1.4 Boiler Overview and Operating Theory

Boilers are often called steam generators because they generate steam. Boilers may also be thought of as energy conversion devices which convert the chemical energy in fuel to heat energy in steam. Combustion, or burning of the fuel, is a chemical process. During combustion, fuel is mixed with air; heat is generated; and flue gas is created. The heat of combustion is transferred to the water circulating in the boiler tubes where the feedwater is converted into steam. The steam is then used in the Abbott Plant and distributed to the University of Illinois campus. To increase efficiency, the flue gas exiting the boiler is cooled by the economizer prior to exiting through the stack. This ensures as much of the heat energy in the fuel as possible is absorbed by the water/steam.

To better understand the Abbott gas boilers, it is important to be familiar with the gas boiler configurations and some operating theory. This section describes water tube boilers, “D” type configuration boilers, and natural circulation.

Water Tube

The gas boilers are water tube boilers, which means that water is inside the boiler tubes and flue gas is on the outside of the boiler tubes. Water tube boilers are more expensive to build compared to fire-tube boilers but are safer. In the event of a failure, a relatively small amount of water is released in a water tube boiler. Also, higher steam flows and operating pressures are possible with a water tube boiler compared to a fire-tube boiler.

“D” Type Configuration

The gas boilers are “D” type boiler configurations, shown in Figure 17. “D” type boiler configurations have one steam drum and one lower drum. The drums are centered over each other with the furnace offset to one side. There is one generating bank located beside the furnace (between the drums) and only one flue gas path. The furnace tubes form a “D” shape, hence the naming of the configuration.

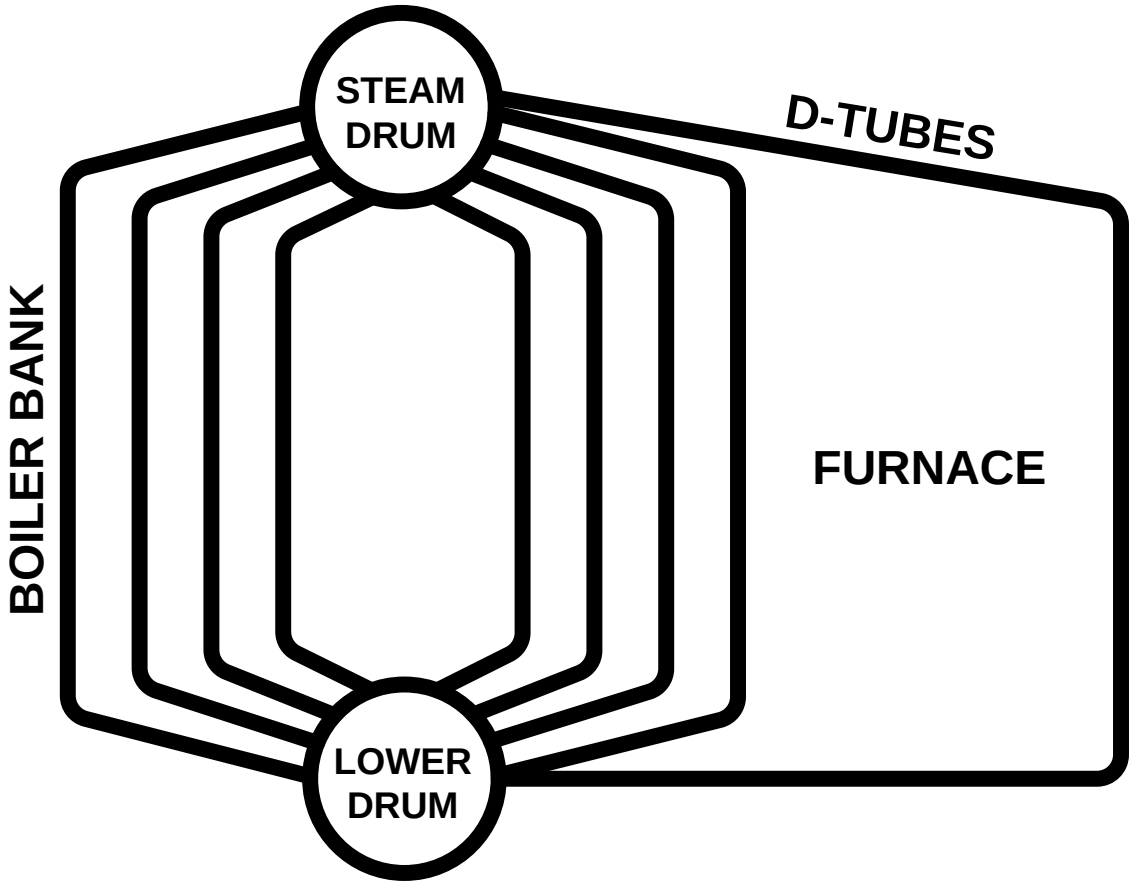

Figure 17 – Basic Boiler Configuration

Natural Circulation

The gas boilers are natural circulation boilers, which means that circulation occurs in the boilers without the use of a pump. Water circulates from the boiler steam drum through downcomer tubes to the mud drum and up through the tubes in the boiler water walls and convection area back to the steam drum. The movement of water in this flow path is caused by temperature differential, which corresponds to a difference in density between steam and water. Natural circulation is illustrated in Figure 18.

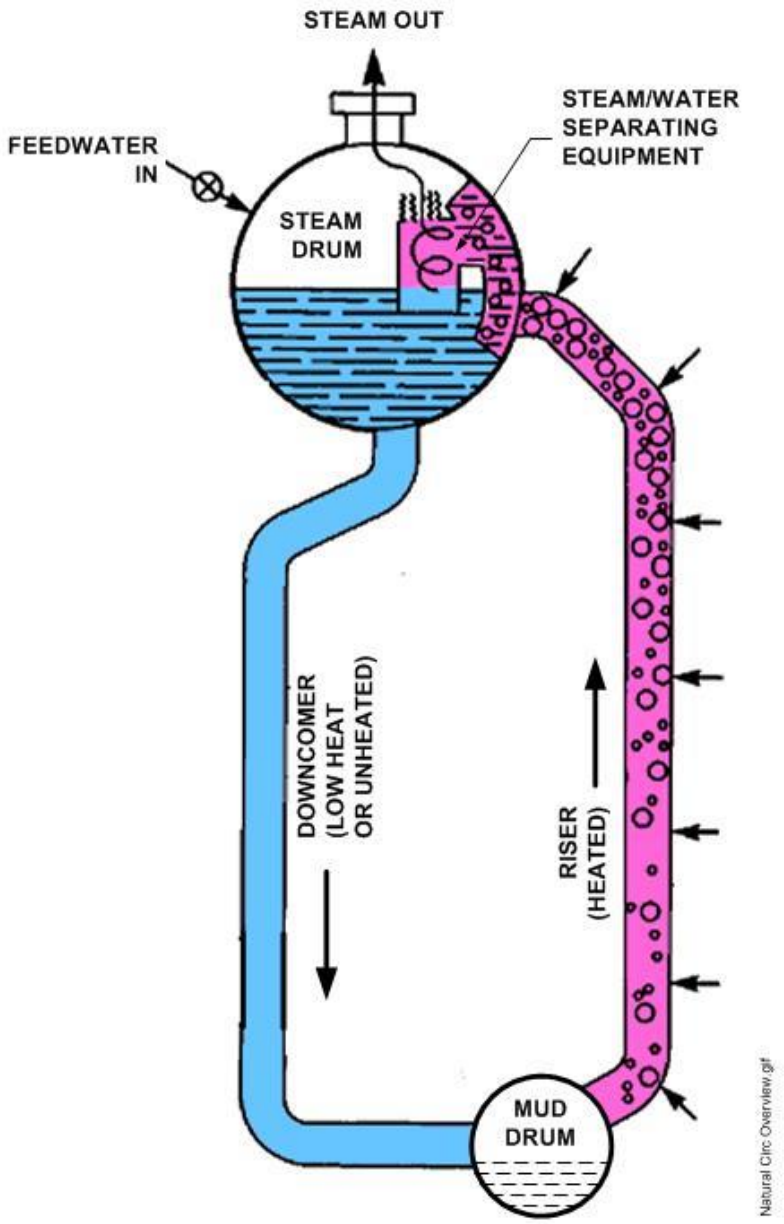

Figure 18 – Natural Circulation Overview

Although the incoming feedwater is preheated, it is still at a lower temperature than the water inside the drum. Because the incoming water is "cooler" than the drum water, it is denser; therefore, circulates downward. The cooler water flows into the downcomer tubes and along the waterwalls at the outer shell of the boiler away from the direct heat from the combustion flue gases. The downcomers route the water to the mud drum which

collects all the water for distribution to the riser tubes. Referring to Figure 19, the downcomer tubes are shown in blue and the riser tubes are shown in red.

While in the riser tubes, the water absorbs thermal energy from the combustion flue gasses. As the water is heated, it expands, becomes less dense, and flows upward through the tubes to the steam drum. Cooler, denser water from the downcomers and the mud drum flows in to take the place of the rising heated water creating natural circulation between the drums.

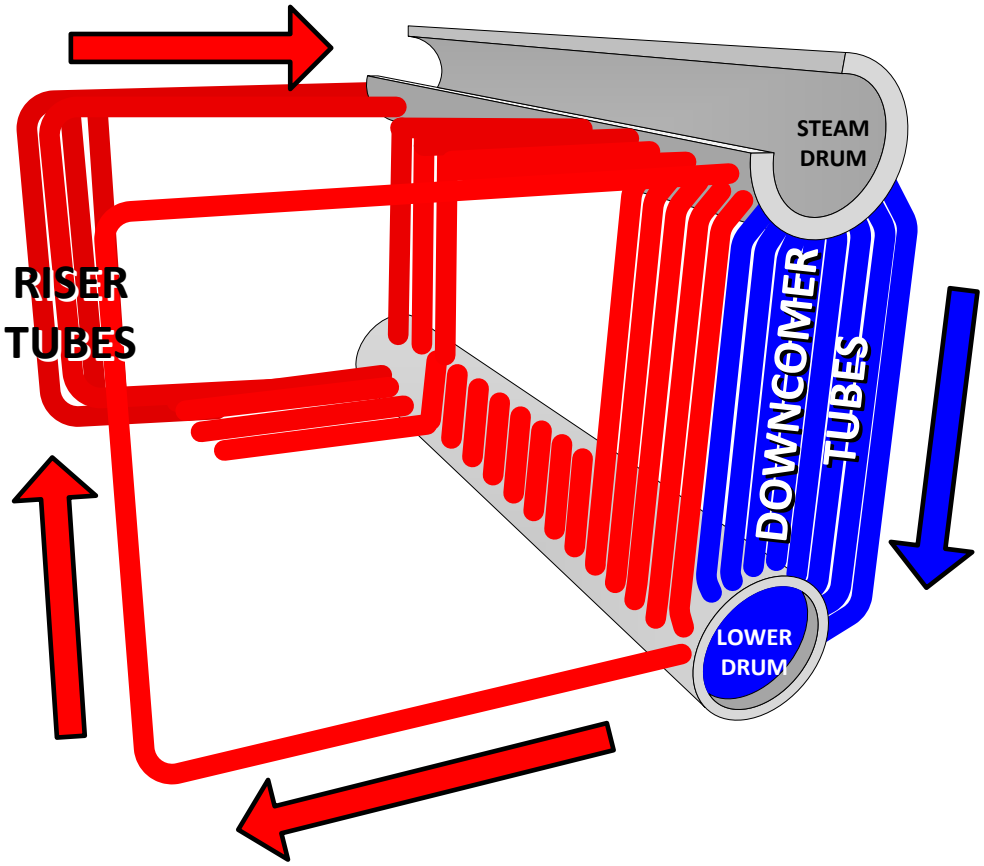

Figure 19 – Natural Circulation

As the water is heated, steam bubbles begin to form resulting in a steam/water mixture within the riser tubes. By the time the mixture reaches the steam drum, a high percentage of the mixture is saturated steam.

Saturated steam entering the steam drum from the risers is separated from the water in the steam drum and after flowing through the superheater, is discharged to the plant steam distribution system. The separated water is mixed with feedwater and this fluid flows to the lower drum through the downcomers. The lower drum distributes the fluid properly into all riser tubes and circulation continues.