# Lesson 4

# Operation and Maintenance

## Lesson Goal and Objectives

### *Goal*

To familiarize you with normal boiler operation and maintenance, including system controls and safety practices.

### *Objectives*

Upon completing this lesson, you should be able to—

1. recognize the use of water columns, fusible plugs, and steam gauges in a boiler,
2. briefly describe the operation of a boiler feedwater regulator,
3. recognize soot blowers and describe their operation,
4. recognize two safety devices used to control the flow of water and steam in a boiler and to detect the presence of flames in burners, and
5. briefly describe the reason for and use of blowdown in a boiler.

## Introduction

The automatic controls used on boilers will depend on the size of the boiler, the fuel that is fired, the operating pressures, and the steam requirements from the boiler. Because the operating and maintenance procedures will be unique for each boiler, it is essential that it be operated accordingly to assure continuous, safe, and efficient operation.

## Controls and Instruments

Controls used on a boiler will provide for safe and efficient operation. A number of variables are measured including steam pressure and flow, furnace pressure and draft, feedwater flow, air flow, fuel supply and feed rate, and flue gas composition ($CO$, $O_2$, and $CO_2$). Many of these variables are also automatically controlled to keep the boiler operating. Most controls consist of a few basic components (TPC Training Systems, 1975):

- *primary element* that senses and responds to cycle changes, such as a drop in steam pressure or too low water level.
- *error detector* that measures and compares an output signal to a set point. This is usually considered to be the actual controller.

- *relaying element* that converts the controller's signal and transmits the signal to control points.
- *power units* that receive the control impulses and then activate a device such as a damper, or close or open a valve, or feed more fuel to the boiler.

## *Water Glasses and Columns*

Maintaining the proper water level of a boiler protects it from overheating and allows it to be adjusted for varying changes in steam demands. Some small boilers have gauge glass, or water gauges, mounted directly on the front of the boiler shell that visually show the water level. Most boilers use water columns to indicate water level. Water columns are small vessels, or tubes, connected to the boiler drum, to which gauge glasses are attached (Figure 4-1). Water columns can be located on the boiler so that they can be easily inspected and maintained. Water columns have a blowdown valve and line. Water is drained during blowdown to remove the scale and dirt that accumulate on the viewing glass. Scale and dirt could cause the water level readings to be off.

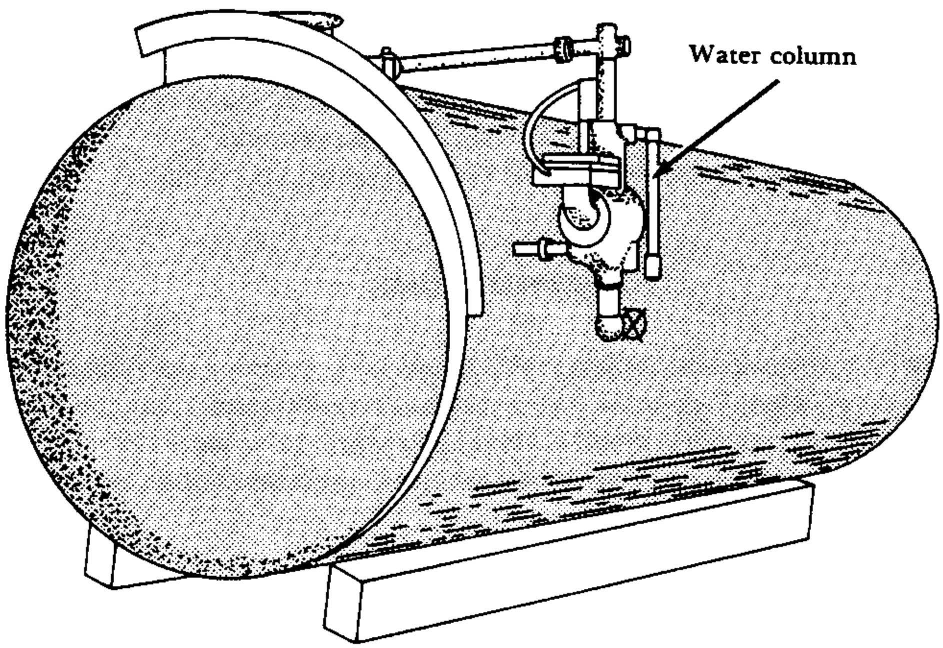



**Figure 4-1. Water column on a horizontal return-tube boiler.**

A simple gauge glass is suitable for boilers operating at pressures below 400 psi. It is a small glass tube fitted with valves at the top and bottom, so that steam and water flows will be shut off if the glass breaks. The gauge glass used on boilers with pressures from 400 to 2000 psi consists of flat glass strips backed with pieces of mica. The mica separate the glass from high-temperature steam and water. A bicolor glass gauge is used on boilers operating with high pressures, 1000 psi to 3000 psi. It operates on the optical principle that light beams bend differently when they pass through water or steam. The illuminated gauge contains a green glass and a red glass sandwiched together. The green glass detects water and the red glass detects steam. The water level is where the two colors appear to meet. If water is in the glass gauge, red light will be bent out of the field of vision and green light will appear. If steam is in the glass gauge, green light will be bent out of the field of vision and red light will appear.

In a fire-tube boiler, the water level must be at least 3 inches above the top row of tubes. In a water-tube boiler, it must be adequate enough to assure that all of the tubes contain water or steam to prevent them from overheating. Overheating in both fire-tube and water-tube boilers could burst the tubes and cause a possible explosion.

Many boilers use alarms to signal when the water level is not adequate. High water alarms signal when the water level is too high and low level alarms signal when the water level is too low.

## *Fusible Plugs*

Fusible plugs are used to sound alarms when the water level in a boiler is low. These are brass or bronze and contain a tapered hole. In an ordinary plug, the hole is filled with tin which has a melting temperature of approximately 450°F. One side of the fuse plug is exposed to hot gases, the other side to water. The water carries the heat away from the plug side exposed to the hot gases. If the water level drops below the plug, the heat will melt the tin and blow it out of the core. This causes a pressure-activated alarm to sound, warning the boiler operator that the water level is low.

Once set off, fusible plugs must be replaced. This can be done by taking the boiler out of service. However, many boilers use fusible plugs installed in a pipe connected to a valve (Figure 4-2). When the fuse blows, the valve can be shut and another fuse inserted without taking the boiler out of service. Fusible plugs should be inspected frequently to check for scale and dirt buildup on the water side and soot deposits on the fire side. These deposits will cause the plug to malfunction.

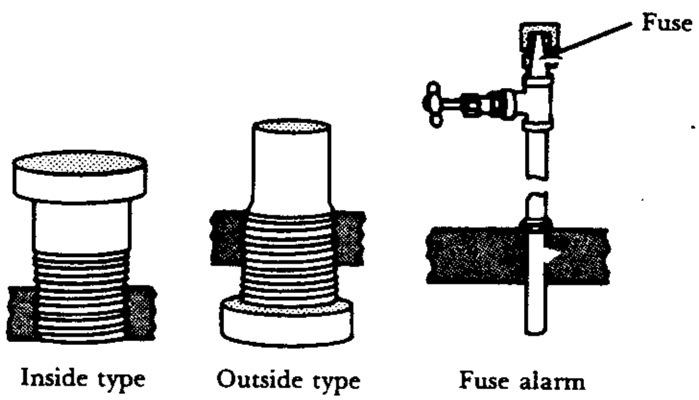



**Figure 4-2. Fusible plugs and fuse alarm.**

## *Presure Gauges*

Pressure gauges are used to measure steam and water pressure in steam drums, feed-water heaters, steam headers, and other boiler equipment. Pressure gauges are the Bourdon tube, manometer, diaphram, and bellows.

The Bourdon tube is the most common gauge used on a boiler. It consists of a curved tube that is sealed at one end (Figure 4-3). The sealed end is connected to a pointer by linkage. The open end of the gauge is the pressure connection. As pressure increases in the tube, the tube straightens out, moving the pointer. As the pressure decreases the tube returns to the normal curved position. Bourdon pressure gauges can measure pressures of steam, air, oil, water, or other fluids. These gauges require careful handling and proper maintenance to keep them operating accurately. They should be removed from their mountings, disassembled and cleaned with a suitable solution regularly.

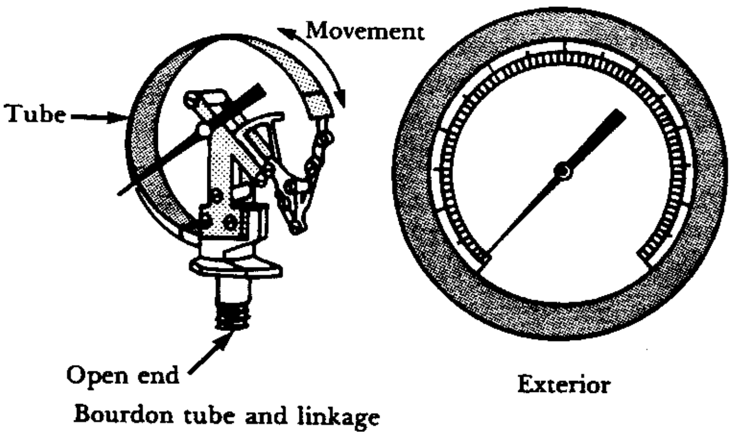



**Figure 4-3. Typical Bourdon pressure gauge.**

Steam gauges for a small boiler are usually mounted on top of the water column. The gauge will directly read the pressure of the boiler. In many boilers, gauges will be mounted on pipes that run from the steam drum to ground level, so that they can easily be read by the operator. At this level, the gauge reads the steam pressure plus the hydraulic head of water in the line. The true steam pressure is the value read on the gauge minus the hydraulic head. For each foot of vertical distance between the connection at the drum and the ground level, the gauge reading must be corrected by subtracting a value of 0.433 psi per foot of head. Gauges can also be mounted above the point of pressure measurement. In this case the pressure due to the hydraulic head must be added to the gauge reading.

Manometers are commonly used to measure low air pressures and pressure differences between two points. Two manometers are the single leg and U-tube. A single leg manometer is a glass tube filled with water or mercury. The top of the tube is open to the atmosphere and the pressure that is measured enters an opening in the well (Figure 4-4a). If the pressure is greater than atmospheric, the fluid in the tube will rise. If the pressure is below atmospheric, the fluid in the tube falls. A U-tube manometer, shown in Figure 4-4b, has two legs filled with water or mercury. When both legs of the manometer are exposed to the same pressure, the manometer shows a zero reading. If there is a difference in pressure in the legs, the liquid level will rise in one leg and fall in the other. A scale beside the tube for either a single leg or a U-tube manometer indicates pressure in inches of mercury or water, depending on the type of fluid used.

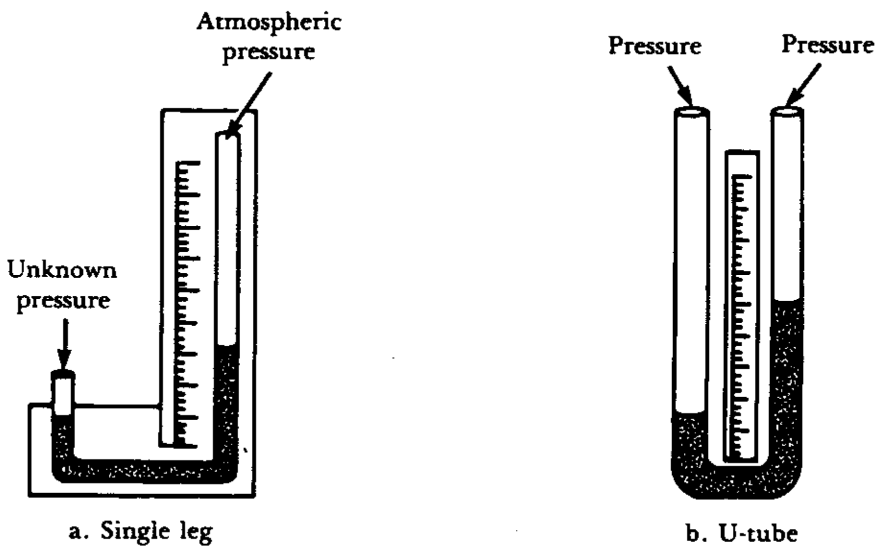



**Figure 4-4. Manometers.**

Manometers are useful in determining if the boiler is operating efficiently. Occasionally, tube sections become coated with heavy deposits of soot or slag that can cause a resistance to the flue gas flow. By using manometers, pressure drops across various boiler components can be detected and appropriate maintenance initiated.

Manometers must be checked regularly to ensure they are free of dirt and dust and that they have the correct amount of liquid in the tubes. All connections should be tight.

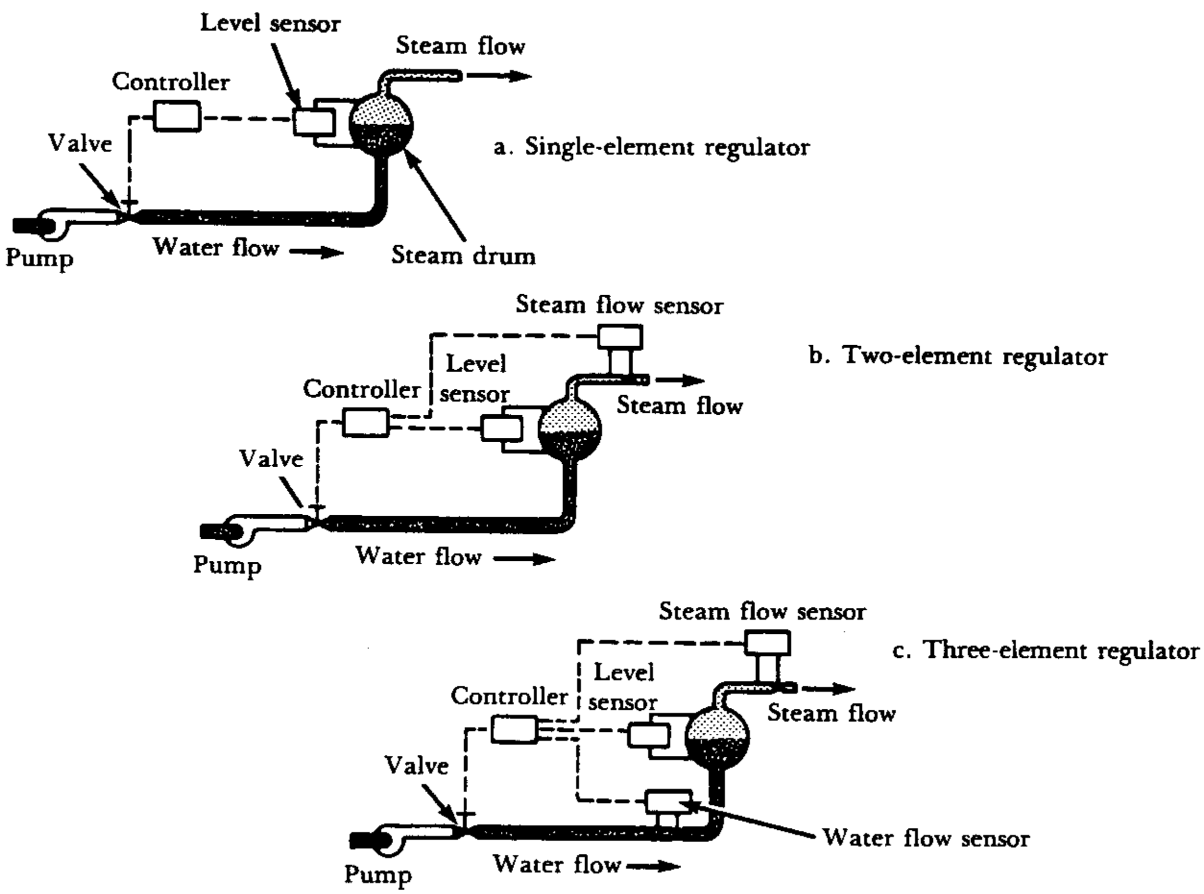
## *Feedwater Regulators*

Feedwater regulators automatically control the water supply. Feedwater regulators reduce the risk of low or high water levels, increasing the safety of boiler operation. Three basic designs for feedwater regulators are the single-element, two-element, and three-element (Figure 4-5).

Small boilers, having infrequent changes in boiler load use single-element regulators (Figure 4-5a). These respond only to a change in water level. If the level of water is inadequate, the sensor sends a signal to the controller. The controller then opens or closes a valve to increase or decrease waterflow. Single-element regulators cannot compensate for water "swells" or shrinkage that occur as the firing rate in the boiler changes. When the firing rate increases, the water in the drum swells because steam bubbles form below the water surface. When the firing rate decreases, the water volume in the drum decreases because the number of steam bubbles and their size decreases. Thus, these regulators are not used on boilers that have rapid changes in firing rates.

A two-element regulator is shown in Figure 4-5b. This regulator responds to changes in water level in the steam drum and to the steam flow from the boiler. A steam flow sensor measures the flow of steam, sending a signal to the controller as the flow of steam changes. The controller then changes the position of the feedwater valve to increase or decrease water flow to the drum. If the water level changes after the drum pressure becomes stable, the controller changes the feedwater valve to restore the proper water level. This regulator thus uses the steam flow to prevent underfeeding and overfeeding of water to the boiler drum and uses the water level sensor to finally adjust the correct water level.

A three-element regulator (Figure 4-5c) responds to changes in the water level, steam flow, and water flow. The three-element regulator maintains the correct water level in the drum by adjusting the feedwater flow to correspond to the changes of steam flow from the boiler. When the boiler load varies, the steam and water flows change immediately. Three-element regulators handle swells and shrinkage better than do two-element regulators and are used on boilers with wide and sudden load changes.




Source: TPC Training Systems.

**Figure 4-5. Feedwater regulators.**

## *Steam Headers*

Steam is transported to processes or turbines through pipes or headers. Headers are cylindrical vessels from which steam is withdrawn as the demand changes. Headers are constructed to withstand internal shock and pressure because high velocity steam passes through them. Headers can also be used in superheaters and in water walls to allow steam or water to move through the boiler circulatory system.

Steam headers are insulated and provided with drains and traps to remove any water that condenses in and to prevent condensing water from entering pumps, engines, or turbines. Main steam headers are connected to branch steam lines from each boiler. This system makes it possible to use one boiler or a combination of boilers to supply steam for various industrial processes and/or turbines.

## *Safety Devices*

### Valves

Boilers are designed to operate at certain maximum pressures. If the operating pressure is exceeded, the boiler may explode. Therefore, all boilers are equipped with at least one or more safety valves. Safety valves will open, releasing steam if the pressure in the drum becomes too high.

In a safety valve, a compressed spring holds a disc snuggly against a seat (Figure 4-6). When the pressure against the disk exceeds a preset limit, the safety valve pops open—causing the disk to move away from the seat. The pressure at which the valve opens can be changed by adjusting the compression spring. When a safety valve opens, it discharges, or blows, steam until the pressure of the boiler decreases to a preset amount. The valve then shuts back into its normal seating arrangement. The pressure difference between the popping pressure and the closing pressure is called *blowback.* The valve must be properly adjusted for sufficient blowback or the valve will leak slightly after popping. Blowback can be adjusted by raising or lowering a ring around the valve seat. Safety valves can also be popped manually by using hand levers. For large boilers, each superheater and reheater will have one or more safety valves. The safety valves are located near the outlets of these tube sections.

If a boiler has several valves, they are set to pop at different pressures. The first valve should open when the pressure exceeds a value approximately 3 to 5% above the boiler operating pressure. The other valves will open at pressures slightly above the first valve, usually 10 to 15 psi (TPC Training Systems).

Safety valves should be checked on a regular basis to make sure that they operate properly. They should be maintained to prevent an accumulation of scale or dirt that would interfere with safe operation.

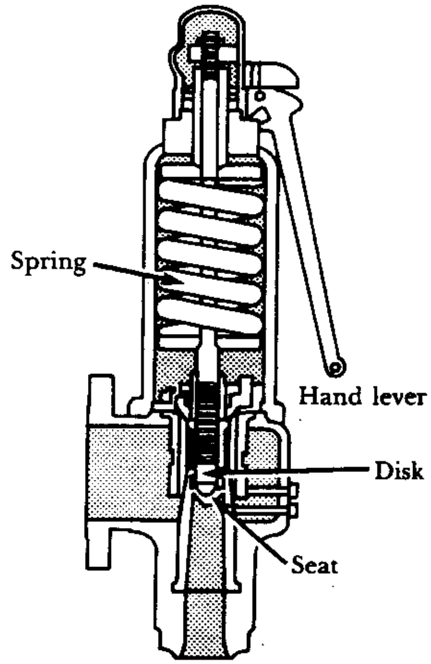



**Figure 4-6. Safety valve.**

## Flame Detectors

Flame detectors, or scanners, monitor burner flames on all boilers and ignitors on coal- and oil-fired boilers. If the flame in a burner or ignitor goes out, a flame detector sends a signal to the fuel feed controls that automatically stop the flow of fuel into the boiler. Thus, the boiler is prevented from operating or igniting while explosive conditions in the furnace exist.

Three flame detectors used on boilers are photocell, ultraviolet, and infrared detectors. Photocells detect visible light, ultraviolet sensors detect ultraviolet light, and infrared sensors detect infrared light in the burner flame or ignitor. These devices are installed in the furnace wall as shown in Figure 4-7.

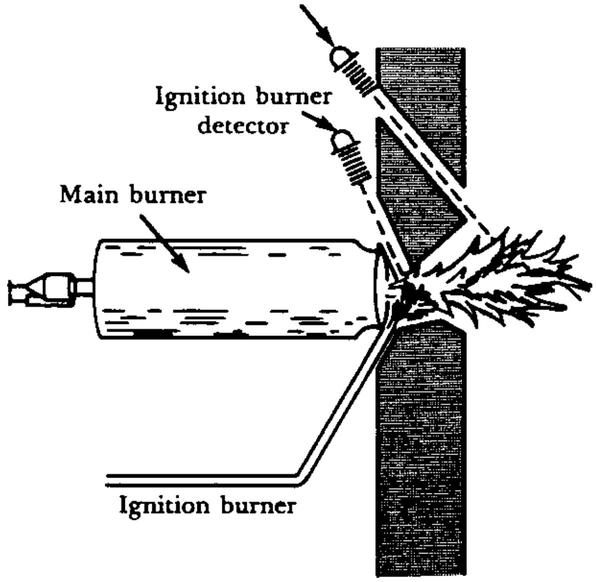



**Figure 4-7. Location of flame detectors.**

## *Combustion Controls*

Combustion controls are used to adjust the amount of air and fuel supplied to the furnace to respond to the changes in boiler steam pressure. Three combustion controls are on-off, positioning, and metering.

On-off controls, the simplest, are used on fire-tube and small water-tube boilers. A change in steam pressure activates a pressurestat or mercury switch to start the stoker, the oil burner, or gas burner and the forced-draft fan. The on-off control system supplies a pre-determined amount of fuel and air. The air and fuel ratio can be altered, if necessary, by manually adjusting fuel and air settings on the controls. When the steam pressure builds up again, the controls shut down the fuel and air supplies. On-off controls cannot supply a steady steam pressure because they work on a cyclic basis. The pressure points are set far enough apart to prevent the on-off sequence from being constantly activated. Combustion efficiency is low because the control system can only vary the length of the on and off cycles.

Positioning controls, used on many boilers, are more flexible and can provide better combustion efficiency than can on-off controls. These controls operate on a continuous basis, providing smoother changes in fuel and air feed, allowing the boiler to maintain a more uniform steam pressure. The control system has a master pressure controller that responds to a change in steam pressure. When the steam pressure changes, power units actuate the damper on the forced-draft fan to control air flow and position the fuel valve to regulate the fuel feed. Furnace-draft controllers operate independently of the positioning controls to maintain the furnace draft. Positioning controls operate effectively on boilers having relatively stable steam demands. The amount of air and fuel feed can be adjusted manually to change the air-to-fuel ratio. These adjustments are required to compensate for boiler load changes, dirty tube surfaces, slagging of fuel on furnace walls, or changes in barometric pressure.

Metering controls are a refinement of positioning controls. As with positioning controls, metering controls also have a master pressure controller that responds to a change in steam pressure. However, the metering control system measures the actual flow of fuel and air. The flow of steam or water is measured to correspond to the amount of fuel fed into the furnace. This can be accomplished by measuring the pressure drop across an orifice, flow nozzle, or venturi. The draft loss across the clean-air side of the combustion air preheater is measured to indicate the air flow through the boiler. The metering controls change the damper and fuel valve positions to maintain the correct air-to-fuel ratio. Metering controls are generally located in a remote station where they can be operated automatically or manually. These control systems allow the boiler to be operated efficiently for wide changes in boiler loads. They can also compensate for changes in the fuel supply and for dirt buildup on the tube surfaces.

# Operation

The procedure for operating a boiler will depend on the boiler size, the type of combustion equipment used, the operating pressure of the unit, and the steam requirements. The boiler manufacturer should supply the operator with specific instructions as to how to bring the unit on line, general operating practices, emergencies, and caring for idle boilers.

## *Bringing the Boiler on Line*

A specific startup procedure should be followed to prevent the boiler from being damaged. The boiler should be inspected thoroughly after it is installed to make sure that all manhole and access covers have been replaced and that all scaffolding, ladders, tools, and other equipment have been removed from the inside and outside of the boiler. Fans, dampers, and combustion equipment should be checked for proper operation.

New boilers and those that have accumulated oil and grease must be cleaned with an alkaline solution. The solution is first prepared and then pumped into all boiler tube sections. The boiler is slowly brought on line to approximately one-third of its normal working pressure and left on line for one to three days. In addition to being cleaned with an alkaline solution, large boilers are also cleaned out with an acid solution. After the cleaning cycle is finished, the boilers are flushed out with water. New boilers are then given a hydrostatic test before placing them into service. This test consists of filling the boiler with water and slowly building up to 1½ times the normal working pressure. During the test, all safety valves are removed or blocked off so they will not open.

All boiler valves, vents, drains, and the feedwater regulators should then be checked according to the manufacturers operating procedures. The boiler is then slowly brought on line while the draft gauges are checked and the fans and dampers are adjusted to establish the correct air flow to and from the boiler. The feedwater regulator is operated and the water level and feedwater-supply pressure are carefully checked. The furnace is slowly fired to prevent excessive temperature differences and resulting unequal expansion of boiler components. Combustion is regulated to bring the boiler up to full operating pressure, usually in approximately 45 minutes for small- and medium-sized boilers and approximately two to three hours for large boilers.

## *Normal Operation*

Operating a boiler is a continuous process. Fuel and air are supplied to produce steam, while waste products of ash and flue gas are discharged. The boiler operator must adjust the flow of these materials to maintain the correct steam pressure. On boilers that do not have automatic controls, the operator must watch the steam gauge and adjust the fuel as is necessary. On automatically-controlled boilers, the change in steam pressure will adjust the fuel feed. However, the operator will still have to check the bed thickness in a coal-fired stoker, and monitor the shape of the flame when pulverized coal, gas, or oil is burned. He will also have to check draft gauges, flue gas analyzers, pressure gauges, thermocouples, damper settings, and ash removal systems and make any necessary adjustments. Instruments and controls should be checked, adjusted, calibrated, and kept in good operating condition.

High combustion efficiency can be achieved by monitoring the flue gas with continuous emission monitors. By measuring the oxygen or carbon dioxide in the flue gas, adjustments for the correct amount of excess air can be made. Too much excess air wastes heat out through the stack. Too little excess air causes a high concentration of combustibles to remain in the ash and smoke and unburned fuel to be discharged from the stack. The operator can use analyzers and draft gauge readings to help keep combustion efficiency high.

The operator will also have to perform certain maintenance functions to keep the boiler operating smoothly. Some of these, such as blowdown and sootblowing, must be done on a regular eight-hour shift basis. Others must be done on a regularly-scheduled basis. Boiler maintenance will be discussed later in the lesson.

## *Emergencies*

Occasionally, emergencies occur and the boiler must be taken off line. An emergency shut-down procedure must be established and all operators should be familiar with it to ensure a safe shut down.

Many boilers are equipped with automatic controls that activate in the event of burner flame out or low water level. Fuel valves automatically close and the boiler is shut down until the difficulty has been corrected. In many large boilers, alarms sound for high and low water levels and the operator must then decide on the appropriate action to be taken.

If the water level becomes low, the operator should make sure that feedwater is added to the boiler. If for some reason the feedwater regulator does not work, the fuel and air feed to the boiler should be stopped. The procedure will depend on the combustion equipment used on the boiler.

Failure in fuel supply, too much primary air, or a disturbance because of improper sootblowing, may cause the flame to blow out in a pulverized-coal-, gas-, or oil-fired boiler. The flame detector will stop the fuel flow to the burner. Fans should be operated to remove combustible fuel and gases from the furnace. Once the corrective action has been completed, fans should be operated for a short time to ensure that no combustibles are present.

Forced-draft and induced-draft fans can fail, safety valves become stuck, and occasionally fires in pulverizers can occur making an emergency shut down imperative. The boiler must be shut down to prevent an explosion from occurring. All plant operators must be ready to initiate safe emergency operating procedures.

### *Care for Idle Boilers*

Boilers must be taken off line for occasional inspection and repairs. Some boilers are only used on a periodic basis to provide heat or steam during colder seasons. When a coal-fired boiler is taken out of service for extended time periods, the coal in the bunkers should be used up before shutting the boiler down. Coal stored for long time periods can be a fire hazard.

The normal procedure for removing boilers from service involves reducing the fuel feed and slowly decreasing the steam pressure. All drain connections should be opened and the feedwater valve should be closed. The boiler should be allowed to cool down slowly to prevent injury because of rapid contraction of metal and refractory materials. All tube sections should be washed out to remove any sludge deposits. Boilers that will be out of service for short time periods can be filled up with an alkaline solution and deaerated water. This will allow the boiler to be ready to be brought back on line, after it is quickly drained and filled with water. Boilers taken out of service for extended time periods should be flushed with water and permitted to thoroughly dry. Containers of unslaked lime or dessicant are then placed in the boiler to absorb any moisture from the air in the confined space. Boilers prepared for storage in these two ways can be returned to service by restoring the water level and bringing the unit on line by the normal startup procedure.

## Maintenance

All boilers operate more efficiently when they are properly maintained. Maintenance schedules vary depending on the boiler component and its location. Boiler tube sections, boiler drums, and heat recovery equipment must be kept free of soot and scale to provide good heat transfer and adequate cooling to tube surfaces. Boiler auxiliary systems such as pumps, fans, valves, and motors must be maintained to operate properly. Boiler manufacturers should provide guidelines to the suggested maintenance schedules and procedures.

## *Sootblowing*

Sootblowing removes soot and ash from the fire-side of boiler tubes and heat recovery equipment. These deposits insulate tube surfaces reducing boiler efficiency. They can also erode and corrode metal surfaces, particularly if fly ash is sharp and contains sulfates and acids. The amount of soot and ash deposited on tube surfaces depends on the content and fusion temperature of the ash in the coal burned, and the combustion efficiency in the furnace. A large amount of ash is produced from burning coal; burning oil produces less, while burning gas produces almost no ash. Hand lances and sootblowers remove soot and ash (slag) from tube surfaces by blasting jets of air or steam against the tubes, while the furnace is on-line. Most large boilers use sootblowers, the two common types being rotary and retractable.

In a rotary sootblower, air or steam flows through a tube, or arm, and discharges at a very high speed through nozzles. The nozzles are spaced to blow steam or air directly into each boiler tube as the arm rotates. In a retractable sootblower, the blower is located outside the furnace. The blower moves in and out of the furnace and can reach far inside a boiler to clean superheaters, reheaters, and economizers.

Sootblowing is done at least once a day and occasionally more often. The time between sootblowings depends on the type of fuel burned and how quickly the tube sections become dirty. An increase in the flue gas temperature exiting the boiler or an increase in pressure drop across the tube sections are good indicators that tubes are dirty. If tubes quickly become dirty again after sootblowing, the operator should check the air-to-fuel ratio. There may be too little air to burn the fuel completely, thus forming soot.

When a boiler is down for service, boiler tubes can be cleaned by washing them with water. Hard slag deposits can be removed by carefully chipping them off with a chisel.

## *Water Treatment*

Boiler feedwater must be treated before it can be used. Suspended solids, dissolved minerals, and dissolved gases can cause corrosion and scale in boiler tubes and affect the quality of steam produced.

Minerals dissolve in water as ions that carry an electrical charge. The ions increase the electrical conductivity and hardness of the water, both of which can damage boiler tubes. Increased electrical conductivity rapidly corrodes metal surfaces. High levels of hardness in the water cause scale and sludge to form on tube surfaces. Boiler feedwater can be treated by softening methods.

Water hardness results when mineral salts of magnesium and calcium dissolve in water. These salts can be removed by using chemical softeners or ion exchangers. Chemical softeners are vessels where soda ash or lime react with dissolved salts to form solid precipitates. The solids settle in the bottom of the vessel while softened water passes through a filter to remove only remaining solids. Ion exchangers are vessels containing a thick bed of grainy material called resins. Hard water flows through the bed where the resin absorbs the hard ions and replaces them with harmless ions. When the resin bed no longer absorbs hardness ions, the bed is regenerated with a strong salt solution to replenish its supply of harmless ions. Another ion exchange process, called demineralization, uses two ion exchange beds, one containing acid, the other containing a caustic soda solution. These systems are designed to produce very pure water.

The measure of the concentration of hydrogen ions in water is called pH. It has a numerical value on a scale of 0 to 14. A pH of less than 7 indicates acidic water and a pH of greater than 7 indicates alkaline water. Boiler feedwater should have a pH of 8.5 to 11.5. Water with low pH values can corrode boiler tubes. Water from lakes and streams that is used in many boilers has a pH ranging from 6.0 to 8.0. The pH of this water may be raised by adding chemicals such as ammonia, phosphates, or caustic soda to boiler feedwater.

Dissolved oxygen in feedwater eats away at the metal, weakening boiler tubes, drums, and piping. One way to remove dissolved oxygen is by using a deaerating heater. Many deaerating heaters consist of trays stacked inside a vessel. Water enters the top of the vessel and flows down through the trays. Steam heats the water as it flows through the vessel causing most of the dissolved oxygen to leave the heater with the steam. Heated, deaerated water is sent to a storage tank where chemicals such as sodium sulfite or hydrazine are added to remove any oxygen still remaining in the water.

Evaporators are also used to remove dissolved impurities from water. An evaporator consists of a steam coil in a tank. Water is fed into the tank and heat, supplied by the steam coil, causes the water to boil. Water leaves the evaporator as a vapor leaving the impurities behind. The vapor enters a heat exchanger where it condenses as pure, distilled water. The sludge left in the evaporator is removed from the bottom.

Boiler feedwater is constantly tested to determine its purity. Impurity tests include checks on dissolved oxygen, silica content, hardness, pH, and conductivity. These tests can be done manually or by using automatic monitoring devices. Even small amounts of impurities in the water can damage boiler equipment and reduce efficiency.

### *Blowdown*

As a boiler generates steam, any impurities in the water become concentrated in the boiler water. As these concentrations increase, they can cause corrosion, scale, or possibly boiler tube failure. A procedure called blowdown reduces the impurity levels (solids) in boiler or cooling water. Blowdown consists of removing water containing a high level of impurities and replacing it with high quality water. Blowdown can be done on a periodic or continuous basis.

In periodic blowdown, a main blowdown, or blowoff, valve is opened allowing water to drain out of the system. This is usually done when the steam demand is low. Most boilers have the blowoff valve connected to the lower, or mud, drum, In cooling towers, blowdown involves opening a blowoff valve that is located in the basin on the tower.

In continuous blowdown, a small amount of water from a boiler or cooling tower is constantly removed. Continuous blowdown valves are usually located in the steam drum. Makeup water that replaces the blowdown water is fed to the drum by the feedwater regulator. Blowdown water is sent to heat exchangers to extract useful heat before disposing of it. Heat, from the blowdown water in a heat exchanger, is transferred to makeup water before it enters the economizer.

Water is tested regularly to determine the level of dissolved solids and, thus, the frequency of blowdown. Conductivity meters that measure the electrical conductivity of the boiler water are used to determine blowdown frequency.

### *Scale Removal*

Scale forms on the inside of tubes in a water-tube boiler and on the outside of tubes in fire-tube boilers. Scale insulates tubes, reducing heat transfer and thus efficiency. As the heat transfer decreases, the metal tubes become hotter. If the temperature becomes too high, the tubes can overheat and eventually rupture, or burst.

Scale formation can be reduced by using water softeners, demineralizers, and evaporators. These devices remove most of the materials that cause scale. However, not all of the minerals are always removed and scale deposits will form in boiler tubes. Scale deposits should be removed as soon as possible. Scale can be removed by internal cleaning while the boiler is on line or by mechanical or acid cleaning when the boiler is down.

For internal cleaning, chemicals such as phosphates are added to boiler water. Phosphate salts react with scale to form sludge. Sludge is removed during blowdown. Mechanical cleaners remove scale from boiler tubes when the boiler is shut down. Mechanical cleaners are power-driven units that contain a cleaning head, a hose, and a motor driven by steam, air, or water. The cleaning head for removing scale from a fire-tube boiler is called a knocker and is shown in Figure 4-8a. The knocker head has lobes that tap the inside of the tube as the cleaner moves through the tube. Mechanical cleaner heads used on water-tube boilers are called cutter heads. The cutter head has several cutting elements made of hard steel (Figure 4-8b). The head is rotated at high speed, pressing the cutter against the tube to remove the scale.

Acid cleaning can also remove scale from boiler tubes and drums. The cleaning solutions consist of acids, such as hydrochloric acid, and other materials called inhibitors to reduce the attack of acid on the metal. The cleaning solutions circulate or soak in the boiler for a few hours. When the cleaning cycle is complete, the boiler is flushed with alkaline and water solutions to remove any traces of acid. Acid cleaning has some advantages over mechanical cleaning in that it requires much less down time to clean the boiler, and it can clean areas and tubes where mechanical cleaners are difficult to reach.

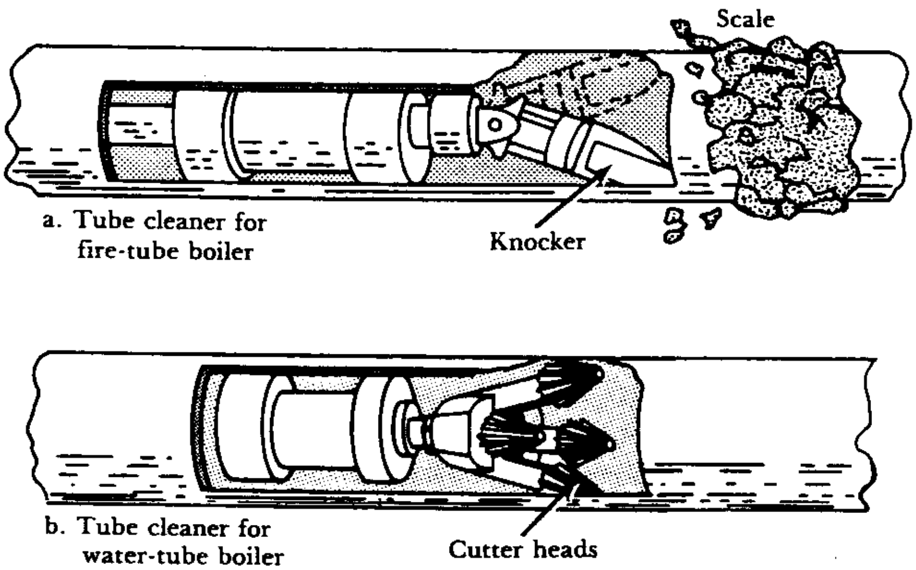



**Figure 4-8. Cleaning heads for fire-tube and water-tube boilers.**

### *Boiler Auxiliaries*

Pumps, valves, safety valves, controls, compressors, and fans are among the many boiler auxiliaries that must be maintained regularly. Pumps require lubrication to keep the bearings from overheating, rusting, or corroding. Pumps can leak around the packing gland. The packing can be tightened somewhat to help stop leaks. Valves should be checked for correct operation and leaks. Valves tend to leak around the valve stems and packing and may need to be repacked occasionally. All moving parts on a valve should be lubricated. Compressors must be lubricated to protect cylinders from heat and wear. If the compressor has its own lubricating system, the oil level should be checked daily, and the oil changed when dirty. Intake filters must be checked and replaced when they become filled with dust. Water jackets and intercoolers should be inspected to make sure they do not become plugged. Fan blades need to be inspected for excessive wear when they are out of service. Dust deposits in the fan housing and ducts should be removed. Dampers should be moved manually to make sure they move freely and close completely. The bearing oil resevoir level should be checked and oil added if necessary.

These are a few of the maintenance functions that must be performed to keep the boiler operating smoothly. The maintenance crew should have a checklist and logsheet for each boiler component. Inspection frequencies and preventive maintenance practices should be established for all boiler equipment by the vendors.

## Summary

This lesson briefly reviewed boiler operation and maintenance. Boilers can be complicated systems and operators and maintenance persons should be properly trained on all aspects of the boiler equipment that they will be operating or maintaining.

## Review Exercise

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| 1. Most boilers use ________ to indicate the water level. | |
| 2. ________ are used to sound alarms when the water level in a boiler is low.<br>a. Gauge glasses<br>b. Water columns<br>c. Fusible plugs | 1. water columns |
| 3. True or False? Bourdon pressure gauges can measure pressures of steam, air, oil, and water. | 2. c. Fusible plugs |
| 4. ________ are commonly used to measure air flow pressures and pressure differences between two points.<br>a. Bourdon gauges<br>b. Manometers<br>c. Fusible water columns | 3. True |
| 5. Feedwater regulators are automatic controls that<br>a. regulate the amount of water that is sent to the cooling tower.<br>b. adjust the water level in the boiler.<br>c. adjust the water level in the condenser. | 4. b. Manometers |
| 6. A three-element feedwater regulator responds to changes in<br>a. water level, water flow, and steam flow.<br>b. air flow, water flow, and water level.<br>c. steam level, water flow, and air flow. | 5. b. adjust the water level in the boiler. |
| 7. In a boiler, headers are used to<br>a. collect condensed steam.<br>b. release steam if the pressure becomes too high.<br>c. transport water and steam. | 6. a. water level, water flow, and steam flow. |
| 8. All boilers are equipped with ________ that are used to release steam if the ________ in the boiler becomes too high.<br>a. blowdown valves, water temperature<br>b. safety valves, pressure<br>c. steam traps, pressure<br>d. all of the above | 7. c. transport water and steam. |
| | 8. b. safety valves, pressure |

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| 9. In a safety valve, the pressure difference between the popping pressure and closing pressure is called __________.<br>a. blowdown<br>b. pressure drop<br>c. blowback | |
| 10. Most boilers use flame detectors to<br>a. detect and adjust the length of the flame.<br>b. detect the presence of a flame and thus prevent the boiler from operating or igniting while explosive conditions in the furnace exist.<br>c. measure and adjust the flame profile, thus ensuring complete combustion conditions. | 9. c. blowback |
| 11. Boilers are cleaned with __________ to remove accumulated oil and grease before bringing them on-line.<br>a. alkaline solutions<br>b. alkaline solutions and acid solutions<br>c. alkaline solutions, acid solutions, and water | 10. b. detect the presence of a flame and thus prevent the boiler from operating or igniting while explosive conditions in the furnace exist. |
| 12. Ash and dust that deposit on the outside surface of boiler tubes can be removed while the boiler is on-line by __________.<br>a. sootblowing<br>b. blowdown<br>c. knocker heads<br>d. all of the above | 11. c. alkaline solutions, acid solutions, and water |
| 13. Sootblowers remove ash and soot from boiler tube surfaces by<br>a. scraping boiler tubes with wire brushes.<br>b. blasting jets of alkaline solution against the tubes.<br>c. blasting jets of air or steam against the tubes. | 12. a. sootblowing |
| | 13. c. blasting jets of air or steam against the tubes. |

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| 14. If the flue gas temperature at the stack exit ________ or the pressure drop across tube sections ________ it is likely that boiler tubes are dirty and sootblowing should be initiated.<br>a. decreases, increases<br>b. increases, decreases<br>c. decreases, decreases<br>d. increases, increases | |
| 15. True or False? Water hardness results when mineral salts of magnesium and calcium dissolve in water. | 14. d. increases, increases |
| 16. What should be the pH of boiler feedwater?<br>a. 5.0 to 7.0<br>b. 8.5 to 11.5<br>c. 11.5 to 14.0 | 15. True. |
| 17. Hardness can be removed from water by<br>a. adding lime or soda ash to the water.<br>b. using ion exchangers.<br>c. using demineralizers.<br>d. all of the above | 16. b. 8.5 to 11.5 |
| 18. True or False? Boiler feedwater should contain a high concentration of dissolved oxygen. | 17. d. all of the above |
| 19. A procedure called ________ reduces the impurity levels (solids) in boiler water and cooling water by periodically removing water from the boiler or cooling tower.<br>a. sootblowing<br>b. deaerating<br>c. blowdown | 18. False. |
| 20. Scale can be removed from boiler tubes by using mechanical cleaners. ________ are used for cleaning fire tubes, while ________ are used for cleaning water tubes.<br>a. Blowdown valves, retractable sootblowers<br>b. Cutter heads, knocker heads<br>c. Knocker heads, cutter heads | 19. c. blowdown |
| | 20. c. Knocker heads, cutter heads |

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