BOILERS AND STOKER SYSTEMS

Shell Boilers for Coal Firing

Multi-tubular shell boilers are readily available as packaged units and are widely used to generate system and hot water for a range of applications.

Most modern designs are of the three-pass wet-pack type. For coal, the combustion system occupies a significant volume of the furnace (or first pass). As a consequence the furnace of a coal-fired boiler must be somewhat larger than that needed for an equivalent oil-or gas-fired boiler and hence the entire boiler will also be physically larger. The furnace chamber and the first-pass reversal chamber are responsible for around 40% of the total heat transferred in the boiler at maximum continuous rating (MCR). In this area a significant amount of heat transfer is by radiation; the remaining heat transfer takes place predominantly through convection in the tube passes. The arrangement and diameter of the tubes control the boiler exit gas temperature which is a key parameter determining the overall boiler thermal efficiency. Small-diameter tubes improve heat transfer but with coal firing the minimum acceptable tube diameter is restricted due to the possibility of deposit build-up at the tube inlet. The minimum diameter would normally be 53mm but local fuel characteristics may dictate even larger-diameter tubes. This factor, coupled with the need for larger furnaces in coal-fired boilers, means that the overall dimensions of a boiler are significantly larger. Although this has negative effects in relation to site access requirements and boiler cost, it can be beneficial in relation to steam-boiler response to rapid load changes. The larger physical size creates a larger water volume within the boiler which allows for the generation of significant volumes of flash steam in response to a small reduction in steam pressure with minimal risk of water carry over into the steam line. This effect has proved extremely important in the laundry, brewing and textile industries which have sudden surges in steam demand.

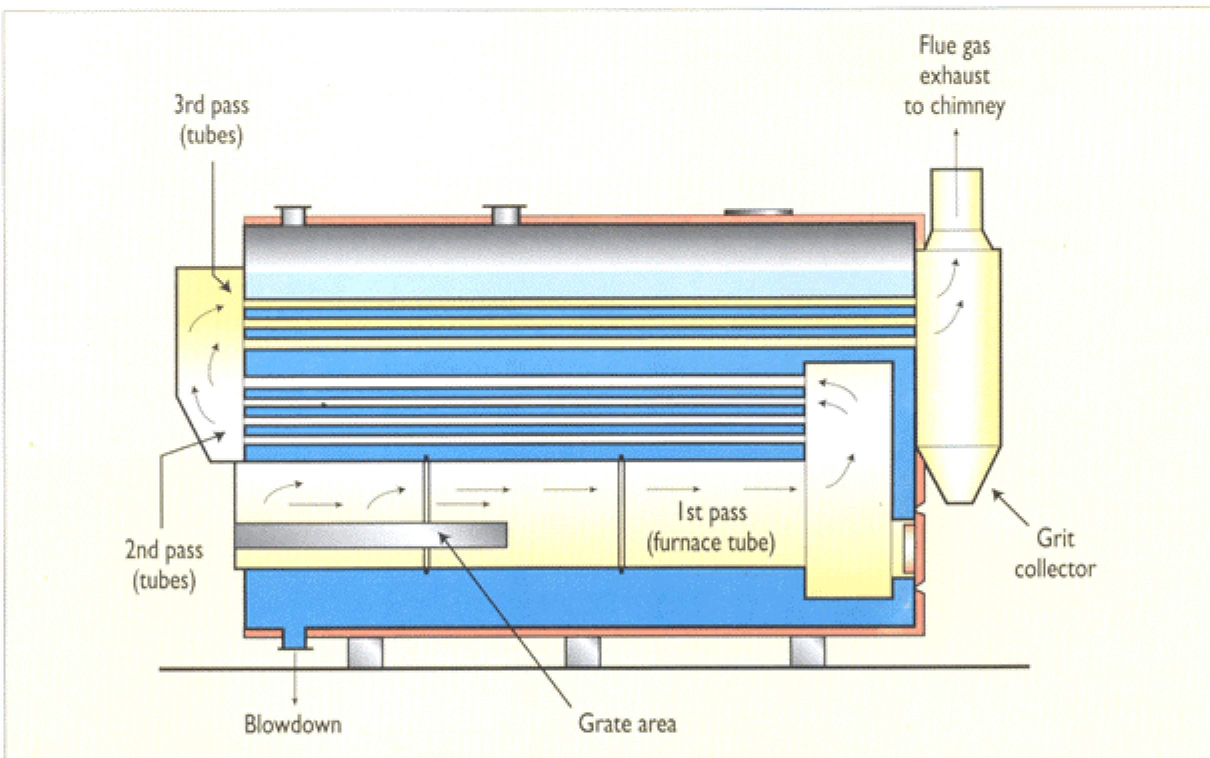

Figure 2 Three-pass, wet-back shell boiler

STATIC GRATE

The static grate principle provides a very flexible coal firing method for use in small boilers. It provides a relatively low-cost package unit over a wide range of boiler output (600kW_{th} to 11 MW_{th}) with a turn down ratio of up to 4:1. The coal is metered through a coal feed screw and fed onto a fixed grate consisting of a number of individual cast-steel grate bars. Ash is removed manually from the grate at intervals. The frequency of de-ashing is dependent primarily on boiler load and fuel ash content. The primary air is supplied through the grate, the pressure drop across the grate ensuring even air distribution. Secondary air is supplied around the coal feed pipe above the bed. This secondary air supply is vitally important for the elimination of smoke and achieving good combustion of the volatile matters. The volume, velocity and direction of this air must all the optimized to ensure satisfactory combustion. A great deal of effort was put into establishing optimum conditions for this type of coal-firing system.

As indicated, the grate bars, when assembled, act as the primary air distribution system. The design of these grate bars is crucial to ensure the correct distribution of the primary air through the fuel-bed. Detailed investigation of the design of these grate bars was undertaken, with aerodynamic modeling of the air spaces in the bars and the furnace being coupled with full-scale site trials, in order to produce an optimal design.

Response to changes in boiler load with this system is good due to the relatively high-intensity combustion and low thermal inertia in the furnace. This has been further improved by development of solid-state proportional integral derivative (PID) control systems and installation of variable speed drive motors for the main air fans and coal feed screws. These modifications offer not only improved response times but facilitate much closer control over air distribution and air/ fuel ratios, leading to higher combustion efficiency and also reduced heat loss to flue gases and thus higher boiler efficiency over the whole operating range.

The main disadvantage of this system has always been the necessity for manual de-ashing. The development of the 'tipping grate' systems has enabled the same combustion principle to be used whilst allowing automatic de-ashing. Whether this would be appropriate de-ashing must be assessed against the additional capital cost of the equipment and the introduction of moving parts into the furnace, leading to additional maintenance costs. Suppliers of this type of system include: Beel industrial Boilers, Hartley Sugden, Saacke and Wellman Robbey. CRE (now a part of EMC Environment Engineering) is the main supplier of the modified grate bars.

The static grate system requires a coal with low swelling characteristics and size-graded between nominally 32 mm top-size and 12.5mm bottom size. Ash content is normally restricted to 5-8% mainly to avoid frequent de-ashing. A washed and size graded coal is therefore a requirement for this type of stoker.

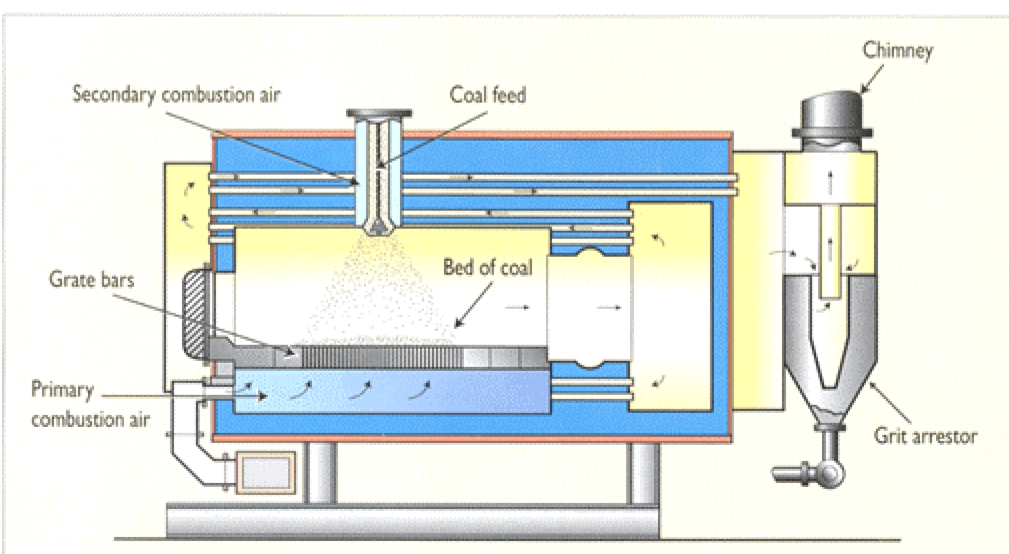

Figure 3. Static grate system

As indicated, the grate bars, when assembled, act as the primary air is fed by a ram from a hopper, mounted at the front of the boiler, onto a

COKING STOCKER

The coking stoker is a very well-established coal-firing system. The principle of operation has changed little over the years. However, modifications to the design have created a good system for automated minimally attended boiler operation. Coking stokers are normally employed in boilers with outputs between 1.8MW_{th} and 6$MW_{th.}$ The coal is fed by a ram from a hopper, mounted at the front of the boiler, onto a grate consisting of a number of reciprocating bars. This is a continuous process and ignition of the coal takes place through back-radiation from a small refractory arch. The reciprocating bars move in sequence, driven via a system of cams, in such a way that the coals is walked along the length of the grate bars. As the coal travels along the grate, primary air is drawn up through the grate bars by an induced draught fan allowing combustion to take place. Ash falls off at the end of the bars and may be removed manually or automatically from beneath the furnace. Secondary air may be supplied above the fire-bed or, alternatively, steam jets may be used to create turbulence above the fire, thereby minimizing smoke emission.

The addition of a rotary valve, or 'firebreak' between the coal feed hopper and the ram eliminates the possibility of the ignition front traveling back towards the coal feed hopper area. The original coking stoker design required manual attention to remove the build-up of ash-based deposits in the furnace. Recent modifications have removed this requirement so modern systems of this type can be automated to a great extent.

Although the response to load changes of a coking stoker is less rapid than that of a static grate system, the use of PID controllers means that this type of coal-firing system can be used in most industrial applications. Incorporation of variable speed motor drives and the 'firebreak' results in better control of air fuel ratio control, thus improving combustion performance and achieving high thermal efficiency. Main suppliers of this system include James Procter, Hodgkinson Bennis, Beel Industrial Boilers and Hartley & Sugden.

The coking stokers normally operate with coals of specification similar to that for static grate stokers. It is possible to use coal of a wider size range with a top size of 25mm to 32mm, but this may increase the loss of unburned coal dropping through the grate bars. Minimisation of the loss of this unburned material is essential for high overall thermal efficiency and does require periodic checking and adjustment of the reciprocating grate bars to ensure appropriate clearance between the bars is maintained.

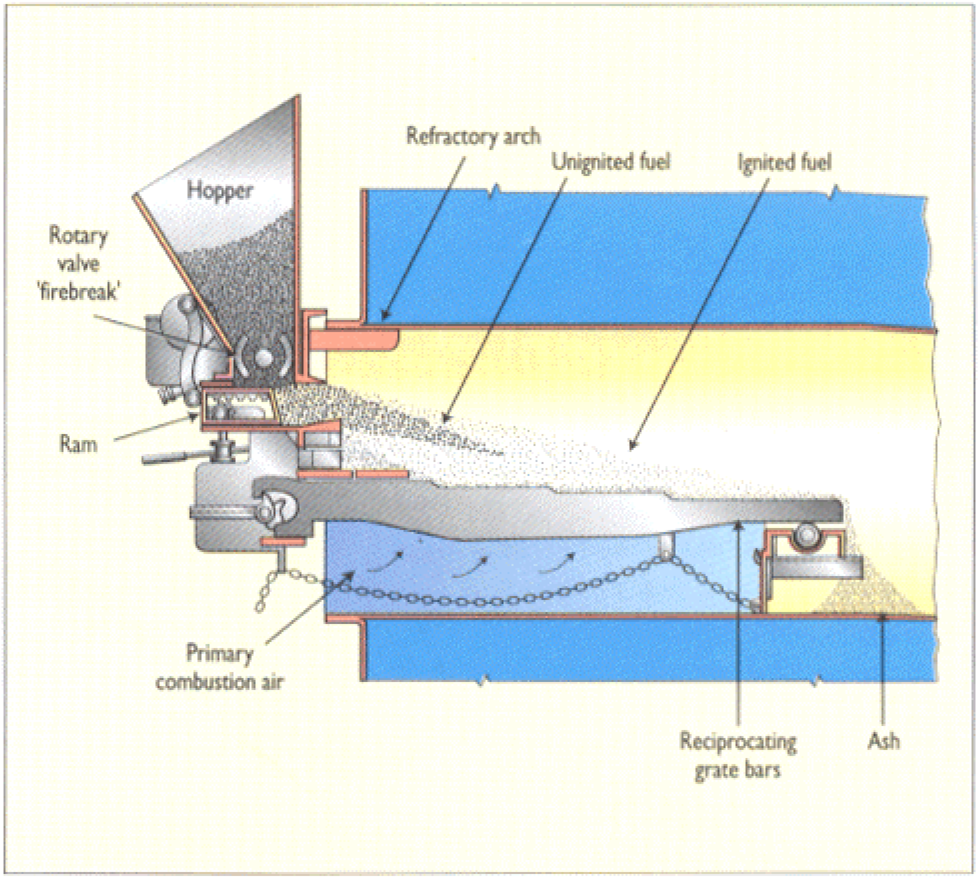

Figure 4. Coking stoker system

CHAIN GRATE STOKER

The chain grate stoker system and the closely related traveling grate stoker are particularly important for the larger end of the industrial boiler market. The outputs available using these systems, however, vary widely (1.5MW$_{th}$ to 80MW$_{th}$) and they offer a versatile coal firing system. There have been many variations on the same theme, but all consist of a partially flexible, looped 'mat' made up of metallic links connected to a drive system. The top surface of the mat remains under tension and acts as a continuously moving grate. As with the coking stoker system, the coal is fed from a hopper at the front of the boiler. The top surface of the grate is driven so that it moves away from the front of the boiler moving the coal with it. Once again, as this is a continuous process, ignition of the coal is effected by radiation from a refractory arch.

Primary combustion air is provided by a forced draught fan feeding into a plenum chamber under the grate and then up through the bed of coal on the grate. Distribution of the air throughout the length of the grate must be carefully controlled as the resistance to flow varies with the thickness of the bed of coal and ash. A great deal of development work has taken place to introduce baffles and control dampers into the plenum chamber to control air distribution through the fire-bed effectively. Additional turbulence is generated above the main fire-bed through the use of secondary air or steam jets. It is usual for the system to also use an induced draught fan.

The 'firebreak' concept has also been applied to this system to increase the level of automation along with modifications to reduce the build-up of deposits within the furnace. The boiler output is controlled by a combination of initial coal-bed thickness and the speed of the grate movement. This produces a very flexible combustion system but, without the 'firebreak', there are potential hazards relating to the ignition front moving towards the coal feeding hopper. Traditionally, grate speed has bee controlled through a mechanical gearbox, using a series of steps to change the speed to a required level. By introducing a variable speed motor drive instead of a gearbox, the grate speed can be varied widely, allowing a very wide turndown ratio to be achieved.

Extensive development work has been carried out in recent years to optimise the control of the key parameters such as:

- Grate speed
- Bed thickness (through the 'firebreak' rotary valve)
- Air distribution
- Air: Fuel ratio.

Insulation improvements and combustion condition monitoring, along with this work, have resulted in a new packaged boiler/stoker system combination. With these additions the response to load changes is good. The main disadvantages of chain grate type of stokers are high capital cost and a comparatively high maintenance requirement. Traveling grates are normally used for larger boiler outputs, typically 15MW$_{th}$ and above. Main suppliers of this system include: James Proctor, Cochran Boilers, Hodgkinson Bennis, Mitsui Babcock Energy and Beel Industrial Boilers.

The chain grate and traveling grate systems can operate on a wide range of coals. One of the most important coal characteristics with this system is the need for an ash content of 5% or greater, as the ash layer on the grate provides protection from the potentially damaging heat in the fire-bed.

Development of neural network controllers for industrial boilers has been undertaken using a highly automated chain grate-fired plant.

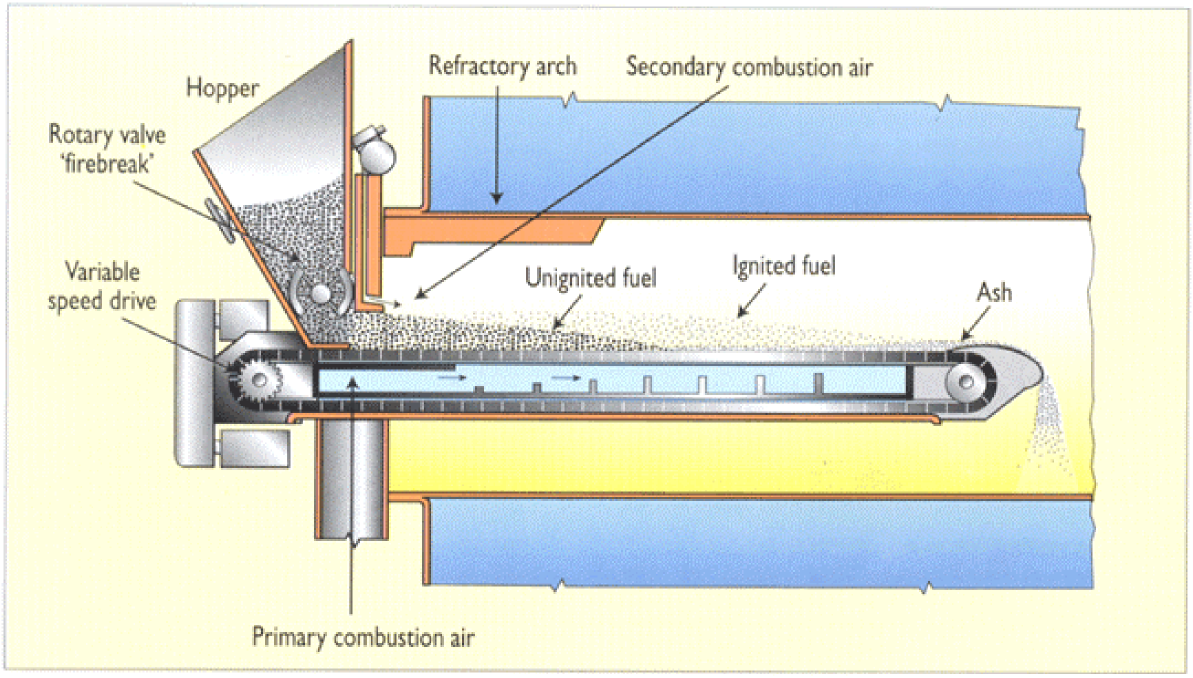

Figure 5. Chain grate stoker system

ATMOSPHERIC-PRESSURE FLUIDISED BED

The use of an atmospheric fluidised bed system, either circulating or bubbling, usually requires a purpose-designated package of boiler and combustor. A bed of inert material (such as silica sand) is agitated by a flow of air, from a forced draught fan, through a distributor plate. The air constitutes the primary combustion air and maintains the bed in a fluidised state. The bed is first heated to around 500^{o} C, usually with gas or oil, and then crushed lump coal is fed to the bed. Secondary air can also be supplied above the bed to help combustion of volatile matters and fine carbon particles escaping the bed. Once the coal is ignited, the bed is maintained at a temperature between 800^{o} C and 950^{o} C with combustion of coal alone without any need of gas/ oil support. A fluidised bed exhibits extremely good mixing characteristics between the solids and the gas and significantly enhances heat transfer between the bed of material and the boiler surfaces.

Fluidised bed combustors are capable of handling a very wide range of fuels, including low-grade fuels and waste-derived materials. No_x emissions from fluidised beds are generally low due to the use of low combustion temperature. Fluidised bed combustion also offers the possibility of sulphur reduction in the bed by the addition of limestone which reacts with SO_2 formed during combustion of coal. Calcium oxide from limestone absorbs SO_2 producing solid calcium sulphate for disposal as a waste. High thermal efficiency can be achieved but the turndown ratio is relatively low (2.5:1). Relatively high pressure drop across the fluidised bed also results I higher consumption of electricity by the forced draught fan and associated higher costs. Great care should be taken in the design of the fuel and ash handling system as these are often neglected, leading to operational reliability problems with the plant. Circulating fluidised beds are generally used with combination water tube and shell boilers, often linked with combined heat and power schemes. Main suppliers of this system/associated services include Mitsui Babcock Energy, M E Engineering, Thermal Engineering International and CRE.

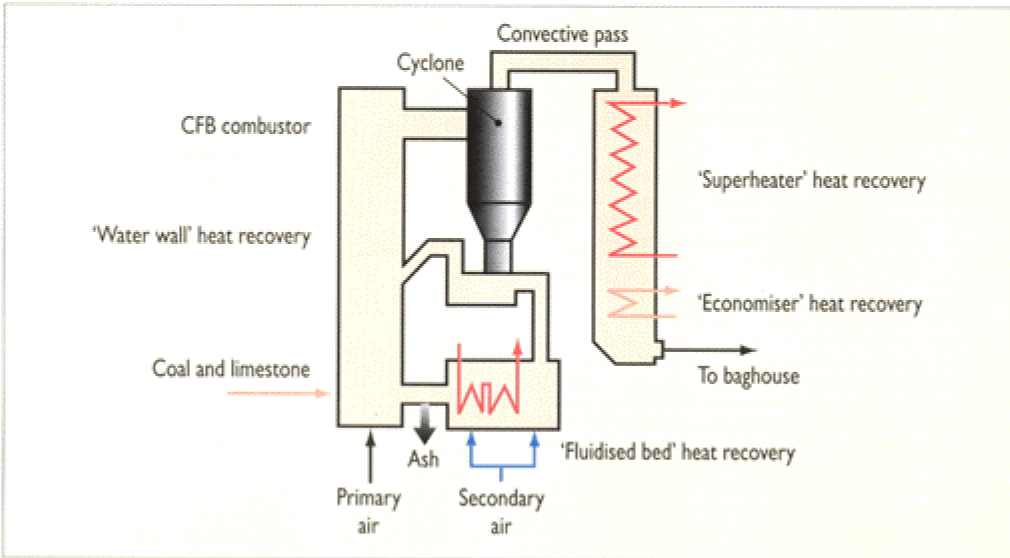

Figure 6. Circulating fluidised bed system

Reference:

U K CAPABILITY

Coal – Fired Industrial Boilers CB001 January 2002