Boiler Operation Maintenance & Safety Study Guide

for MTAA Boiler Operator Trainee □ Certification

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MTAA Boiler Operator Trainee Certification Study Guide

Boiler Design and Construction

A boiler is a closed vessel in which water is heated, steam is generated, superheated or any combination thereof under pressure or vacuum by the direct application of heat.

Boiler Classifications

Boilers are classified by their pressure capacity, their design type and by their use.

High & Low Pressure Boilers –
The **M.A.W.P** or Maximum Allowable Working Pressure is the highest amount of pressure that the vessel is designed to withstand. Pressure is measured in terms of pounds per square inch or **psi**. **Psig** (gauge) indicates gauge pressure, which ignores the atmospheric pressure. **Psia** (absolute) is the sum of gauge pressure plus the atmospheric pressure at that location, which varies based on altitude. A **compound gauge** measures indicates pressure and vacuum.

- **Low-pressure boilers** are designed to withstand a maximum of 15 psig steam or a M.A.W.P. 160 psig water.
- **High-pressure boilers** are designed to withstand pressures above 15 psig steam and / or 160 psig water.

Boiler Design Types
- A **firetube boiler** has fire or gases of combustion in the tubes, and water surrounding the tubes. Types of firetube boilers include: **firebox, Scotch marine, vertical, horizontal return tube (HRT) and locomotive**.
  - The firebox and horizontal return tube (HRT) boilers have a furnace (firebox) separate from the pressure vessel
  - The Scotch marine and vertical type have the furnace contained within the pressure vessel.
- **Water-tube boilers** have water running through the tubes and fire or gases of combustion surrounding the tubes. The watertubes are connected into a steam drum at the top and a mud drum at the bottom. The fire is in the **combustion chamber**.

The boiler design can also be identified by the shape of the tube configuration, with the common types being called A, O, and D style boilers.

The **cast iron sectional boiler** is neither firetube nor watertube though it has some operating characteristics of a watertube boiler. The water is inside the sections and the fire is outside the sections. Cast iron sectionals used for steam heating may have distinct operating problems that are not typically found in other boiler types, such as the intolerance for poor water chemistry.

Boiler Use
- A boiler may be classified as either a **steam boiler** or **hot water boiler**. The vessels are the same and the **boiler trim** (controls & piping) determine the use of the vessel. A steam boiler must maintain a water level covering the top of the heating (tube) surfaces while leaving room for steam production. A hot water boiler is completely full of water over the top of the boiler into the expansion tank.

Draft

Air and fuel flow into the furnace or combustion chamber, where they are mixed and ignited.

Air and fuel flow into the furnace and flue gas flows out. The force driving this flow is the differential pressure between the gases inside the furnace and those outside the furnace. Furnace pressure is commonly referred to as **draft** or **draft pressure**. The draft is maintained slightly negative to prevent the combustion products and ash from being discharged from the furnace into surrounding areas through inspection ports, doors, feeders, etc. For greatest efficiency, the controlled pressure should be as close as possible to atmosphere, thereby minimizing the ingestion of "tramp air" or excess air drawn through the openings in the furnace ductwork that cool combustion gases.

Draft is the difference in pressure between two points that causes air or gases to flow.

A **natural draft** furnace uses the **stack** (chimney) effect. Gases inside the stack are less dense than those outside the chimney. The gases in the stack will rise, creating a vacuum (suction) which will draw the combustion air into the furnace and combustion gases or flue gas out of the furnace. Natural draft furnaces naturally operate below atmospheric pressure.

An **induced draft** fan draws the gases through the furnace and the combustion air into the furnace. An induced draft fan is located between the boiler and the stack and makes high stacks unnecessary. Control is accomplished by regulating the fan speed or damper operation. An induced draft furnace is operated slightly below atmospheric pressure.

A **forced draft** furnace uses a fan or blower to force combustion air through the system. Control is accomplished by regulating the fan speed or damper operation. This type of furnace is operated slightly above atmospheric pressure.

Boiler Design Safety

- The ends of the furnace are protected by **refractory material**, which refracts (reflects) heat away from the metal such as the boiler doors.
- The boiler is subjected to the pressures developed by the heating process and must be protected from over-pressurization to prevent failure or explosion. Boilers contain safety valves and relief valves as the primary means of preventing overp-ressurization.
- Boiler pressure vessel design and construction is done in accordance with the **American Society of Mechanical Engineers (ASME)** Pressure Vessel Construction Code. Installation, repair, and alteration are specified by the **National Board Inspection Code (NBIC)**. The **National Fire Protection Association (NFPA)** codes are also used in part for specification of electrical and piping installation as well as combustion safety.

Thermodynamics: the Study of Heat

Heat & Temperature

Heat is the amount of energy contained in a material; **temperature** is the intensity of that energy. **Sensible heat** is the heat that can be felt and can be measured by an ordinary thermometer. **Latent heat** cannot be measured with a thermometer. Often called hidden heat, latent heat causes the material to change state (i.e. liquid to vapor) rather than change temperature. The sum of sensible heat and latent heat is called **total heat**, often referred to as **enthalpy**. **Superheat** is heat added to a vapor or a gas, after a change of state, above its saturation temperature.

Heat is measured in Btus or calories; temperature is measured in degrees (Fahrenheit or Celsius). A **Btu** or *British thermal unit* is defined as the amount of heat necessary to change the temperature of one pound of water by one degree Fahrenheit. The Btu is used to rate heating and cooling system capacity. A **calorie** is the metric version of the Btu. One calorie is the amount of heat necessary to raise the temperature of one gram of water by one degree Celsius (centigrade).

The **steam table** is a chart that shows the amount of heat carried by a pound of steam at various pressures.

Laws of Thermodynamics

The **First Law of Thermodynamics** states that heat, which is a form of energy, cannot be created nor destroyed. Energy can be changed in form (mechanical, thermal, electrical, chemical) and moved, but it cannot be created nor destroyed.

The **Second Law of Thermodynamics** states that heat always moves from a warmer material to a colder material. Heat moves from a warmer place to a cooler place by the following methods:

- **Conduction** is the transfer of heat from molecule to molecule by contact.
- **Convection** is the movement of heat by use of a medium such as air or water.
- **Radiation** is heat transfer by waves that are absorbed by solid objects.

Temperature difference between two materials may be referred to as "**T.D**." or "**Delta T**". If there is T.D., there will be heat transfer. If there is no T.D., there will be no transfer.

Heat Transfer & Change in State of Matter

Matter can commonly be found in the states of solid, liquid, and vapor. The amount of heat in the material determines its state.

- **Evaporation** transfers heat by changing the state of the medium from liquid to vapor.
- **Condensation** transfers heat by changing the state of material from vapor to liquid.

Water is **saturated** (ready to change state) at approximately 212°F at sea level during normal atmospheric conditions (14.7 psia). The **boiling point** increases as the pressure increases and decreases as the pressure decreases.

The **Specific Heat (S.H.)** of a material is the amount of heat necessary to change the temperature of one pound of that material by one degree Fahrenheit. Specific Heat varies by the material, and also by the state of the material. For example, the S.H. of water is 1, the S.H. of ice is .50, and the S.H. of steam is .48.

Heat transfer is affected by the:

- The material's Specific Heat. The lower the S.H. of a material, the faster the heat transfer.
- The temperature of the material. The greater the "T.D." or "Delta T", the faster the heat transfer.
- The amount of surface area. Increase surfaced area speeds heat transfer.
- The time allowed for the heat to transfer. The more time allowed the more heat transfer that occurs.

Heat Value of Fuels

Different fuels have different heating values.

- Natural gas contains approximately 1000 Btu per cubic foot
- Liquefied Petroleum (LP) gas averages 2500 Btu per cubic foot
- **Number 2 fuel oil** has about 141,000 Btu per gallon, and **number 6 fuel oil** has almost 156,000 Btu per gallon on average. The higher the fuel number, the higher the heating value.
- Coal has approximately 12,000 Btu per pound, but differs by coal type.

Application of Thermodynamics in Boilers

- The burner flame radiates heat to all heat exchange surfaces in direct sight of the flame
- Heat passes through the steel heating surface by conduction
- The heat is transferred into the water by convection
- Evaporation transfers useful heat into the steam to do the work

Combustion

Combustion Process

Combustion is the rapid oxidation of fuel accompanied by the production of heat and/or heat and light. In order for combustion to occur, three things must be present: fuel, oxygen, and a source of ignition. In a boiler, combustion occurs in the **combustion chamber**.

Perfect combustion, also called **Stoichiometric combustion**, can occur only with precisely using the correct and minimal amounts of air and fuel. This can happen only in a laboratory environment. **Complete combustion** needs excess air to ensure enough air for good combustion, which is the goal in the boiler process. **Incomplete combustion** occurs when there is insufficient air, leaving unburned fuel as part of the flue gases.

Complete combustion depends on the **3 T's of Combustion**: time, temperature and turbulence (mixture and atomization of fuel).

Air in Combustion

The air we breathe is 79% nitrogen (N_2) and 20.9% oxygen (O_2). Nitrogen is not a combustible nor does is support combustion. Oxygen is not a combustible, but it greatly enhances the combustion of most fuels. We mix air in with the burner fuel in order to create better combustion.

- **Excess air** is the additional air required above the amount needed for perfect combustion.
- **Primary air** is air mixed to the fuel before ignition
- **Secondary air** is air added to the combustion process to ensure complete combustion. Secondary air is added after ignition. Excess air is always part of secondary air.
- **Total air** is the sum of primary air, secondary air and excess air.
- **Dilution air** is the air necessary to move the flue gases (gases of combustion) up the stack. Dilution air is added near the boiler breeching by the barometric damper. On smaller burners a draft hood may be used to attach the vent (stack), allowing air to be pulled in around the base of the stack.

In an **atmospheric burner**, primary air is added by use of a venturi in the gas line and secondary air is brought in by atmospheric pressure around the burner. A **power burner** uses a fan to supply both primary and secondary air.

For complete combustion:

- Approximately 1,600 to 2,000 cubic feet of air is required to burn 1 gallon of #2 fuel oil at 80% efficiency.
- About 15 cubic feet of air (3 cubic feet) is the theoretical amount required to burn one cubic foot of natural gas, resulting in an efficiency of no more than 75%. Typical burners will use between 10 and 15 cubic feet of air per cubic foot of gas.

A **purge cycle** is used to remove any unburned gases from the furnace.

By-products of Combustion

When a carbon/hydrogen fuel (such as gas or oil) is completely burned, the common by-products are heat, light, carbon dioxide (CO_2), water vapor (H_20), oxygen (O_2), nitrogen (N_2), and often sulfur dioxide (SO_x) and nitric oxide (NO_x).

If incomplete combustion occurs as a result of insufficient oxygen, **carbon monoxide** (CO) and smoke may also be by-products. Carbon monoxide is deadly as it displaces oxygen. The NFPA fuel gas/oil code requires a minimum of one square inch of outdoor opening in the boiler room wall for each 4,000 Btu of boiler burner input. This number increases if the opening is not directly to the outdoors.

Boiler Burners and Burner Controls

Boiler Controls are designed to control the activity within a boiler while ensuring safe and efficient operation. Boiler controls are characterized as "waterside" or "fireside". **Waterside Controls** determine pressure, control temperatures and water level. **Fireside Controls** include burner control, flame detection, fuel temperature, and fuel pressure.

Gas is burned with either **high pressure** or **low pressure burners**. Fuel Oil is delivered for burning by using an **atomization burner** or a **rotary cup burner**. A Rotary Cup Burner atomizes fuel oil using a spinning cup and high velocity air. A **Steam Atomizing Burner** uses either air or steam to vaporize the liquid fuel oil. **A Pressure Atomizing Burner** compensates for load change by increasing or decreasing delivery pressure.

Number 2 oil is ignited by **spark ignition**. Numbers 5 and 6 oils are typically ignited by a gas (LP or natural) **pilot burner**. Oil must be vaporized before it will burn. Heavy oils (Nos. 5 and 6) must be heated in order to pump them from the tank to the burner.

Combustion Control Systems regulates furnace fuel and air ratio within limits for continuous combustion and stable flame throughout the demand operating limits of the boiler and includes draft control.

The **fuel valve** maintains the fuel flow and the **air damper** maintains the air flow. The **jackshaft** is a shaft that drives the air damper and fuel valve on a power burner. The air damper and fuel valve are mechanically linked and the jackshaft simultaneously moves both to maintain the desired system pressure or temperature. A **Parallel control system** has one actuator for the fuel valve and one actuator for the air damper.

A steam boiler is controlled by a pressure control (commonly called a **pressuretrol**), while a hot water boiler is controlled by a temperature switch called an **aquastat**.

Boiler burners can be designed to operate the burner and steam production as an **'on-off' system**, which simply turns the burner on and off as load (demand) changes; or as a **modulating system**, which increases or decreases the burner firing rate as the load changes.

The boiler burner **primary control** is the device that safely manages the burner operation. Sometimes called the **programmer** or **burner management system**, the primary control allows fuel to flow only when all of the safe conditions for fuel ignition are met.

The sequence of burner operation does not allow fuel to flow unless all controls and safety devices agree that the burner can safely operate. Called '**permissives**', the safety controls include the **low water fuel cut-out (LWCO)**, the burner fan, high pressure or high temperature cut-out, fuel valves, gas pressure switches, etc. If all the permissives agree, the fuel valves will open as directed by the burner control. If any one of the permissives is not satisfied, fuel cannot flow, as the permissives are wired in a series circuit.

The **flame safeguard system** 'proves' flame in order to safely allow fuel to flow to the burner. There are five types of flame detectors when used with combustion heating equipment. They are:

1. CAD Cell (Cadmium Sulfide) the photocell changes resistance as cadmium sulfide is responsive to light
2. Infrared (IR) Light is sensitive to the infrared radiation emitted by the combustion of fuels such as natural gas, oil and coal.
3. Photocell sensors that detect visible light
4. Ultraviolet (UV) Light sensors that detect ultraviolet radiation emitted from all flames
5. Flame Rod is a sensor that has the ability to use a small amount of current, which is conducted by and through the flame.

The **double block** and **bleed gas train** uses redundant safety shut-off gas valves (blocking valves) to provide a positive method of preventing gas flow to the burner. Between the two safety shut-offs, a bleed valve allows any gas in the line to safely flow out of the building.

Boiler Operation and Maintenance

Maintenance Basics

The **boiler operator** is responsible for operating and maintaining the boiler in a safe and efficient manner through the use of sound engineering practices and manufacturer's specified maintenance procedures. Most boiler accidents are caused by operator error and poor maintenance.

The **Chief Engineer** of a boiler plant holds the responsibility for directing boiler operations, procedures and maintenance. The information used by the Chief Engineer comes from manufacturer's recommendations, the ASME and NBIC codes, and generally accepted maintenance practices.

Log sheets are a paper record of boiler operation and maintenance, and should be used in all boiler rooms to help ensure safe operation. A log sheet will specify the task to be performed, such as blowing down the low water cut-out (LWCO), and the operator can then mark the sheet to show that this operation was completed.

General Boiler Operations include:

- **Startup** - Cold iron start up and new plant start up. Most furnace explosions occur during start up and when switching fuels, so always follow the manufacturer's guidelines.
- **Operation & General Maintenance** – requires proper training, equipment familiarity and routine maintenance procedures
- **Shutdown** – Whether for a short time or long time, different procedures exist. If the boiler is to be placed out of service for an extended period of time, proper lay-up procedures are required and must be followed.

Normal Operating Water Level

The most important task in boiler maintenance is maintaining the **normal operating water level (NOWL)** in the boiler. A low water condition is the most common cause of boiler failure. The first thing a boiler operator should do when entering the boiler room or taking over boiler operation is to check the NOWL.

An **automatic boiler feedwater regulator** is designed to maintain the proper water level in the boiler. A **low water alarm** in the system is designed to alert the boiler operator of a low water level. In the event of a low water alarm, secure the fire first before adding water to the boiler.

The **gage glass** (sight glass) is a tube that indicates the water level in the boiler. It is installed either directly on the boiler or on the water column. It is connected at the top into the steam section of the boiler and at the bottom into the water section, thus showing the true boiler water level. The water level in the gage glass is tested by opening and then closing the gauge glass blowdown valve.

In addition to the gage glass, some boilers also have **try-cocks** installed to indicate the water level. The three try-cocks (which are drain valves) are placed on the water column at various levels. If the boiler water level is at the NOWL, the bottom try-cock will vent water, the middle try-cock will vent water/steam, and the top try-cock will vent steam.

Blowdowns

Boiler blowdown is removal of water from the boiler. It is done in order to remove the amount of solids in the water, and is performed as either bottom (sludge) blowdown, or continuous (surface) blowdown. The blowdown frequency and duration is primarily determined by the boiler water analysis. The water quality will vary greatly based on boiler type and size, amount of condensate return, and boiler water treatment program.

Inspections

A boiler **internal inspection** is performed to allow the boiler inspection a view of all internal surfaces, i.e. tubes, shell, drum, welds, refractory, etc. The boiler is taken off line, cooled, drained, opened and cleaned in preparation for the internal boiler inspection. All hand holes and manholes are opened, and the low water cut-outs are opened and cleaned.

An **external inspection** can be performed by

- Viewing the outside of the boiler while operating
- Viewing the outside of the boiler while shut down but not open
- Hydrostatic inspection or Operational inspection which is performed while the boiler is on line. This is a water-pressure test of new installations and repaired boilers.

A **handhole** provides access to the waterside of the firetube boiler for inspection.

Boiler trim, Valves, Fittings, and Controls

Boiler trim is the controls and fittings used to operate the boiler. The trim determines whether the pressure vessel is used for steam or hot water production. Trim includes devices such as the low water cut-out, the gage glass (sometimes called the sight glass), the pressure gauge, etc.

Valves

The **safety valve** (also referred to a relief valve, pop-off valve, or safety relief valve) provides protection to the pressure vessel from over pressurization and is the primary safety control on all boilers. Safety valves are designed and installed in accordance with ASME and NBIC code. They must be of sufficient size (capacity) to keep the boiler from developing more steam pressure than the valve can relieve, and must be set at or below the boiler MAWP (Maximum Allowable Working Pressure). Valve pressure settings cannot be changed by plant personnel, but must be calibrated by a certified repair facility. There should be no shut off valves between the boiler and the pop-off valve. Boilers with more than 500 sq ft. of heating surface require two or more safety valves.

Safety valves are spring loaded valves and should be regularly tested by the boiler operator on duty, unless plant policy states otherwise. Testing a safety (relief) valve is performed by simply lifting the test lever on the side of the valve. This test is done while the boiler is operating at between 75% and 100% of its operating pressure. Prior to the test, determine that the valve discharge is piped to a safe place.

A **gate valve** is an isolation valve, and is used only for the purpose of stopping or allowing flow. Gate valves are used as steam stop valves, blowdown valves, etc. Gate valves should always be fully open or completely closed, never in-between.

An **Outside Stem and Yoke or OS&Y valve** is a gate valve designed for boiler room service. The stem and yoke are outside the valve body. A rising stem valve allows the boiler operator to know the position of the valve by looking at the stem. If the stem is extended (up or out) the valve is open. In an open position, the valve provides no resistance to the flow of steam. If the stem is down or in, the valve is closed. These valves are typically seen in steam lines.

A **globe valve** is a modulation valve, not an isolation valve. A globe valve disrupts the flow of the fluid, even in the fully open position.

A **check valve** allows flow in one direction only. These are often seen in feedwater lines between the pumps and the boiler.

When opening any manual valve, the boiler operator should open the valve slowly in order to prevent water hammer.

Low Water Fuel Cut-Out (LWCO)

The **LWCO** is designed to protect the boiler from a low-water condition. The control opens the burner circuit, stopping the burner if it senses a low-water level. An LWCO that controls only the burner circuit (such as the secondary LWCO on a steam boiler) is called a **single element control**.

Controls may also operate the feedwater pump or valve or a make-up water valve as well as the burner. They are called **dual or triple element controls**.

If the LWCO is mechanical (a float), it must be blown down (drained) on a regular basis to prevent sediment from accumulating in the float chamber. If it is electronic, this procedure is not necessary. Both types should be disassembled and cleaned at least once per year.

Testing the LWCO is done by draining the float chamber to see if the burner stops, called a **controlled blowdown test**. This test should be performed on a regular basis.

The electronic control is tested by the evaporation or slow drain method. This test requires the feedwater supply to be secured, and the burner is allowed to operate normally. If the control is functioning properly the burner will shut off when the water level goes below the NOWL. As the water supply has been shut off to the boiler, this test is extremely dangerous and should only be done by qualified operators.

Boiler Water Treatment

There are three phases of water treatment in a boiler system:

- **Blowdown**, which maintains the TDS (total dissolved solids) in the system
- **External Treatment**, which removes hard salts, minerals and oxygen before the water enters the boiler
- **Internal Treatment**, which maintains proper water chemistry by adding chemical additives to the boiler water

The primary goal of boiler water treatment is to control solids that cause deposits in the boiler and control gases that cause corrosion.

The boiler **feedwater system** includes the necessary equipment to supply the boiler with the heated / treated water at the NOWL for maximum boiler efficiency. A **feedwater pump** pumps the water from the feedwater system to the boiler.

Hardness & Scale

City and well water supply contains minerals and solids**.** **Calcium** and **magnesium** are the most common of the minerals found in water supplies. Water may also contain silica, iron, and other trace minerals that vary by geographic location. The build up of minerals on a surface is referred to as **scale**. The build up of scale on a heating surface insulates and overheats metal surfaces, reducing the life of the boiler and making it less efficient. Additionally, the scale can travel downstream of the boiler clogging ports and surfaces of other equipment.

Hardness of water is the measurement of mineral content or scale forming salts in water. **Hard water** is water than contains more than 25 ppm of scale-forming minerals. **Soft Water** is water with low mineral content.

Conductivity is a measurement of how many solids are in the water, based on the conductance (ability to conduct electricity) of the water. The more solids, the better the water conducts electricity and the more scale will build up. Water treatment programs use conductivity as a way to measure and control the solids level in the boiler water. The water treatment program should specify the maximum amount of conductivity allowed in the boiler water. Conductivity is controlled by blowdown.

Water can be softened by the use of a **water softener** (sodium zeolite) that removes hardness minerals before the water enters the boiler, or softened chemically while the water is in the boiler. Most boiler plants in hard water locations use both methods to ensure hardness removal.

Phosphates (tri-sodium phosphate, dipotassium phosphate), chelants, and polymers are used for steam boiler scale and corrosion inhibitors. **Sodium nitrite** and **sodium molybdate** are used as inhibitors in hot water systems.

In addition, boiler water treatment compounds usually contain **tannins** and **lignins** for settling and dispersal of sediment in order to prevent the sludge from adhering to the boiler surfaces.

pH

pH, the potential of Hydrogen ions, is a measurement of the acidity or basicity of the water. The pH scale runs from 0 – 14, with the low end being acid and the high end being base. Untreated ground or surface water is usually in the pH range of 6 – 8. Ideal water pH for boilers will range from 8 pH to 12.7 pH, depending on the type of boiler, so the pH level of the water sometimes needs to be increased. **Sodium hydroxide** (caustic soda) and **sodium carbonate** are often used to raise the pH of the boiler water in steam systems, while **sodium borate** is commonly used in hot water boilers.

Gases

Steel boilers are prone to attack from the oxygen in the boiler water, which causes **pitting**, a severe form of corrosion. Pitting damage is irreversible. As the water is heated, gases (oxygen and carbon dioxide) are driven out of the water and settles on the metal surface, causing a corrosion cell.

Water treatment programs minimize the damage caused by water as it contacts the boiler metal. Oxygen can be removed mechanically using a **deaerator**, and chemically (scavenged) with such compounds a **sodium sulfite**, **bisulfite**, and **hydrazine**. High pressure boiler plants typically utilize a deaerator followed by addition of chemicals to the boiler water, while low-pressure plants generally use only the chemical method of oxygen scavenging.

Volatile amines, of either the filming or neutralizing type, are used for prevent of pitting and corrosion in steam and condensate return lines. Common examples are cyclohexylamine, morpholine, and DEAE.

Carryover

Carryover is the term used to describe water being carried with the steam into the steam system. Carryover can lead to water hammer and wet steam.
Water hammer occurs when water is being pushed through the steam lines by the steam. This can result in damage to the system piping, valves, and fittings. **Wet steam** is water droplets being contained within the steam. Wet steam may not cause problems in low pressure systems, but can cause serious damage to high pressure turbines.

Carryover can be caused by several factors, including higher than normal water level surface and impurities such as oil or foam.

Boiler Efficiency

The efficiency of the burner determines the amount of heat being lost in the combustion process. **Burner efficiency** is calculated by obtaining a flue gas sample and analyzing the by-products of combustion, such as carbon dioxide, oxygen, carbon monoxide, nitric oxide, sulfur dioxides, etc. and comparing those readings to the stack temperature.

Boiler efficiency includes not just the burner, but the entire heat exchange process. Boiler efficiency is a calculation of the amount of heat content (in Btu) purchased in the fuel compared to the heat of the steam (in pounds) that is produced. Total boiler efficiency includes radiation and convection losses as well as combustion loss.

The biggest problem in boiler efficiency is poor waterside care, which leads to scale and corrosion of the heat exchange surfaces. Poor care of the fireside (mainly when burning oil), and loss of heat through un-insulated or poorly insulated surfaces are also big sources of efficiency losses, but not as significant as waterside losses.

A regular **burner checkup** and tuning will maximize combustion efficiency. The burner technician will maximize CO_2 while minimizing O_2, and maintain as low as possible stack temperature.

Condensate is steam that has given up its heat and should be returning to the boiler. Lost condensate is lost money, as the water has been purchased, heated, and chemically treated, all costing money. Returning the condensate to the boiler instead of dumping it to a drain can save thousands of dollars per year.

The **steam trap** is designed to hold steam in the piping or heat exchanger until it has given up its latent heat. When this has occurred, the steam will condense, or change state back to a liquid. The steam trap will let condensate pass through, but will not allow steam to pass.

There are several types of steam traps. All are designed with the same goal: allow condensate, but not steam, to pass through the trap.

The **inverted bucket steam trap** consists of a bucket that will rise when steam enters the trap, blocking the discharge. As the steam cools and condenses, the bucket falls, allowing the condensate to pass.

The **float and thermostatic (F&T) trap** has a float that rises when condensate enters the trap, opening the discharge. The thermostatic element allows air to vent, but closes when steam enters the trap. The thermostatic trap uses a bellows filled with fluid that expands when the steam enters the trap, closing the discharge.

An **economizer** is installed in the stack of some boilers. The economizer saves energy by using heat that would otherwise be lost to the atmosphere. The economizer is a heat exchanger that pre-heats the boiler feedwater with heat from the flue gases. Flue gases can also be used to heat the combustion air being brought into the burner.

