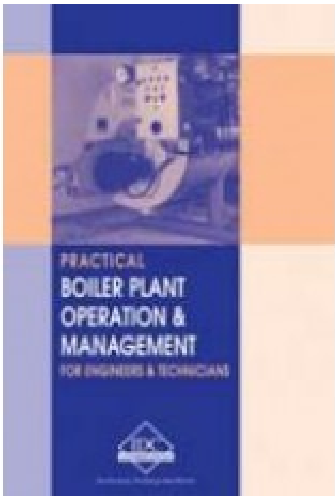
IDC Technologies - Books - 1031 Wellington Street West Perth
WA 6005

Phone: +61 8 9321 1702 - Email: books@idc-online.com

BL-E - Boiler Plant Operation and Management



Price: $139.94

Ex Tax: $127.22

Short Description

This manual provides the most up-to-date information and practical understanding of the installation, operation, maintenance and management of boiler plants. It will give you the ability to recognize and solve boiler problems simply, easily and with confidence.

Description

This manual provides the most up-to-date information and practical understanding of the installation, operation, maintenance and management of boiler plants. It will give you the ability to recognize and solve boiler problems simply, easily and with confidence.

Table of Contents

Download Chapter List

Table of Contents

First Chapter

Introduction to Practical Boiler Plant Operation and Management for

Engineers and Technicians

1 Introduction

This chapter commences with an introduction to the fundamentals of boiler operation and outlining what exactly happens in a boiler. This is followed by a discussion on the design & functional aspects of various boiler components such as shell, header, waterwall, flue, tube, combustion chamber etc. During the course of the discussion, an attempt is also made to obtain a clear understanding of different boiler terminologies & definitions. The chapter further provides a detailed overview of the common boiler types & configurations, along with their application.

Learning objectives

- Boiler fundamentals and operation.
- Common terminologies and definitions associated with boilers.
- General requirements and selection criteria.
- Boiler components and functions.
- Packaged boiler types and their applications.

1.1 Fundamentals

Boilers are closed vessels in which heat is applied to transform water under pressure, into steam. This heat is in turn generated from the combustion of fuels (solid, liquid and gaseous) or by the use of nuclear energy or electricity. In the case of waste-heat boilers, hot gas turbine gases serve as the heat source. It is important that there is efficient transfer of heat to the water and the boiler is designed accordingly to accomplish this. The various operations that take place in a boiler are best explained in the following diagram.

Figure 1.1

Boiler Operation

The design of a boiler must be such that it is able to absorb the maximum amount of heat released during the combustion process. This heat is transmitted to the boiler by conduction, convection or radiation and therefore each of this must be given special consideration during the design process. Boiler design is also important from the point of view of safety and efficiency of the fuel-burning equipment.

Boilers are manufactured in a variety of shapes and sizes to satisfy conditions peculiar to the individual plant and also to meet varying requirements. In view of the escalating fuel costs, greater attention is being given to improving combustion efficiency and many boilers are designed to burn multiple fuels, to take advantage of the fuel that is most economically available.

Following are the requirements of an ideal boiler:

- Simple in design and construction.
- Safe and reliable operation with minimum maintenance.
- Adequate strength of all components.
- High efficiency with increased availability and low maintenance costs.
- Maximum rate of heat transfer with a highly efficient combustion process.
- Responsive to sudden demands and upset conditions.
- Adequate space for circulation of water and steam.
- Good water circulation and delivery of clean steam.
- Easy accessibility for inspection, cleaning and repair.
- Design that accommodates expansion and contraction properties of materials.
- Factor of safety meeting code requirements.

Although boiler selection may depend on various factors, the following criteria must be kept in mind for a particular application:

- Quantity of steam/water required.
- Load characteristics.
- Location/purpose of installation.
- Pressure, temperature and the required steam quality.
- Fuel characteristics.
- Space availability and limitations.
- Economic considerations.
- Selection of auxiliary equipment.
- Maintenance and operating conditions.
- Anticipation of future needs.

1.2 Types of Package Boilers and their Applications

Packaged boilers are steam boilers equipped and shipped, complete with the following:

- Fuel burning apparatus
- Feedwater apparatus
- Mechanical draft equipment
- Safety appliances
- All necessary controls for manual/automatic operation.

Basically, boilers are categorized as

1. Fire-tube boilers
2. Water-tube boilers and
3. Electrical boilers

In the case of fire-tube boilers, the combustion gases pass through the inside of the tubes, with water surrounding the outside. On the other hand, in water-tube boilers, the combustion gases pass over the outside of the tubes with water / steam flowing inside the tube. The steam in electrical boilers is generated by conducting current through the water. It is important for the water conductivity to be monitored & controlled. Electrical boilers have small water volume and quick response times and are similar in operation, control & safety devices to fired boilers.

Let us discuss each of these boiler types in detail.

1.2.1 Fire-tube Boilers

Fire-tube packaged boilers may comprise the following types:

- Vertical fire-tube boilers
- Horizontal return tubular fire tube boilers
- Economic boilers
- Scotch marine boilers

Vertical fire-tube boilers

Vertical fire-tube boilers are portable boilers requiring minimum foundation. They consist of a cylindrical shell with an enclosed firebox. The tubes extend from the crown sheet in the firebox to the upper tube sheet. In vertical exposed-tube boilers, the upper tube sheet & tube ends are above normal water level and extending into steam space. In submerged-tube boilers, the tubes are rolled into the upper tube sheet which is below the water level. The sectional view of a vertical fire-tube boiler is shown in the first figure followed by a graphic that illustrates different vertical fire-tube boiler configurations.

Figure 1.2

Vertical Fire-tube Boiler

Figure 1.3

Vertical Fire-tube Boiler Configurations

Horizontal return tubular fire-tube boilers

Horizontal return tubular fire-tube boilers have a long cylindrical shell supported by furnace sidewalls. They are set on saddles equipped with rollers to permit movement during expansion or contraction. They may also be suspended from hangers & supported by overhead beams.

Figure 1.4

Horizontal Return Tubular Fire-tube Boiler

While the original designs had the required shell length secured by riveting several plates together, modern designs have their plates joined by fusion welding. As there are no joints to overheat, higher firing rates are permitted leading to increased boiler life & reduced maintenance.

Economic boilers

Economic boilers are an adaptation of horizontal return tubular boilers, but give somewhat greater heating surface per square area of floor space. Also, the unit is self-supporting in its special casing and therefore the required amount of brickwork is much less. The construction principles, circulation and piping connections of economic boilers are essentially the same as horizontal return tubular boilers. A 2-pass fire tube economic boiler is shown.

Figure 1.5

Economic Boiler

Scotch marine boilers

Scotch marine boilers were originally designed for marine service. They usually have large diameters but require minimum space & brickwork. They are compact and economical with simple installation and also have same sized tubes. The graphic shows an adaptation of a scotch marine boiler having multiple passes and with high ratings & operating efficiency.

Figure 1.6

Scotch Marine Boiler

Some of the common configurations of scotch marine boilers are shown.

Figure 1.7

Scotch Marine Boiler Configurations

Fire-tube boiler applications

Fire-tube boilers are used in most industrial plants where saturated steam demand is less than 50,000lb/h & pressure requirements less than 350 psig. With some exceptions, nearly all modern boilers of this type are packaged & can be installed in operation in a short period of time. They provide process saturated steam to the following:

- Food processing (packaging, dairies)
- Hospitals
- Restaurant equipment
- Laundry equipment
- Building heating
- Manufacturing processes (steel, tires, paper)
- Petrochemical industry

1.2.2 Water-tube Boilers

While early water tube boilers were straight tubes with header boxes, modern bent tube package boilers have one or two drums (‘D’ or ‘A’ type or ‘O’ type). They are supplied completely equipped with firing equipment, safety devices and instrumentation. A 2-drum integral furnace boiler is illustrated below followed by a D type 2-drum water-tube boiler for firing oil or gas.

Figure 1.8

2-drum integral furnace water-tube boiler

Figure 1.9

D type 2-drum water-tube boiler

Straight tube water–tube boilers

As the name suggests, these boilers have straight tubes placed in the furnace and were one of the earliest designs used. The shell is used primarily as storage for water & steam. Straight tube boilers may comprise of one or more drums and are usually classified on basis of header type & direction of tubes or drums.

Figure 1.10

Straight tube water-tube boiler

Bent- tube boilers

Bent-tube boilers have greater flexibility and allow for free expansion & contraction of the assembly. They also allow more heating surface to be exposed to the radiant heat of flame. This design provides more flexibility in boiler tube arrangement as well as greater accessibility for inspection, cleaning & repair.

The main elements are essentially drums (or drums & headers) connected by bent tubes. With a water-cooled furnace, the tubes are arranged in such a manner so as to form a furnace enclosure, thus making it integral with the boiler. A two drum O-type boiler is shown.

Figure 1.11

2 Drum O type boiler

Another type of water-tube boiler is the 3-drum A-type inclined tube boiler. It has two lower mud drums with a blowdown valve for sludge removal. One upper Steam and water drum is provided in this design.

Figure 1.12

3 Drum A type inclined tube boiler

Water tube boiler applications

In industrial applications, these boilers provide

- Larger and higher pressures and rating than packaged units.
- Process and / or power generation steam.
- Saturated steam or incorporate super-heaters and reheaters.
- Greater efficiency and use air-pre-heater and economizer heat recovery surfaces.

In power generation utilities, water-tube boilers are provided in the form of large boilers primarily designed for providing steam to a turbine for power generation. The boilers in such applications is of the high pressure, high temperature type and may be either oil/gas fired or coal fired. Boilers used in power generation may be classified as sub-critical or super-critical. While the sub-critical types may have natural or forced circulation, the super-critical boilers come with the once-through design having forced circulation.

Water-tube boilers are also used in certain special applications as

- Fluidized bed boilers
- Waste heat recovery boilers
- Waste or refuse fired boilers and

- Black liquor boilers

1.2.3 Electrical Steam Boilers

Electrical steam boilers are packaged units generating steam for the heating & process industries. They provide steam at about 150 psig pressure. While small units (1000-10,000lb/h) may have low voltage, the large ones (7000-100,000lb/h) may have voltage in the range of 13,800 V. These boilers are normally used in offices, hospitals & processing plants.

Advantages of Electrical steam boilers:

- Compact in size.
- Emission-free.
- No stack requirements.
- Quiet/safe operation.
- Low maintenance.
- Ability to use power during off-peak hours.
- Responsiveness to demand.

Disadvantages:

- Consumes high voltage
- High power costs & availability when used during periods other than off-peak.

1.3 Boiler Components

A boiler by definition technically includes only the containing vessel and the convection heating surfaces. It is part of the heat generating unit which also includes a firebox or furnace in which the fuel is burned. With the advent of water-cooled furnace walls, super-heaters, economizers and air heaters, the term “Steam Generator” seems better suited for describing the heat generating unit. In the event of the furnace or firebox being integral, the term “boiler” is generally understood to be descriptive of the heat generating unit. Let us study and understand the functions of the various components comprising the boiler and the heat generator unit.

1.3.1 Shell

It is the structure forming the outer envelope of a boiler drum. The shell consists of one or more plates properly joined or of seamless construction. It does not include tube sheets or heads.

1.3.2 Heads

Heads are the ends of a boiler. They may be of the flat or dished type, stayed type or unstayed type. While dished heads are formed to a segment of a sphere or hemispherical or elliptical section, stayed heads are supported in whole or in part by stays, furnaces, flues, tubes, etc.

1.3.3 Header

The header in a boiler is a hollow forging pipe or welded plate.

Figure 1.13

Header

It may be cylindrical, square or rectangular in cross section. Headers serve as manifold to which tubes are connected.

1.3.4 Waterwall

They are a series of tubes or elements spaced along or integral with a furnace wall. They protect the wall & provide additional heating surface.

Figure 1.14

Waterwall

1.3.5 Furnace

Furnace is a firebox or large flue where the fuel is burned. It directs the combustion gases to the boiler heating surfaces. A good economical design would comprise the smallest allowable unit that can completely burn the fuel.

Boiler furnaces may be of the plain or corrugated type. Plain designs are cylindrical shells usually made in sections joined by means of riveting or welding. In the corrugated design, the cylindrical shells are provided with circumferential corrugations for added strength & provide for expansion.

1.3.6 Combustion Chamber

Combustion chamber forms part of an internally fired boiler in which combustion gases may be burned after they leave the furnace. A common combustion chamber may also be connected to two or more boiler furnaces.

1.3.7 Air Pre-heater

They are used to preheat the incoming air before combustion and are thus responsible for the final heat recovery from boiler flue gases. This results in some fuel savings which otherwise would be used in heating the air-fuel mixture up to its ignition point. One important consideration here is that the flue gas temperature must not be reduced below its dew point as this tends to result in moisture condensation. This would lead to water combining with sulfur and possibly carbon-monoxide and carbon-dioxide, to form highly corrosive sulfurous and carbonic acids. The figures below depict two types of air-heater designs.

Figure 1.15

Air Heater Designs

The design in the first figure has the air passing inside the tubes, while the hot gas crosses at right angles. The second figure shows a design in which the hot gases flow through the tubes, while the air is directed across the tubes by baffles.

1.3.8 Economizer

Economizers are feedwater heaters used to absorb heat from the waste gases. They serve as traps for removal of heat from the flue gases at moderately low temperature, after the gases have been discharged from the steam-generating and superheating sections of the boiler. The feed water is heated in the economizer by this residual waste heat, thereby increasing the overall efficiency of the unit. Economizers are usually located in boiler uptakes or casings. The figure below shows a commonly used economizer design.

Figure 1.16

Economizer

1.3.8 Superheater

Super-heaters are appliances used for increasing steam temperature. They are used to heat the steam above saturation temperature and are normally required by turbine installations only. A superheater coil unit is shown.

Figure 1.17

Superheater tubes

1.3.9 Reheater

A Reheater is essentially a type of super-heater used for boosting plant efficiency. The super-heater takes steam from the boiler drum, whereas the re-heater obtains used steam from the high pressure turbine at a pressure which is below boiler pressure.

1.3.9 Flues

Flues provide additional heating surfaces & form a path for combustion products. They are basically cylindrical shells made of seamless or welded tubing. They may also be constructed with a riveted longitudinal joint, with the ends being attached by welding or riveting.

1.3.9 Tubes

Tubes are cylindrical shells of comparatively smaller diameter. They constitute the main heating surface part of the boiler or super-heater. Common designs include seamless without any longitudinal joint, electric-resistance welded or thick walled stay tubes.

1.4 Common Boiler Related Terminologies and Definitions

Absolute Pressure

Equals the sum of gauge pressure (measured by a gauge) and atmospheric pressure (14.7 psi at sea level) and is indicated by a barometer.

Attemperator

Attemperator is also known as de-superheater. It reduces the temperature of superheated steam at higher loads, to permit a constant temperature of steam over a defined load range.

Bag

It refers to a deep bulge in the shell of a fire-tube boiler

Banking

The burning rate of solid fuel on a grate that is adequate to maintain ignition only. This also refers to a combustion rate that is just sufficient to maintain normal operating pressure, but with no steam capacity.

Boiling point of water

This is the boiling point of water at atmospheric pressure which is 100º C or 212 º F.

British thermal unit (Btu)

It is used to measure heat energy and is defined as the quantity of heat required to raise the temperature of 1 lb of water by 1º F.

Condensation

This refers to the change of state of steam or any other vapor which reduces them to a liquid state.

Critical Pressure

Critical pressure is that pressure at which there exists no difference between the liquid and vapor states of water.

Deaeration

This refers to the removal of air and gases from boiler feedwater prior to its introduction.

De-mineralizer

It is an ion-exchange system used for removing solids from water.

Design Pressure

This is the pressure used in boiler design for the purpose of determining the minimum permissible thickness of pressure components and other boiler characteristics.

Dew Point

This refers to the temperature at which a vapor liquefies.

Draft

Draft refers to the difference between atmospheric pressure and a lower pressure that is present in a boiler.

Draft Loss

It is the pressure drop of flue gas between two points within a system that is caused by a resistance to flow.

Economizer

It is a heat transfer surface that transfers heat from the flue gas to the boiler feedwater.

Enthalpy

It refers to the number of Btus that is contained in a substance, above a specific datum. For water and steam, the reference is taken as water at 32 ^{o} F.

Evaporation

It is the process by which a liquid changes into vapor or gas.

Feedwater

Feedwater is the water that enters a boiler during operation and includes the makeup water and condensate from the condenser.

Fluidized Bed Combustion

This refers to the process in which a fuel is burned in a bed of granulated particles (sand) that are maintained in a mobile suspension by the upward flow of air and combustion products.

Freezing Point of Water

This is the temperature at which water freezes which is 32 º F or 0 º C.

Total Heat (Heat content of steam)

This is the Btus that must be added to produce steam at the condition in question. The starting point is usually taken as water at 32 º F.

Horsepower

It is a unit of power and is defined as the rate at which work is being performed.

1 HP = 33,000ft. lb/min.

Kilowatt

It is a unit of electric power and is equal to 1000 Watts.

Kilowatt hour

It is equal to 1 kW of energy expended continuously for 1 hour.

Latent Heat of Evaporation

A large amount of heat is required for vaporizing a liquid. As this heat does not increase the temperature, it is known as latent heat. The value for water at atmospheric pressure is 970.3 Btu.

Mechanical Equivalent of Heat

This is also sometimes referred to as Joule's equivalent. 778 ft-lb of mechanical energy is equivalent to 1 Btu of heat energy.

Municipal Solid Waste

This refers to the solid waste material that is collected from households and commercial sources.

Package Boiler

Package boiler is a unit that is shipped complete with fuel-burning equipment, mechanical draft equipment, controls and accessories.

Primary Air

This refers to the combustion air that is introduced along with the fuel at the burners.

Reheater

It is the boiler portion that adds heat to steam to raise its temperature after a part of its work has been performed by steam.

Saturated Steam

This refers to that steam which has no moisture. Addition of heat will raise the temperature above the boiling point and removal of heat will result in water formation.

Secondary Air

This is the combustion air that is supplied to a furnace and supplements the primary air.

Specific Heat

The specific heat of any substance is the heat required to raise 1 lb of it by 1 ^{o} F.

Stoker

This is part of a boiler system that includes a fuel-feeding mechanism and a grate.

Superheated Steam

Superheated steam is that steam whose temperature has been raised to a value higher than the boiling temperature corresponding to the boiling pressure.

Superheater

It is a heat transfer surface that transfers heat from the flue gas to the steam in order to raise the steam temperature above its saturation temperature.

Tertiary Air

It is the combustion air supplied to a boiler furnace and supplements both the primary as well as the secondary air.

Utility Boiler

This refers to a boiler that is designed to produce steam for electricity generation in the utility industry.

Viscosity

It refers to the resistance offered by a fluid to flow and varies with temperature.

Wet Steam

This is referred to steam containing water particles that have not been evaporated.