved before altering plant operation. Calibration, wiring resistance, sensor placement, and the reference instrument should be checked. Changing chilled-water flow, refrigerant charge, or ventilation to force agreement would adjust the process around a potentially false measurement rather than correct the cause.

**44. D** — When cooling loads are light, a warmer supply-air setpoint can reduce excessive cooling and the reheat needed to maintain zone temperature, provided humidity and ventilation remain acceptable. Reset strategies should respond to real zone demand. They do not require full VAV airflow, increased boiler firing, or elimination of outdoor-air requirements in the building operating sequence.

**45. C** — The supplied sensible-heat relationship gives 1.08 times 8,000 cfm times 16°F. Multiplication produces 138,240 Btu per hour. The 1.08 factor incorporates customary air-property assumptions for this simplified calculation. In field work, measured airflow and temperature difference should be taken under comparable steady conditions before using the result as a performance estimate.

**46. A** — A three-way mixing valve combines two water streams, commonly warmer and cooler, in varying proportions so the outlet approaches a controlled temperature. Depending on piping arrangement, three-way valves can also divert flow, but the stated mixing application is hydraulic. The valve is not a refrigerant pressure device, humidity sensor, or electrical disconnect.

**47. D** — For a simple dry-bulb weighted average, multiply 92°F by 0.25 and 72°F by 0.75, then add the results. That gives 23 plus 54, or 77°F. The calculation assumes the two airflow fractions total one and ignores moisture and fan heat. Actual mixed-air enthalpy analysis can be more detailed. Use operating trends to confirm the diagnosis.

**48. B** — When many VAV boxes are open and duct static pressure is below the control target, the supply fan generally needs more speed or capacity, subject to programmed limits. Increasing fan output restores pressure so terminals can receive required airflow. Outdoor-air and chilled-water decisions are separate and should respond to their own loads, sensors, and sequences.

**49. C** — Rubber dust around sheaves together with reduced fan performance suggests belt wear or slip, often related to poor tension, worn grooves, or misalignment. These mechanical problems can reduce driven-fan speed even though the motor runs. Chilled-water strainers, boiler blowdown, and refrigerant receivers do not create rubber debris at the fan drive.

**50. D** — Deposits on a fan wheel can disturb blade shape, reduce efficiency, and create uneven mass that contributes to vibration. Cleaning must preserve blade geometry and balance. Dirt does not improve electrical insulation or guarantee higher pressure, and it cannot transform one fan type into another. Vibration and airflow trends help show whether fouling is affecting operation.

**51. B** — A flexible connector isolates some fan and equipment vibration from rigid ductwork and tolerates small movement or alignment differences. It should remain intact and properly supported because tears can become leakage paths. The connector is not intended to increase static pressure by restriction, replace a listed fire damper, or deliberately transmit vibration into the building.

**52. A** — The pressure-drop increase is the later reading minus the earlier reading: 0.95 minus 0.35 equals 0.60 inch water column. The change, rather than either absolute reading alone, can be trended against the filter replacement criterion. Confirm that both readings were taken at comparable airflow because pressure drop also changes with flow.

**53. B** — A pitot traverse measures velocity pressure at multiple points across a duct so the technician can estimate average air velocity and, with duct area, airflow. Multiple points are needed because velocity is not uniform across the section. The method is unrelated to refrigerant moisture, boiler chemistry, or direct measurement of motor winding temperature.

**54. C** — Closing a damper adds resistance to the branch, generally reducing airflow through that path while changing system pressure relationships. Other branches may receive more flow depending on fan control and duct balance. The damper does not directly alter refrigerant subcooling or motor phase configuration. Airflow should be measured after adjustments rather than judged only by blade position.

**55. A** — For geometrically similar fan operation under the stated assumption, airflow changes directly with speed. The speed ratio is 1,200 divided by 1,000, or 1.2. Multiplying 7,500 cfm by 1.2 gives 9,000 cfm. Actual system resistance, motor loading, and control limits should still be checked after a speed change. Use operating trends to confirm the diagnosis.

**56. D** — Fan pressure varies approximately with the square of rotational speed under similarity assumptions. A 10 percent speed increase gives a speed ratio of 1.10; squaring it gives 1.21, or about a 21 percent pressure increase. Fan power changes more steeply, approximately with the cube, so motor loading must also be considered.

**57. D** — A duct smoke detector samples moving air and can initiate a programmed fire-safety response such as fan shutdown, alarm signaling, or damper actions depending on the building sequence. It does not measure refrigeration superheat, balance hydronic flow, or lubricate dampers. Its location and response must match the system design and applicable fire-safety controls.

**58. A** — Gradual transitions help airflow change velocity and direction with less separation and turbulence than abrupt geometry. Lower turbulence generally reduces avoidable pressure loss, noise, and uneven velocity profiles. The transition does not compress refrigerant, improve operation through intentional fan imbalance, or guarantee that all branches are correctly balanced without additional adjustment.

**59. C** — Increasing bearing temperature and vibration together are meaningful condition trends that can indicate lubrication trouble, looseness, misalignment, bearing damage, or another mechanical defect. The pattern is more informative than a single isolated reading. It does not prove filter condition or fan efficiency, and refrigerant charge is unrelated to lubrication of the fan bearing.

**60. B** — Average duct velocity equals volumetric airflow divided by cross-sectional area. Dividing 6,300 cubic feet per minute by 3.5 square feet gives 1,800 feet per minute. The area units cancel one factor of feet, leaving feet per minute. Actual velocity profiles are nonuniform, so field traverses use multiple measurement points. Use operating trends to confirm the diagnosis.

**61. D** — A centrifugal fan wheel may continue turning when rotation is reversed, but the blade geometry then operates poorly and airflow and pressure can be far below design. That makes visual rotation verification important after phase or drive changes. Reverse rotation does not self-correct and can be mistaken for a duct restriction or undersized fan.

**62. B** — Return-air temperature provides an entering condition that can be compared with mixed or supply air to determine sensible temperature change and evaluate load. It must be interpreted with outdoor-air fraction, humidity, airflow, and coil operation. A temperature reading does not measure refrigerant mass, water hardness, or prove uniform terminal distribution across the building.

**63. A** — Dirt on a cooling coil can block fin passages and add thermal resistance, increasing airside pressure drop while reducing airflow and heat-transfer effectiveness. The fan may operate at a different system point as resistance rises. Fouling does not improve electrical insulation or guarantee the absence of condensation. Coil condition should be checked with pressure and temperature trends.

**64. C** — If motor speed follows commanded frequency for this simplified comparison, the new speed fraction is 40 divided by 50, which equals 0.80. Therefore the fan operates at approximately 80 percent of its original speed. Airflow may also change roughly in proportion, while pressure and power follow different affinity relationships under similar conditions.

**65. D** — Ohm law gives current as voltage divided by resistance. Dividing 208 volts by 26 ohms gives 8 amperes. The other choices do not satisfy the stated voltage-resistance relationship. A field measurement that differs substantially would justify checking actual supply voltage, resistance, connections, and whether the heater is operating under the simplified resistive assumption.

**66. A** — For the stated single-phase resistive load, power equals voltage times current. Multiplying 240 volts by 15 amperes gives 3,600 watts, or 3.6 kilowatts. The calculation intentionally ignores power factor. Real motors and other reactive loads may require a different power relationship, so the equipment type must be known before applying this simplification.

**67. B** — The normally closed STOP contact carries control current during normal operation. Pressing STOP opens the control circuit, deenergizing the starter coil and dropping out the contactor. This arrangement supports fail-safe behavior for a broken control wire. The pushbutton does not bypass overload protection, reverse phases, or boost control voltage during acceleration.

**68. C** — A control transformer uses electromagnetic induction to provide a different AC voltage level, commonly reducing line voltage to a value suitable for coils, relays, and controls. It does not directly increase motor horsepower, create pneumatic pressure, or measure current. Its primary and secondary circuits still require appropriate protection and safe troubleshooting practices.

**69. C** — If the contactor coil is truly energized but no line voltage reaches the motor, the fault may lie in the main power contacts, disconnect, fuses, circuit breaker, or conductor path rather than the low-voltage command. The power circuit should be traced safely. Thermostat preference, boiler chemistry, and condensate drainage do not explain missing motor line voltage.

**70. B** — The equipment grounding path bonds exposed conductive parts so a fault to the enclosure can produce sufficient current for protective devices to operate promptly. It is not intended to carry normal load current, increase voltage, or replace overcurrent protection. Grounding and bonding should remain continuous so a fault does not leave metal parts energized.

**71. A** — The active span is 16 mA because 20 minus 4 equals 16. A 16 mA reading is 12 mA above the 4 mA live zero. Dividing 12 by 16 gives 0.75, or 75 percent command. The calculation assumes a linear 4-20 mA scaling from zero to one hundred percent. Use operating trends to confirm the diagnosis.

**72. D** — A motor overload relay responds to sustained current conditions that can overheat windings and damage insulation. Short-circuit and ground-fault protection are normally provided by other protective devices coordinated with the circuit. The overload setting should match the motor and application rather than being increased simply to prevent trips caused by a mechanical or electrical problem.

**73. B** — An interposing relay allows a controller to operate a separate circuit through electrically isolated contacts and can provide additional contact arrangements or handle a different control voltage or current. It does not perform refrigeration compression, airflow measurement, or mechanical lubrication. Coil voltage and contact ratings must match the actual control application.

**74. D** — For a conventional three-phase induction motor, interchanging any two phase conductors reverses phase sequence and therefore the rotating magnetic field. The motor should then be checked for the correct driven-equipment direction. Overload settings, grounding, and control-transformer voltage do not intentionally reverse phase sequence and should not be altered as a substitute.

**75. A** — Cavitation occurs when local pressure falls low enough for vapor bubbles to form and then collapse as pressure recovers. It can produce crackling noise, vibration, erosion, and unstable performance. Suction restriction, high liquid temperature, or inadequate available NPSH are possible causes. The symptom is hydraulic and not explained by unrelated lighting or boiler-chemistry conditions.

**76. C** — Throttling the suction side adds pressure loss before the impeller, reducing the absolute pressure available at the pump inlet and potentially increasing cavitation risk. Flow control is commonly performed on the discharge side or by speed control when appropriate. Suction-valve position does not determine phase rotation or automatically increase pump capacity.

**77. D** — Wear rings provide replaceable close-clearance surfaces between rotating and stationary pump parts, limiting internal recirculation from high pressure back toward the suction region. As clearance increases through wear, pump efficiency and capacity can decline. The rings are mechanical hydraulic components, not electrical, deaeration, or water-treatment control devices. Use operating trends to confirm the diagnosis.

**78. B** — Parallel pumps discharge into a common system so their combined operation can provide more flow than one pump at a particular system head. Actual sharing depends on pump curves, system resistance, speed, and condition. Parallel operation does not guarantee equal flow, eliminate discharge check valves, or simply double head as series operation is more associated with added head.

**79. C** — With gauges at the same elevation for this simplified problem, differential pressure is discharge pressure minus suction pressure. Subtracting 12 psi from 58 psi gives 46 psi. Adding the readings or using only one gauge does not represent the pressure rise produced across the pump. Gauge accuracy should still be considered in field diagnosis.

**80. A** — Using the conversion provided in the stem, multiply 42 psi by 2.31 feet of water per psi. The result is 97.02 feet, which rounds to 97.0 feet. This converts pressure difference to equivalent water head for the stated density assumption. Different fluids require adjustment because head-pressure relationships depend on fluid density.

**81. B** — A discharge check valve closes when flow attempts to reverse, helping prevent header pressure from driving water backward through a stopped pump. This is especially important on parallel installations. The valve does not raise suction pressure by venting, provide bearing lubrication, or balance electrical current. Its condition should be checked if reverse rotation or backflow occurs.

**82. A** — Flow varies directly with speed under the stated affinity-law assumption. The speed ratio is 1,575 divided by 1,800, or 0.875. Multiplying 640 gpm by 0.875 gives 560 gpm. Real system resistance

and pump efficiency can shift the actual operating point, so the result is a similarity estimate rather than a guaranteed field flow.

**83. C** — A clogged suction strainer adds resistance before the pump, reducing inlet pressure and limiting flow. The lower suction pressure can reduce available NPSH and promote cavitation. Cleaning the restriction may restore hydraulic conditions if no other damage exists. The restriction does not improve NPSH, increase flow, or correct shaft alignment between the motor and pump.

**84. D** — Moving either machine can change the relative shaft centerlines. Excessive angular or offset misalignment places extra load on couplings, bearings, and seals and can increase vibration. Proper alignment therefore supports mechanical life and reliable operation. It is not a water-treatment adjustment, an efficiency benefit from friction, or merely an electrical continuity requirement.

**85. C** — Conductivity generally rises as the concentration of dissolved ionic material increases. If makeup quality is stable, a sudden boiler-water increase can point toward concentration, contamination, or inadequate blowdown, subject to the treatment program. The reading should be confirmed with a proper sample. Mechanical fan and motor-control problems do not directly change boiler-water conductivity.

**86. D** — A functioning sodium-cycle softener exchanges hardness ions such as calcium and magnesium for sodium. Testing treated water for hardness can reveal breakthrough when the resin becomes exhausted or the unit malfunctions. The test is a water-treatment check and does not measure compressor oil, duct pressure, or gas-train pressure in a burner system.

**87. A** — On the standard pH scale, a value below 7 is acidic, 7 is neutral, and a value above 7 is alkaline. Therefore pH 6.2 is acidic. The number alone does not state dissolved-oxygen saturation or identify every corrosion risk, so other chemistry measurements and the specific treatment program remain important when evaluating system water.

**88. B** — Mineral scale forms an insulating layer that adds resistance to heat flow. More temperature difference or firing input may then be required to transfer the same useful heat, and metal temperatures can rise on the hot side. Scale does not improve conductivity, remove the driving temperature difference, or chemically convert oxygen into nitrogen.

**89. C** — For the simple conductivity estimate, cycles of concentration equal circulating-water conductivity divided by makeup conductivity. Dividing 2,250 by 500 gives 4.5 cycles. The ratio assumes conductivity is a suitable tracer and that the samples are comparable. Actual treatment control can also consider specific ions, chemical additions, drift, leakage, and blowdown.

**90. B** — Evaporation removes primarily water while leaving many dissolved solids behind, so their concentration rises in the circulating water. Controlled bleed removes part of that concentrated water and allows lower-solids makeup to replace it. Bleed does not add hardness or recover evaporated water, and it cannot eliminate the need for makeup because evaporation remains a water loss.

**91. A** — An oxygen scavenger is used to react chemically with residual dissolved oxygen that remains after mechanical deaeration, helping reduce oxygen-related corrosion where the treatment program calls

for it. It does not intentionally increase oxygen or hardness and does not filter combustion air. Feedwater temperature, deaerator performance, and chemical residual should be evaluated together.

**92. D** — Hot, pressurized samples can be hazardous and can produce inconsistent readings if test temperature varies. A proper sample cooler reduces temperature and pressure to safer, more repeatable conditions for many tests. Cooling does not force conductivity to zero, remove all treatment chemicals, or make hardness chemically disappear from the water being analyzed.

**93. C** — Microorganisms can form slime and biofilm on wetted surfaces, restricting flow and adding heat-transfer resistance. Deposits can also create localized conditions that support under-deposit corrosion. Biocide and monitoring programs are therefore used where appropriate. Biological growth does not improve heat transfer, eliminate mineral scale, or remove the need to replace evaporated cooling-tower water.

**94. A** — Measuring pressure on both sides of a gas regulator helps determine whether supply pressure is adequate and whether the regulator maintains the required downstream condition as load changes. An unstable outlet can result from supply, regulator, valve, or flow problems. Gas-pressure readings do not replace water-level, hydronic-flow, or mechanical bearing measurements.

**95. B** — Excess air is combustion air supplied above the theoretical stoichiometric requirement. Some excess is normally needed to promote complete mixing and combustion, but too much carries additional heat out the stack and can reduce efficiency. Too little air can increase incomplete combustion products. Excess air is therefore an operating balance, not unburned fuel or steam addition.

**96. D** — Increasing carbon monoxide is a warning that combustion may be incomplete or unstable. Fuel-air ratio, burner cleanliness, draft, flame condition, fuel pressure, and analyzer validity should be checked under safe procedures. The reading does not call for changing water hardness or pump lubrication, and it should never be dismissed as proof that combustion is complete.

**97. C** — A timed ignition trial limits how long fuel can be admitted without a proven flame. If ignition fails, the safety sequence closes fuel valves rather than allowing combustible mixture to accumulate. The trial is not intended to raise steam pressure, cycle the safety valve, or permanently stop combustion air. Purge and restart requirements then follow the burner sequence.

**98. D** — Combustion-air proving verifies that fans, dampers, and pressure or airflow conditions satisfy the burner permissive before fuel is admitted. This reduces the risk of firing without adequate combustion air. It does not control boiler-water solids or steam traps, and it does not eliminate the need for flame detection and other protective interlocks after ignition.

**99. B** — Heat input equals volumetric fuel-use rate multiplied by heating value. Multiplying 95 standard cubic feet per hour by 1,020 Btu per standard cubic foot gives 96,900 Btu per hour. The standard-cubic-foot units cancel. The calculation gives fuel energy input, not boiler output, because actual boiler efficiency is not included. Use operating trends to confirm the diagnosis.

**100. A** — Excessive combustion air must be heated from its inlet temperature toward flue-gas temperature and then leaves through the stack, carrying energy that could otherwise support useful heat

transfer. Some excess air promotes complete combustion, but too much can reduce efficiency. High excess air does not force flue oxygen to zero or directly control boiler water level.