

Low Pressure Boilers fifth edition

Answer Key

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5 6 7 8 9 – 19 – 9 8 7 6 5 4 3 2 1

Printed in the United States of America

ISBN 978-0-8269-4374-3



AMERICAN TECHNICAL PUBLISHERS
Orland Park, Illinois

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Boiler Operation Principles

SECTION 1.1—BOILERS IN INDUSTRY _____ 4

1. A boiler is a closed metal container (pressure vessel) in which water is heated to produce steam or heated water.
2. Steam is the vapor that forms when water is heated to its boiling point.
3. James Watt of Scotland, born in 1736, is credited with the development of the reciprocating steam engine.

SECTION 1.2—BOILER OPERATION THEORY _____ 19

1. In a steam heating system, steam produced in the boiler is used throughout the system. In a hot water heating system, hot water produced in the hot water boiler is pumped throughout the system.
2. The first law of thermodynamics, the law of conservation of energy, states that energy cannot be created or destroyed but can be changed from one form to another. The second law of thermodynamics states that heat always flows from a material having a higher temperature to a material having a lower temperature.
3. Sensible heat is heat that causes a temperature change that can be measured with a thermometer or sensed by a person. Sensible heat raises the measurable temperature of a substance and does not involve a change of state. Latent heat is heat identified by a change of state and no temperature change of the substance. Latent heat is heat added to ice that changes it to water or heat added to water that changes it to steam.
4. A British thermal unit (Btu) is the amount of heat energy required to raise the temperature of 1 lb of water 1°F.

5. Conduction is heat transfer that occurs when molecules in a material are heated and the heat is passed from molecule to molecule through the material. Convection is heat transfer that occurs when currents circulate between warm and cool regions of a fluid. Radiation is heat transfer that occurs as radiant energy (electromagnetic waves) without a material carrier.
6. The three types of combustion are perfect, complete, and incomplete.
7. Primary air is the air supplied to a burner to mix directly with gas or to atomize fuel oil and control the rate of combustion, thus determining the amount of fuel that can be burned. Secondary air is the air supplied to the furnace to control combustion efficiency by controlling how completely the fuel is burned. Excess air is air supplied to the burner above the theoretical amount required to burn the fuel to ensure complete combustion.
8. Saturated steam is pure steam at a temperature that corresponds to the boiling point of water at a specific pressure.

SECTION 1.3—BOILER SYSTEMS _____ 21

1. A feedwater system is a boiler system that supplies the proper amount of water to the boiler.
2. A fuel system is a boiler system that provides fuel for combustion to produce the necessary heat in the boiler.
3. A draft system is a boiler system that regulates the flow of air to and from the burner.
4. A steam system is a boiler system that collects, controls, and distributes the steam produced in the boiler. Steam is directed through piping to the point of use.

SECTION 1.4—BOILER DESIGN AND CONSTRUCTION _____ 35

1. The maximum allowable working pressure (MAWP) of a boiler is the maximum

pressure in pounds per square inch (psi) at which a boiler can safely be operated. The MAWP is determined by the design, materials, and construction of the boiler.

2. A low pressure boiler is a boiler with an MAWP of not more than 15 psi. The MAWP for low pressure boilers may vary in some states and should be verified with local authorities.
3. In a firetube boiler, heat from the flame and gases of combustion passes through the tubes while the water surrounds the tubes. The gases of combustion make two, three, or four passes, depending on the design.
4. In a watertube boiler, heat from the flames and gases of combustion is transferred to the water passing through the tubes. Baffles direct the gases of combustion for multiple passes to obtain maximum efficiency.
5. A cast iron boiler is a boiler that has gases of combustion flowing around cast iron sections that contain water. There are no tubes in a cast iron boiler. The cast iron sections function similar to water tubes in a watertube boiler.
6. Two other common types of boilers use alternative fuels or heat energy that otherwise might be wasted. A refuse boiler is a boiler that uses the municipal solid waste that would normally go to landfills. A waste boiler is a boiler that uses fuel or waste heat from an industrial process that would normally be wasted.

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Steam Boiler Fittings

SECTION 2.1—SAFETY VALVES _____ 44

1. A safety valve is an automatic, full-opening, pop-action valve, opened by

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overpressure in a boiler, used to relieve the overpressure before damage occurs. A safety valve is used for gas or vapor service and prevents a boiler from exceeding its maximum allowable working pressure (MAWP).

2. A safety valve's capacity is listed on the data plate attached to the safety valve.
3. The *ASME Boiler and Pressure Vessel Code Section VI, Recommended Rules for Care and Operation of Heating Boilers* states that a try lever test should be performed every 30 days that a boiler is in operation and after any period of inactivity.
4. For low pressure steam boilers, the minimum pressure required for a try lever test is 5 psi.
5. Adjustments or repairs to a safety valve must be performed by the manufacturer or an authorized representative of the manufacturer.
6. The huddling chamber causes a safety valve to open quickly (pop) as the total force is greatly increased after the valve opens. This relieves boiler pressure quickly and reduces wear on the valve seat from steam passing.

SECTION 2.2—STEAM PRESSURE GAUGES _____ 49

1. A steam pressure gauge is a boiler fitting that displays the amount of pressure in pounds per square inch (psi) inside the boiler.
2. Hydrostatic pressure is the weight of water (0.433 psi per vertical foot).
3. Steam is prevented from entering a Bourdon tube by a siphon. A siphon is a bent tube installed between the boiler and a boiler fitting that provides a water seal to prevent contact with steam. A water seal in the siphon is formed by the collection of condensate.
4. A vacuum gauge is a pressure gauge typically used to indicate the amount of vacuum present in a boiler.
5. Pressure gauges should be checked for calibration and repaired or replaced as needed at least once per year.

SECTION 2.3—WATER COLUMNS _____ 53

1. Water should never be added to an operating boiler if water is not present in the gauge glass. Adding water to a boiler with a low water condition could cause a boiler explosion.

2. A water column is a boiler fitting that reduces the turbulence of boiler water to provide an accurate water level in the gauge glass.
3. A gauge glass is a tubular glass column that indicates the water level in a boiler. When the boiler is producing steam, the water inside the boiler is constantly in motion. This makes it difficult to determine how much water is in the boiler. The water column reduces water turbulence, allowing the true boiler water level to be indicated by the water level in the gauge glass.
4. Both the water column and gauge glass should be blown down each shift. Free flow of boiler water in the water column and gauge glass is crucial for providing an accurate boiler water level reading.

SECTION 2.4—BLOWDOWN VALVES _____ 58

1. Bottom blowdown is performed for water level control, sludge and sediment removal, or dumping the boiler.
2. When performing a bottom blowdown, the valve closest to the boiler is always opened first and closed last. The boiler operator must not remove his or her hands from an open bottom blowdown valve.
3. Larger boiler plants may recover the heat from hot blowdown water and use it to preheat boiler makeup water. In a heat exchanger, the hot blowdown water flows on one side of the heat exchanger, and the boiler makeup water flows on the other side. Heat flows from the hotter side to the cooler side of the heat exchanger to cool the blowdown water and warm the feedwater. The cooled blowdown water then flows down the drain.
4. A surface blowdown valve is a valve located on the surface blowdown line used to release water and surface impurities from the boiler.
5. The surface blowdown line is piping located at the NOWL of the boiler used to direct water to the blowdown tank.

SECTION 2.5—BOILER VENTS _____ 60

1. A boiler vent (air cock) is a boiler fitting used to vent air from inside the boiler.
2. A boiler vent line is 1/2" or 3/4" piping connected to the highest part of the steam side of the boiler.
3. A vacuum in a boiler can result in possible injury and/or damage to boiler parts.

SECTION 2.6—PRESSURE CONTROLS _____ 66

1. A pressure control is a switch that starts a burner, controls the firing rate, or shuts down a burner based on steam pressure.
2. For additive pressure control, the sum of the cut-in pressure and the differential pressure is the cut-out pressure. The cut-in pressure and differential pressure are set separately to develop an operating range. For subtractive pressure control, the difference between the cut-out pressure setting and the differential setting is the cut-in pressure setting. The cut-out pressure and differential pressure are set separately to develop an operating range.
3. A modulating control is a pressure control that works with an operating control to vary a burner firing rate. An operating control is a pressure control that senses steam pressure and automatically signals the burner to initiate the start-up sequence when steam pressure is needed and initiate the burner shutdown sequence when steam demand is met.
4. Modern boilers typically have integrated boiler controls to manage steam pressure. Many boilers have touchscreen control systems that show boiler status. They often contain graphic displays showing burner firing rate, stack temperature, steam pressure, boiler water temperature, and stack emissions levels. Most integrated boiler controls also display the status of the boiler feedwater pumps, deaerator water temperature, and boiler water level. Integrated boiler controls typically receive signals from sensors that measure temperature, pressure, and level.

SECTION 2.7—HEAT EXCHANGERS _____ 69

1. A heat exchanger is an auxiliary device commonly used with a boiler to transfer heat from a hotter fluid to a cooler fluid.
2. If process fluid is a liquid that can be trapped within a heat exchanger by closed valves, the heat exchanger must be protected from overpressure from thermal expansion. The usual protection devices are either a thermal expansion safety relief valve or a rupture disc.
3. Steam is converted to condensate as heat is transferred. The condensate must be removed from the heat exchanger to allow more steam to enter. Therefore, the steam connections are at the top of the heat exchanger, and the condensate connections are at the bottom of the exchanger.

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Steam Boiler Feedwater Systems

SECTION 3.1 — FEEDWATER ACCESSORIES _____ 77

1. A feedwater system is a boiler system that supplies the proper amount of water to a boiler.
2. A feedwater accessory is a component that is not directly attached to a boiler that controls the quantity, pressure, and/or temperature of water supplied to the boiler.
3. A check valve is a valve that permits fluid flow in only one direction. A check valve operates automatically to prevent water from flowing out of a boiler through the feedwater line.
4. A gate valve is a valve that stops or starts fluid flow by raising or lowering a gate into the valve passageway. Gate valves are normally used for isolation instead of for controlling the flow rate. A globe valve is a valve that allows fluid to flow by raising or lowering a valve disc against a seat. If a valve is used to regulate the flow of a fluid, a globe valve should be used.
5. A condensate return tank is a boiler accessory that collects condensate returned from heating units.
6. A surge tank is a boiler system component that supplies the extra capacity to handle changing loads and peak flows of condensate. Normally, a surge tank is fitted with automatic makeup water fittings and controls along with a feedwater pump and controls.

SECTION 3.2 — MAKEUP WATER SYSTEMS _____ 80

1. The backflow preventer prevents the undesired flow of boiler water back to the city water supply.
2. The automatic makeup water feeder consists of a float that is connected to a valve in the city water line. If the water level in the boiler drops, the float drops. This opens the valve in the city water line to feed water into the boiler. As the water level builds up in the boiler, the float rises and shuts the automatic makeup water valve OFF.
3. The automatic makeup water feeder is equipped with a blowdown valve so it can be blown down regularly to prevent buildup of sludge and sediment.

SECTION 3.3—FEEDWATER REGULATORS _____ 83

1. A feedwater regulator is a boiler accessory that maintains the NOWL in a boiler by controlling the amount of feedwater pumped to the boiler from the surge tank.
2. Feedwater regulator designs vary, but all designs include a sensing element located at the boiler NOWL. The sensing element is connected to the boiler in the same manner as the water column and the low water fuel cutoff. The top line is connected to the highest part of the steam side of the boiler, and the bottom line is connected to the water side of the boiler well below the NOWL.
3. When the water level in a boiler drops, the feedwater regulator starts the feedwater pump. When the water in the boiler is at the NOWL, the feedwater regulator stops the feedwater pump.

SECTION 3.4 — LOW WATER FUEL CUTOFFS _____ 88

1. A low water fuel cutoff is a boiler fitting that shuts the burner OFF in the event of a low water condition.
2. The low water fuel cutoff is located slightly below the NOWL. The top line connects to the highest part of the steam side of the boiler. The bottom line connects to the water side well below the NOWL.
3. A float-type low water fuel cutoff actuates a switch when the float drops. A probe-type low water fuel cutoff performs the same function, except the probe uses the conductivity of the water to complete the burner control circuit.
4. An evaporation test is a more reliable test than a blowdown test because it simulates an actual low water condition. Low water fuel cutoff testing by blowdown should be performed daily or more often depending on plant procedures and requirements. At least once a month, the low water fuel cutoff should be tested with an evaporation test.

SECTION 3.5 — PUMPS _____ 96

1. A dynamic pump is a pump that operates by adding momentum to the liquid while taking in and discharging fluids in a continuous flow across an unsealed chamber.
2. A positive-displacement pump is a pump that operates by moving a fixed amount of a substance with each cycle, stroke, or rotation.

3. A gear pump is a positive-displacement pump consisting of two meshing gears enclosed in a close-fitting housing. A reciprocating pump, or piston pump, is a pump in which fluid flow is produced by reciprocating pistons.
4. A vacuum pump is a boiler accessory that produces a negative pressure on condensate return lines to draw condensate back from the system.
5. Vacuum pumps are used to create a vacuum in condensate tanks, process heat exchangers, steam turbine condensers, and many other vessels.
6. Common applications of a variable-speed-drive pump are as a circulating pump used to move water through a boiler or piping system or as a metering pump to feed chemicals into the water treatment system.
7. Priming is the process of overcoming suction lift and getting liquid to a pump inlet.
8. Cavitation is the process in which microscopic gas bubbles expand in a vacuum and suddenly implode when entering a pressurized area.
9. A mechanical seal is an assembly of mechanical parts installed around a pump shaft to prevent leakage of the pumped liquid along the shaft. Packing is an assembly of compressible sealing material installed around a pump shaft to prevent the pumped liquid from leaking along the shaft.

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Steam Systems

SECTION 4.1 — STEAM DISTRIBUTION _____ 106

1. A main steam stop valve is the valve used to cut the boiler in on-line or take the boiler off-line. To cut the boiler in on-line allows steam to flow from the boiler into the steam header.
2. A nonreturn valve, or automatic non-return valve, is a type of globe valve that allows a boiler to be cut in on-line automatically when the boiler pressure is at or above the header pressure and allows the boiler to be taken off-line automatically if the pressure in the boiler drops below the header pressure.
3. An os&y valve allows steam to flow when the gate is lifted to open the valve, and it stops steam flow when the gate is lowered to close the valve.

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4. A steam header distributes steam to branch lines. Steam headers are constructed of pipe that is strong enough to withstand the pressure and velocity of steam that passes from the boiler to the branch lines.
5. Expansion bends and expansion joints in steam lines allow movement from expansion and contraction without causing damage to piping.
6. A heating unit is a heat exchanger, such as a radiator, in which heat transported by steam or hot water is transferred to air in a building space.

SECTION 4.2—STEAM TRAPS AND STRAINERS _____ 115

1. A steam trap is a steam system accessory that removes air and condensate from steam lines and heating units. Air must be removed from the steam lines because it prevents steam from reaching heat transfer surfaces.
2. Common types of steam traps include return steam traps, nonreturn steam traps, thermostatic steam traps, float thermostatic steam traps, and thermodynamic steam traps.
3. Steam traps should be tested as a part of overall plant maintenance tasks. Maintenance work should be scheduled at the first sign of underheating heating units/heat exchangers, a temperature increase of returned condensate, and/or pressure buildup in the condensate return tank. Trap problems in smaller, low pressure boiler systems can sometimes be detected visually but are typically tested using a contact thermometer, a temperature-indicating crayon, a flow indicator, an ultrasonic tester, an infrared thermometer, and/or a sensor that measures conductivity.
4. A steam strainer is a boiler accessory that is located in a steam line before a steam trap to remove foreign matter from steam that could cause a steam trap malfunction.
5. A steam strainer is cleaned by securing the steam line, removing the cap and strainer basket, and cleaning out foreign matter.



SECTION 5.1—GAS SYSTEMS _____ 122

1. Natural gas (or gas) is a colorless and odorless fossil fuel.

2. In a low pressure gas system, gas is mixed with air in a mixing chamber before entering the burner.
3. In a high pressure gas system, gas is supplied and mixed with air inside the burner.
4. In a low pressure gas system, gas pressure is reduced from supplier gas pressure to approximately 0 pounds per square inch (psi) at the burner. Most manufacturers that make small hot water and steam boilers call this type of burner a power burner. The gas pressure regulator reduces city gas pressure to zero. In a high pressure gas system, gas is supplied through a high pressure gas main at a higher pressure than a residential gas supply line.

SECTION 5.2—FUEL OIL SYSTEMS _____ 139

1. Fuel oil is a liquid fossil fuel that consists primarily of carbon, hydrogen, and moisture.
2. The most common grades of fuel oil used in low pressure boilers are No. 2 fuel oil, No. 4 fuel oil, No. 5 fuel oil, and No. 6 fuel oil.
3. In a fuel oil system, fuel oil leaves the fuel oil tank through the suction line. The fuel oil is discharged from the fuel oil pump under pressure through the discharge line. Some fuel oil goes to the burner. The remaining fuel oil is directed through the fuel oil pressure regulating valve to the return line into the fuel oil tank.
4. Fuel oil heaters are used to heat heavy fuel oil for ease in pumping and efficient burning. Both steam and electric fuel oil heaters are used. Heavy fuel oil accessories for package boilers are installed on the boilers before shipping from the factory.
5. Fuel oil burners commonly used include atomizing and rotary cup burners.

SECTION 5.3—COMBUSTION CONTROLS _____ 154

1. A combustion control is a control that regulates fuel supply, air supply, air-to-fuel ratio, and removal of gases of combustion in a boiler.
2. An ON/OFF control system is a combustion control system that starts and stops the burner to control the amount of steam produced. A modulating control system is a combustion control system that controls the amount of steam produced by changing the burner firing rate.

3. A flame safeguard system is a system of burner control equipment that monitors the burner start-up sequence and the main flame during normal operation. The flame safeguard also monitors the shutdown sequence.
4. A flame safeguard programmer sequences burner function in a set order including the following functions: prepurge, ignition trials, pilot-flame establishing period, main burner flame-establishing period, run period, and postpurge.
5. The primary function of a boiler management and control system is combustion safety. The control of high fire, purge, supervised low fire start, and tamper resistance programming are performed as necessary.
6. Ethernet systems and the Internet allow remote monitoring of a boiler control system from anywhere in the world. System technicians, maintenance personnel, and building owners can access building operation controls. Some systems even allow authorized users to remotely adjust system settings. Remote monitoring is particularly helpful when outside consultants are needed to troubleshoot system problems. Some issues may be resolved by monitoring system information via the Internet, reducing the need for expensive on-site visits.
7. Different types of flame sensors include flame rod sensors, photocell sensors, ultraviolet sensors, and infrared sensors.
8. Use the following procedure to test a flame scanner:
 1. Remove the flame scanner with the burner firing and cover the scanner eye to simulate a flame failure. The main fuel valve closes immediately, and the flame failure alarm sounds. The burner control should begin a postpurge cycle to remove any residual fuel from the furnace.
 2. Reinstall the flame scanner.
 3. Reset the programmer and check for proper operation.

SECTION 5.4—AIR POLLUTION _____ 157

1. A pollutant is matter that contaminates air, soil, or water.
2. A primary pollutant is a pollutant emitted directly from identifiable sources. A secondary pollutant is a pollutant formed from the interaction between two or more primary pollutants.
3. The Clean Air Act controls air pollution from stationary and mobile sources, controls the release of air toxins, controls acid rain pollutants (sulfur oxides

and nitrogen oxides), establishes a comprehensive permit program, sets up enforcement provisions, and establishes many miscellaneous programs.

4. A state implementation plan (SIP) is a plan that gives the states the responsibility for developing their own programs to reduce air pollution.

6 Draft Systems

SECTION 6.1—DRAFT _____ 170

1. Draft is the flow of air or gases of combustion caused by a difference in pressure between two points.
2. A draft system is a boiler system that regulates the flow of air to and from the burner.
3. In a natural draft system, air for combustion is heated and expands and becomes lighter. Colder, heavier air pushes in to replace the hot gases of combustion. A difference in pressure is created as the cold air for combustion replaces the hot gases of combustion rising up the stack.
4. By adding cold air to the gases of combustion going up a stack, the flow rate and the temperature of the gases can be reduced. Dampers or draft regulators allow cold air to pass directly into a stack.
5. Forced draft is mechanical draft from air pushed through a boiler with fans located in the front of the boiler furnace. Induced draft is mechanical draft from air pulled through a boiler furnace with fans located in the breeching. Balanced draft is mechanical draft from fans located before and after a boiler.
6. A variable-speed drive (VSD) is a motor controller used to vary the frequency of the electrical signal supplied to an AC motor in order to control its rotational speed. A VSD can save energy because it can precisely control the fan motor speed so that the fan volume more efficiently matches the boiler air flow requirements.
7. A manometer is a device that measures draft by comparing pressures at two locations with a U-tube or inclined tube gauge.
8. Measurements are expressed in inches of water column (in. WC) when measuring draft.

SECTION 6.2—DRAFT CONTROL _____ 172

1. Improper adjustments to a draft system can create environmental problems, such as smoke emissions from the boiler stack. Improper adjustments can also cause internal damage to the burner and/or boiler from a furnace explosion.
2. Proper control of draft in a draft system maintains high combustion efficiency. High combustion efficiency keeps smoke and air pollution to a minimum and produces the maximum amount of heat from the fuel. In addition, by removing gases of combustion from the furnace before the heat has been transferred to the water, heat is lost up the stack.
3. Many people prefer to use the word “stack” for steel construction and the word “chimney” for brick and mortar construction, although this usage is not universal. High-efficiency condensing boilers may use steel or PVC stacks because of the low stack temperatures in these types of boilers.
4. Condensation can occur with low stack temperatures. Stack condensation in conventional boilers is most likely to occur in heating boiler installations where light loads and intermittent firing cause a cool stack condition, which can result in condensation of the water vapor in the gases of combustion.
5. Stack condensation is a problem with draft systems because the acidic stack condensation accelerates corrosion of steel stacks or breechings. An offset stack with a bottom cleanout and drain connection prevents condensed water from draining back into the boiler and allows access for maintenance.

7 Boiler Water Treatment

SECTION 7.1—BOILER WATER CONDITIONS _____ 182

1. Feedwater is water that is treated for use in a boiler.
2. Dissolved solids are impurities such as calcium, silica, and iron that have dissolved into a solution.
3. Scale is the accumulation of minerals such as calcium and magnesium on the water side of boiler heating surfaces. All city water and most other water sources

contain scale-forming minerals such as natural salts and silica. Corrosion is the rusting or pitting of boiler metal. Corrosion is primarily caused by oxygen in the boiler water.

4. Priming is a condition that occurs when large slugs of boiler water are carried into the steam lines. Carryover is a condition that occurs when small particles of boiler water are carried into the steam lines. Both of these conditions can be caused by a high water level in the boiler. Priming and carryover can also be caused by a high concentration of chemicals in the boiler water, impurities in the boiler water that cause a high surface tension (such as oil), and/or opening a main steam stop valve too quickly. Foaming is a boiler water condition caused by the formation of steam bubbles trapped below a film on the boiler water surface. Foaming is commonly caused by high surface tension from impurities such as leakage of fuel oil in boilers using No. 4, No. 5, or No. 6 fuel oil.

SECTION 7.2—BOILER WATER ANALYSIS _____ 186

1. The purpose of boiler water analysis is to test the condition of boiler water and use the results to determine the feedwater treatment required. Boiler water is analyzed to determine the frequency of blowdown and the amount of chemicals necessary.
2. pH is a measure of the acid-alkaline balance of a solution and is indicated on a scale from 0 to 14.
3. Conductivity is measured with a conductivity meter. A conductivity meter is an instrument used to determine total dissolved solids present in boiler water.
4. Boiler water tests and water treatment activities are recorded in a water treatment log similar to a boiler room log.

SECTION 7.3—BOILER WATER TREATMENT _____ 199

1. Types of equipment used for external boiler water treatment include pre-treatment equipment (such as filters and water softeners), deaerators, package feedwater systems, surge tanks, and chemical feeders.
2. Internal boiler water treatment is treating boiler water after it has entered the boiler.
3. A bottom blowdown is performed regardless of whether or not continuous blowdown is employed. Continuous blowdown is performed for the purpose of removing TDS or other impurities that have concentrated near the surface of the boiler water. Bottom blowdown is performed to

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remove sludge and sediment, to control high water, and to control the chemical concentration in the boiler.

4. When performing a bottom blowdown, the valve located closest to the boiler, usually a quick-opening valve, is opened first. The slow-opening valve, located farthest away from the boiler, is opened last. The valves are left open for a specified amount of time to blow out the sludge and impurities from the bottom of the boiler. After the bottom blowdown is complete, the valves are closed in the reverse order. The slow-opening valve, located farthest away from the boiler, is closed first. The valve located closest to the boiler is closed last.



SECTION 8.1—TAKING OVER A SHIFT _____ 207

1. The first task a boiler operator must perform when taking over a shift is to check and log the water level of all the boilers on-line.
2. A shift log helps to ensure quality and consistency when performing various tasks. It is developed in conjunction with a boiler log to ensure that critical duties, such as safety valve testing, are performed.
3. Bottom blowdown is performed to remove sludge and sediment, to control high water, and to control the chemical concentration in a boiler.
4. An evaporation test is a method of testing a low water fuel cutoff by intentionally causing a low water condition to occur.
5. It is important to test a flame scanner because a flame failure can result in a furnace explosion from the ignition of accumulated fuel in the burner.

SECTION 8.2—STARTUP AND SHUTDOWN _____ 211

1. If the water used to fill a boiler during first-time startup is too cold, high humidity can cause sweating that makes it difficult to see leaks.
2. During a first-time boiler start-up, strainers should be installed in fuel lines to remove foreign matter.

3. When the boiler being started up is a few pounds below the header pressure, slowly open the main steam stop valve and allow the pressure to equalize.
4. When opening a valve, it is good practice to open the valve completely and then close the valve one to one-and-a-half turns. This helps ensure that the valve will not bind in the open position as the valve heats and expands.
5. It is important to slowly cool down a boiler during a routine shutdown because fast cooling can cause damage from flaking of the surface of the brickwork. Frequent fast cooling of the boiler tubes can cause the tubes to crack.
6. The boiler vent should be opened when the steam gauge shows approximately 1 lb to 2 lb of pressure.

SECTION 8.3— MAINTENANCE _____ 223

1. It is important to use established procedures because they ensure the overall quality of performed maintenance and reduce possible plant downtime.
2. When cutting a replacement gauge glass, allow $\frac{1}{4}$ " less than the inside measurement for expansion from heat.
3. A slow increase in the flue gas temperature can indicate a loss in heat transfer and soot buildup on fire-side surfaces, baffle leakage, or scale buildup on water-side surfaces.
4. A boiler inspection is performed as a part of plant procedures and/or requirements by an inspection agency. The boiler inspector thoroughly examines the boiler and related equipment for corrosion, overheating, and other possible damage.
5. Wet layup is the storage of a boiler filled with warm, chemically treated water. Wet layup is used when the boiler may be needed on short notice. Dry layup is the storage of a boiler with all the water drained. Dry layup is used when the boiler is expected to be out of service for a long period of time or if the water in the boiler has a possibility of freezing.

SECTION 8.4—HANDLING BOILER CONDITIONS _____ 229

1. A low water condition can be dangerous because it can damage the boiler drum, the furnace, and the tubes from overheating.
2. The immediate danger with a high water condition is the possibility of carryover of water in the steam. This can result in water hammer and damage to steam lines.
3. In an overpressure condition, the pressure controls and safety valve have failed.

4. A furnace explosion can be caused by leaking fuels or a flame failure.

5. During a low water condition, water should not be added until the actual water level in the boiler is determined. The lowest visible part of the gauge glass must be a minimum of 1" above the lowest permissible water level recommended by the boiler manufacturer. As long as the heating surface is covered with water, it is safe to add water to the boiler.

6. In an overpressure situation, the burner should be shut off immediately if the boiler is still firing, the boiler pressure is above its MAWP, and the safety valve is not open. The safety valve should not be opened manually, as this could cause a boiler explosion. The boiler should be allowed to cool, and the cause of the overpressure condition should be determined.

7. To correct a steambound feedwater pump, water fed to the pump must be cooled. Water that is drawn from a condensate return tank may be cooled by adding water from the makeup system. Cool water can be carefully poured directly on the feedwater pump without spilling water on the motor if the problem persists. Steam traps on the condensate return line should also be tested for proper operation.



SECTION 9.1—HOT WATER HEATING SYSTEMS _____ 236

1. Water in a hot water heating system remains in the piping system at all times. It cools slowly in the pipes and heating units. This allows for an even rate of heat transfer. When steam pressure is lost in a steam heating system, the steam flows out of the heating units. This results in a more rapid loss of heat transfer than in a hot water heating system. In addition, a steam heating system has a longer recovery time than a hot water heating system and will take longer to produce heat after the boiler is shut down.
2. A typical hot water heating system operates at about 170°F for supply water and about 150°F for return water, although these temperatures can vary considerably from that range.
3. A natural-circulation hot water heating system, or gravity feed system, is an

older type of open, unpressurized heating system that circulates hot water using the difference in water density (weight per unit volume) between hot water supplied to heating units and cool water returned to the boiler.

- When water is heated, it increases in volume (expands), and the density decreases. The less dense water rises up through the supply line and branch lines to the heating units. When the water cools, it decreases in volume (shrinks), and the density increases. The more dense water sinks down through the return line back to the boiler.
- A forced-circulation hot water heating system is a closed, pressurized system that circulates hot water using a circulating pump.
- A circulating pump is a hot water heating system accessory that moves water through the boiler, hot water system piping, and heating units.

SECTION 9.2—HOT WATER BOILERS _____ 245

- Low pressure boilers for steam or hot water are constructed in accordance with the *ASME Boiler and Pressure Vessel Code*, Section IV. Section IV covers steam boilers with operating pressures not exceeding 15 psig and hot water boilers to be operated at pressures not exceeding 160 psig and temperatures not exceeding 250°F.
- High pressure power boilers are designed and constructed according to the *ASME Boiler and Pressure Vessel Code*, Section I. Section I covers steam boilers with pressures over 15 psig and hot water boilers with pressures over 160 psig and operating temperatures over 250°F.
- A condensing boiler has an added heat exchanger (secondary heat exchanger) to remove the required additional heat from the gases of combustion in order to allow the water vapor to condense.
- To avoid corrosion, the materials used to construct a boiler must be able to withstand the condition caused by the acidic condensate. In high-temperature areas, like the heat exchanger, aluminum alloys and stainless steel are commonly used. In low-temperature areas where the gases of combustion are cooler, PVC and polypropylene are commonly used. A condensate drain must be installed. To prevent corrosion, a neutralizer can be added to the condensate to adjust the acidity (pH) to an acceptable level.
- An electric boiler is a boiler that uses electrical heating elements to heat water

for residential or light commercial hot water heating systems.

- A tankless boiler is a hot water boiler that heats water without the use of a tank.

SECTION 9.3—BURNERS AND IGNITERS _____ 248

- A burner is the heat-producing component of a combustion boiler where fuel is burned.
- Common types of burners used with hot water boilers include tubular burners and power burners.
- An igniter is a device used to set fire to the fuel in a burner.
- Common types of igniters used with hot water boilers include pilot burners, electric spark igniters, and hot surface igniters.

SECTION 9.4—HOT WATER BOILER FITTINGS _____ 260

- The relief valve should be located on the highest part of a boiler and should discharge to an open drain in the boiler room.
- A low water fuel cutoff is a boiler fitting that shuts the burner off in the event of a low water condition. The primary function of a low water fuel cutoff is to de-energize the burner safety circuit and shut down the burner if the water level in the system drops below a safe operating level.
- It is important to use a water flow-proving switch in a hot water system because it is a fail-safe device. If the switch should fail, the contact will not be made and the boiler will not be allowed to start.
- A snubber has an orifice that slows the transmission of a pressure surge so the gauge is not damaged by the surge.
- A temperature-pressure gauge is a boiler fitting that indicates both the temperature and pressure of the water leaving the boiler.
- Altitude pressure gauges typically have one black needle and one red needle. The red needle is manually set at the proper water pressure for the system. The black needle indicates the true water pressure and varies as the pressure changes. When the black needle covers the red needle, the system is properly filled with water. The red needle can be reset to conform to the water pressure in the system and the compression tank by manually positioning the needle.
- An aquastat is a hot water boiler fitting that measures the water temperature in

the boiler and controls the temperature by starting and stopping the burner.

- The purpose of a hot water reset control is to reduce energy use and improve system efficiency.
- An outside air thermostat is a thermostat used to measure the temperature of outside air and then send signals to control the temperature of the water in a hot water boiler. The thermostat or sensor shuts down the boiler above a setpoint when heat is no longer needed.



SECTION 10.1—HOT WATER BOILER ACCESSORIES _____ 281

- A circulating pump propels water through the boiler, the system piping, and the terminal units of a hot water heating system.
- When a pipe-mounted pump is installed on return piping, the outlet water flows into the boiler.
- Sometimes, air enters a system as tiny bubbles trapped in the water. Other times, the air is dissolved in the water.
- An air separator's dip tube extends into the water below the air accumulation area. The water flows through the dip tube into the piping toward the heating units. The air can flow around the tube and into the pipes leading to a tank fitting on the compression tank where the air can be vented out of the piping system.
- An expansion tank is a hot water system tank used to relieve pressure in a natural-circulation hot water heating system. A compression tank is a hot water system tank used to absorb changes in water pressure in a forced-circulation hot water heating system.
- A compression tank must be placed on the suction side of a circulating pump.
- A closed water system typically uses only a small amount of makeup water because the introduction of any fresh water introduces additional minerals and oxygen. The small amount of makeup water minimizes corrosion, scale, and microbiological problems.
- Chemicals are usually added to closed water systems using a bypass feeder.

SECTION 10.2—HOT WATER SYSTEM VALVES _____ **290**

1. A swing check valve is a check valve that prevents backflow through the use of a hinged disc within the valve body.
2. A lift check valve is a check valve that prevents backflow through the use of a disc that moves vertically within the valve body.
3. A spring check valve is a check valve that prevents backflow through the use of a conical or cylindrical brass disc held in place by a spring.
4. A balancing valve is a hot water system control valve that regulates the rate of fluid flow through a hot water piping system to meet system design requirements. A flow control valve is a hot water boiler accessory that opens and closes automatically to prevent natural circulation in a hot water heating system when the circulating pump is not operating.
5. A thermostatic control valve is a nonelectric hot water system control valve that provides reliable temperature control for a hot water terminal unit.
6. A zone control valve is a hot water system control valve that opens fully on a call for heat from a thermostat installed in a circuit or zone regulated by the valve.

SECTION 10.3—PIPING SYSTEMS _____ **297**

1. A one-pipe hot water heating system, or one-pipe system, is a piping system that uses one pipe as a supply line from the boiler to the heating units and the same pipe as a return line from the heating units to the boiler. A two-pipe hot water heating system, or two-pipe system, is a piping system that uses one pipe as a supply line from the boiler to the heating units and a separate pipe as a return line from the heating units to the boiler.
2. Balancing is the adjustment of the flow rate through the piping loops in a system to assure that the proper amount of water flows through each heating unit for the amount of heat required.
3. A three-pipe hot water heating and cooling system, or three-pipe system, is a piping system that uses one pipe as a supply line from the boiler, one pipe as a supply line from the chiller, and one pipe as the return line from the heating units to the boiler and chiller. A four-pipe hot water heating and cooling system, or four-pipe system, is a piping system that uses one pipe as a supply line from the boiler, one pipe as a supply line from the chiller, one pipe to return warm water

to the boiler, and one pipe to return cool water to the chiller.

4. Four-pipe systems are more economical to operate than three-pipe systems because the hot and cold return water are separated.
5. A combination heating system is a type of heating system that uses hot water and steam to control building-space temperature.
6. A converter is a tube-and-shell heat exchanger used to heat water in a combination heating system.

**SECTION 11.1—COOLING SYSTEM PRINCIPLES** _____ **307**

1. In a chilled water system used for cooling building spaces, heat is removed from building spaces and transported to another location using water as the medium. Cooling units are located to transfer heat efficiently from the building spaces. Chilled water flows through insulated risers (pipes) to the cooling units, where heat is released to the chilled water. The water then flows to the chiller, where the heat is released to the refrigerant and the water is chilled to repeat the cycle.
2. In the pasteurization process, heated milk is cooled in a cooler. The milk enters at the top of the cooler and flows around piping containing chilled water. Heat in the milk is released by contact with the piping. The water is warmed by the milk, and the warm water is returned to the chiller. The cooled milk is collected in the trough and directed to piping for packaging. Chilled water is circulated through the piping continuously to ensure the proper cooling temperature.
3. Sensible heat is heat that causes a temperature change that can be measured with a thermometer or sensed by a person. Latent heat is heat identified by a change of state and no temperature change of the substance.
4. Heat transfer is the movement of heat from one material to another.
5. A ton of cooling is the amount of cooling provided by melting 1 ton (2000 lb) of ice within a 24-hr period.

6. The three states of matter are solid, liquid, and gas.
7. At atmospheric pressure, R-134a boils or condenses at -14°F . If the pressure in a container of R-134a were to increase to 12 psig, the refrigerant would boil and condense at approximately 10°F . This relationship between temperature and pressure can be related to comfort cooling.

SECTION 11.2—COOLING SYSTEMS _____ **328**

1. A centrifugal compressor is a rotary compressor that has rotating impellers to pressurize refrigerant. A scroll compressor is a compressor that has two meshing spiral scrolls that oscillate relative to each other to compress refrigerant. A screw compressor is a large capacity compressor that has one or more rotating screws that produce progressively smaller cavities to compress refrigerant.
2. A condenser is a heat exchanger that removes heat from a high-pressure refrigerant vapor.
3. A metering device is a component of a refrigerant system that controls the flow of refrigerant into the evaporator.
4. An evaporator is a heat exchanger used to absorb heat from an area to be cooled and transfer the heat into refrigerant.
5. A direct-expansion system, or direct cooling system, is a cooling system in which the evaporator is in direct contact with air in a building space.
6. The most common direct-expansion systems used for cooling are air conditioners and heat pumps.
7. A chilled water system, or indirect cooling system, is a cooling system in which water or other liquid is chilled and circulated to a building space.
8. An absorption chiller system is a nonmechanical refrigeration system that uses a fluid with the ability to absorb a vapor when it is cool and release a vapor when heated.
9. The absorbent in an ammonia-water absorption chiller system is a solution of ammonia and water.
10. The absorbent in a lithium bromide-water absorption chiller system is a solution of lithium bromide and water.

SECTION 11.3—REFRIGERANTS _____ **338**

1. If accidentally released into the environment, many refrigerants eventually reach the upper atmosphere, or stratosphere,

and react with ozone, causing ozone depletion. Ozone in the stratosphere acts as a screen against the ultraviolet (UV) radiation from the sun. However, ozone in the lower atmosphere, or troposphere, is a pollutant that causes smog.

- The three classifications of refrigerants most technicians work with today are chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs).
- The four certification types available for refrigeration service technicians are Type I, Type II, Type III, and Universal.
- There are many hazards in the refrigeration and air conditioning industry. Some of those hazards are associated with the proper handling and storage of the refrigerants. Safety concerns with refrigerants can exist because the refrigerants are often stored in pressurized containers or are under pressure in a system. When released to the atmosphere, refrigerants can cause frostbite to unprotected skin and freezing of the eyes, and can create environmental problems in the form of ozone depletion and global climate change.
- Handling tanks and cylinders of refrigerants and other gases used in the refrigeration industry can be dangerous. These cylinders can be heavy and awkward to handle. Without the protective cap, the valve could break off, turning the cylinder into an uncontrolled projectile that could cause serious injury or extensive damage.
- An HCFC, or hydrochlorofluorocarbon, is a refrigerant that contains the elements hydrogen, chlorine, fluorine, and carbon.

12 Boiler Operation Safety

SECTION 12.1—REGULATORY AGENCIES AND STANDARDS ORGANIZATIONS _____ 346

- A government regulatory agency is a federal, state, or local government organization that establishes rules and regulations related to safety, environment, health, and equipment installation and operation.
- Federal agencies that establish rules and regulations involving boiler operation include the Occupational Safety

and Health Administration (OSHA) and the Environmental Protection Agency (EPA).

- A technical society is an organization composed of groups of engineers and technical personnel united by professional interest. A trade association is an organization that represents the producers of specific products.
- The National Fire Protection Association (NFPA) publishes the National Electrical Code® (NEC®), NFPA 70E, and the NFPA Hazard Signal System.

SECTION 12.2—BOILER ROOM SAFETY PROGRAMS _____ 359

- Fuel, heat, and oxygen are required to start and sustain a fire.
- A fire safety plan establishes procedures that must be followed if a fire occurs.
- The four classes of fires are Class A, Class B, Class C, and Class D fires.
- Confined spaces in and around a boiler room may include fuel oil tanks, feed-water heaters, deaerators, sewers, and underground tunnels.
- Confined-space permits are required for work in confined spaces based on safety considerations for workers.
- Right-to-know (RTK) information is important because it conveys hazards of chemicals according to federal and state standards.
- A safety data sheet (SDS) is an informational form used to relay chemical hazard information from a manufacturer, importer, or distributor to an employer.
- The boiler operator is the person responsible for the safe and efficient operation of the boiler and safety in the boiler room. The boiler operator must practice safety habits that reduce the possibility of personal injury, injury to others, and damage to equipment.

SECTION 12.3—PERSONAL PROTECTIVE EQUIPMENT (PPE) _____ 364

- Personal protective equipment (PPE) is a device or clothing worn by a boiler operator to prevent injury.
- OSHA and ANSI have requirements related to PPE.
- Devices that can be used for ear protection include earplugs and ear muffs.
- Documentation from the manufacturer verifies that gloves meet standards for safety and protection such as OSHA 29 CFR 1910.138 – *Hand Protection* or MIL G43976 (revised).

SECTION 12.4—ELECTRICAL SAFETY _____ 366

- OSHA and the National Electrical Code® (NEC®) have requirements that state, "Employees shall be trained in and familiar with the safety-related work practices, safety procedures and other safety requirements in this section that pertain to their respective job assignments. Employees shall also be trained in and familiar with any other safety procedures (such as pole top and manhole rescue) that are not specifically addressed by this section, but that are related to their work and are necessary for their safety."
- A qualified person is a person who is trained in, and has specific knowledge of, the construction and operation of electrical equipment or a specific task, and is trained to recognize and avoid electrical hazards that might be present with respect to the equipment or specific task.
- Two common electrical hazards caused by poor electrical equipment maintenance are arc flash and electrical shock.
- Additional PPE that may be required when working on electrical equipment includes flame-resistant and/or flash-resistant clothing, jackets, and coveralls; arc flash face shields and hoods; dielectric protective helmets and footwear; and rubber insulating gloves and leather protectors.

SECTION 12.5—GENERAL SAFETY PROGRAMS _____ 369

- Lockout is the placement of a device on an energy-isolating device, in accordance with an established procedure, ensuring that the energy-isolating device and the equipment being controlled cannot be operated until the lockout device is removed. Tagout is the process of attaching a danger tag to a source of power to indicate that the equipment may not be operated until the tag is removed.
- An authorized employee is a person who locks out or tags out machines or equipment in order to perform servicing or maintenance on that machine or equipment.
- An emergency plan is a document that details procedures, exit routes, and assembly areas for facility personnel in the event of an emergency.
- An accident report is a document that details facts about an accident in the facility.

1

Boiler Operation Principles

Section 1.1 Boilers in Industry

True-False _____ 1

- 1. T
- 2. F
- 3. T

Multiple Choice _____ 1

- 1. B
- 2. A
- 3. D

Section 1.2 Boiler Operation Theory

True-False _____ 3

- 1. T
- 2. T
- 3. T
- 4. F
- 5. T
- 6. T
- 7. T
- 8. F
- 9. T
- 10. T
- 11. F
- 12. F
- 13. F
- 14. F
- 15. T

Multiple Choice _____ 4

- 1. D
- 2. B
- 3. D
- 4. B
- 5. C
- 6. A
- 7. B

- 8. C
- 9. C
- 10. D
- 11. D
- 12. D
- 13. D
- 14. B
- 15. C

Steam Heating Systems _____ 6

- 1. D
- 2. G
- 3. E
- 4. I
- 5. C
- 6. H
- 7. A
- 8. B
- 9. F

Section 1.3 Boiler Systems

True-False _____ 7

- 1. T
- 2. F
- 3. T
- 4. T
- 5. F

Multiple Choice _____ 7

- 1. B
- 2. D
- 3. A

Boiler Systems _____ 8

- 1. A
- 2. C
- 3. B
- 4. E
- 5. D

Section 1.4 Boiler Design and Construction

True-False _____ 9

- 1. T
- 2. T

- 3. F
- 4. T
- 5. F
- 6. F
- 7. T
- 8. F

Multiple Choice _____ 9

- 1. A
- 2. B
- 3. C
- 4. C
- 5. A
- 6. A
- 7. D
- 8. A
- 9. A
- 10. B

Scotch Marine Boilers _____ 11

- 1. B
- 2. A
- 3. D
- 4. C

Straight-Tube Watertube Boilers _____ 12

- 1. E
- 2. F
- 3. B
- 4. A
- 5. C
- 6. D

2

Steam Boiler Fittings

Section 2.1 Safety Valves

True-False _____ 13

- 1. T
- 2. F

12 LOW PRESSURE BOILERS ANSWER KEY

- 3. T
- 4. F
- 5. F
- 6. F
- 7. T
- 8. T
- 9. F
- 10. T

Multiple Choice _____ 13

- 1. B
- 2. B
- 3. C
- 4. D
- 5. A
- 6. C
- 7. C
- 8. B
- 9. A
- 10. D
- 11. A
- 12. B
- 13. C
- 14. A
- 15. A

Safety Valves _____ 16

- 1. F
- 2. E
- 3. A
- 4. B
- 5. H
- 6. C
- 7. D
- 8. G

Safety Valve Huddling Chambers _____ 16

- 1. D
- 2. E
- 3. A
- 4. F
- 5. C
- 6. B

Section 2.2 Steam Pressure Gauges

True-False _____ 17

- 1. T
- 2. T
- 3. T
- 4. T
- 5. T
- 6. F

Multiple Choice _____ 17

- 1. B
- 2. B

- 3. D
- 4. A
- 5. C
- 6. A
- 7. D
- 8. C

Steam Pressure Gauge Operation _____ 18

- 1. C
- 2. E
- 3. D
- 4. G
- 5. F
- 6. A
- 7. B

Section 2.3 Water Columns

True-False _____ 19

- 1. T
- 2. F
- 3. T
- 4. T
- 5. T
- 6. T
- 7. T
- 8. F
- 9. F
- 10. T

Multiple Choice _____ 19

- 1. C
- 2. A
- 3. B
- 4. D

Water Columns and Gauge Glasses _____ 20

- 1. C
- 2. D
- 3. A
- 4. I
- 5. G
- 6. F
- 7. H
- 8. B
- 9. E

Section 2.4 Blowdown Valves

True-False _____ 21

- 1. F
- 2. T
- 3. F
- 4. T
- 5. F
- 6. T

Multiple Choice _____ 21

- 1. D
- 2. D
- 3. B
- 4. B
- 5. D
- 6. B
- 7. A
- 8. C

Bottom Blowdown Valves _____ 22

- 1. D
- 2. A
- 3. B
- 4. C

Section 2.5 Boiler Vents

True-False _____ 23

- 1. T
- 2. F
- 3. T
- 4. F
- 5. T

Multiple Choice _____ 23

- 1. C
- 2. B
- 3. C
- 4. A
- 5. D
- 6. A
- 7. B
- 8. C

Section 2.6 Pressure Controls

True-False _____ 25

- 1. T
- 2. T
- 3. T
- 4. F
- 5. T
- 6. T
- 7. T
- 8. F
- 9. F
- 10. T

Multiple Choice _____ 25

- 1. B
- 2. C
- 3. D
- 4. B
- 5. A
- 6. B
- 7. B
- 8. D

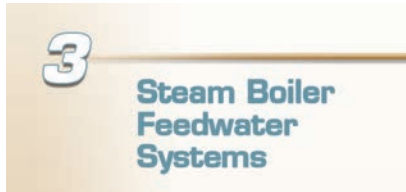
Section 2.7 Heat Exchangers

True-False _____ **27**

- 1. T
- 2. T
- 3. F
- 4. F
- 5. T
- 6. T
- 7. F
- 8. T

Multiple Choice _____ **27**

- 1. B
- 2. C
- 3. A
- 4. A
- 5. C



Section 3.1 Feedwater Accessories

True-False _____ **29**

- 1. T
- 2. T
- 3. F
- 4. T
- 5. F
- 6. T
- 7. T
- 8. T
- 9. T
- 10. F
- 11. T
- 12. T

Multiple Choice _____ **30**

- 1. C
- 2. B
- 3. D
- 4. B
- 5. B
- 6. B
- 7. A
- 8. D

Feedwater Systems _____ **31**

- 1. C
- 2. E
- 3. J
- 4. I

- 5. F
- 6. G
- 7. L
- 8. N
- 9. A
- 10. B
- 11. M
- 12. D
- 13. H
- 14. K

Feedwater Lines _____ **32**

- 1. B
- 2. D
- 3. E
- 4. A
- 5. C

Section 3.2 Makeup Water Systems

True-False _____ **33**

- 1. F
- 2. F
- 3. T
- 4. T
- 5. T

Multiple Choice _____ **33**

- 1. B
- 2. B
- 3. D

Makeup Water Systems _____ **34**

- 1. H
- 2. A
- 3. F
- 4. G
- 5. J
- 6. E
- 7. B
- 8. C
- 9. I
- 10. D

Section 3.3 Feedwater Regulators

True-False _____ **35**

- 1. T
- 2. F
- 3. F
- 4. T
- 5. T

Multiple Choice _____ **35**

- 1. C
- 2. D
- 3. A

Feedwater Control _____ **36**

- 1. A
- 2. B
- 3. F
- 4. E
- 5. C
- 6. I
- 7. D
- 8. H
- 9. G

Section 3.4 Low Water Fuel Cutoffs

True-False _____ **37**

- 1. T
- 2. F
- 3. T
- 4. T
- 5. T

Multiple Choice _____ **37**

- 1. C
- 2. B
- 3. B
- 4. C
- 5. A

Low Water Fuel Cutoff Testing _____ **38**

- 1. D
- 2. B
- 3. A
- 4. E
- 5. C

Low Water Fuel Cutoff Parts _____ **38**

- 1. B
- 2. E
- 3. A
- 4. F
- 5. C
- 6. D

Low Water Fuel Cutoff Operation _____ **38**

- 1. B
- 2. F
- 3. C
- 4. D
- 5. A
- 6. E

Section 3.5 Pumps

True-False _____ **39**

- 1. F
- 2. F

14 LOW PRESSURE BOILERS ANSWER KEY

- 3. T
- 4. T
- 5. T
- 6. F

Multiple Choice _____ 39

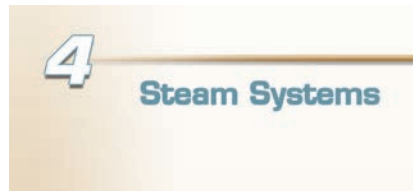
- 1. D
- 2. A
- 3. C
- 4. C
- 5. D

Vacuum Pumps _____ 40

- 1. E
- 2. F
- 3. B
- 4. G
- 5. A
- 6. D
- 7. C

Centrifugal Water Pumps _____ 40

- 1. B
- 2. F
- 3. C
- 4. E
- 5. A
- 6. D



Section 4.1 Steam Distribution

True-False _____ 41

- 1. T
- 2. F
- 3. T
- 4. T
- 5. T
- 6. F
- 7. F
- 8. T
- 9. T
- 10. T

Multiple Choice _____ 41

- 1. B
- 2. C
- 3. D
- 4. A
- 5. D
- 6. B

Main Steam Stop Valves _____ 42

- 1. D
- 2. B
- 3. E
- 4. A
- 5. G
- 6. I
- 7. F
- 8. H
- 9. C

Section 4.2 Steam Traps and Strainers

True-False _____ 43

- 1. F
- 2. T
- 3. T
- 4. F
- 5. T
- 6. F

Multiple Choice _____ 43

- 1. C
- 2. A
- 3. D
- 4. D
- 5. B
- 6. A
- 7. D
- 8. B
- 9. A
- 10. B

Steam Traps _____ 45

- 1. C
- 2. A
- 3. D
- 4. B

Steam Trap Operation _____ 45

- 1. A
- 2. B
- 3. D
- 4. C
- 5. C
- 6. A
- 7. D
- 8. B
- 9. D
- 10. B
- 11. C
- 12. A
- 13. C
- 14. A
- 15. B
- 16. D

Steam Trap Location _____ 46

- 1. F
- 2. E

- 3. H
- 4. A
- 5. K
- 6. G
- 7. J
- 8. D
- 9. I
- 10. B
- 11. C

Steam Trap Testing Devices _____ 47

- 1. C
- 2. D
- 3. B
- 4. A
- 5. E

Testing Steam Traps _____ 48

- 1. B
- 2. C
- 3. A



Section 5.1 Gas Systems

True-False _____ 49

- 1. T
- 2. T
- 3. T
- 4. F
- 5. T
- 6. T
- 7. T
- 8. F

Multiple Choice _____ 49

- 1. B
- 2. A
- 3. C
- 4. D
- 5. B

Low Pressure Gas Systems _____ 50

- 1. I
- 2. E
- 3. L
- 4. A
- 5. N
- 6. G
- 7. K
- 8. D
- 9. H
- 10. B

- 11. M
- 12. C
- 13. J
- 14. F

High Pressure Gas Systems _____ 51

- 1. L
- 2. E
- 3. I
- 4. A
- 5. M
- 6. J
- 7. D
- 8. G
- 9. B
- 10. F
- 11. K
- 12. C
- 13. H
- 14. N

Section 5.2 Fuel Oil Systems

True-False _____ 53

- 1. T
- 2. T
- 3. F
- 4. T
- 5. F
- 6. T
- 7. F
- 8. F
- 9. T
- 10. T
- 11. T
- 12. F
- 13. T
- 14. F
- 15. T
- 16. F
- 17. T
- 18. T
- 19. T
- 20. T
- 21. T
- 22. T

Multiple Choice _____ 54

- 1. D
- 2. B
- 3. B
- 4. C
- 5. A
- 6. B
- 7. C
- 8. C
- 9. B
- 10. A
- 11. D
- 12. C
- 13. D
- 14. D
- 15. B

Fuel Oil Pumps _____ 56

- 1. B
- 2. E
- 3. A
- 4. F
- 5. C
- 6. D

Fuel Oil Burners _____ 57

- 1. D
- 2. A
- 3. C
- 4. B

Fuel Oil Systems _____ 57

- 1. G
- 2. L
- 3. A
- 4. E
- 5. J
- 6. C
- 7. N
- 8. H
- 9. F
- 10. K
- 11. B
- 12. M
- 13. I
- 14. D

Fuel Oil Strainer _____ 58

- 1. A
- 2. E
- 3. B
- 4. D
- 5. C
- 6. F

Section 5.3 Combustion Controls

True-False _____ 59

- 1. T
- 2. T
- 3. F
- 4. T
- 5. F
- 6. F
- 7. T
- 8. T
- 9. T
- 10. T

Multiple Choice _____ 59

- 1. A
- 2. C
- 3. C
- 4. D
- 5. B
- 6. B
- 7. D
- 8. A
- 9. C

- 10. C
- 11. B
- 12. B
- 13. C
- 14. C
- 15. B
- 16. B
- 17. C
- 18. A
- 19. B
- 20. D
- 21. D
- 22. B
- 23. C
- 24. B
- 25. A

Modulating Control _____ 63

- 1. C
- 2. D
- 3. B
- 4. A

Flame Sensors _____ 64

- 1. C
- 2. A
- 3. D
- 4. B

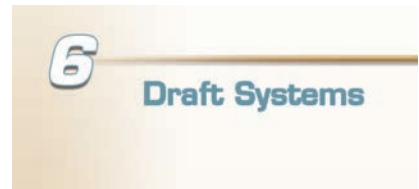
Section 5.4 Air Pollution

True-False _____ 65

- 1. T
- 2. T
- 3. F
- 4. F
- 5. F
- 6. T
- 7. F
- 8. T

Multiple Choice _____ 65

- 1. D
- 2. D
- 3. C
- 4. A
- 5. B



Section 6.1 Draft

True-False _____ 67

- 1. T
- 2. F
- 3. F

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- 4. T
- 5. T
- 6. T
- 7. F
- 8. T
- 9. T
- 10. F
- 11. T
- 12. T
- 13. F
- 14. F
- 15. T
- 16. T
- 17. T
- 18. T

Multiple Choice _____ 68

- 1. B
- 2. D
- 3. A
- 4. B
- 5. C
- 6. A
- 7. A
- 8. D
- 9. B
- 10. C

Manometer Readings _____ 69

- 1. C
- 2. A
- 3. B

Natural Draft _____ 70

- 1. E
- 2. C
- 3. A
- 4. F
- 5. B
- 6. D

Forced Draft _____ 70

- 1. F
- 2. J
- 3. A
- 4. G
- 5. I
- 6. B
- 7. H
- 8. D
- 9. E
- 10. C

Section 6.2 Draft Control

True-False _____ 71

- 1. T
- 2. T
- 3. F
- 4. F
- 5. T

Multiple Choice _____ 71

- 1. B
- 2. D
- 3. B

Draft Control _____ 72

- 1. E
- 2. B
- 3. H
- 4. G
- 5. C
- 6. F
- 7. D
- 8. A

Stacks _____ 72

- 1. B
- 2. G
- 3. D
- 4. C
- 5. F
- 6. E
- 7. A
- 8. H
- 9. I



Section 7.1 Boiler Water Conditions

True-False _____ 73

- 1. T
- 2. T
- 3. F
- 4. F
- 5. T
- 6. T
- 7. F
- 8. T
- 9. T
- 10. T
- 11. F
- 12. T
- 13. F
- 14. T
- 15. T
- 16. T
- 17. T
- 18. F

Multiple Choice _____ 74

- 1. B
- 2. C

- 3. B
- 4. B
- 5. A
- 6. A
- 7. D
- 8. D
- 9. D
- 10. D
- 11. A
- 12. B

Sludge Removal _____ 75

- 1. D
- 2. A
- 3. C
- 4. E
- 5. B

Priming and Carryover _____ 76

- 1. D
- 2. A
- 3. B
- 4. E
- 5. C

Foaming _____ 76

- 1. B
- 2. E
- 3. D
- 4. A
- 5. C

Section 7.2 Boiler Water Analysis

True-False _____ 77

- 1. T
- 2. F
- 3. T
- 4. T
- 5. T
- 6. T
- 7. T
- 8. F

Multiple Choice _____ 77

- 1. A
- 2. B
- 3. C
- 4. D
- 5. B

Water Treatment

Log Readings _____ 78

- 1. 10.9
- 2. 45
- 3. 16
- 4. 0
- 5. 2700

Section 7.3 Boiler Water Treatment

True-False _____ **79**

1. T
2. F
3. F
4. F
5. T
6. T
7. F
8. T
9. T
10. T
11. F
12. T

Multiple Choice _____ **79**

1. D
2. C
3. A
4. B
5. A
6. D
7. B
8. C

Bypass Feeders _____ **81**

1. E
2. B
3. D
4. A
5. C
6. F



Section 8.1 Taking Over a Shift

True-False _____ **83**

1. T
2. T
3. T
4. F
5. F
6. T
7. F
8. T
9. F
10. T
11. T
12. T

Multiple Choice _____ **83**

1. D
2. C

3. B
4. B
5. B
6. C
7. D
8. A
9. A
10. A

Section 8.2 Startup and Shutdown

True-False _____ **85**

1. T
2. F
3. F
4. T
5. F
6. F
7. F
8. F

Multiple Choice _____ **85**

1. B
2. D
3. A
4. A
5. A
6. D

Section 8.3 Maintenance

True-False _____ **87**

1. F
2. T
3. T
4. F
5. T
6. T
7. T
8. F
9. T
10. F
11. T
12. F
13. F
14. F
15. T
16. F
17. T
18. T

Multiple Choice _____ **87**

1. C
2. D
3. B
4. B
5. A
6. D
7. B
8. C

Section 8.4 Handling Boiler Conditions

True-False _____ **89**

1. T
2. T
3. T
4. F
5. F
6. T
7. F
8. T

Multiple Choice _____ **89**

1. D
2. C
3. A
4. C
5. C
6. B
7. C



Section 9.1 Hot Water Heating Systems

True-False _____ **91**

1. T
2. F
3. F
4. T
5. F
6. F
7. F
8. T
9. T
10. F

Multiple Choice _____ **91**

1. C
2. B
3. D
4. A

Natural-Circulation Hot Water Heating Systems _____ **92**

1. G
2. A
3. H
4. C
5. F
6. E
7. B
8. D

Forced-Circulation Hot Water Heating Systems _____ 93

- 1. K
- 2. A
- 3. Q
- 4. H
- 5. T
- 6. E
- 7. O
- 8. S
- 9. B
- 10. P
- 11. F
- 12. L
- 13. D
- 14. I
- 15. M
- 16. G
- 17. C
- 18. N
- 19. J
- 20. R

Section 9.2 Hot Water Boilers

True-False _____ 95

- 1. T
- 2. T
- 3. F
- 4. T
- 5. F
- 6. T
- 7. T
- 8. F

Multiple Choice _____ 95

- 1. B
- 2. D
- 3. C
- 4. A
- 5. B

Section 9.3 Burners and Igniters

True-False _____ 97

- 1. T
- 2. F
- 3. T
- 4. T
- 5. F

Multiple Choice _____ 97

- 1. C
- 2. A
- 3. D

Section 9.4 Hot Water Boiler Fittings

True-False _____ 99

- 1. T
- 2. F

- 3. T
- 4. T
- 5. T
- 6. T
- 7. T
- 8. F
- 9. F
- 10. F

Multiple Choice _____ 99

- 1. A
- 2. A
- 3. A
- 4. C
- 5. C
- 6. C
- 7. A
- 8. D
- 9. B
- 10. B

Hot Water Reset Controls __ 101

- 1. B
- 2. G
- 3. I
- 4. D
- 5. F
- 6. H
- 7. C
- 8. E
- 9. A

Relief Valves _____ 102

- 1. D
- 2. F
- 3. B
- 4. E
- 5. A
- 6. G
- 7. C



Section 10.1 Hot Water Boiler Accessories

True-False _____ 103

- 1. F
- 2. T
- 3. T
- 4. T
- 5. T
- 6. F
- 7. T
- 8. F
- 9. T
- 10. T

Multiple Choice _____ 103

- 1. B
- 2. D
- 3. C
- 4. B
- 5. C

Section 10.2 Hot Water System Valves

True-False _____ 105

- 1. T
- 2. F
- 3. T
- 4. F
- 5. F

Multiple Choice _____ 105

- 1. C
- 2. D
- 3. B
- 4. A
- 5. C

Section 10.3 Piping Systems

True-False _____ 107

- 1. T
- 2. F
- 3. F
- 4. T
- 5. T

Multiple Choice _____ 107

- 1. B
- 2. A
- 3. C
- 4. D
- 5. A



Section 11.1 Cooling System Principles

True-False _____ 109

- 1. T
- 2. T
- 3. T
- 4. T
- 5. T
- 6. F
- 7. F
- 8. T
- 9. F
- 10. T
- 11. F
- 12. F

Multiple Choice _____ 109

- 1. C
- 2. A
- 3. D
- 4. B
- 5. A

**Cooling System Application –
Pasteurization Process _____ 110**

- 1. D
- 2. A
- 3. C
- 4. G
- 5. F
- 6. B
- 7. E

Section 11.2 Cooling Systems

True-False _____ 111

- 1. F
- 2. T
- 3. F
- 4. T
- 5. T
- 6. F
- 7. T
- 8. T
- 9. T
- 10. F
- 11. T
- 12. T
- 13. F
- 14. T
- 15. T
- 16. F
- 17. T
- 18. T

Multiple Choice _____ 112

- 1. D
- 2. B
- 3. A
- 4. C
- 5. A
- 6. C
- 7. A
- 8. D
- 9. C
- 10. A
- 11. B
- 12. C
- 13. A
- 14. D

Refrigeration Cycle _____ 114

- 1. D
- 2. B
- 3. F
- 4. E
- 5. C
- 6. A

Centrifugal Compressors __ 115

- 1. A
- 2. E
- 3. C
- 4. D
- 5. B

**Ammonia-Water Absorption
Chiller Systems _____ 115**

- 1. G
- 2. B
- 3. C
- 4. F
- 5. D
- 6. A
- 7. E

Chilled Water Systems _____ 116

- 1. B
- 2. D
- 3. F
- 4. A
- 5. E
- 6. G
- 7. C

Section 11.3 Refrigerants

True-False _____ 117

- 1. T
- 2. F
- 3. T
- 4. F
- 5. F
- 6. T

Multiple Choice _____ 117

- 1. B
- 2. C
- 3. C
- 4. D



**Section 12.1 Regulatory
Agencies and Standards
Organizations**

True-False _____ 119

- 1. T
- 2. F
- 3. F
- 4. T

- 5. T
- 6. F
- 7. T
- 8. T

Multiple Choice _____ 119

- 1. C
- 2. C
- 3. D
- 4. A

**Section 12.2 Boiler Room
Safety Programs**

True-False _____ 121

- 1. T
- 2. T
- 3. F
- 4. T
- 5. F
- 6. T
- 7. T
- 8. F
- 9. T
- 10. T

Multiple Choice _____ 121

- 1. D
- 2. B
- 3. A
- 4. C
- 5. B

**Hazardous Material Container
Labeling – RTK Labeling _____ 122**

- 1. D
- 2. F
- 3. A
- 4. E
- 5. B
- 6. C

**Section 12.3 Personal
Protective Equipment (PPE)**

True-False _____ 123

- 1. T
- 2. F
- 3. T
- 4. F

Multiple Choice _____ 123

- 1. C
- 2. B
- 3. D
- 4. A

Section 12.4 Electrical Safety

True-False _____ 125

- 1. T
- 2. T

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- 3. F
- 4. T
- 5. F
- 6. T

Multiple Choice _____ 125

- 1. B
- 2. D

Section 12.5 General Safety Programs

True-False _____ 127

- 1. T
- 2. T
- 3. F
- 4. T
- 5. F
- 6. T
- 7. F
- 8. T

Multiple Choice _____ 127

- 1. C
- 2. A
- 3. D



Sample Exam 1

True-False _____ 129

- 1. T
- 2. F
- 3. T
- 4. F
- 5. F
- 6. T
- 7. T
- 8. F
- 9. T
- 10. T
- 11. T

Multiple Choice _____ 130

- 1. A
- 2. B
- 3. B
- 4. C
- 5. C
- 6. A
- 7. A
- 8. C
- 9. D
- 10. C

- 11. A
- 12. B
- 13. B
- 14. A
- 15. C
- 16. D
- 17. C
- 18. C
- 19. A
- 20. B
- 21. D
- 22. C
- 23. A
- 24. D
- 25. B
- 26. B
- 27. A
- 28. D
- 29. D
- 30. B
- 31. B
- 32. B
- 33. C
- 34. C
- 35. D
- 36. A
- 37. A
- 38. B
- 39. B

Sample Exam 2

True-False _____ 137

- 1. T
- 2. F
- 3. F
- 4. T
- 5. T
- 6. F
- 7. T
- 8. T
- 9. F
- 10. T

Multiple Choice _____ 137

- 1. C
- 2. D
- 3. B
- 4. C
- 5. C
- 6. B
- 7. B
- 8. A
- 9. A
- 10. C
- 11. D
- 12. D
- 13. C
- 14. B
- 15. D
- 16. B
- 17. A
- 18. A
- 19. A
- 20. B
- 21. A
- 22. C

- 23. C
- 24. A
- 25. D
- 26. B
- 27. D
- 28. A
- 29. B
- 30. B
- 31. D
- 32. B
- 33. C
- 34. D
- 35. A
- 36. B
- 37. C
- 38. A
- 39. C
- 40. C

Sample Exam 3

True-False _____ 143

- 1. F
- 2. T
- 3. T
- 4. F
- 5. T
- 6. T
- 7. F
- 8. T
- 9. T
- 10. T

Multiple Choice _____ 143

- 1. D
- 2. A
- 3. D
- 4. B
- 5. D
- 6. C
- 7. A
- 8. A
- 9. B
- 10. B
- 11. B
- 12. C
- 13. B
- 14. C
- 15. A
- 16. D
- 17. C
- 18. A
- 19. A
- 20. A
- 21. D
- 22. B
- 23. B
- 24. D
- 25. A
- 26. A
- 27. A
- 28. B
- 29. B
- 30. B
- 31. D
- 32. D

- 33. A
- 34. D
- 35. A
- 36. A
- 37. A
- 38. A
- 39. A
- 40. C

Sample Exam 4

True-False _____ **149**

- 1. T
- 2. F
- 3. F
- 4. T
- 5. T
- 6. F
- 7. T
- 8. F
- 9. F
- 10. T
- 11. F

Multiple Choice _____ **149**

- 1. B
- 2. A
- 3. C
- 4. C
- 5. A
- 6. B
- 7. C
- 8. D
- 9. A
- 10. C
- 11. D
- 12. C
- 13. B
- 14. D
- 15. A
- 16. D
- 17. C
- 18. B
- 19. C
- 20. D
- 21. B
- 22. D
- 23. D
- 24. C
- 25. D
- 26. C
- 27. C
- 28. B
- 29. A
- 30. B
- 31. D
- 32. B
- 33. D
- 34. C
- 35. C
- 36. B
- 37. C
- 38. A
- 39. C
- 40. B
- 41. A

Sample Exam 5

True-False _____ **155**

- 1. T
- 2. F
- 3. T
- 4. F
- 5. T
- 6. T
- 7. T
- 8. T
- 9. F
- 10. T
- 11. F
- 12. F

Multiple Choice _____ **155**

- 1. D
- 2. A
- 3. B
- 4. C
- 5. B
- 6. C
- 7. B
- 8. C
- 9. C
- 10. A
- 11. D
- 12. C
- 13. A
- 14. B
- 15. A
- 16. C
- 17. B
- 18. B
- 19. C
- 20. C
- 21. C
- 22. C
- 23. C
- 24. C
- 25. C
- 26. C
- 27. C
- 28. B
- 29. A
- 30. C
- 31. C
- 32. C
- 33. B
- 34. D
- 35. A
- 36. D
- 37. D
- 38. A
- 39. A

Sample Exam 6

True-False _____ **161**

- 1. T
- 2. T
- 3. F
- 4. F
- 5. T
- 6. T
- 7. T

- 8. F
- 9. T
- 10. F
- 11. F
- 12. T
- 13. F
- 14. F
- 15. T

Multiple Choice _____ **161**

- 1. B
- 2. C
- 3. C
- 4. C
- 5. C
- 6. B
- 7. B
- 8. D
- 9. B
- 10. C
- 11. D
- 12. A
- 13. B
- 14. D
- 15. A
- 16. D
- 17. C
- 18. D
- 19. C
- 20. A
- 21. D
- 22. C
- 23. A
- 24. C
- 25. B
- 26. C
- 27. D
- 28. D
- 29. A
- 30. C
- 31. B
- 32. A
- 33. B
- 34. B
- 35. C
- 36. D
- 37. A
- 38. B

Sample Exam 7

Essay _____ **167**

1. Report to work 10 to 15 minutes early. Check the water level on all the boilers on the line by blowing down the gauge glass, water column, and low water fuel cutoff. *Note:* (1) The burners should be firing when the low water fuel cutoff is blown down. This not only removes any sludge and sediment from the lines, but also shuts off the burner to ensure its proper operation. (2) When blowing down the gauge glass, the water should leave the gauge glass quickly and return quickly when the gauge glass blowdown valve is closed. This indicates that the lines are clean.

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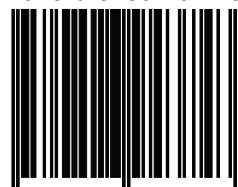
2. The different ways of getting water into a boiler are the vacuum pump, feedwater pump, automatic city water makeup feeder, and hand-operated city water makeup valve.
3. The pressure control is sensitive to pressure and controls the boiler operating range. It starts and stops the burner on steam pressure demand.
4. Safety valves are tested by hand or by pressure. The ASME code recommends that safety valves be tested at least once a month by raising the boiler pressure and causing the safety valve(s) to pop open. When testing a safety valve by hand there should be at least 5 psi of pressure before lifting the test lever. The hand test lever is lifted to fully open the safety valve and is released to allow the safety valve to snap shut. *Note:* Check with local inspectors or the mechanical inspection bureau regarding the proper testing of safety valves.
5. According to Section VI of the ASME code, safety valves on low pressure boilers should be tested by hand once every 30 days the boiler is in operation. The ASME code also recommends the testing of safety valves under pressure once a year, preferably before the start of the heating season. In addition to the ASME code, safety valves should be tested according to recommendations of the local boiler inspector.
6. The function of the low water fuel cutoff is to shut the burner off to protect the boiler heating surface from becoming overheated due to low water in the boiler.
7. The two methods of testing a low water fuel cutoff are by hand or by an evaporation test. When testing the burner by hand, the blowdown valve on the low water fuel cutoff is opened, and steam and water rushing out cause the float in the low water fuel cutoff to drop, resulting in the burner shutting off. When performing an evaporation test, the vacuum pump, feedwater pump (if the boiler has one), and the automatic city water makeup feeder must be secured. The water level will drop in the boiler and the float in the low water fuel cutoff will fall slowly, shutting the burner off. *Note:* When the burner shuts off, there must always be water still visible in the gauge glass.
8. The maximum allowable working pressure (MAWP) for a low pressure steam boiler is 15 psi. A safety valve must pop (open) whenever pressure exceeds the safety valve setting to prevent the boiler from exceeding its MAWP. Any time a safety valve pops, the boiler operator must determine the cause and take corrective action.
9. The safety valves on low pressure steam boilers are set to pop open at 15 psi.
10. Purging a furnace is the part of the firing cycle when the burner fan blows air into the furnace to remove any mixture of gases or fumes of a combustible nature that might cause a furnace explosion. The furnace is always purged before the burner lights off (prepurge) and again after the burner shuts off (postpurge).
11. The most important valve on the boiler is the safety valve. The safety valve prevents the boiler from exceeding its MAWP. If the safety valve exceeds its MAWP, a boiler explosion could result.
12. The steam boiler should be given a bottom blowdown whenever tests of the boiler water indicate high chemical concentration or high total dissolved solids. The boiler should also be blown down when a high water level develops.
13. The flame scanner can be tested in two ways. One method is to remove the scanner from its sighting tube and cover it with your hand, which should shut off the burner. The second method is to secure the fuel going to the burner to simulate a fuel failure, which should cause the scanner to shut the burner off on safety lockout.
14. There are two methods of determining the water level in a boiler. One method is to blow down the gauge glass and watch the action of the water leaving and returning to the glass. The second method is to use the three try cocks and observe what comes out of the top try cock, middle try cock, and bottom try cock when they are opened. With an NOWL, the top try cock should discharge steam, the middle try cock should discharge a mixture of water and steam, and the bottom try cock should discharge water.
15. Smoke is the result of incomplete combustion. For example, in fuel oil-burning plants, smoke could be caused by cold fuel oil, poor atomization, insufficient primary and secondary air, a dirty burner, or fuel oil impinging on the brickwork.
16. The two types of draft used in boilers are natural draft and mechanical draft. Mechanical draft can be further classified as forced draft, induced draft, or combination forced and induced draft.
17. The check valve on a feedwater line prevents water from leaving the boiler when the vacuum pump or boiler feedwater pump stops. A check valve controls the flow of feedwater in one direction only.
18. The stop valve is located on a feedwater line as close to the shell of the boiler as practical between the boiler and the check valve. The stop valve is required in the event the check valve malfunctions (sticks open or closed). The stop valve could then be secured (closed) and the check valve repaired without having to dump the boiler.
19. The safety valve popping and steam pressure of 30 psi would indicate malfunction of the safety valve(s). The procedure to follow would be to: (1) Secure the burner. (2) Allow steam pressure to drop to approximately 15 psi. (3) Use the safety valve test lever to test the safety valve(s) by hand. (4) If the safety valve(s) pop open and reset at the proper blowback, raise the steam pressure to see if the safety valve(s) popped by pressure. (5) If the safety valve(s) popped by pressure, determine why the pressure control did not function properly. *Note:* The boiler in question should not be left unattended. A new boiler should be warmed up and cut in on the line if there is one available. If this is the only boiler in the plant, it must be attended 24 hours a day until it can be taken off-line and given a complete safety check.
20. Perfect combustion is the burning of all the fuel using the theoretical amount of air. Perfect combustion can only be achieved in a laboratory setting. Complete combustion is the burning of all the fuel using the minimum amount of excess air. Incomplete combustion is when all the fuel is not burned, resulting in soot and smoke.
21. Furnace explosions are caused by a buildup of highly combustible gases or fumes that ignite when exposed to a spark, pilot flame, or radiant brickwork. In addition, furnace explosions can result from improper purging of the furnace after a flame failure, a leaking fuel valve allowing fuel to enter the furnace, or the operator bypassing safety interlocks in order to light the burner faster after a fuel interruption.
22. Before a boiler can be inspected, it must be taken off-line. Once a boiler is off-line, the following safety checks must be made: (1) The main steam stop valve(s) (some boilers have two) must be closed, locked out, and tagged out. To tag out a valve means to mark it so it will not be opened by mistake. Some plants attach a sign to the valve wheel that reads "Danger! Personnel in boiler—do not open." (2) The boiler vent or top try cock should be checked to see that it is open. This ensures there is no vacuum inside. (3) The feedwater line to the boiler must be closed, locked out, and tagged out. If there is an automatic city water makeup valve, it must be secured also.

23. A gauge glass should be blown down once a shift or whenever the operator questions the level of water in the boiler.
24. In a forced-circulation system, the system is closed to the atmosphere and water is forced (circulated) through the heating system using circulating pumps. In a natural-circulation system, the system is open to the atmosphere. It works on the principle that water when heated increases in volume (expands) and becomes less dense. The warmer water rises and cold, denser water flows back into the bottom of the boiler.
25. In order to do a hydrostatic test on a boiler, the boiler must be completely filled with water. To perform a hydrostatic test, the following operations must be carried out: (1) If the water column has a whistle valve, it must be removed and plugged. (2) The main steam stop valve must be closed. (3) The safety valve(s) must be removed and blank flanges installed, or the safety valves must be gagged. (A gag is a clamp that prevents the valve from popping open without damaging the valve.) (4) The boiler vent must remain open until water comes out and then is closed. (5) Pressure on the boiler is brought up to $1\frac{1}{2}$ times the MAWP. (The pressure must be under control so that it does not exceed this pressure by more than 10 pounds.)
26. NOWL stands for "normal operating water level." In a steam boiler, the NOWL is approximately one-third to one-half a gauge glass.
27. MAWP stands for "maximum allowable working pressure" of a boiler. The MAWP of a given boiler is determined by the ASME code.
28. Carryover can be caused by (1) carrying too high a water level, (2) high boiler water surface tension, and (3) opening the boiler main steam stop valve too quickly.
29. Natural draft is created by the height of the stack and the difference in temperature of the gases of combustion in the stack and the air outside the stack. Mechanical draft is caused by a fan.
30. A feedwater pump becomes steam-bound when the temperature of the water in the open feedwater heater gets too hot and water in the suction line going to the feedwater pump flashes into steam.
31. A fast gauge is a pressure gauge that reads more steam pressure than is actually present in the boiler. A slow gauge is a pressure gauge that reads less steam pressure than is actually present in the boiler.
32. Foaming is caused by impurities in the boiler water. A surface blowdown is used to remove impurities in the boiler water that cause foaming.
33. An open gate valve offers no restriction to the flow of the material passing through it. A gate valve must always be fully open or fully closed. A globe valve has material flowing under a valve seat and has some resistance to flow. A globe valve is used for throttling (varying the rate of flow) service by partly opening or closing.
34. In a watertube boiler, water passes through tubes that are surrounded by gases of combustion. In a firetube boiler, gases of combustion pass through tubes that are surrounded by water.
35. A water column must be located at the NOWL so that the lowest visible part of the gauge glass is a minimum of 1" above the highest heating surface. The top line to the water column is connected to the highest part of the steam side of the boiler. The bottom line to the water column is connected approximately 6" below the center line of a firetube boiler.
36. The best time to give a steam boiler a bottom blowdown is when the boiler is at its lightest load. This allows sludge and sediment to fall to the bottom.
37. The function of a boiler vent is to: (1) vent air from the boiler when filling it with water, (2) vent air from the boiler when warming up prior to cutting in on the line, and (3) prevent a vacuum from forming in the boiler when taking the boiler off-line.
38. The high and low fire of the burner are controlled by the modulating pressure control through the modulating motor.
39. An os&y valve is open when its stem is visible in the up position.
40. The purpose of a vacuum pump is to help return the condensate back to the vacuum tank. At the vacuum tank, air is vented to the atmosphere, and water is pumped directly back to the boiler or a condensate return tank.
41. The automatic city water makeup feeder is a safety device that ensures that the boiler will have water if the vacuum pump fails or condensate is lost in the system. For maximum protection and safety, the automatic city water makeup feeder should be blown down daily to ensure its proper operation in an emergency.
42. The steam traps most commonly used are the nonreturn type. This type includes thermostatic, inverted bucket, and float thermostatic.
43. The two methods most commonly used to test the proper function of steam traps are strap-on thermometers and temperature-indicating crayons.
44. Fuel oil strainers should be cleaned daily and whenever unusually high suction readings occur when fuel oil is at its proper temperature.
45. Two types of fuel oil burners commonly used in low pressure plants are rotary cup burners and air atomizing burners.
46. The advantage of using a combination burner is plant flexibility. The operator can burn the fuel that is cheapest, change from one fuel to another if problems occur, and keep the plant operating if there is a shortage of a fuel.
47. Air used in the combustion process is broadly classified as primary, secondary, and excess air. Primary air controls the combustion rate, which determines the amount of fuel burned. Secondary air controls combustion efficiency by controlling how completely the fuel is burned. Excess air is supplied to the burner above the theoretical amount required to burn the fuel.
48. A flame safeguard system is burner control equipment that monitors the burner start-up sequence and the main flame during normal operation. The flame safeguard programmer sequences burner function in a set order including prepurge, ignition trials, pilot flame-establishing period, main burner flame-establishing period, run period, and postpurge.
49. Hydrostatic pressure is pressure caused by the weight of water (approximately 0.433 psi per vertical foot). Hydrostatic pressure can affect a steam pressure gauge reading depending on the distance from the steam boiler connection. Hydrostatic pressure must also be considered when sizing circulating pumps for hot water heating systems in multiple-story buildings.
50. Three types of heat transfer that occur in a boiler are conduction, convection, and radiation. Conduction is heat transfer that occurs when molecules in a material are heated and the heat is passed from molecule to molecule through the material. Convection is heat transfer that occurs when currents circulate between warm and cool regions of a fluid. Radiation is heat transfer that occurs as radiant energy (electromagnetic waves) without a material carrier.
51. A backflow preventer is a boiler accessory that prevents the flow of water back to the potable water supply. A backflow preventer is located on the makeup water supply line and functions like a check valve to allow water flow in one direction only.
52. Expansion bends are sometimes required on steam lines to allow for the expansion and contraction which occurs from temperature variation. Without proper

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- expansion bends, damage to piping may occur from movement in steam lines.
53. An evaporation test is a test performed to ensure proper operation of a low water fuel cutoff. During an evaporation test, a low water condition is simulated by securing all water fed to the boiler. The boiler water level is then gradually lowered and the low water fuel cutoff should shut off the burner. Because a low water condition is created, an evaporation test must only be performed under the close supervision of authorized personnel.
54. A boiler room log is a record of information pertaining to the operation of a boiler during a given period of time. Maintaining a boiler room log allows evaluation of boiler performance history such as steam pressure generated, water treatment, water levels, fuel consumption, and condensate returns. Boiler room log information can be used to determine the cause of a malfunction or help prevent a future problem.
55. An aquastat is a hot water boiler fitting that measures the water temperature in the boiler and controls the temperature by starting and stopping the burner. An aquastat functions like a switch using a boiler water temperature setpoint to turn the burner ON or OFF.
56. A compressor is a mechanical device in a cooling system that compresses refrigerant vapor. It is similar to a pump that circulates the refrigerant in the system. The suction side of a compressor creates low pressure by pulling the refrigerant vapor through the refrigerant line. The low pressure vapor then enters the suction line to the compressor. The discharge side of a compressor creates high pressure. The refrigerant vapor leaving the compressor is at a higher temperature and pressure than the vapor that entered.
57. A confined space is a space large enough and so configured that an employee can physically enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. To ensure employee safety, each facility must have specific confined space procedures to comply with OSHA standards in the Code of Federal Regulations. Depending on the confined space and task, a confined space permit may be required. A confined space permit is a document that details requirements such as lock out, personal protective equipment, and ventilation requirements. An entry permit must be posted at confined space entrances before entering a permit-required confined space.
58. A boiler operator license is obtained by meeting the requirements established by the specific jurisdiction in which the boiler is operated. These requirements include passing a boiler operator licensing examination. The licensing jurisdiction can be a state, county, city, or other authority that has specific grades of licensing examinations for different sizes of boilers and related equipment. Some jurisdictions require experience in the field prior to taking a licensing examination. For specific requirements, the licensing jurisdiction should be contacted directly.
59. Wear the proper hand and eye protection. Close the gauge glass steam and water valves and open the gauge glass drain valve. Tighten the leaking gauge glass nut one flat of the nut and test for leaks. Repeat procedure until the leak stops or the nut cannot be turned any more. If the leak cannot be fixed in this manner, the gauge glass needs to be isolated so the gauge glass washers can be replaced with new ones. If the gauge glass shows any wear, the gauge glass will also need to be replaced.
60. The main steam stop valve should be opened slowly when the boiler pressure is a few pounds per square inch less than the header pressure. The valve should be opened fully and then closed a half turn to prevent the valve from seizing up from the expansion of the valve body as it is heated.
61. This is a dangerous low water condition. Secure the fuel to the boiler and secure the pump. Allow the boiler to cool and open the boiler for internal inspection by a qualified inspector. Determine the reason the feedwater pump did not have water supplied to it and remedy the problem. Inspect the feedwater pump to determine if there was any damage to the pump and repair as needed.
62. A boiler that has been off-line for several days should have been completely filled with treated water to prevent corrosion. Open the boiler bottom blowdown valve(s) to decrease the boiler's water level to slightly below the normal operating water level (NOWL). The water will expand as the water in the boiler heats up, raising the level of the water to the NOWL.

ISBN 978-0-8269-4374-3



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