Boiler Types and Applications

An Online Continuing Education Course for Engineers

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Boiler Types and Applications

Combustion boilers are designed to use the chemical energy in fuel to raise the energy content of water so that it can be used for heating and power applications. Many fossil and non-fossil fuels are fired in boilers, but the most common types of fuel include coal, oil, and natural gas. During the combustion process, oxygen reacts with carbon, hydrogen, and other elements in the fuel to produce a flame and hot combustion gases. As these gases are drawn through the boiler, they cool as heat is transferred to water. Eventually the gases flow through a stack and into the atmosphere. As long as fuel and air are both available to continue the combustion process, heat will be generated.

Boilers are manufactured in many different sizes and configurations depending on the characteristics of the fuel, the specified heating output, and the required emissions controls. Some boilers are only capable of producing hot water, while others are designed to produce steam. Various studies have been conducted to estimate the number of boilers in the United States, but no data source provides a complete representation of the existing boiler population.[1]

In the United States, boilers are typically designed and constructed as either power or heating boilers in accordance with applicable requirements adopted by the American Society of Mechanical Engineers (ASME). Rules for power boilers are as well.[2] These rules apply to steam boilers that operate above 15 psig and hot water boilers that operate above 160 psig or 250°F. Common design pressures are 150, 200, 250, and 300 psig, but higher pressures are possible. [3] For example, boilers for certain pulp and paper industry applications are now designed for pressures as high as 1,500 psig. Corresponding rules for heating boilers are provided later in this course.[4] According to these rules, heating boilers that produce hot water are not allowed to operate above 160 psig or at temperatures above 250°F at or near the boiler outlet. Additional rules limit heating boilers that produce steam to a maximum operating pressure of 15 psig.

Many boilers with heat input capacities more than 250 million British thermal units per hour (MBtu/h) are classified as utility boilers because they are used at power plants to produce electricity. Some boilers of this size are also used at paper mills and institutions and for other industrial applications. Smaller boilers with less capacity are categorized as ICI boilers. Industrial boilers are used extensively by the chemical, food processing, paper, and petroleum industries. They have heat input capacities up to and sometimes more than 250 MBtu/h. Commercial and institutional boilers are used in many other applications including commercial businesses, office buildings, apartments, hotels, restaurants, hospitals, schools, museums, government buildings, and airports.

In the past when emissions were less regulated, choosing the right boiler and combustion equipment for a particular application generally involved matching the process requirements with the boiler's output capacity. Proper sizing and selection required knowledge of the peak process requirements and an understanding of the load profile. This boiler selection philosophy emphasized energy conversion at the lowest possible cost. Reduced emphasis was placed on controlling emissions. Public concerns about air and water quality and enactment of federal, state, and local regulations have shifted this emphasis. The current design objective is to provide low-cost energy with an acceptable impact on the environment. As discussed in an engineering manual published by the American Boiler Manufacturer's Association (ABMA), control of PM, NO_x, CO, and SO_2 emissions is now a significant consideration in the overall boiler and combustion equipment design and selection process.[3]

Types of Ici Biolers

Information in this course focuses primarily on a broad class of steam and hot water generating units known as ICI boilers. Because of differences in their features and characteristics, ICI boilers can be classified in at least three ways.

- Boilers are commonly subdivided into watertube or firetube units. These designations reflect the way the water and combustion gases are designed to pass through the unit.
- Boilers are sometimes classified by their heat sources. For example, boilers are often referred to as oil-fired, gas-fired, coal-fired, or solid fuel-fired boilers. Coal-fired boilers can be further divided based on the equipment used to fire the boiler. The three major coal-fired boiler subclasses are pulverized-coal (PC) fired, stoker-fired, and fluidized-bed combustion (FBC) boilers.
- Boilers are occasionally distinguished by their method of fabrication. Packaged boilers are assembled in a factory, mounted on a skid, and transported to the site as one package ready for hookup to auxiliary piping. Shop-assembled boilers are built up from a number of individual pieces or subassemblies. After these parts are aligned, connected, and tested, the entire unit is shipped to the site in one piece. Field-erected boilers are too large to transport as an entire assembly. They are constructed at the site from a series of individual components. Sometimes these components require special transportation and lifting considerations because of their size and weight.

The basic purpose of any ICI boiler is to convert the chemical energy in fuel into thermal energy that can be used to generate steam or hot water. Inside the combustion chamber, two fundamental processes must occur to achieve this objective. First, the fuel must be mixed with sufficient oxygen to allow sustained combustion. The heated gases produced by the combustion process must then transfer the thermal energy to a fluid such as water or steam. Various components inside the boiler are required to promote efficient combustion and heat transfer. Their design depends on factors such as the type of fuel and the method selected to transfer thermal energy.

The ICI boilers are manufactured in a wide range of sizes to burn coal, oil, natural gas, biomass, and RDFs as well as other fuels and fuel combinations. Most ICI boilers are classified as either watertube or firetube boilers, but other designs such as cast iron, coil-type, and tubeless (steel shell) boilers are also produced. Descriptions of some of the more typical boiler designs are presented below. Additional details about ICI boilers and their design, construction, and operation are available from other sources.[3,5–7]

Firetube Boilers

Firetube boilers consist of a series of straight tubes that are housed inside a water-filled outer shell. The tubes are arranged so that hot combustion gases flow through the tubes. As hot gases flow through the tubes, they heat the water that surrounds the tubes. The water is confined by the outer shell of the boiler. To avoid the need for a thick outer shell, firetube boilers are used for lower-pressure applications. Generally, the heat input capacities for firetube boilers are limited to 50 MBtu/h or less,[5] but in recent years the size of firetube boilers has increased.

Firetube boilers are subdivided into three groups. Horizontal return tubular (HRT) boilers typically have horizontal, self-contained firetubes with a separate combustion chamber. Scotch, Scotch marine, or shell boilers have the firetubes and combustion chamber housed within the same shell. Firebox boilers have a water-jacketed firebox and employ, at most, three passes of combustion gases. Boiler configurations for each type are shown in Figs. 1–3, respectively.

Most modern firetube boilers have cylindrical outer shells with a small round combustion chamber located inside the bottom of the shell. Depending on construction details, these boilers have tubes configured in either one, two, three, or four pass arrangements. Because the design of firetube boilers is simple, they are easy to construct in a shop and can be shipped fully assembled as a package unit.

Table 1 identifies various types of firetube boilers and the associated fuels that they typically burn.

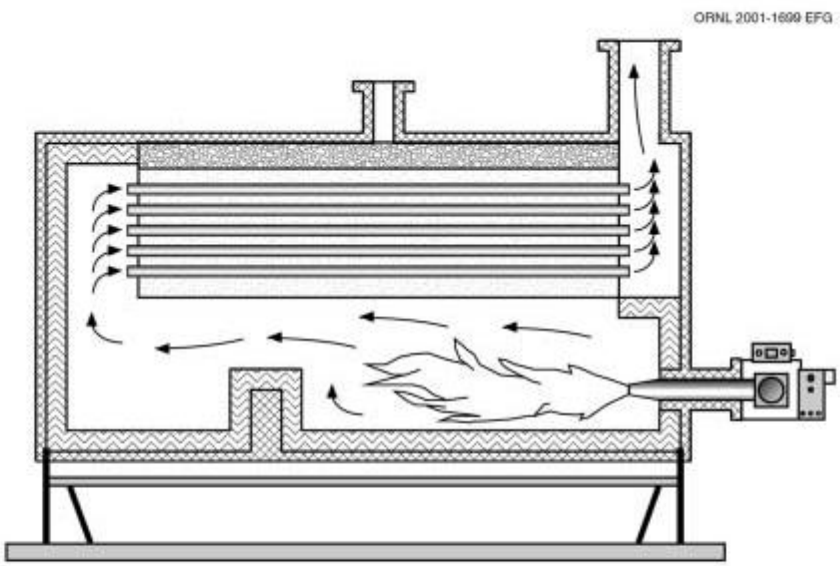

Fig. 1. Configuration of HRT firetube boiler.

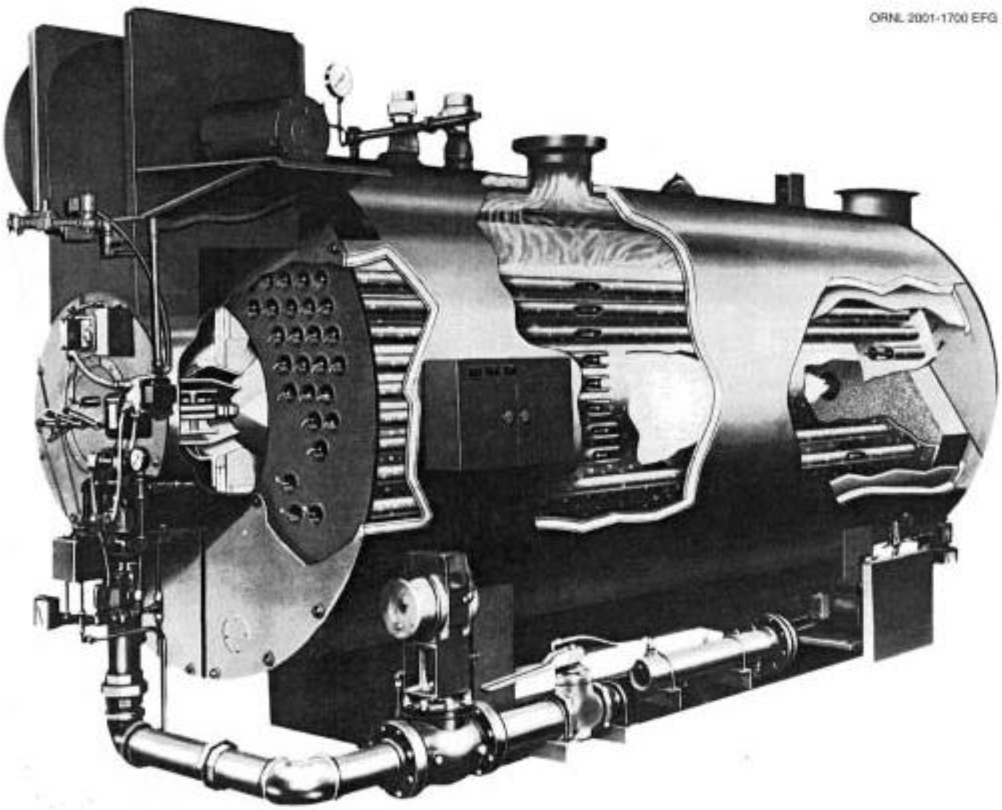

Fig. 2. Configuration of Scotch package firetube boiler. Source: Reprinted from Ref. 6.

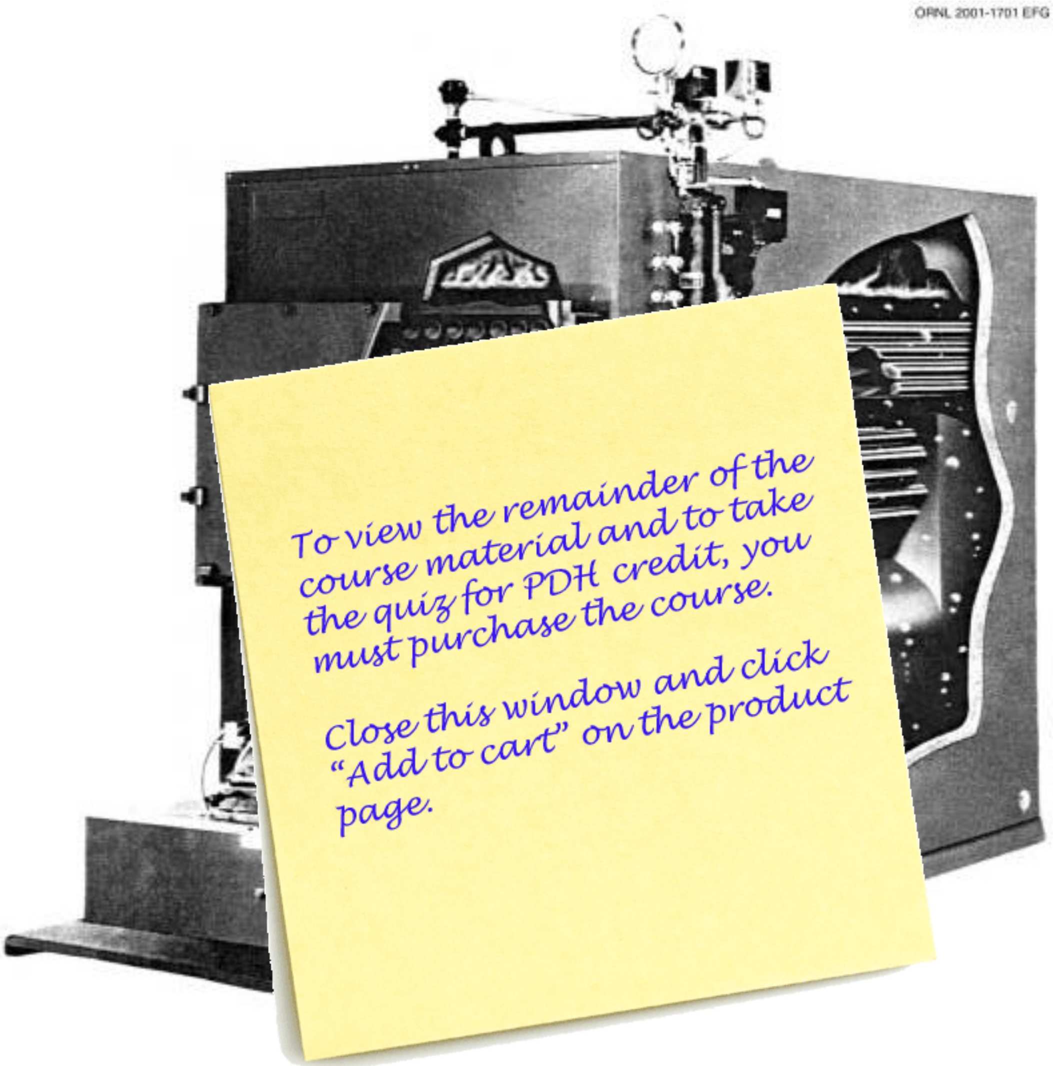

Fig. 3. Configuration of firebox firetube boiler. Source: Reprinted from Ref. 6.

Firetube boiler type	Fuel				
	Coal	Fuel oil	Natural gas	Biomass	Refuse-derived
HRT boilers	Yes	Yes	Yes	Yes	Yes
Scotch boilers	Yes	Yes	Yes	No	No
Firebox boilers	Yes	Yes	Yes	Yes	Yes

Table 1. Fuels typically fired in ICI firetube boilers