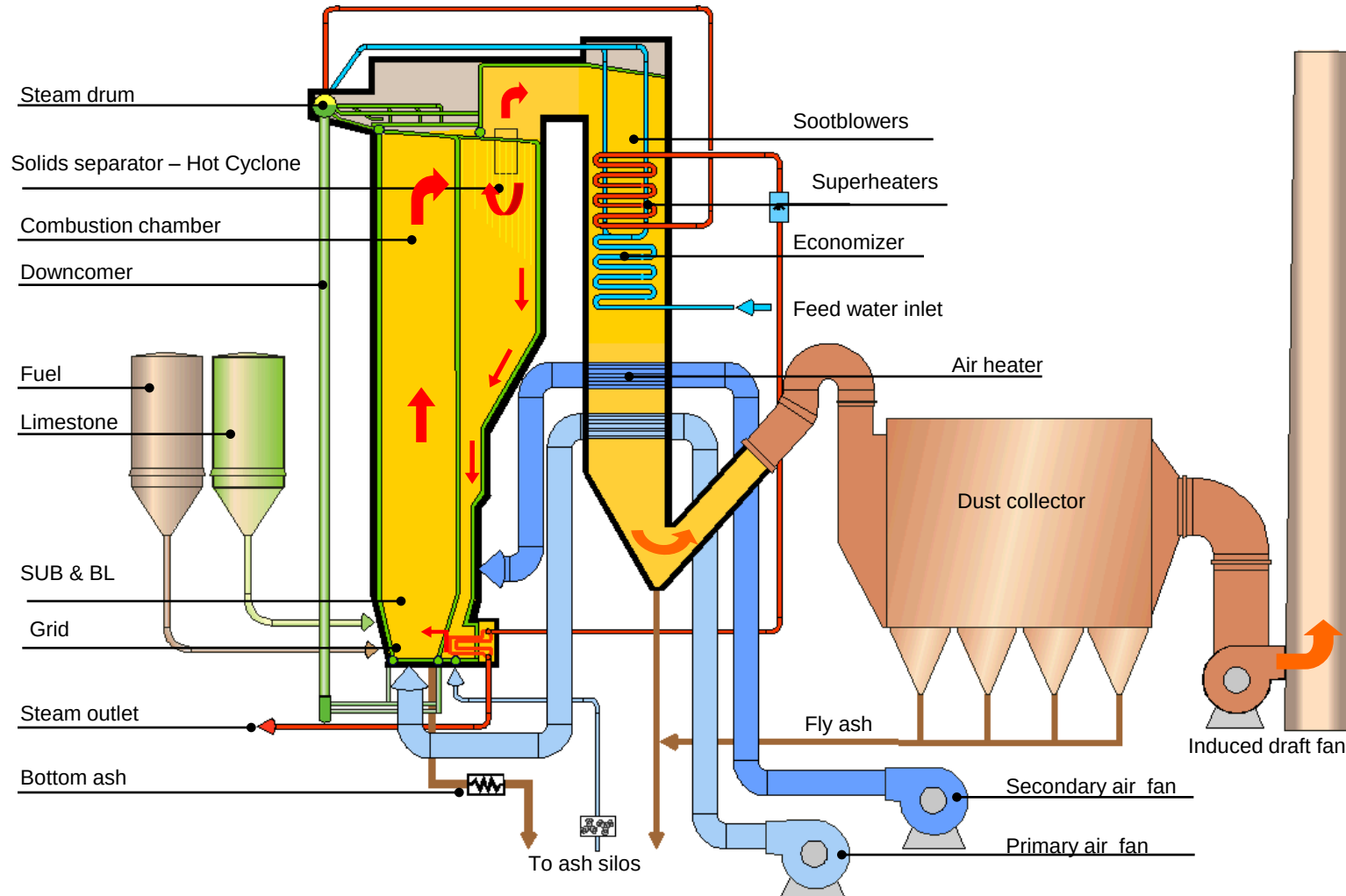

TCP Training

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CFB Boiler Components

Foster Wheeler Energia Oy
Jyrki Appelgren

CFB Boiler – Components



CFB Boiler Components - Eco

Boiler economizer

Flue gas leaves the furnace and transfers heat to the economizer. The economizer is a vertical bare tube heat exchanger. The tubes are arranged in multiple tube banks. Water is inside the tubes while hot flue gas flows over the tubes. The flow of the water is upstream and the flue gas is counterflow in the second pass. After leaving the economizer, the water flows to the steam drum and the gas flows to the electrostatic precipitator.

CFB Boiler Components - Drum

Boiler drum

Boilers operating below the critical point are customarily provided with a steam drum in which saturated steam is separated from the steam-water mixture discharged by the boiler tubes. The remaining water is then recirculated together, with feedwater, to the heat absorbing surfaces. Saturated steam leaves and feedwater enters this drum through their respective nozzles attached to the steam drum plate.

Also, the steam drum does serve as a vessel for boiler water treatment by chemicals and any necessary blowdown for reduction of solids concentration in the boiler water. However, the primary functions of this drum are to provide a free controllable surface for separation of saturated steam from water and a housing for any mechanical separating devices.

CFB Boiler Components - Drum

Boiler drum

Water level in the steam drum is regulated with existent 3-element control where primary variable is water level measurement and it is manipulated with difference of steam and feedwater flows to achieve a stable water level under fluctuating steaming-rate conditions. Water level is also supervised with the remote control unit from the control room.

The steam drum should be equipped with the necessary separators, demister or cyclones to produce steam going to the superheater that should be about 99.9 percent dry.

CFB Boiler Components - Drum

Continuous Blow Down

Continuous blow down system (CBD) is used to remove the precipitated impurities from the boiler water system from under water surface in the boiler drum. The system comprises perforated pipe collecting blow down inside the drum. This pipe is connected to the stub equipped with manually operated valves from which the blow down is discharged via the blow down pipeline to the blow down tank. Blow down flux is determined on the basis of the boiler water analysis (or measured by the measuring element and the flow is adjusted by a DCS controlled control valve basing on the setting set by the operator taking into account up-to-date boiler water quality analyses).

Water from the drum tank is discharged to the blow down tank (BDT).

CFB Boiler Components – Boiler tubes

Boiler water circuit – wall tubes

The boiler is a natural circulation boiler and the tubes are arranged so that as the water is evaporated to steam it is free to rise up into the drum. Unheated down comer pipes take the water from the lower part of the drum to the combustion chamber inlet headers. The combustion chamber wall tubes are heated by the flue gases and the water is partly evaporated to steam. Water and steam rise through tubes and riser pipes back to the steam drum where the steam is separated from the water in cyclone separators and drum roof demisters and the water is returned to the circulating system. Note that feed water only replaces the evaporated steam and the amount of water circulating is much greater than the feed water flow.

CFB Boiler Components – Boiler tubes

Boiler water circuit – wall tubes

The process of boiling water to make steam is a well-known phenomenon. Thermodynamically, boiling is the result of heat addition to the working substance, usually water, at a constant-pressure and constant-temperature. The heat that must be supplied to change water into steam without raising its temperature is called "the heat of evaporation" or vaporization.

CFB Boiler Components – Combustion Chamber

The combustion chamber is designed to contain a slight negative pressure and consists of a membrane wall gas-tight enclosure.

The lower combustion chamber section has an air distribution grid for introducing the primary air and a bottom ash removal system. The lower combustion chamber also has openings for the recirculated solids, secondary air nozzles, fuel, limestone, make-up sand and recycled fly ash feed, startup burners and bed lances as required. There are no heat transfer tubes inside the high-density lower combustor. In this region, a rapid change of solids flow pattern occurs, thus heat transfer wall tubing is protected by a thin layer of abrasion-resistant refractory.

Fuels fed into the lower combustion chamber mix quickly and uniformly with bed materials. There is no visible bed level in the CFB combustor. Instead the bed density decreases progressively with height.

CFB Boiler Components – Combustion Chamber

In typical full load operation, about 40 to 50 % of the heat generated by combustion is absorbed by the water-cooled membrane walls of the combustion chamber. Also, the high circulating solids and back-mixing intensity provide the high heat transfer rate typical of circulating fluidized beds.

The amount of primary air needed for initial fluidization of the bed material has to be maintained under all conditions. The proportion of the total air that is introduced as primary air varies from 40 to 70 % depending on the fuel. The remaining portion of the combustion air is typically divided between upper and lower secondary air levels. The distribution of air between primary and secondary air location is important to avoid excessively high temperatures in the lower combustion chamber and to insure good combustion efficiency as well as low NO_x production.

CFB Boiler Components – Combustion Chamber

Refractory

Refractory is required in all Foster Wheeler BFB/CFB boilers to provide safe, reliable operation and maintenance of the boiler. There are 2 reasons for designing Foster Wheeler boilers with refractory:

1. Erosion Protection and
2. Combustion Process

Erosion Protection

The prevention of erosion on boiler pressure parts is very important for long term reliability. Experience has shown that erosion in the Foster Wheeler CFB boiler can be eliminated through attention to design details of pressure part arrangements and abrasion resistant refractory coverage in key areas.

CFB Boiler Components – Combustion Chamber

Refractory

- **Lower combustion chamber** - The lower bed is where the dense bed material (sand) mixes vigorously and causes turbulence. The bed material is mixing with incoming fuel and is being fluidized by the grid air. The smaller particles are entrained in the upward flow and the heavier particles fall back toward the grid floor. The particles in this area are very abrasive.

Penetrations and discontinuities - Foster Wheeler CFB boiler operating experience has shown that erosion in the majority of the combustion chamber does not occur if there are no discontinuities that would change the direction of downward and upward flowing bed particles. Thus the system is designed to eliminate unnecessary discontinuities. In locations where discontinuities must exist, such as in-furnace surface penetrations, erosion protection is designed into the systems with refractory coverage or a combination of protection methods.

CFB Boiler Components – Combustion Chamber

Refractory - Combustion Process

The combustion process is enhanced by coating the waterwall tubes with refractory because it limits the absorption of combustion heat to the lower portion of the combustion chamber. This allows a higher temperature to be generated during the combustion process to burn off unwanted products.

CFB Boiler Components – Solids Separator

The solids separator

is a vital part of the CFB technology. The solids separator is primarily designed to provide an efficient separation of the entrained solids from the hot flue gas and return most of the unburned carbon and available calcined limestone for more efficient use. Inert ash particles are also returned, these particles are needed to maintain the proper bed inventory and quality. The separator, located at the outlet of the combustion chamber, collects particles greater than 60 microns with 99.5 % or higher efficiency. The solids captured in the separator are recirculated through a non-mechanical sealing device back to the combustion chamber.

CFB Boiler Components – Solids Separator

Mechanical design of the solids separator varies in both construction and shape. Based on customer preference, fuel fired, unit size and/or cycle condition the separator walls may be steam cooled, water cooled or of refractory construction. The conventional solids separator design is a refractory lined, uncooled cyclone. This type of cyclone is lined with a two-layer refractory, the inner refractory layer is abrasion resistant material to resist the erosive effects of high velocity ash particles. The outer refractory layer, against the metal shell, provides insulation to minimize heat loss and protect the carbon steel outer casing from overheating. The amount of refractory in this type of cyclone is very large and therefore high maintenance costs and availability problems are envisioned. However in low labor costs countries uncooled cyclones may be acceptable, but typically a cooled separator design desired.

CFB Boiler Components – Solids Separator

In a solids return from uncooled cyclone to combustor, a loop seal is used to provide the gas seal for pressure difference between lower furnace and separator. Loop seal has similar mechanical structure as the cyclone, i.e. it is manufactured of carbon steel plate and lined with a two-layer refractory. This further increases the amount of refractories. A split loop seal design is used particularly in larger units to provide two solids outlets from one cyclone. The bottom of the loop seal is fluidized with high-pressure air.

Expansion joints are provided at the inlet of the uncooled cyclone and in loop seal to compensate different thermal expansion of combustor and cyclone.

CFB Boiler Components – Solids Separator

A state-of-the-art separator design is a Foster Wheeler solids separator, which nowadays is of totally water and/or steam cooled structure. The form of the separator is angular as it is fabricated of machine-welded membrane panel walls. The interior of the solids separator is lined with thin abrasion resistant material for erosion protection.

With cooled separators a wall seal -design is used to provide the gas seal. Wall seal is constructed of water cooled panel walls minimizing the amount of refractories. The bottom of wall seal is fluidized with high-pressure air.

In case of a water cooled separator no expansion joints are required as there is no temperature difference between separator and furnace. In case of a steam cooled separator a flexible connection is provided at separator inlet and a small expansion joint at the outlet to wall seal.

CFB Boiler Components – Bottom Ash Removal

The purpose of the bottom ash system is to regulate the removal of the bottom ash material from the combustion chamber based on the overall bed quantity and quality.

Typical bottom ash system used with the CFB boilers consist of number of ash drain chutes with manual isolation slide gates, air cannon system, water cooled bottom ash discharge screws and a chain conveyor. The chain conveyor discharges bottom ash to a screen (sieve) where bigger particles are separated before the bottom ash is transported to a bottom ash silo. Alternatively, these fine particles may be returned to bed material silo (if applicable) for recirculation, purpose of which is to minimize the unburned material removed from the furnace within bottom ash.

The bottom ash discharge screws are typically equipped with variable speed drive (i.e. frequency converter). The bottom ash chain conveyor and other rotating devices are respectively direct driven devices (depending on the application).

CFB Boiler Components – Bottom Ash Removal

The essential function of the bottom ash mechanical handling system is to maintain the proper quantity of bed material in combustion chamber (furnace bed). This is necessary for a proper operation of the boiler (CFB process).

The devices for bottom ash discharge are typically controlled by operational sequences managed by the bed pressure control.

CFB Boiler Components – Flue Gas

Introduction

Typically the boiler flue gas system comprises one (two) Induced Draft (ID) alias flue gas fan with inlet vane or inlet damper, and the shut-off dampers before and after the fan. Alternatively the control vanes can be replaced with a frequency converter controlled fans.

Furnace pressure transmitters (typically three pcs) are located at the same elevation in upper section of the furnace.

Between the ID-fan and the back pass of the furnace is located the electrostatic precipitator that removes fly ash from flue gas before the gas enter to a stack where the purity of flue gas is analyzed. The oxygen measuring points are intended to locate as near the furnace as practically possible (considering the flue gas temperatures), in order to minimize time delay (lag) in the measurement(s).

CFB Boiler Components – Flue Gas

Operation

The furnace pressure (draft) is one of the boiler interlock signals. Thus there is typically three measurements in parallel, and the interlock signal is formed of the measuring signals (two-of-three selection).

Furnace pressure is controlled with the inlet vane or damper or alternatively with the frequency controlled motor of ID-fan. The furnace pressure control is operating with a constant setpoint.

The flue gas dew point temperature have to be avoided for corrosion in the flue gas duct. Temperature of flue gas in boiler outlet is controlled with the primary and secondary air temperature controllers by providing to them the remote set point.

CFB Boiler Components – Flue Gas

The flue gas oxygen content is the one of boiler interlock signals (for burning). The excess air of combustion is kept in balance with the flue gas oxygen control. Typically there are three separate oxygen controllers in the system, the one that trim the secondary airs or alternatively the one that trim fuel feeding in proportion to combustion air flow quantity, and the one that is limiting the boiler master operation if the oxygen measurement pass the specific minimum limit (typically 1.0 % O₂).

Flue gas temperatures and pressure drops are measured throughout the system mainly to indicate the condition of the boiler and the need of sootblowing. Simultaneously flue gas is analyzed for O₂, CO, NO_x and SO₂ to indicate the efficiency of combustion and possible malfunctions in operation as far as emissions are concerned.

CFB Boiler Components – Electrostatic Precipitators

ESP

Polluted flue gases flow through the electrostatic precipitator in strong electrical field generated between corona and collecting electrodes. Collecting electrodes are grounded, while the corona electrodes are connected to the negative end of DC voltage source. Electrostatic precipitator supply voltage level is typically between 50-106 kV. High voltage applied to corona electrodes causes corona discharge. Corona effect is a source of free electrons. The free electrons ionise gas particles with negative and positive ions. Gas ions driven by the electric field force travel to the opposite polarity electrodes. Negative gaseous ions driven by electric field force travel to the collecting electrodes, collide with dust particles flowing in the flue gas flux and transfer negative electric polarity to them. Dust particles with negative polarity forced by the electric field change direction of movement, flowing towards collecting electrodes.

CFB Boiler Components – Electrostatic Precipitators

Dust particles after contacting the collecting electrodes or dust layer already precipitated on the collecting electrodes, lose electric charge and deposit on collecting electrodes forming thicker and thicker layer that tear off under its own weight or as a result of electrode rapping and fall to the discharge hoppers.

Positive ions generated in the area of corona discharge travel over very short distance to the negative corona electrodes so they load insignificant number of dust particles and as a result of this very limited amount of dust deposit on corona electrodes. The dust deposit is removed from the corona electrodes using electrode rappers.

CFB Boiler Components – Combustion Air

Typically the boiler air system comprises separate primary and secondary air systems that are furnished with own air fans, shut-off and control dampers and possible air preheaters.

Assignment of the primary air system is to fluidize sand in the bed of furnace and mix solid fuel around the bed to achieve equable burning. The primary air constitutes a part of combustion air whose relative part may decrease in ratio when the boiler load increases.

Assignment of the secondary air system is to fulfil the need of combustion air for solid fuel that is fed into the furnace. The secondary air constitutes rest part of combustion air whose relative portion may increase in ratio when boiler load increases.

The combustion air to the start-up burners is taken from the secondary air duct, having own measurements and control devices.

CFB Boiler Components – Primary Air

Primary air system

Primary air (PA) is supplied by one 100% capacity centrifugical fan. Primary air is draft from inside (or outside) of boiler house through the flow measurement. (In some cases air is heated by steam or water coil air heater and flue gas air pre-heater.) main primary air flow is led to a boiler windbox under the grid of the combustion chamber. It is used as the source of fluidizing air for the fluidizing bed of fuel and sorbent in the combustion chamber and supplies most (~55%) of the combustion air for the process. PA is also used as lower level combustion air above the grid.

Before wind box PA ducts have a flow measurement or calculated flow in DCS. Air flow to the grid must be always above the minimum flow set point for proper bed material fluidization. Low air flow activates the boiler trip signal, Main Fuel Trip (MFT) and fuel feeding is automatically stopped by DCS. PAF is controlling the main PA flow.

CFB Boiler Components – Secondary Air

Secondary air system

Secondary air (SA) is supplied by one 100% capacity centrifugical fan. Secondary air is draft from inside of the boiler house through flow measurement. (In some cases air is heated by steam or water coil air heater and flue gas air pre heater.) Air flow is led to secondary air ring ducts around the combustion chamber. Air drops connect the ring ducts to the combustion chamber. Secondary air is used to complete the combustion process (staged combustion), supplies cooling and combustion air for all startup burners, and is used to maintain the proper amount of excess air for safe boiler operation (O_2 -control).

SAF is controlling the SA duct pressure measured after the fan.

CFB Boiler Components – Solid Fuel feeding

Introduction

The CFB type boiler is burning solid fuel which is mixed into the bed material. The solid fuel can comprise from large variety of solid agents that are burnable, but typically there are separate feeding lines for bio fuel and for coal fuel in use. Bio fuel consists of various renewable fuels like a bark, sludge, wood chips, wood dust, waste/recycled wood. Coal consists of various types of coal, like a bituminous coal, coal slurry, brown coal, lignite, petroleum coke, anthracite.

Liquid fuels like heavy oil or light oil, and gases are typically used as supplementary fuels for boiler start-up and abnormal situations.

Solid fuel is added to the furnace according to boiler power demand that typically is set in MW (mega watt), which is transformed to a mass flow unit (kg/s) for fuel set point. Before the demand from boiler master enters to the solid fuel flow controllers, the power signal is divided to the feeders in use at the fuel division.

CFB Boiler Components – Solid Fuel feeding

Operation

The boiler power control procedure is based on the operation of boiler master that set the demands for combustion air and solid fuel feed into the furnace. This operation can only be accomplished if the lower level controllers are available for the boiler master.

For appropriate solid fuel feeding, there is in use a flow controller per a feeding line and those are maintaining that the boiler master demand is met.

The fuel feeding into the furnace is controlled separately per feeding lines, and typically feeding is kept in balance between the lines. When needed, fuel feed division can be allocated between the feeding lines and between the types of fuel. Also the control procedure concerns for disturbances of the feeding lines so that a control gap on a feeding line is compensated by increasing the demand of others respectively before the lack of solid fuel reveals in the pressure of main steam.

CFB Boiler Components – Start Up Burners

Start Up Burners – SUB

The purpose of the start-up burner system is to bring the bed temperature up to the permissible fuel ignition temperature (above 600 °C), to provide stability for the combustion of solid fuel during upset conditions, and to maintain desired main steam pressure during startup and shutdown. The most important of these functions is the warm-up of the bed before the introduction of solid fuel into the combustion chamber.

The typical start-up burner system consists of a rack-mounted main auxiliary fuel shut-off valves, rack-mounted individual burner control, shut-off and clearing medium valves, individual burner guns with electrical high energy (H.E.) igniters or ignition gas gun with transformer and air cooled flame scanners all mounted on the boiler front, and air ducting with control dampers.

CFB Boiler Components – Start Up Burners

Start Up Burners – SUB

The startup burner system can be designed to fire a variety of auxiliary fuels including heavy oil, light oil, and fuel gas (natural gas and propane). Each auxiliary fuel merits special considerations that have to be accounted for in the design of the system. Liquid fuels (i.e. oil) have to be atomized, the heavy oil also requiring heating and recirculation. Natural gas fuel requires an automatic header vent and individual burner vent valves, while propane fuel cannot have any automatic vent valves at all, since propane is heavier than air. The system that use fuel gas require a double shut-off valve arrangement for each burner, while for the liquid fuels only a single shut-off valve is required (officially; however, typically also the oil burners are equipped with double shut-off valves).

CFB Boiler Components – Start Up Burners

SUB Operation

The boiler steam pressure control may be supported with start-up burners. This is possible when a start-up burner oil flow controller is set in remote mode and the oil master is capable to control the fire power of furnace.

Typically oil gun and all other related devices like valves, ignition transformer, ignition gun and also the oil flow and air flow controllers of the start-up burner, are controlled either with an individual logic or with a sequence program(s).

The start-up burner procedure implementation may comprise the burner automation that starts pre-defined start-up burners according to the load demand of oil master (if oil pressure or oil flow quantity into to the burners in service is exceeding a maximum limit of start-up burner). Respectively when oil pressure or oil flow reduces to the level that equals to minimum limit of the start-up burners, the burner automation will stop one burner.

CFB Boiler Components – Bed Lances

Introduction

The bed lance is a burner-like device for burning oil or natural gas in the combustion chamber. The bed lance is not a “conventional” burner, because it does not ignite the fuel, but sprays oil or gas among the bed solids where the sprayed fuel is ignited by high temperature of bed material.

CFB Boiler Components – Bed Lances

Operation

The bed lance procedure may comprise the lance automation that starts pre-defined bed lances according to the demand of bed temperature controller (if the bed temperature pass a specific minimum limit). Respectively when bed temperature exceeds specific maximum limit, the burner automation stops the bed lances.

If the bed temperature does not stay high enough during solid fuel firing, the first pre-selected bed lance is started, manually or according to the start automation. If the bed temperature continues to decrease, the set point of fuel oil flow is increased and the next bed lance is started. When bed temperatures increase over the specific temperature limit, one of the bed lances is stopped and respectively the oil flow controller set point is decreased that equals to number of running lances.

CFB Boiler Components – Bed Lances

Operation

The bed lance combustion air control is typically concerned in context of primary and secondary airflow controls so that the combustion air quantity is increased in proportion to fuel oil flow of bed lances.

Typically the oil gun and all other related devices like valves and the oil flow controller of the bed lances are controlled either with an individual logic or with a sequence program(s).

CFB Boiler Components – Sootblowers

Sootblowers

Several sootblowers are installed to remove fly ash buildups on the gas-side heat transfer surfaces of the boiler bank and convection passes. Sootblowers are located on right side of the boiler in boiler bank and convection pass. All sootblowers are rotary type sootblowers.

Each sootblower is a separate motor-driven device controlled from either the control room or at the locally-mounted control box. Steam operating pressure at 25 bar is used but steam pressure at each sootblower can be adjusted for the desired blowing pressure and should be checked annually.

Steam taken from the main steam line is used for the sootblowing system. The use of steam is an energy loss and it will have a negative impact on plant operating costs.

CFB Boiler Components – Sootblowers

The purpose of sootblowers is to keep clean the boiler heat surfaces to avoid heat transfer capability decreasing for smutty heat surfaces, at which time the boiler efficiency is reduced. The heat surfaces are typically cleaned frequently with steam spray of the sootblowers. The steam for sootblower set is fed from a same steam pipeline, and typically also the electric control system is implemented in a way that it inhibits more than one sootblower to be in operation at a time. This is to minimize disturbance what the sootblower causes for the steam production.

The type of fuel burned at the plant will determine how often the operator needs to use the sootblowing system. With low ash fuels, the operator will not have to blow soot as often as if the fuel has high ash content, above 20%. Other factors such as exit flue gas temperature and CO emissions will influence the frequency and pattern of sootblower operation. If the exit gas temperature is high, that indicates that the effectiveness of the heat transfer surfaces have been reduced by ash build up. Normally once per shift should be adequate to prevent big ash build up's.

CFB Boiler Components – Sootblowers

The sootblowers can be controlled individually either locally or from the boiler control room. Typically the sootblowers are run set by set with the sequence(s) that concerns adequate running order.

The operation mode of the sequence typically there are three operating modes in use:

Manual mode: At which time the sootblowing steam line is warmed up and dewatered first with the sequence and sootblowers are started manually.

Auto-mode: At which time the sootblowing steam line is warmed up and dewatered first and the sootblowers are started in the fixed running order with the sequence. All available sootblowers are determined in downstream order of the flue gas flow.

CFB Boiler Components – Sootblowers

Auto-mode: At which time the sootblowing steam line is warmed up and dewatered first and the sootblowers are started in free running order with the sequence. The operator determines the order of the sootblowers.

Before the run of sootblowers, the sootblowing steam pipelines had to be warmed up and dewatered.

After a pipeline dewatering the sootblowers are operated one by one till the end in determined order.

After when the sootblowing cycle is completed, the sootblowing steam pipeline pressure controller is set to manual mode and output is set 0% and the sootblowing steam shut-off valve is closed.

CFB Boiler Components – Sootblowers

The warm up and dewatering procedure is as follows.

The sootblowing steam shut-off and the sootblowing steam dewatering valves are opened first and the sootblowing steam pressure controller is set to manual mode.

The controller output is opened up to determined value (e.g. 5%) over the specific time (typically 4 minutes), after the delay it is opened by a ramp till the temperature of the sootblowing pipeline is reached up to the minimum sootblowing temperature limit (LL). When the limit is exceeded, the control valve opening is accelerated to minimize the dewatering time.

When the sootblowing pipeline temperature is reached up to the sootblowing temperature limit (L) the pressure controller is set to Auto-mode and the dewatering valve is closed, so after this the pipeline is ready for operation.

CFB Boiler Components – Sootblowers

If the sootblowing pipeline temperature passes the minimum sootblowing temperature limit (LL) during sootblowing cycle, the sootblowing sequence is inhibited over the re dewatering.

The dewatering valve is opened again and kept open till the sootblowing pipeline temperature is reached up the sootblowing temperature limit (L). The dewatering valve is closed and the sootblowing cycle proceeds from the status where it was stopped.

So in the Auto-mode, operation of sootblowing steam pipeline drain valves are controlled by the sootblowing steam line temperature.

CFB Boiler Components – Sootblowers

Typically the sootblower is furnished with a safety and a local control switches. Those determine the sootblower operation as follows.

If the safety switch is turned on (position-1), the sootblower is in remote control mode. The sootblowing interlocking is valid, see below.

If the safety switch is turned off (position – 0), the sootblower is interrupted at the time of sootblowing cycle and it is returned directly to the home limit. The sootblowing sequences passes-by the sootblower whose safety switch is turned off.

If the safety switch is off (position-0) and the local control switch is turned on, the sootblower is started. The sootblowing interlocking is not valid, see below.

CFB Boiler Components – Sootblowers

Typically the temperature control of the sootblowing steam pipeline is implemented by the on/off method where the sootblowing steam drain temperature is controlling the sootblowing steam pipeline dewatering valves according to temperature limits .