Lesson 3

Supplying Air and Fuel

Lesson Goal and Objectives

Goal

To familiarize you with the methods of introducing fuel and air into a boiler.

Objectives

Upon completing this lesson, you should be able to—

1. identify the location where primary, secondary, and tertiary air are brought into the furnace,
2. briefly describe six types of coal-fired boilers: hand-fired, chain and traveling-grate stoker, underfeed stoker, spreader stoker, pulverized, and fluidized bed, and
3. briefly describe how fuel oil and gas are burned in a boiler.

Introduction

Boilers are carefully designed to burn the proper amount of air and fuel in the firebox of the furnace. Air enters the furnace through burners, registers, or ports depending on the design of the unit. Fuel enters the furnace through burners, grates, or fuel beds. To achieve complete combustion air and fuel must be intimately mixed. Combusted fuel produces hot flue gas that moves through the boiler transferring heat to the boiler tubes. Flue gas is most often pushed through or pulled through the boiler by a fan before exiting through a stack or chimney. This lesson will look at how air and fuel are introduced into a boiler.

Combustion Air

As stated in Lesson 2, a stoichiometric amount of air is needed for combustion. Actually, a small amount of excess air is needed to ensure complete combustion. Air enters the furnace at different locations depending on the size, sophistication, and design of the boiler. In small boilers, combustion air enters through openings in the burner or through the openings in the bottom of the furnace, called registers. In larger boilers, the primary air used to support combustion is occasionally brought in through the burners, through openings in the furnace walls, or through openings in the grates. Occasionally boilers will be equipped with openings that provide secondary air for combustion. Secondary air helps combust any volatile gases produced in the initial combustion phase. Some boilers use burners that have openings for primary, secondary, and tertiary air. Others bring secondary air into the furnace through a windbox. A forced-draft fan moves air through the windbox into openings in the furnace wall. Secondary and tertiary air are used in large boilers to ensure that all of the fuel is completely burned.

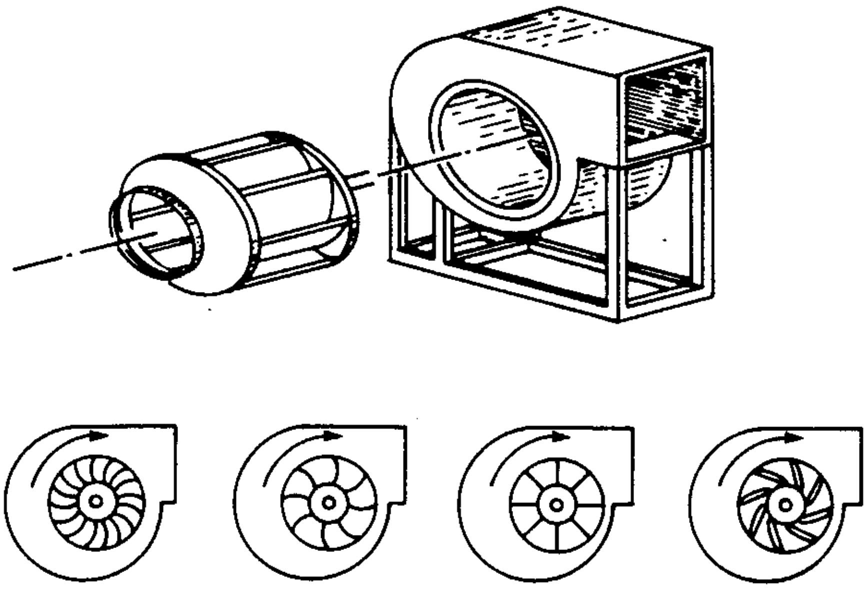
Draft

Boilers are usually equipped with chimneys to produce the draft necessary to move combustion air into the furnace and to discharge the combustion products, or flue gas, to the atmosphere. Just as in a home fireplace, the draft must be produced high enough to provide enough air to burn the fuel without causing it to smoke and to move the flue gas up the chimney. A natural draft boiler system uses chimneys to move gases through the system.

Natural-draft chimneys are generally used on small, simple boilers that do not use economizers and air preheaters. Larger boilers that use heat-recovery equipment and air pollution control devices must use fans to move air through the system because of the high draft losses produced by this add-on equipment.

Fans applied to boiler systems fall into three categories—forced draft, induced draft, and balanced draft. In a forced-draft system, a fan pushes air into the furnace, causing combustion products to flow through the boiler and from the stack. The boiler is maintained at a pressure above atmospheric pressure to force the flue gas through it. These boilers are also called pressurized furnaces. In an induced-draft system, a fan is located after the boiler, pulling the air into the furnace, through the boiler, and from the stack. The boiler is maintained at a pressure slightly below atmospheric pressure. In a balanced-draft system, a forced draft fan pushes air into the furnace and an induced-draft fan (or chimney) produces a draft to pull flue gas through the boiler to exit from the stack. This boiler is maintained at a pressure slightly less than atmospheric pressure, usually from 0.05 to 0.10 in. of water.

Boiler systems generally use centrifugal fans. Gas is introduced into the center of a revolving wheel, or rotor, and exits at a right angle (90°) to the rotation of the blades (Figure 3-1). Centrifugal fans are classified by the shape of the blades used in the fan. The forward-curved fans (Figure 3-1a) have blades that are curved toward the direction of the wheel rotation. The blades are smaller and spaced closer together than are the blades of other centrifugal fans. These fans are not used to move flue gas containing dust or sticky materials. They are generally used only as forced-draft fans. Backward-curved fans (Figure 3-1b) have blades that are curved away from the direction of the wheel rotation. The blades clog when the fan is used to move flue gas containing dust or sticky fumes. They may be used on the clean-air discharge of air pollution control devices or to provide clean combustion air for boilers. Radial fans (Figure 3-1c) use straight blades that are attached to the wheel of the rotor. These fans are built for high mechanical strength and can be easily repaired. Fan blades may be constructed of alloys or coated steel to help prevent deterioration when handling abrasive and corrosive flue gas. Radial fans are frequently used for induced-draft systems—particularly with air pollution control devices. Airfoil fans (Figure 3-1d) have thick teardrop-shaped blades that are curved away from the wheel rotation. Airfoil fans can also clog when handling dust or sticky materials.



a. Forward-curved b. Backward-curved c. Radial d. Airfoil

Figure 3-1. Centrifugal fans.

Coal-Fired Boilers

Coal is fed into a boiler and then burned in a number of ways depending on the design and size of the boiler. The oldest and simplest method is that of hand firing. When coal is stoked, it travels on a moving grate or is fed onto a grate by a moving ram or spreader. Many large boilers *pulverize* coal into fine powder and then feed it into the furnace through burners. Coal-fired boilers will vary depending on the sophistication of the system and on the type of coal that is burned.

Hand-Fired

Hand firing is seldom used today, only in very small boilers used for heating or in small industrial processes. Coal is fed manually onto a cast iron grate by a fireman. The grate is sloped slightly towards the rear of the furnace to aid the fireman in moving the coal to the furnace rear. The boiler size is limited to 6 or 7 ft long because of the physical limitation of the fireman to maintain the fire. The actual area of the grate depends on the heating surface of the boiler and the kind of fuel burned. To start the boiler, a layer of approximately 3 to 4 inches of coal is shoveled by hand onto the grate. Wood shavings are placed on top of the coal bed. The bed is usually ignited by using oily rags. Once the coal bed has ignited, coal can be fed onto the burning bed to keep the fire going. Most of the hand-fired units have been replaced by more sophisticated designs.

Stoker-Fired

A number of stokers are in use today. They differ in the way coal is fed onto the grate, and the way ash is removed from the grate. Stokers can be grouped into three major categories: underfeed stokers, overfeed stokers, and spreader stokers.

Underfeed Stokers

In an underfeed stoker coal is fed into the furnace through long troughs called retorts. As the name implies, coal is forced up from underneath the burning fuel bed. Air comes in through openings in the grate, called tuyēres (pronounced twēē-yars). The smallest underfeed stokers use single or double retorts. A screw feeder on a mechanical ram forces the coal through the length of the retort and upward. Ash is usually discharged into ash pits by side-dumping grates. Figure 3-2 shows a single-retort underfeed stoker. Single- and double-retort underfeed stokers fire boilers that can produce 3000 to 30,000 pounds of steam per hour.

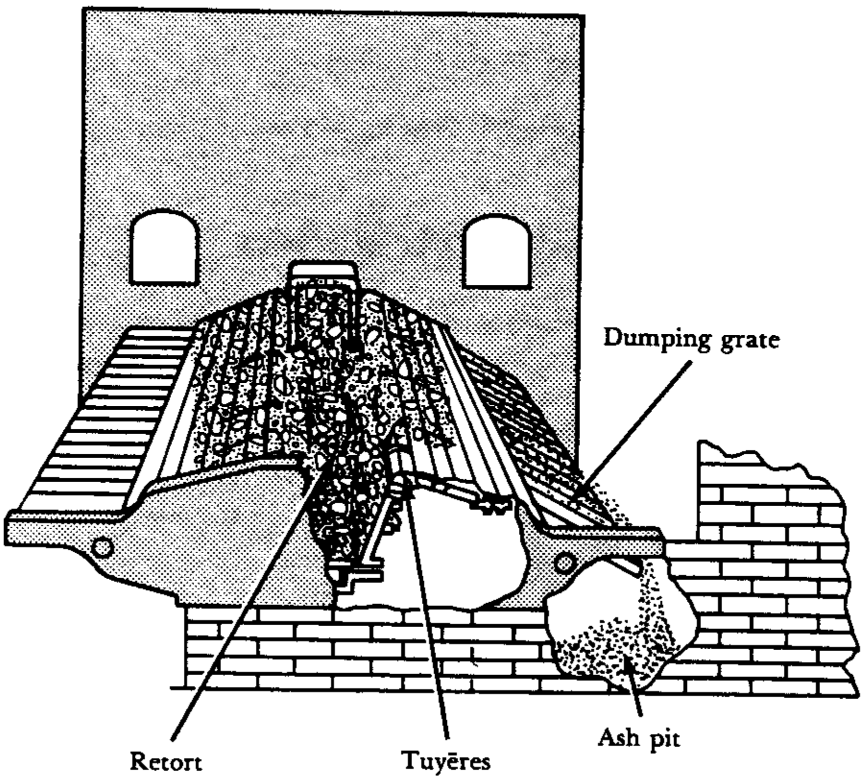


Figure 3-2. Single-retort underfeed stoker.

Some retorts use grates that move up and down to break up the coke that forms as coal burns and to also provide good air distribution through the burning fuel bed. Most modern underfeed stokers use overfire-air jets, also called secondary airports, to mix the volatile gases with air and burn them.

In underfeed stokers using feed rams, the ram forces coal from a hopper into the retort. During normal operation, green, or raw, coal is continually pushed out over the grate tuyēres. The burning coal slowly moves from the retort over grates toward the sides of the furnace. After combustion is completed, ashes are dumped into an ash pit located at the bottom of the furnace.

Larger underfeed stokers use multiple retorts, sometimes as many as twelve. To aid in moving the coal and ash through the furnace, these retorts are inclined 25° to 30° from the rams toward the ash-discharge end of the furnace. The multiple-retort stoker consists of single retorts placed side by side with tuyēres between each of them. Each retort is equipped with a primary ram to feed coal from a hopper. The fuel is moved slowly toward the furnace rear and at the same time forced up over the tuyēres by secondary (distribution) pushers or by moving the bottom of the retort. Most of the combustion air comes in through tuyēres. However, some overfire air is used to ensure that the fuel is completely burned. Ash is discharged at the rear of the furnace by dump grates, or plates. Dump grates are operated by air or steam cylinders. Ash falls from the dump grates into an ash pit where water sprays are used to cool the ash. Figure 3-3 shows a multiple-retort underfeed stoker. These units are used in boilers that produce 20,000 to 500,000 pounds of steam per hour.

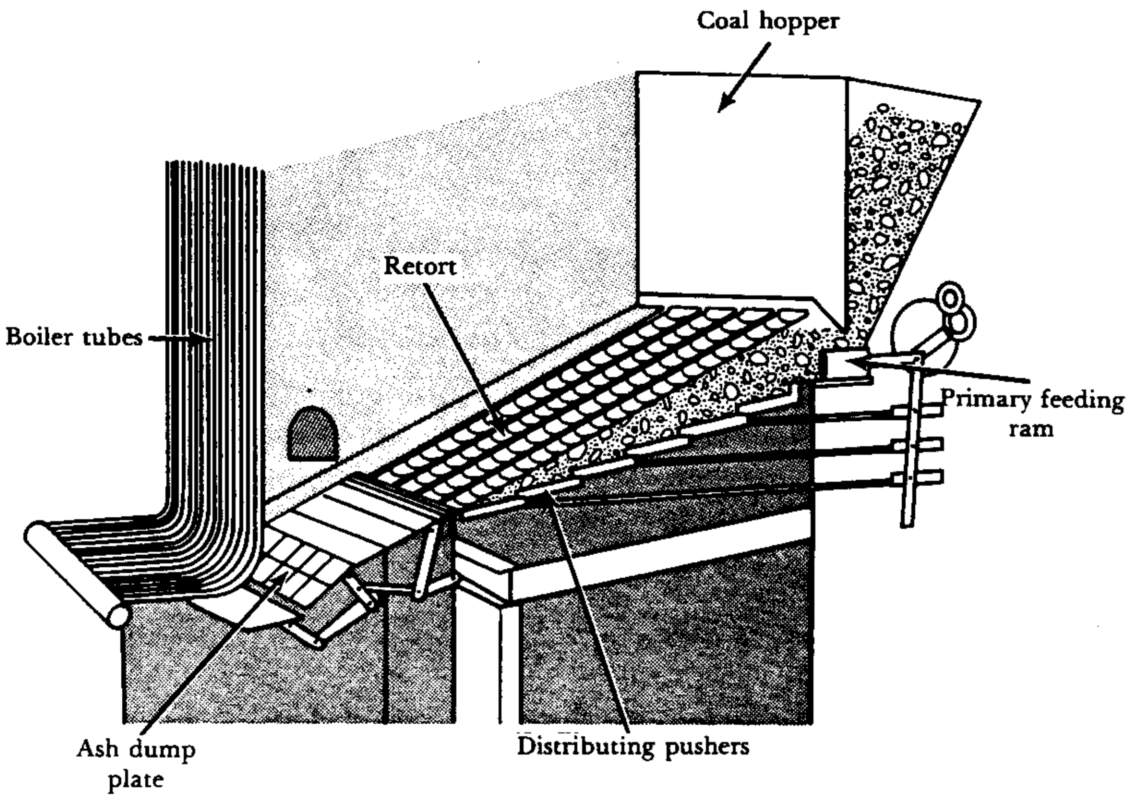


Figure 3-3. Multiple-retort underfeed stoker.

Underfeed stokers can suitably burn both anthracite and bituminous coals and are especially good for burning high-volatile coals. Burning low-ash coal may result in excessive temperatures on the grate and consequently high maintenance. In addition, if the ash in the coal fuses at a low temperature clinkers can form and clog the openings in the tuyères. Underfeed stokers are very responsive to changes in steam demand because the fuel bed on the grate is very thick. An increase in airflow through the bed quickly increases the heat in the furnace when the need for steam increases. Conversely, if the steam demand drops, the airflow through the bed can be decreased resulting in a lower amount of heat in the furnace.

Overfeed Stokers

In overfeed stokers, coal is fed onto a grate from hoppers. Three overfeed stokers are called the chain grate, traveling grate, and vibrating grate.

The chain-grate stoker uses a continuously moving grate constructed of closely fitted links of steel and chrome-cast iron. Coal is deposited onto one end of the grate from a coal hopper. The coal depth, regulated by a gate, ranges from 4 to 12 inches thick. Coal is burned as the grate moves through the furnace at less than 30 ft/hr. Ash is continuously dumped into an ash pit located at the rear of the furnace. Figure 3-4 shows a typical chain-grate stoker.

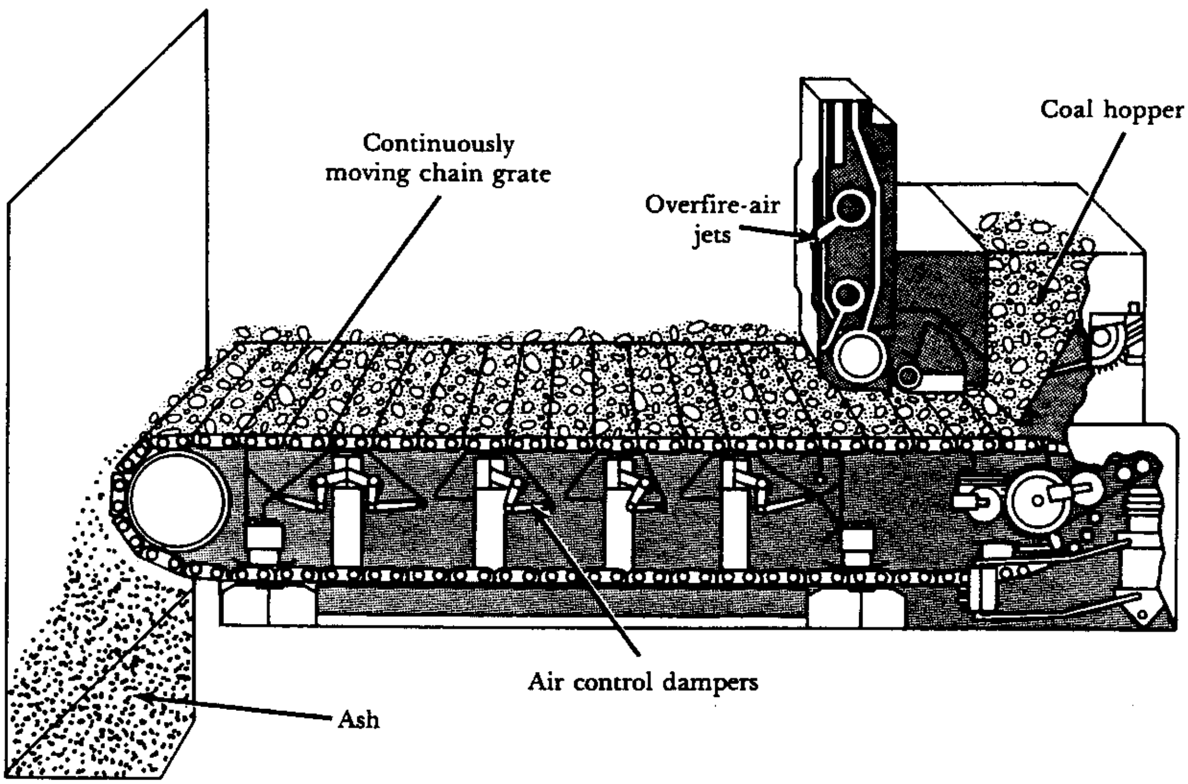


Figure 3-4. Chain-grate stoker.

The traveling-grate stoker differs from the chain-grate stoker only in the type of grate used. The traveling grate is made of steel bars, or links attached to separate carrier chains. Generally, two carrier chains support and drive each grate. Figure 3-5 shows a traveling-grate stoker.

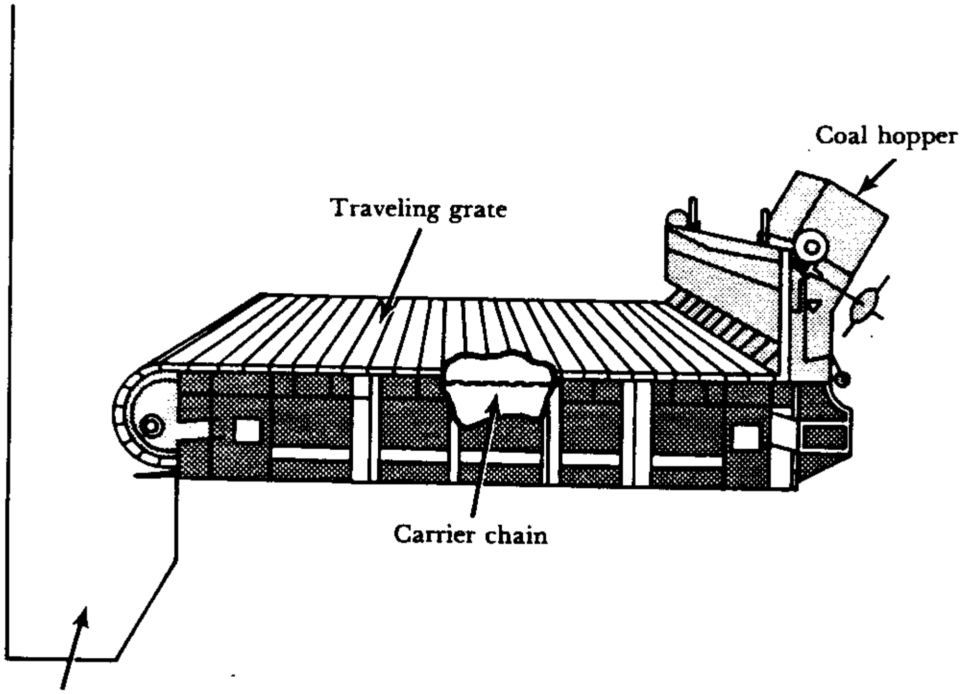


Figure 3-5. Traveling-grate stoker.

In both traveling-grate and chain-grate stokers, air enters the furnace through openings in the grates. The amount of air is manually controlled by the stoker operator. These units also use overfire-air jets located in the front wall of the furnace to mix the volatile gases with air for more complete combustion. Chain-grate and traveling-grate stokers are used on boilers that can produce as much as 200,000 pounds of steam per hour.

The vibrating-grate stoker, shown in Figure 3-6, uses vibration and gravity to move coal through the furnace. The grate is made of cast-iron blocks attached to water-cooled tubes. The water-cooled grate is tied into the boiler-circulating system. Cooling the grate allows the burning of low ash coals without overheating the grate. As with traveling-grate and chain-grate stokers, coal is fed from a hopper and the fuel bed depth is regulated by a gate. The vibrating force is provided by a generator located at the front of the stoker underneath the coal hopper. The grate is vibrated for approximately 5 seconds every 2 minutes. The interval and duration of the vibration is automatically controlled. Ash is discharged into an ash pit located in the rear of the furnace. The vibrating stoker has individually controlled air sections underneath the grate to supply air for the varying changes in the boiler output. The boiler often has a rear arch to direct any volatile gases in the burnout zone back into the active combustion zone. These units also have overfire-air jets located in the front wall.

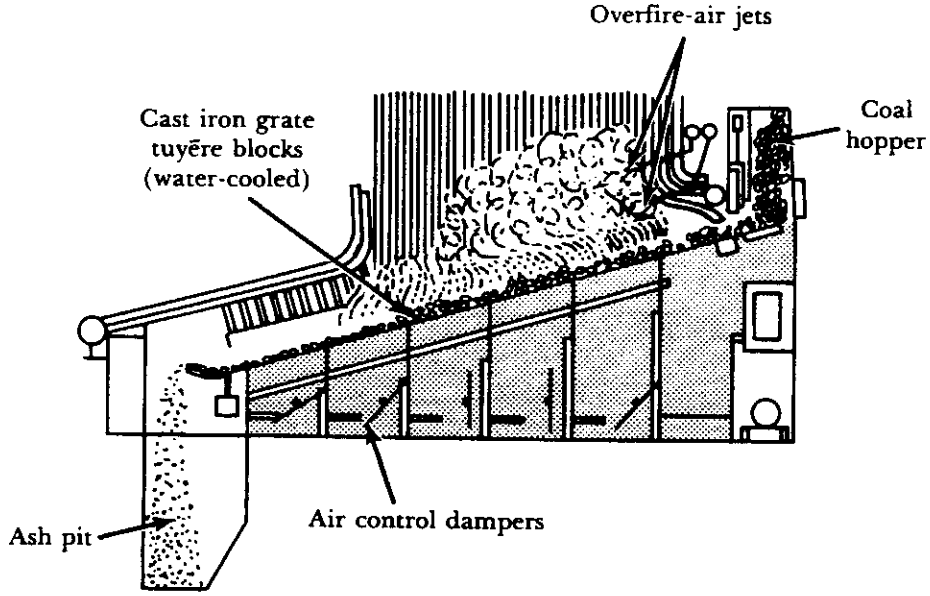


Figure 3-6. Vibrating-grate stoker.

These three stokers are used to burn different coals. Chain-grate stokers are used for noncaking high-volatile, high-ash coals. Traveling-grate stokers are used for lignite, and small-sized pieces of anthracite coal and coke breeze. Vibrating-grate stokers are used for medium- and high-volatile bituminous coals, low-volatile bituminous and subbituminous coals, and lignite at reduced burning rates. Overfeed stokers are not as suitable for burning high-coking coals than are underfeed stokers.

Spreader Stokers

In a spreader stoker, coal is spread over a grate by mechanical feeders located in the front of the furnace. Fine particles of coal and volatile gases burn while suspended above the grate. The remainder of the coal fed into the furnace falls onto the grate forming a thin bed of burning fuel. A forced-draft fan blows air through openings in the grate. Some of this air is used to burn the thin bed of coal on the grate, the remainder passes up through the furnace to burn the fine particles of coal in suspension and the volatile gases. Overfire-air jets on the front wall of the furnace supply additional air for suspension burning and produce turbulence. Many spreader stokers use overfire-air jets on the front and back walls of the furnace to help provide turbulence for mixing volatile gases, to prevent the flames from scorching the furnace walls and to keep them out of the coal-feeder throat.

A number of different mechanical feeders are used on spreader stokers. Most of the feeders use adjustable rotor speeds, a feed plate, and a deflector to distribute the coal evenly on the grate. Coal is fed from hoppers on the front wall of the furnace to a revolving motor with protruding blades. By varying the speed of the rotor and the place for coal to fall on the rotor blades, the operator can distribute the coal to various locations in the furnace. One mechanical feeder for a spreader stoker is shown in Figure 3-7.

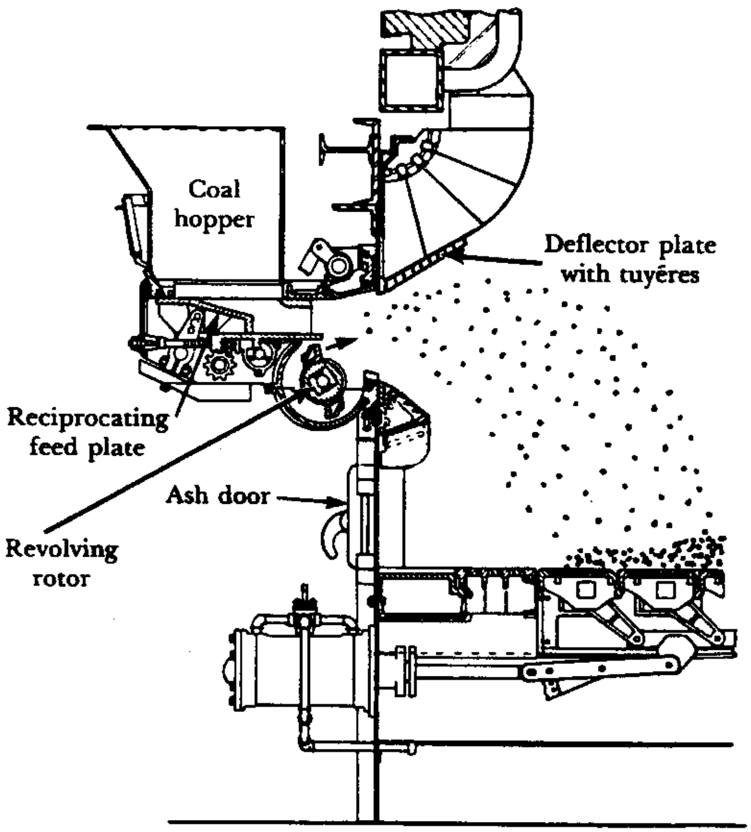


Figure 3-7. Mechanical feeder on a spreader stoker.

Spreader stokers use a wide variety of grates and ash removal methods. Simple units use stationary grates similar to those used in hand-fired boilers. These units use at least two feeders that deposit coal onto the grate. When the ash deposits fill a grate, its feeder taken out of service, the fuel bed burns down, and the ash is raked through the furnace door.

Dumping grates can also be used to remove ash from the grate. One feeder is taken out of service, the flow of air through the grate is stopped, and the ash is dumped into ash pits located below the furnace (Figure 3-8). The dumping grates can be operated by hand or by steam- and air-powered cylinders. During the dumping cycle, the coal feed to other furnace sections is increased to prevent a drop in steam pressure in the boiler. Dumping grates have been used on spreader stokers that can produce 15,000 to 75,000 pounds of steam per hour.

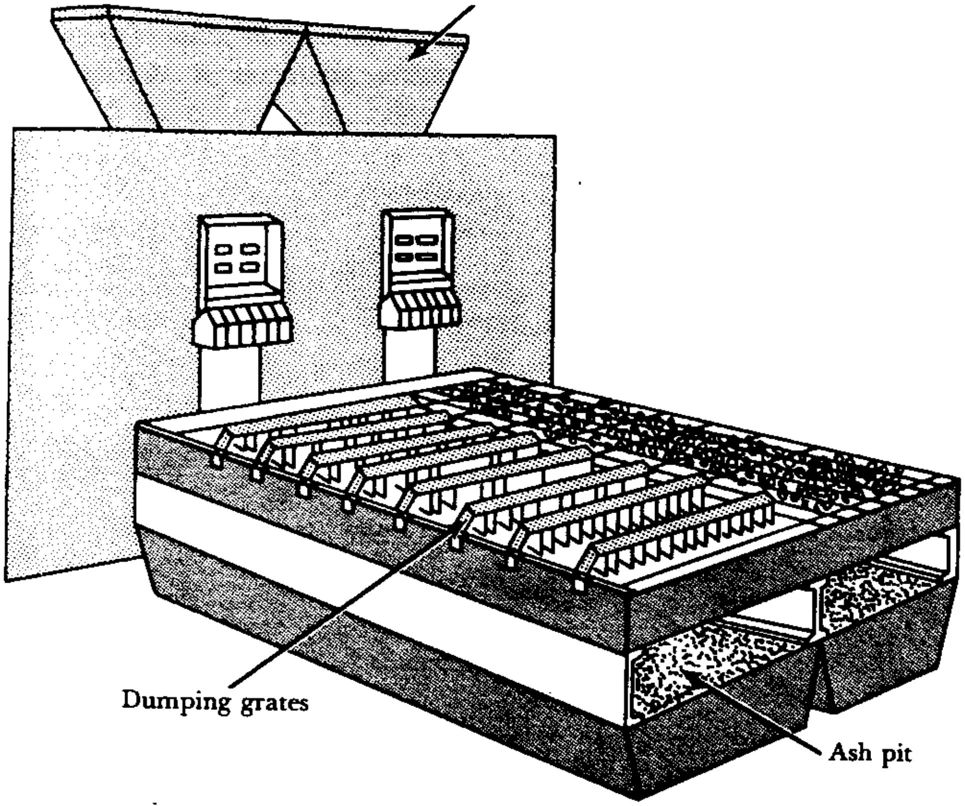


Figure 3-8. Spreader stoker with a dumping grate.

Large spreader stokers use a continuous ash removal system. Vibrating grates have been used, but the most popular are traveling grates. These operate similarly to those used in overfeed stokers. A traveling grate ash removal system used on a spreader stoker is shown in Figure 3-9. Coal is thrown onto the grate, and is burned while the grate slowly moves through the furnace. The ash is dumped into an ash pit located below the grate. Most traveling grates dump ash into ash pits located in the front wall beneath the stoker. However, some have been designed to use ash pits located in the furnace rear. Spreader stokers can produce as high as 400,000 pounds of steam per hour.

In many spreader stokers, collected fly ash, cinders, and bottom ash are reinjected into the furnace. Because a portion of the coal is burned in suspension, some of it is carried out of the furnace as cinders by the flue gas before it is completely burned. Cinders are collected in hoppers located beneath the convection section of the boiler. Fly ash is usually collected in cyclones or electrostatic precipitators. Some unburned carbon is also deposited in the ash pit. These collected cinders, fly ash, and bottom ash are occasionally reinjected into the furnace through openings in the rear wall improving stoker efficiency by as much as 3 to 5%. However, maintenance increases because reinjection piping may become plugged and dust collectors, ducting, and fans may be subject to abrasion.

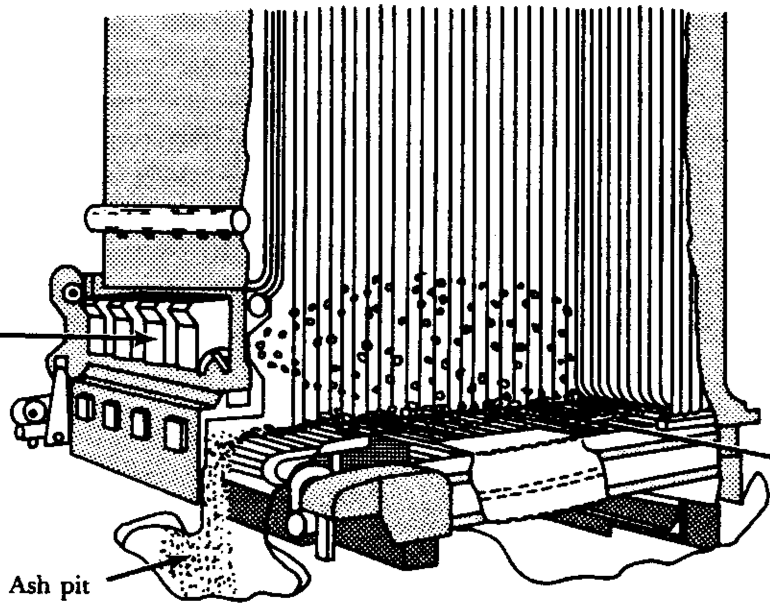


Figure 3-9. Spreader stoker with a traveling grate.

In the spreader stoker, the fuel bed is thin and a portion of the coal burns in suspension. As a result, the spreader stoker can respond rapidly to changes in steam demand. It will burn a variety of coals ranging from lignite to semianthracite. Coals that tend to form clinkers on the grate can be burned because of the spreading action in the furnace. The spreader stoker can also burn municipal solid waste, bark, bagasse, woodchips, sawdust, and coffee grounds.

Pulverized-Fired

Some large industrial boilers and most electric utility boilers use pulverized-coal (PC) firing. Pulverizing the coal creates a large surface area to be exposed to oxygen, thus accelerating combustion. Each boiler uses one or more pulverizing units where coal is pulverized into a powder before it passes to the burners in the furnace. Coal is fed to the pulverizers to meet the steam demand to the boiler. Warm air from the air preheater dries the coal in the pulverizer. This preheated air also carries the pulverized coal from the pulverizers to the burners. Combustion occurs as the fuel and primary air leave the burner tip. Secondary combustion air passes through openings in the burner, where it mixes with coal and primary air to create the necessary turbulence to burn the coal in suspension.

Pulverizers

Three types of pulverizers are used—contact mills, ball mills, and impact mills. Each of these is designed to pulverize bituminous coal so that approximately 65 to 70% will pass through a 200-mesh sieve and 99% will pass through a 40-mesh sieve.

A contact mill contains stationary and power-driven grinding elements. Coal passes between the elements where a rolling action pulverizes it into fine powder.

The grinding elements can be balls rolling in rings, or races; or they can be rings that move around stationary rollers. Figure 3-10 shows a contact mill using a ball and race arrangement. The balls are located between the two grinding elements, or races—an upper race that is stationary and a lower race that is power driven. Coal is fed through a hopper into the contact mill. The coal is pulverized between the balls and the lower race. This pulverized coal is blown up into a rotary classifier where oversized pieces are sent back to the balls and races and are repulverized. The fines are blown to the burners. A forced-draft fan supplies hot air to dry the coal, and to move it through the mill to the burners. The mill is therefore slightly pressurized and if the casing leaks, pulverized coal may be blown into the room where the mill is located.

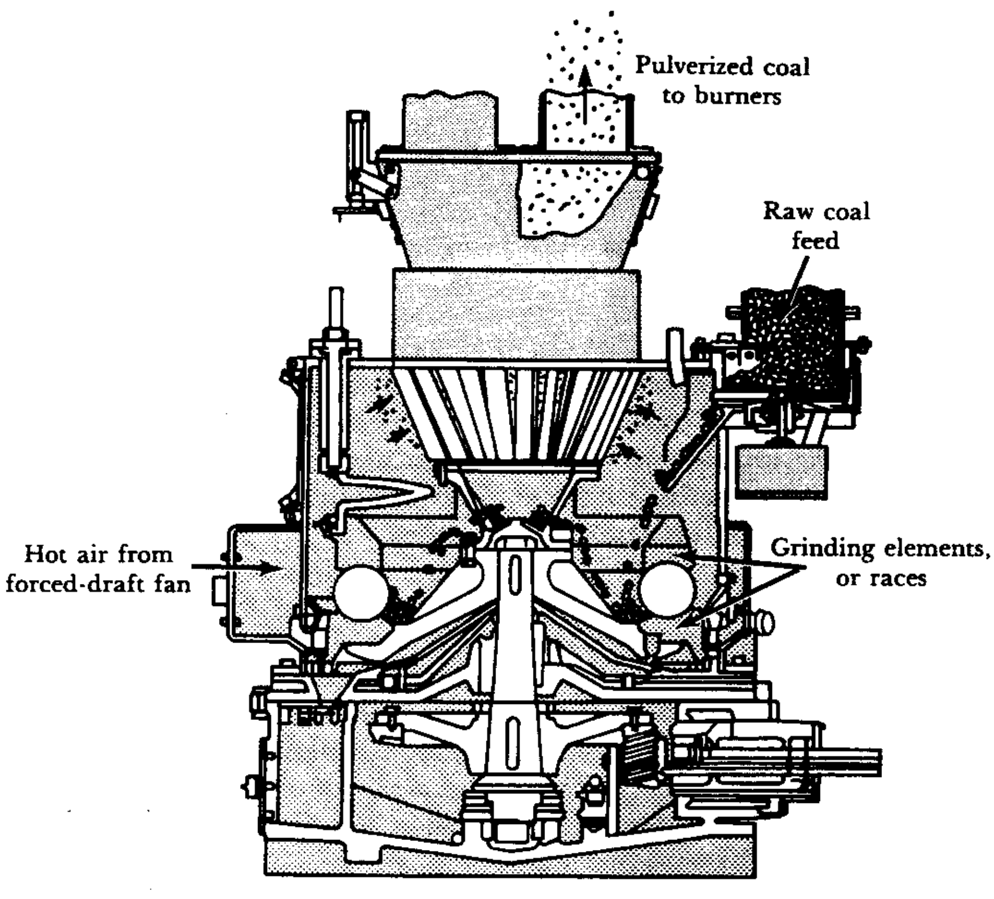


Figure 3-10. Contact mill using balls and races used to pulverize coal.

The contact mill shown in Figure 3-11 uses rollers and a ring as grinding elements. The ring is power driven and revolves around two or three stationary rollers, or tines. The rollers rotate as the ring revolves and the coal is ground between the two surfaces. The ground coal is carried by primary air through a classifier where oversized pieces are separated and reground. Pulverized fines are sent to the burners.

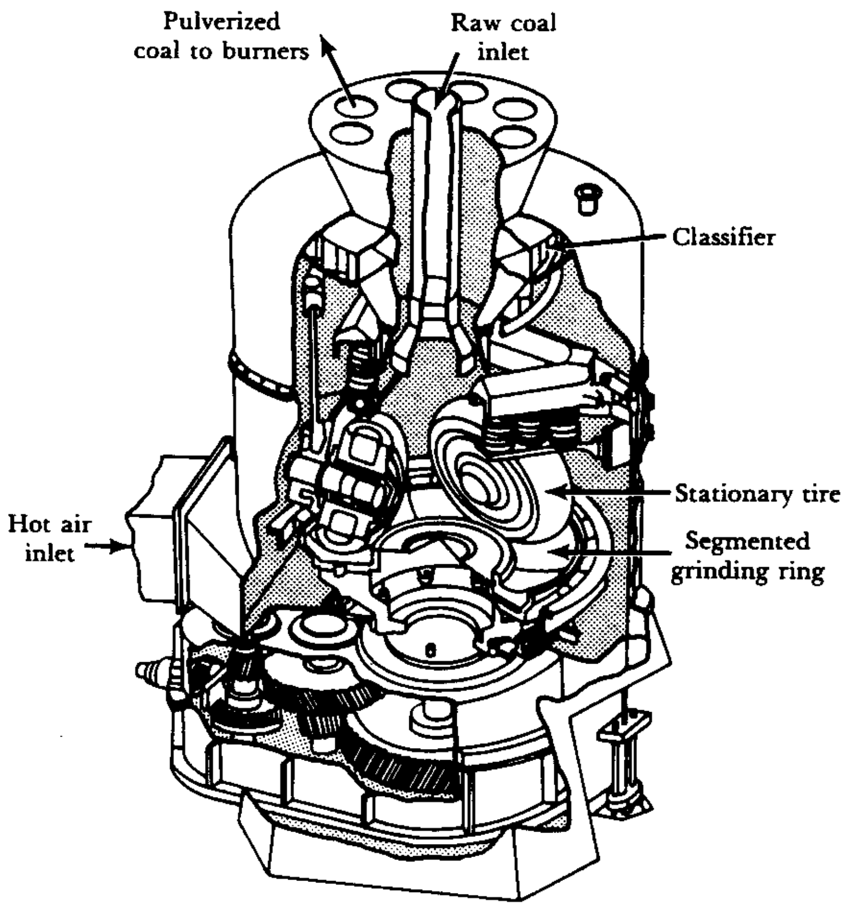


Figure 3-11. Contact mill using a revolving ring and roller (stationary tires) used to pulverize coal.

A typical ball mill, shown in Figure 3-12, consists of a drum partly filled with steel balls of varying sizes. The drum slowly rotates as coal is fed into it. Coal is crushed as the balls rub against each other. Hot air is blown into the drum to dry the coal during the pulverizing step. Pulverized coal passes through classifiers, then to the burners. Oversized pieces from the classifier are returned to the drum for additional grinding.

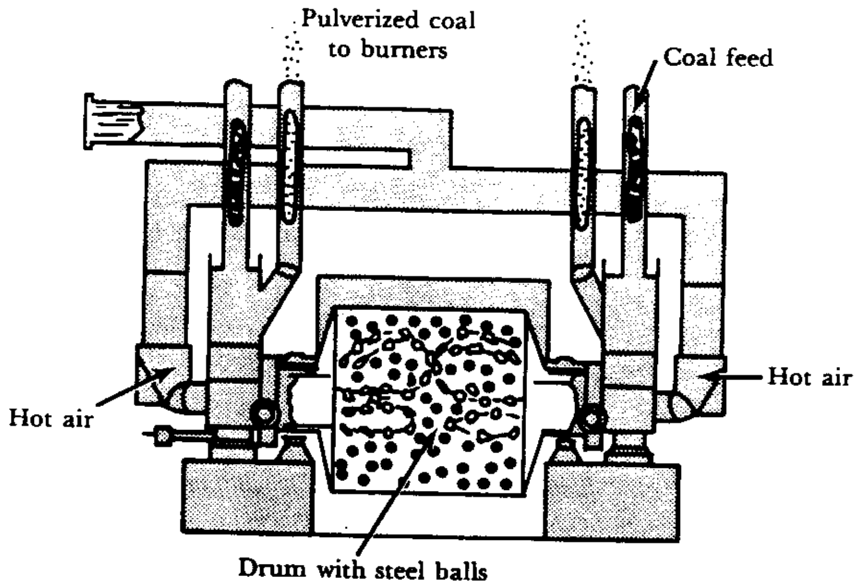


Figure 3-12. Ball mill used to pulverize coal.

In an impact mill, shown in Figure 3-13, the coal remains in suspension during the entire pulverizing process. The grinding elements and the primary air fan are connected to the same shaft. An induced-draft fan pulls heated air and coal (in suspension) through the mill. Coal is ground to a granular state by hammers in the primary grinding stages. In the final grinding stages, rotating disks move between stationary pegs. The coal moves toward the center of the pulverizer where rotating scoop-shaped rejector arms throw large coal particles back into the grinding sections. The fines are passed through the fan and discharged into the burners. These mills can adjust very rapidly to changes in steam demand. Impact pulverizers are also called Atrita pulverizers.

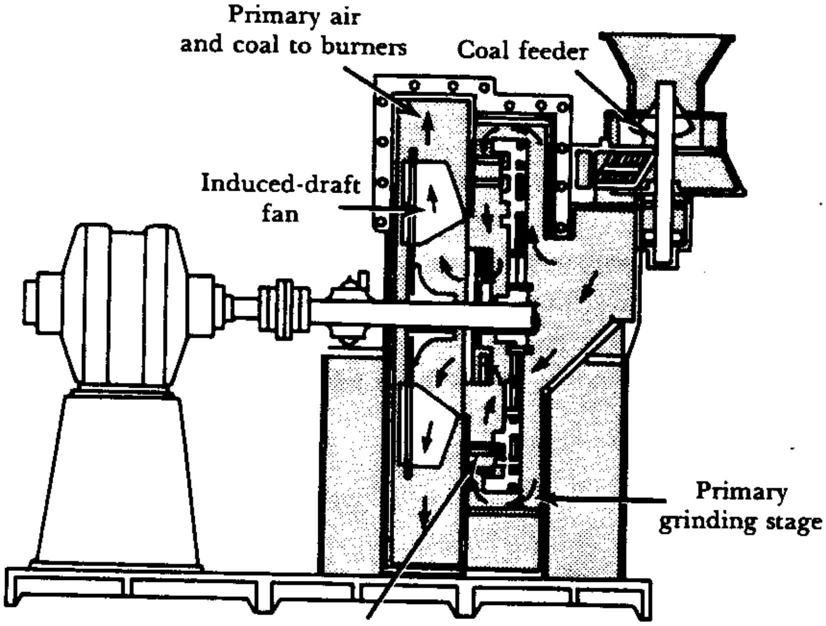


Figure 3-13. Impact mill used to pulverize coal.

Burners

Burners are designed to efficiently mix air with fuel to promote complete combustion. Coal and heated primary air usually move through the center part of the burner. Secondary combustion air is supplied from the windbox to the burner by a forced-draft fan. The amount of secondary air coming in through the burner is controlled by dampers. Occasionally, tertiary air will be brought into the furnace through openings, or ports, on the furnace wall or through openings around the outside wall of the burner. Coal is ignited by inserting a burning gas, oil, or kerosene torch into the burner.

Many different burner designs are used in pulverized coal-fired boilers. Figure 3-14 shows a typical wall-mounted burner. In this burner, fuel and air are mixed by impellar vanes. The boiler is usually equipped with a number of these burners mounted on the walls of the furnace.

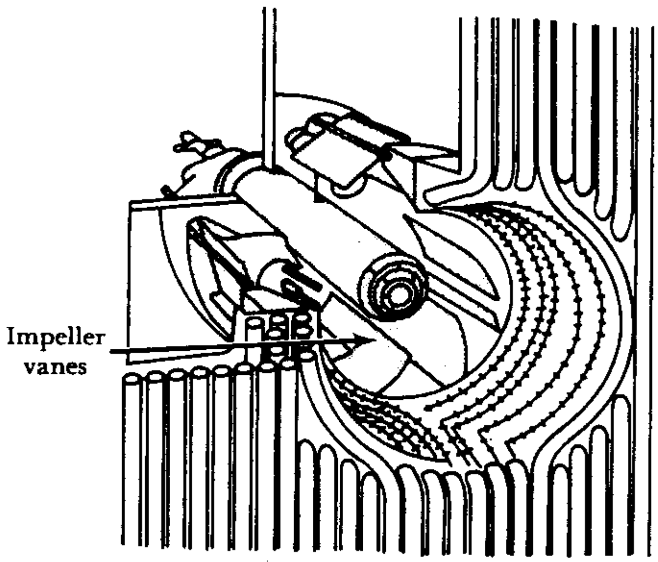


Figure 3-14. Typical burner used for pulverized coal firing—circular register burner.

The intervane burner, shown in Figure 3-15, imparts a rotary motion to the coal and primary air mixture in a central nozzle. This rotary motion provides good air and fuel mixing (turbulence). Secondary air flows into the furnace from a register that surrounds the nozzle. Coal is ignited by using an oil igniter.

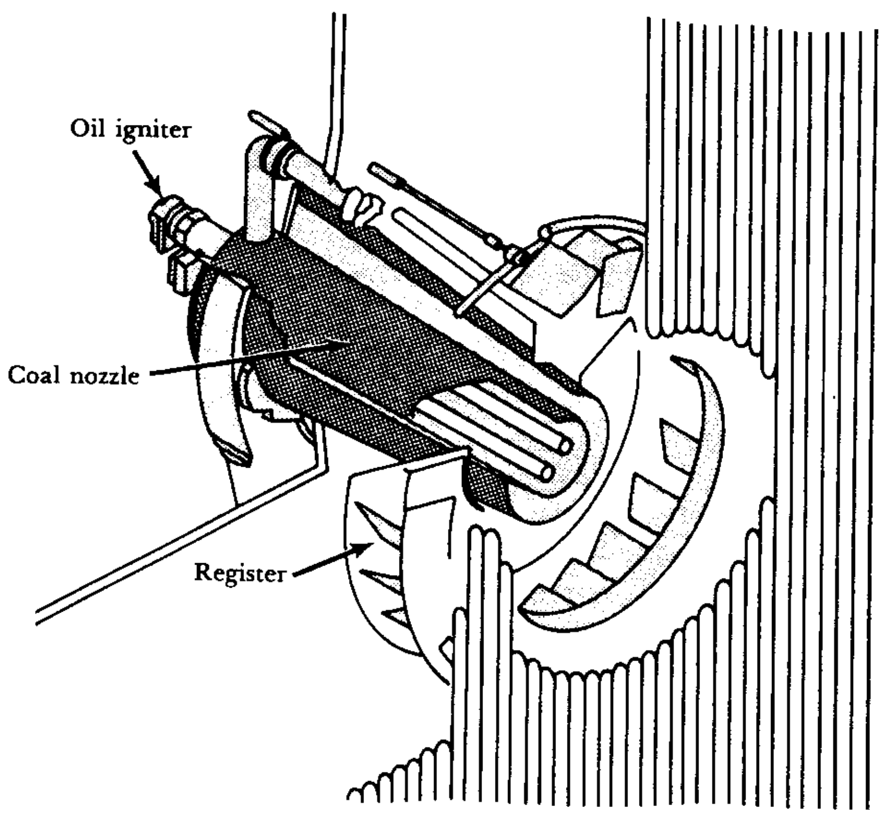


Figure 3-15. Intervane burner used for pulverized coal firing.

In the horizontal burner, shown in Figure 3-16, coal is fed through a central nozzle with internal ribs. The nozzle is surrounded by a housing containing adjustable vanes to control air turbulence and flame shape. Coal is ignited by inserting an ignition torch through the central tube.

The shape of the flame in the furnace depends on the type of burner used and location or firing pattern shown in Figure 3-17. In vertical firing, burners placed at the top of the furnace produce a long U-shaped flame. In horizontal firing, burners extend through the furnace wall producing a turbulent cone-shaped flame. Burners can be mounted on one side or on opposite sides of the furnace. In tangential firing, the furnace has one or more burners in each corner. The flames move toward the furnace center forming a large swirling ball of flames.

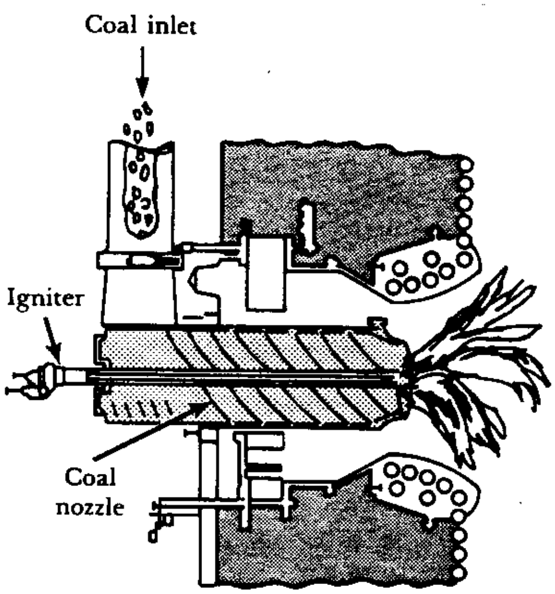


Figure 3-16. Horizontal burner used for pulverized coal firing.

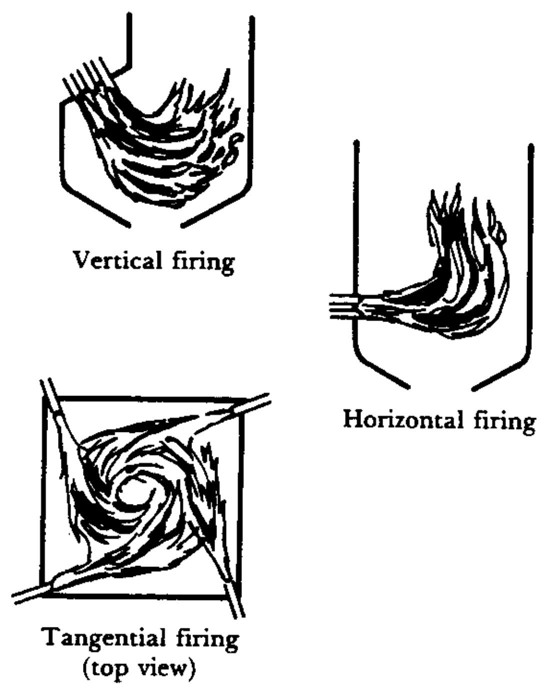


Figure 3-17. Various firing patterns of pulverized coal-fired boilers.

Advantages and Disadvantages

The ash in the coal can present operating and maintenance problems that must be considered when designing the furnace. Small- and medium-sized furnaces have ash removed in the dry state, and are called *dry bottom* units. The temperature of the furnace must be maintained below the ash-fusion temperature of the coal being burned. If this precaution is not taken, large quantities of slag can form, fouling the boiler surfaces. In some larger furnaces, the furnace temperature is maintained above the ash-fusion temperature of the coal. In this case the bottom ash is in the molten state, called slag. The slag is tapped from the furnace and then chilled by water. The rapid change in temperature causes the molten slag to shatter into small pieces of ash. These pulverized units are referred to as *wet bottom*.

Pulverized coal-fired boilers have the following advantages and disadvantages (Woodruff and Lammers, 1977):

Advantages

- Can adjust very quickly to varying steam demands.
- Requires low amount of excess air.
- Reduces or eliminates heat losses due to furnace banking.
- Can be repaired without cooling down the furnace because most of the equipment is located outside the furnace.
- Can burn a variety of coals.
- Can use high-temperature preheated air successfully—thus increasing furnace efficiency.
- Easily adapted to automatic combustion control.

Disadvantages

- Costly to install.
- Requires skilled personnel to operate because of explosion possibilities.
- Has high fly ash carryover—requiring the use of electrostatic precipitators or baghouses to meet emission regulations.
- Requires multiple mills and burners to obtain satisfactory operating ranges.
- Slag deposits may form on lower boiler tubes.
- Requires extra power to pulverize coal.

Fluidized-Bed

Fluidized-bed boilers have recently been used in some industrial and electric utility steam generators. These boilers are frequently referred to as atmospheric fluidized-bed (AFB) combustion units. The technology of fluidized-bed boilers evolved in oil refineries and chemical plants where they were used in many processes and also to destroy gaseous, liquid, and solid wastes.

In a fluidized-bed boiler, coal and an inert material such as sand, alumina, ash (from the fuel), or limestone, are suspended in a combustion chamber by air blowing up through the bed. Fluidizing the fuel bed provides turbulent mixing required for good combustion. The amount of fluidization that occurs depends on the size of coal and inert material and the velocity of the air moving through the bed. The fluidized-fuel bed essentially behaves as a liquid. The resulting improvement in fuel mixing allows the fuel to burn at lower temperatures, approximately 1500 to 1600°F, compared to other coal-fired boilers. Thus, the combustion chamber of a fluidized-bed releases heat at an equivalent level to that of a conventional boiler, but at lower temperatures without any theoretical loss in efficiency.

Fluidized-bed boilers offer some advantages over conventional designs in terms of reducing air pollutants. Because the operating temperatures are relatively lower, nitrogen oxide emissions will be lower. In fluidized-beds using limestone in the fuel bed, sulfur oxides, formed as the sulfur in the coal oxidizes, combine with the limestone to form calcium sulfate and sulfite particles that can be collected in an electrostatic precipitator or a baghouse.

Figure 3-18 shows a typical fluidized-bed boiler. Some fluidized-bed boilers use underbed feed systems, where coal is fed underneath the fluidized-bed. Others use overbed feed systems, and/or a combination of underbed and overbed feed systems. Overbed feed systems consisting of gravity-feed pipes or conventional spreader-stoker mechanisms have been successfully used. Many systems use perforated plates with equally-spaced holes that distribute air evenly through the fuel bed providing uniform fluidization. Some systems use steam tubes placed directly in the fluidized bed, while others use separate combustion chambers followed by convection sections, superheaters, and economizers.

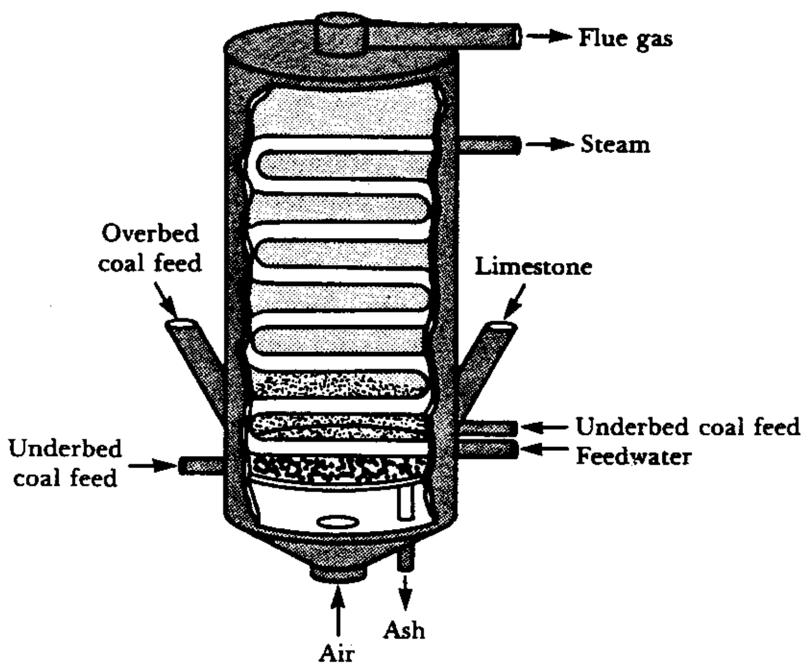


Figure 3-18. Schematic of a fluidized-bed boiler.

Fluidized-bed boilers can be designed to burn many different grades of coal, wood chips, solid wastes, and shredded tires. Fluidized-bed boilers are capable of producing 10,000 to 600,000 pounds of steam per hour.

Summary

Boiler designs affect the application of air pollution control and the response time to generate steam. Underfeed and overfeed stokers usually have lower fly ash carryover than do spreader stokers or pulverized-coal-fired boilers. Fine powdery fly ash is more readily carried with the flue gas. Data available on the fluidized-bed indicate that the fly ash carryover from these units are less than from pulverized-coal boilers. In terms of response time, in other words, the unit's ability to start up and change for various steam demands, pulverized-fired boilers are the quickest. These units are followed in order by fluidized beds, spreader stokers, overfeed stokers, and underfeed stokers.

Oil-Fired Boilers

Oil is used as fuel in many commercial and industrial boilers and in some utility boilers. The design of the combustion system depends on the grade of fuel oil burned and on the size of the boiler. As stated in Lesson 2, fuel oils are graded according to gravity and viscosity, the lightest being No. 1 and the heaviest being No. 6. Light distillate oils, such as No. 1 (kerosene), will readily vaporize in simple burners. Heavy fuel oils such as No. 6 must be heated to be adequately pumped to and burned in the burners.

Boiler Sizes

Boilers generate steam or heat for many commercial establishments. Commercial-sized boilers typically burn Nos. 4, 5, and 6 fuel oil at a rate of 3 to 100 gallons per hour (gph) (EPA, 1980). Electric heat is often used to decrease the viscosity of heavier fuel oils so that they will vaporize at the burner tip. Steam can also be used to heat heavy fuel oils. If distillate oils, Nos. 1 and 2, are burned, they do not need to be heated. Commercial-sized units are designed to use approximately 20 to 30% excess air. Fire-tube and water-tube (packaged) boilers are used for commercial establishments.

Industrial-sized boilers usually burn Nos. 4, 5, and 6 fuel oil at a rate of 70 to 3500 gph (EPA, 1980). Steam heaters are often used to heat these heavy fuel oils. Industrial boilers are shipped as packaged units or fabricated at the plant site. These boilers are designed to operate with approximately 10 to 15% excess air.

Utility boilers firing fuel oil burn No. 6, Bunker C, at rates of 3500 to 60,000 gph (EPA, 1980). These boiler systems usually include steam or electric heaters, insulated and/or heat traced piping, suction strainers for removing sludge, meters, and regulating and safety valves. Utility boilers are usually erected in the field and are designed to operate with approximately 2 to 4% excess air.

Burners

Steam-, air-, or pressure-atomizing burners are most frequently used for firing oil. Oil is atomized into very fine particles by the burner before it is burned. A steam-atomizing burner (internal mix) is shown in Figure 3-19. The oil is atomized as the steam contacts it, before reaching the burner tip, forming a short, bushy flame. These burners are used on commercial, industrial, and utility boilers at firing rates up to 1100 gph. An air-atomizing burner is shown in Figure 3-20. This burner uses low-pressure air to atomize the oil. Oil enters the rear of the burner and flows through a central tube. Oil combines with primary and secondary air at the end of the tube. Primary air moves through tangential vanes causing air to swirl as it passes around the stream of oil. This mixture combines with secondary air at the burner tip. These burners can burn No. 2 fuel oil or Nos. 4 and 5 fuel oil when used on commercial-sized boilers. A mechanical pressure-atomizing burner is shown in Figure 3-21. Oil flows at high pressure through a center tube and is discharged through tangential slots in a swirling chamber. The swirling oil passes through a sprayer-plate into an orifice where some of the oil moves through an orifice plate while a portion is returned to the suction pump. The amount of oil returned is determined by the position of the return-line control valve. Oil leaving the burner tip forms a conical spray.

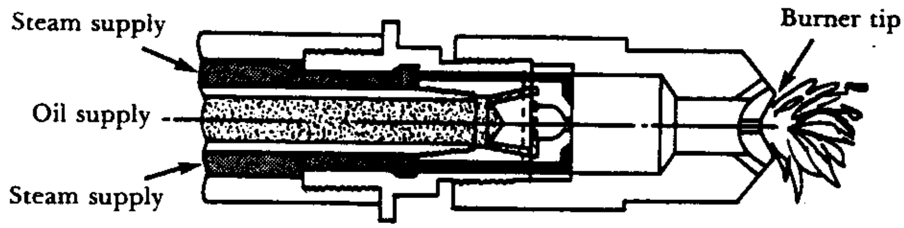


Figure 3-19. Internal mix steam atomizing burner used for oil firing.

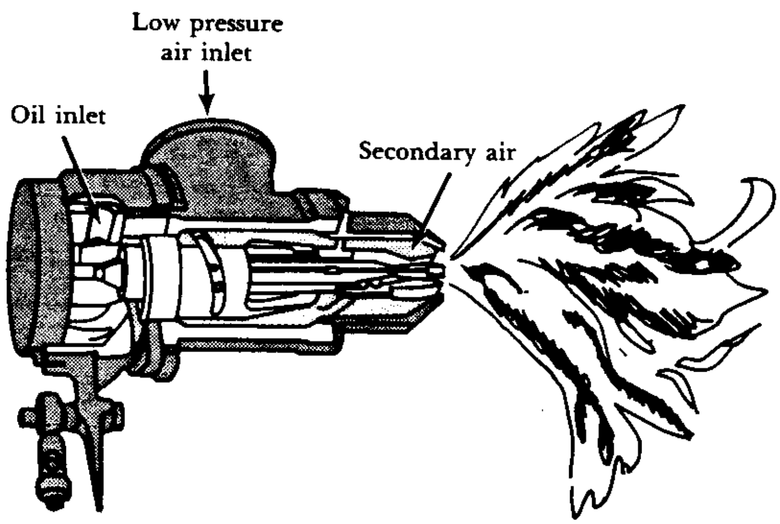


Figure 3-20. Air atomizing burner used for oil firing.

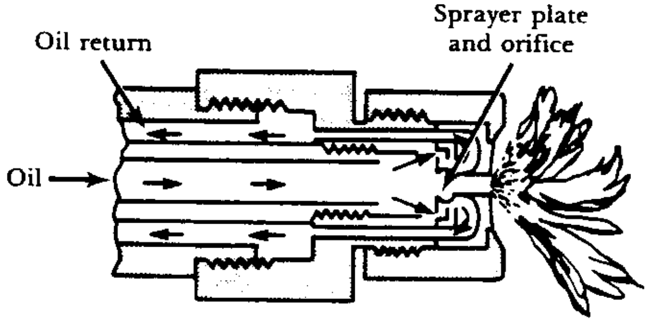


Figure 3-21. Mechanical pressure-atomizing burner used for oil firing.

Summary

Fuel oil burned in boilers to generate steam has the following advantages over coal (Woodruff and Lammers, 1977):

- Oil can be stored without deteriorating or combusting spontaneously.
- Plants can be operated with less labor than coal-burning steam plants, because of ease in operating oil transporting and burning equipment and because less ash is produced when oil is burned.
- Combustion processes can be automatically controlled.
- Initial plant costs are less than for coal-burning plants because coal- and ash-handling equipment are not necessary.
- Plants are easier to keep clean.
- Plants produce lower amounts of air pollutants than coal-burning plants.

Gas-Fired Boilers

Gaseous fuels burned in boilers are natural gas, by-product coke oven gas, blast furnace gas, refinery gas, and manufactured gas. Natural gas is readily available because of the vast network of gas pipelines. Other gases are used in the plants where they are produced or in neighboring plants. Natural gas is burned in smaller boilers, usually for residential or commercial establishments. Gas is occasionally used as a back-up fuel for industrial and utility boilers. It is also used for igniting pulverized coal-fired boilers.

Burners

Gas burners vary in the way they mix air and fuel. A simple premix burner is shown in Figure 3-22. Gas and primary air are mixed upstream of the burner tip. Secondary air is brought in at the burner tip. These burners are used on small residential- and commercial-sized boilers. Industries that have a large supply of blast-furnace or coke-oven gas readily available occasionally use them in boilers to produce steam or electricity.

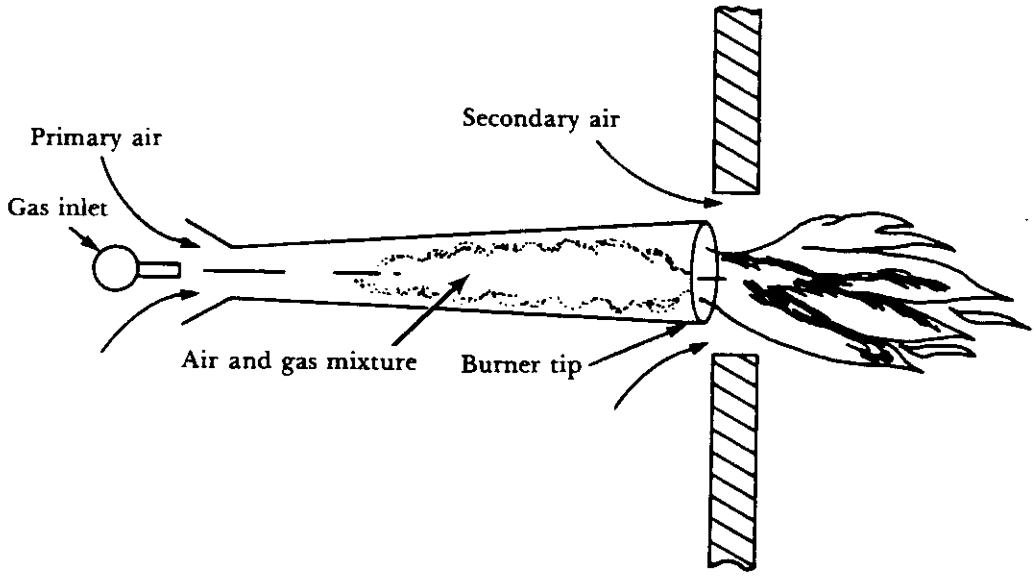


Figure 3-22. Premix burner used for gas firing.

A burner that can be used to fire gas and/or oil is shown in Figure 3-23. Gas enters through a large circular ring at the burner throat. Air from a windbox enters at the back end of the burner tube. Curved vanes impart a whirling motion to the air. Air mixes with the gas in the burner tube. The oil tube runs through the center of the burner.

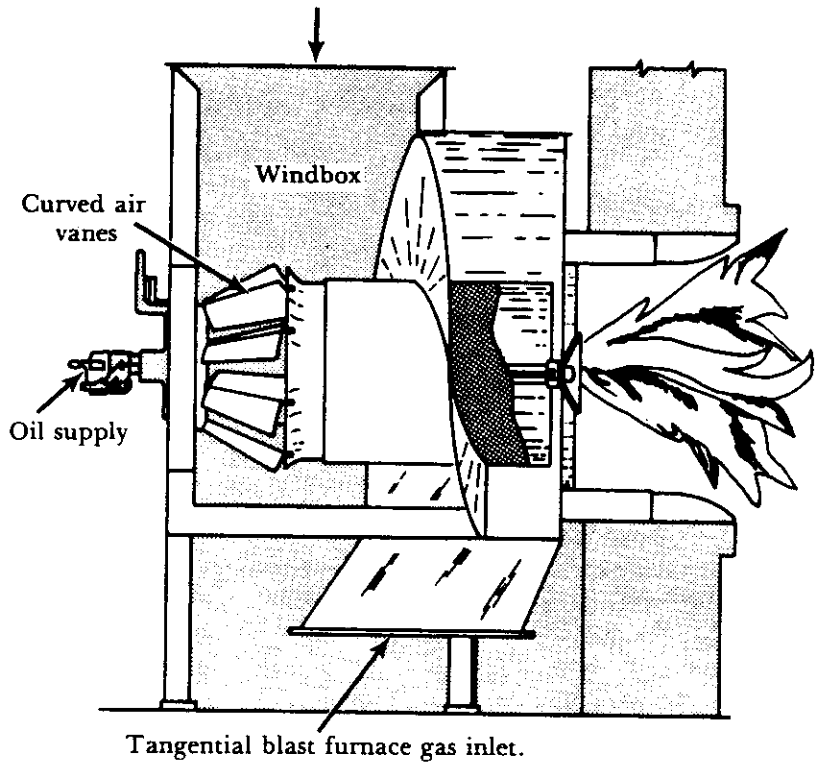


Figure 3-23. Combined blast furnace gas and oil burner.

Summary

The maintenance of gas-fired boilers is usually less than either oil-fired or coal-fired boilers. However, gas burners must be maintained because burners can become clogged. Air register mechanisms must be in good operating conditions and the boiler settings must be frequently checked to reduce air inleakage. Burning gas produces less air pollutants than do either oil or coal, because gas contains very little sulfur and virtually no ash.

Review Exercise

1. In a ________ system, a fan located after the boiler pulls air through the boiler and out the stack. a. natural-draft b. forced-draft c. induced-draft	
2. ________ fans are frequently used for induced-draft systems, especially if the flue gas contains a high concentration of dust. a. Radial b. Backward-curved c. Forward-curved	1. c. induced-draft
3. In a(an) ________, coal is fed into the furnace through long troughs called retorts. a. overfeed stoker b. underfeed stoker c. traveling-grate stoker d. spreader stoker	2. a. Radial
4. In an underfeed stoker, a ________ forces coal through the length of the retort and upward. a. mechanical spreader b. chain grate c. screw feeder d. mechanical ram or screw feeder	3. b. underfeed stoker
5. True or False? Multiple retort underfeed stokers are inclined slightly to aid in moving the coal and ash through the retorts.	4. d. mechanical ram or screw feeder
	5. True

6. In underfeed stokers, combustion air comes through openings in the grate called a. tuyères. b. windboxes. c. over-fire air jets.	
7. Chain-grate and traveling-grate stokers are a. underfeed stokers. b. overfeed stokers. c. spreader stokers.	6. a. tuyères.
8. ________ stokers use grates constructed of closely fitted links of steel and cast iron while ________ stokers use grates made of steel bars attached to a separate chain. a. Spreader, chain-grate b. Chain-grate, traveling-grate c. Traveling-grate, chain-grate d. Chain-grate, vibrating-grate	7. b. overfeed stokers.
9. In both traveling-grate and chain-grate stokers, combustion air enters the furnace through openings in the ________, and through ________ located on the front wall. a. tuyères, grates b. grates, tuyères c. grates, overfire-air jets	8. b. Chain-grate, traveling-grate
10. In vibrating-grate stokers, the grate is made of a. cast-iron blocks attached to water-cooled tubes. b. closely fitted bars attached to a separate chain. c. steel bars that continuously move from the front to the back of the furnace.	9. c. grates, overfire-air jets
11. In a ________, fine particles of coal and volatile gases burn while suspended above the grate. a. single-retort underfeed stoker b. spreader stoker c. overfeed stoker d. vibrating-grate stoker	10. a. cast-iron blocks attached to water-cooled tubes.
12. Spreader stokers use ________ to feed coal into the furnace. a. shovels b. traveling grates c. pulverizers d. mechanical feeders	11. b. spreader stoker
	12. d. mechanical feeders

13. In most spreader stokers, ash is removed from grates by _________ or _________. a. traveling grates, dumping grates b. vibrating grates, mechanical rams c. screw conveyors, tuyēres	
14. True or False? In pulverized-coal firing, coal is heated by hot air from the air preheater.	13. a. traveling grates, dumping grates
15. Coal can be pulverized into a very fine powder by using a. ball mills. b. contact mills. c. impact mills. d. all of the above	14. True.
16. In a contact mill, coal is crushed as it moves between grinding elements. These elements are a. balls rolling in rings, or races. b. rings that move around stationary rollers. c. a drum filled with steel balls. d. a. and b. above e. all of the above	15. d. all of the above
17. True or False? In burners used for pulverized-coal firing, coal is ignited by inserting a burning-gas, oil, or kerosene torch.	16. a. and b. above
18. In most burners used for pulverized-coal firing, _________ move(s) through the center part of the burner. a. secondary air b. primary air c. coal and primary air d. none of the above	17. True.
19. A pulverized-coal-fired boiler using a tangential-firing pattern has a. six burners mounted on the front and back walls of the furnace. b. one or more burners in each corner of the furnace. c. two rows of burners in both the top and bottom of the furnace.	18. c. coal and primary air
	19. b. one or more burners in each corner of the furnace.

20. In pulverized-coal boilers, if the bottom ash is removed from the furnace while it is in a molten state, these units are referred to as a. dry bottom. b. slag spreaders. c. wet bottom. d. none of the above	
21. In fluidized-bed boilers, coal and inert materials are suspended in the combustion chamber by a. a chain grate. b. mechanical rams and screw feeders. c. electrical fluidizers and bar grates. d. air blowing down through the bed. e. air blowing up through the bed.	20. c. wet bottom.
22. True or False? Fluidized-bed boilers are capable of reducing both SO_2 and NO_x emissions. This is because limestone in the fuel bed combines with NO_x to form calcium nitrate. Because the furnace temperature is relatively low, SO_2 formation is also reduced.	21. e. air blowing up through the bed.
23. Which of the following has the highest fly ash carryover from a boiler furnace. a. underfeed stoker b. traveling-grate stoker c. spreader-stoker d. pulverized-coal-fired boiler e. fluidized-bed boiler	22. False. SO_2 combines with limestone to form calcium sulfate and NO_x emissions are reduced because of the low furnace temperatures.
24. Which of the following fuel oils is(are) usually heated before being pumped to and burned in burners? a. No. 1 and No. 2 b. kerosene c. No. 5 and No. 6	23. d. pulverized-coal-fired boiler
25. True or False? Fuel oils are atomized in the burner by using steam, air, or mechanical pressure.	24. c. No. 5 and No. 6
	25. True.

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