

Engineering Conferences International ECI Digital Archives

10th International Conference on Circulating
Fluidized Beds and Fluidization Technology -
CFB-10

Refereed Proceedings

Spring 5-3-2011

High Sulfur Lignite Fired Large CFB Boilers- Design and Operating Experience

M. Lakshminarasimhan
Bharat Heavy Electrical Limited

B. Ravikumar
Bharat Heavy Electrical Limited

A. Lawrence
Bharat Heavy Electrical Limited

M. Muthukrishnan
Bharat Heavy Electrical Limited

Follow this and additional works at: <http://dc.engconfintl.org/cfb10>

 Part of the [Chemical Engineering Commons](#)

Recommended Citation

M. Lakshminarasimhan, B. Ravikumar, A. Lawrence, and M. Muthukrishnan, "High Sulfur Lignite Fired Large CFB Boilers-Design and Operating Experience" in "10th International Conference on Circulating Fluidized Beds and Fluidization Technology - CFB-10", T. Knowlton, PSRI Eds, ECI Symposium Series, (2013). <http://dc.engconfintl.org/cfb10/65>

This Article is brought to you for free and open access by the Refereed Proceedings at ECI Digital Archives. It has been accepted for inclusion in 10th International Conference on Circulating Fluidized Beds and Fluidization Technology - CFB-10 by an authorized administrator of ECI Digital Archives. For more information, please contact franco@bepress.com.

HIGH SULPHUR LIGNITE FIRED LARGE CFB BOILERS: DESIGN & OPERATING EXPERIENCE

M.Lakshminarasimhan, B.Ravikumar, A.Lawrence, M.Muthukrishnan
Building 79, Bharat Heavy Electrical Limited, Trichy, Tamil Nadu, India 620014
phone:+91 431 2574049 e-mail: mlsimhan@bheltry.co.in

INTRODUCTION

One of the measures of the prosperity of a nation is per capita consumption of electricity. In developing countries like India the gap between supply and demand is strongly increasing. The demand for all forms of energy is expected to increase substantially in the foreseeable future and is forecasted to double by 2020.

Although coal would continue to be a major energy source in India due to its availability, lignite is fast emerging as an alternate source of fuel for electricity generation. In India the total lignite potential is 4177 million tonnes. The varieties found in India (Gujarat & Rajasthan region) have moderate to high sulphur (1 to 15 %wt dry ash free) content. It has become economically necessary to use this lignite for power generation in view of spurt in energy demand while caring for the environment (by controlling the SO₂ emission).

CFB boilers with their in-furnace SO₂ capturing capability perfectly suit these demands and are very attractive while their utilization in comparison with pulverized fuel boilers would require very expensive add-on flue gas conditioning systems. The CFB boiler technology designed by BHEL (see Notation list for acronyms) has been successfully demonstrated for utilities at the 2x125 MWe power project at Surat. Based on the excellent performance of the units at SLPP, BHEL has bagged order for 2x125 MWe CFB power plant for RVUNL at Giral, Rajasthan and 1x75 MWe CFB power plant for GEB, at Kutch, Gujarat. The plant at Giral is now operating after overcoming unique challenges for firing >15%daf sulphur lignite (one of highest sulphur-content fuel used in CFB utility-scale units).

This paper provides an overview of the CFB process, its advantages, the development of CFB technology, and the experience gained from these units in particular attention to lignite fired units of 125 MWe capacities. The teething problems experienced during initial operation and their resolution form part of this paper. With the experience gained at Giral, firing high-sulphur lignite, BHEL is uniquely placed among CFB boiler manufacturers to meet market requirement of using such demanding fuels for power generation. The successful operation of the boiler after surmounting the issues is bound to stimulate utility users to adopt CFB technology for their proposed projects for such challenging fuels also. Many other large capacity BHEL CFB boilers (firing range of fuel: from Indonesian coal, lignite with high/medium sulphur to petroleum coke) are under various stages of commissioning and will be in operation in another few months.

ROLE OF LIGNITE IN THERMAL POWER PROJECTS IN INDIA

With growing energy consumption, India is looking at utilizing its potential energy resource in economically and environmentally sustainable manner. The coal

varieties found in India are of high ash content, heating values, and sulphur content. This requires substantial refinement of conventional pulverised fuel combustion technology by BHEL to suit Indian conditions. The focus has now shifted to utilizing low-grade lignite varieties with typically high moisture and ash levels with wide variation in sulphur content. The lignite in India is concentrated geographically to three states - Tamil Nadu, Rajasthan and Gujarat. The total resource estimated is around 39 billion tons with proven resource of 4.2 billion tons

Table 1. Lignite resources

State	Potential million tons	Proven million tons
Tamil Nadu	31327	2831
Rajasthan	4485	561
Gujarat	2663	785
Puduchery	417	0
Jammu & Kashmir	28	0
Kerala	10	0
West Bengal	1	0
Total	38931	4177

As per the latest indication, share of lignite based thermal projects is bound to receive an impetus and therefore requires careful selection of combustion technology. The lignites found at the three major states have different composition and their own unique behavior. The level of sulphur, ash and moisture, key parameters for any boiler design, shows remarkable variation among the regions. This view has been further strengthened by the operating experience of the CFB power plants designed by BHEL for these fuels

Table 2. Lignite – Key parameters influencing CFB design

Parameter	Gujarat	Rajasthan	Tamil Nadu
HHV(MJ/kg)	11-13	12-16	10-11
Sulphur (%wt)	1.0-4.0	<6.0	<1.0
Moisture(%wt)	<42	<40	<55
Ash (%wt)	<19	<20	<14

BHEL'S EXPERIENCE IN CFB BOILER

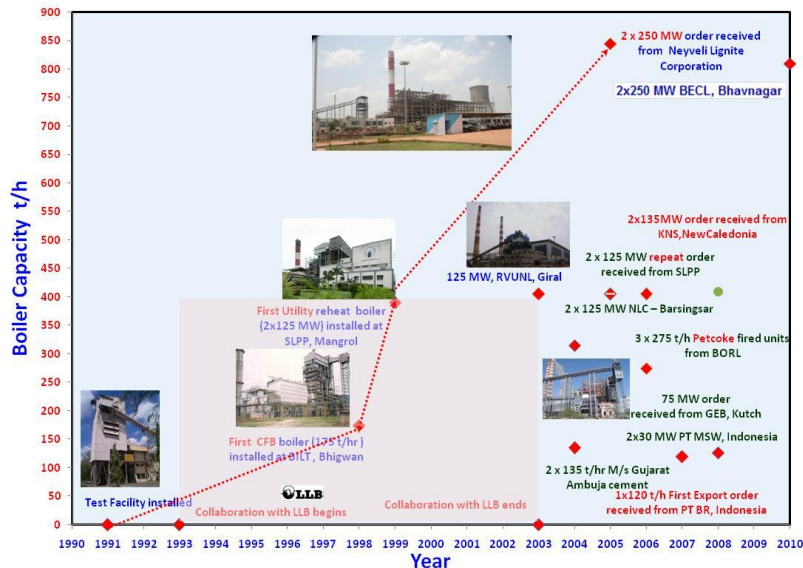
BHEL has developed bubbling fluidized bed technology in response to the national need to utilize low-calorific fuels in an environmentally sustainable way as early as in 1977. As fluidized bed technology was maturing, BHEL established a test facility in 1991 and good progress has been made in basic understanding of the CFB technology. In response to the customer's requirements and with a view to introduce this technology quickly, BHEL tied up with LURGI LENTJES BABCOCK (LLB) as collaboration partner in the year 1993. In 1995, BHEL was able scale-up to 175 t/hr boiler (scale of 30 in thermal heat input terms). The first CFB utility boiler was introduced in India in the year 1999 after securing an order for 2x125MWe CFB boiler (scaling by a factor of 3), which was the largest CFB boiler in the country till recently. The collaboration agreement period with LLB ended by the year 2003. The successful application of this technology resulted in installation of similar units at Giral & Barsingar in Rajasthan, designed and supplied by BHEL, and a repeated

order at Surat Gujarat. BHEL further scaled up the CFB unit size by securing an order for 250MWe units at Neyveli, Tamilnadu.

The first unit of 175t/hr for a paper plant has given a reliability of over 98% till date while firing a variety of fuels ranging from imported Indonesian coal to Indian coals. The CFB unit at Surat has also given excellent operating results with the availability being over 90% and the plant load factor of 85%.

BHEL has recently focused its efforts to diversify into the international market and secured the first export order in Indonesia for a 120 t/hr boiler in 2007, which is in successful operation firing low-ash, high-moisture Indonesian coal with unburnt carbon levels in fly ash of less than 2%. A recent order for a 135 MWe CFB power plant of the Xstrata group for their prestigious Koniambo Nickel project at New Caledonia demonstrates the capability of the BHEL CFB boiler in meeting the strict environmental norms required by the project.

Figure 1. BHEL’s experience in CFB design.



ADVANTAGE OF BHEL’S CFB BOILER

The flue gas flow rate from a unit varies depending on the fuel characteristics, predominantly its moisture and ash contents. A controlled portion of the solids sliding down the return leg to the seal pot is diverted via the cone valve (a mechanical ash-flow control valve) to the FBHEs, while the remaining solids are returned directly to the combustor at the same temperature. By adjusting the cone valve opening, the solids flow to the FBHE can be varied, thereby maintaining the heat absorbed in the combustor constant and consequently its temperature and combustion conditions for different fuels and loads.

In the absence of the FBHE this variation of the heat absorption in the primary loop (Combustor, Cyclone and Recycle System) due to variations in fuel quality or load can be achieved only by:

- (a) Varying bed density (by altering the primary to secondary air ratio and/or bed inventory), which becomes operationally difficult;
- (b) Varying combustor temperature; or
- (c) Varying excess air.

The above variations alter the combustion performance and reduce the boiler efficiency, and therefore BHEL CFB boiler design for lignite utilizes external fluidized bed heat exchangers (FBHE) to maintain combustor and steam temperatures. This provides excellent operational flexibility while maintaining optimum process conditions. FBHE also provides a unique option of achieving the rated reheat temperature down to even 50 % of MCR without any attemperation by only controlling the solids flow through the FBHE containing the reheater coils. This has enabled operators to handle boiler turndown operation smoothly without undue concern regarding combustor temperatures.

HIGH SULPHUR LIGNITE CFB BOILER DESIGN

The fuel and steam design parameters of the 125 MWe CFBC units are elaborated in Table 3.

Table 3. CFB boiler steam parameters

Parameters	Units	Design	Parameters	Units	Value
Main Steam			Proximate Analysis (as fired)		
Flow	kg/s	112.5	Moisture	%wt	40.0
Pressure	bar	134.6	Ash	%wt	15.0
Temperature	°C	540	Volatile matter	%wt	20.0
Reheat Steam			Fixed carbon (by diff)	%wt	25.0
Flow	kg/s	93.3	High Heating Value	MJ/kg	12.56
Outlet Pressure	bar	33.2	Ultimate Analysis (dry ash free)		
Outlet Temperature	°C	540	Carbon	%wt	66.9
Feed Water			Hydrogen	%wt	4.9
Temperature	°C	236.8	Sulphur	%wt	13.3
			Nitrogen	%wt	0.9
			Oxygen	%wt	14.0

Solid System (Fuel, Bed Material, Limestone & Ash System)

The pre-crushed lignite is withdrawn from the bunkers by two variable speed extraction drag-link chain conveyors and fed into the seal pot through self-cleaning type of rotary valves and slide gates, which shut off the fuel feed system from the combustor in case of an emergency. The system has two parallel trains both of which need to be operated for optimal fuel combustion. Inert material such as bed ash or sized sand, required for initial start-up, is fed to the combustor directly by gravity through a rotary valve. Sized limestone stored in silos is discharged through variable speed rotary valves at a required rate based on the SO₂ content in the flue gas and is fed by gravity to the seal pot.

Ash is removed from four different locations in the system. Coarse bed ash from the lower combustor, bed ash from the FBHE, fly ash from the collection hoppers below

the convective pass and air heater sections, and fly ash from the electrostatic precipitator. In order to maintain an appropriate solids inventory in the combustor, bed ash is continuously extracted from the lower combustor and FBHE through ash discharge devices cooled in fluidized bed ash coolers.

Air and Gas System

Combustion air is supplied to the combustor by two main streams. Two fans supply primary air after being heated in a tubular heater. The air is introduced through a wind box and grate assembly located at the bottom of the lower (refractory lined) section of the combustor. Similarly two fans supply secondary air, which after being heated in a tubular air heater is admitted into the lower combustor region by means of multiple ports located on the walls. Fluidizing air for FBHEs, seal pots, ash coolers and purge & seal air also form part of the combustion air. Flue gas leaves the combustor and passes through the cyclones, convective pass, tubular air heaters, and electrostatic precipitators. Two centrifugal-type induced draft fans ensure near atmospheric pressure at the outlet of the cyclones. The convective back pass consists of horizontal superheater, reheater and economizer surfaces with tubular air heaters for additional heat recovery.

Start-up System

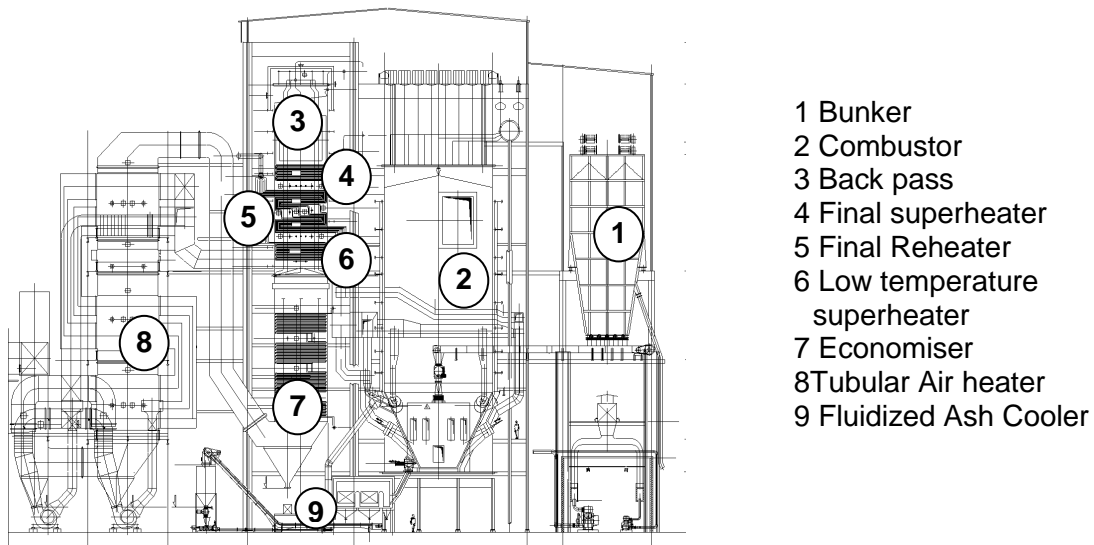
The start-up system consists of two independent start-up burners supplied with air from the secondary air fans arranged on the sidewalls of the combustor. They are used for preheating the combustor system and the ash inventory to the ignition temperature of fuel oil. Fuel oil lances (six units) are then used to further heat up the ash inventory to the ignition temperature of main fuel - lignite.

Steam-Water Circuits

Feed water enters the in-line horizontal economizer tubes located in the convective back pass. The steam drum receives sub-cooled water from the economizer and feeds the evaporators. The evaporative surfaces of the boiler consist of the combustor water walls, the FBHE water walls and a tube bundle in the FBHE. A system of down-comers, distribution supply pipes and headers and relief tubes ensure adequate flow through the evaporator circuits. Drum internals separate and purify the saturated steam before it feeds the steam-cooled hanger tubes and the enclosure of the convective pass. The steam is further heated in the superheater stage I (a horizontal in-line tube bundle) located above the economizer in the convective pass. After a first stage attemperation the steam flows to the second stage superheater, which is arranged in two parts in the FBHEs. The second stage attemperation is arranged between second stage superheater and the final superheater. The final superheater is the first heat transfer surface in the back pass and is an in-line horizontal tube bundle.

Cold reheat steam enters the first stage reheater located in the FBHE. The final reheater stage is located in the convective pass after the final superheater and before the economizer. Reheat steam temperature is primarily controlled by the FBHE cone valve, that controls the ash flow through the FBHE containing the reheater. A spray type attemperator located between two stages of reheater is used as a secondary control. Refer to Fig. 2 for the arrangement of the boiler surfaces.

Figure 2. Arrangement of heat transfer surfaces of boiler



ISSUES FACED WHILE FIRING HIGH SULPHUR LIGNITE

Standpipe Blockage

There were three occurrences of unit stoppage due to ash hold-up in the cyclone at very low loads of about 20 MW and one suspected hold-up at about 70 MW load.

Analysis & Improvements Carried Out

Ash samples and boiler operating conditions were collected. The chemical compositions of the lignite, limestone and cyclone ash were analyzed. One critical factor noticed early during cyclone choking was low combustor temperature (<750°C) and excessively high limestone addition due to non functional SO₂ measurement equipment.

The phenomenon of recarbonation of calcined limestone not reacted with sulphur dioxide was suspected as a primary cause for the loose bonding of material at the cyclone standpipe leading to blockage of the cyclone. This was also reflected in the analysis by the presence of free lime. The following steps were taken up to relieve the situation:

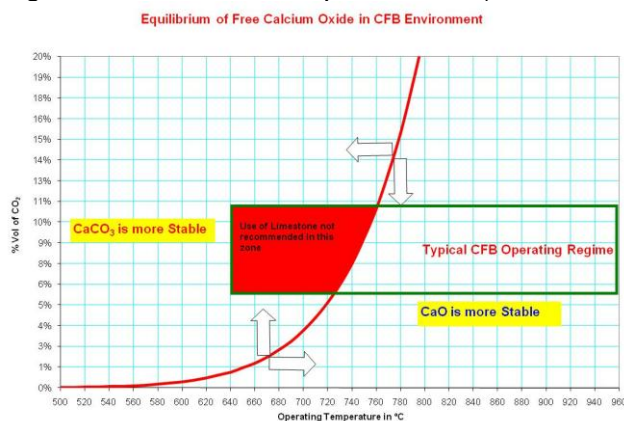
- a) Limestone feed size was checked continuously with more sampling;
- b) Limestone feeder size was optimized by blanking some of its pockets;
- c) The operation procedure was revised to maintain higher combustor temperatures before start of limestone addition;
- d) Incorporation of automatic pincing air arrangements at the junction of cyclone and standpipe to disturb the agglomeration.

It was found from samples that the limestone size was much finer than recommended. This also resulted in high throughput during low loads because SO₂ measurement was not available to control the volumetric feeder of the limestone. It should be noted that these incidents occurred during boiler commissioning and initial stabilization period.

Results

After incorporation of the changes in the operation procedure and the pinging air arrangements, the issue stands resolved. The timing of pinging air has been subsequently reduced, as it was found that the temperature regime (stable free lime) is one of key parameter in avoiding the situation of blockage. Figure 3 shows specific recommendations on avoiding the recarbonation-prone regime for limestone addition. The curve denotes the limit of equilibrium of calcium compounds. On the left-hand side of the curve CaCO_3 is stable. On the right-hand side CaO is stable. CaO is abundant if excess limestone is added to the furnace. When the temperature is reduced into the critical range indicated in the figure recarbonization may take place, creating a rather sticky carbonate that may cause agglomerates or deposits on tubes.

Figure 3. Recarbonation prone zone (reference 4).



Back Pass Tube Fouling

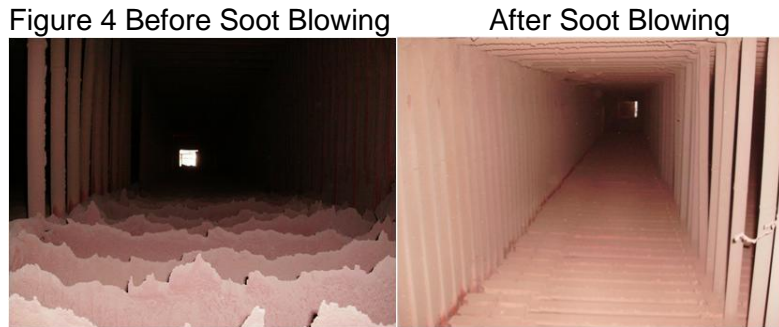
Heavy and rapid deposit build-up on the flue gas side of the heat transfer tubes has been experienced in the back pass of the boiler. Deposit buildup seems most severe at the low temperature superheater tube bank. Also growth of ash deposit in final-stage reheater tube bank is observed during the initial period of operation. This deposit increases the gas-side pressure drop and in turn operation of the ID fans with high current, causing boiler trips.

Analysis & Improvements carried out

The issue of deposits cropped up during loading the boiler after sorting out the cyclone blockage problem when the limestone feed rate was increased to maintain the SO_2 emission within limits. The same phenomenon as with the cyclone was suspected as initiator also for this issue. In order to ascertain the root cause, samples were taken by an exposure probe in the back-pass tube location to collect short-term ash deposits, as long term exposure converts calcium carbonate to calcium sulphate. The results of the detailed study clearly points to recarbonation of free lime followed by slow sulphation of the deposit as the primary mechanism of fouling. Improvements in the soot blowing mechanism along with an increase in its frequency have helped in overcoming the fouling issue.

Results

After implementation of high pressure soot blowers (See Fig. 4) along with a fluidization arrangement for smooth evacuation of the ash falling onto the hoppers, full load operation with limestone addition to ensure sulphur capture of more than 98% (vs. 97% design) was achieved.



CONCLUSION

CFB technology has emerged as a reliable and cost-effective process for environmentally friendly power generation. Besides eliminating the need for add-on equipment for control of emission at a huge cost, the process also accepts wide variation in fuel quality, eliminates the need for pulverizer, minimizes oil requirement, and avoids slagging. The issues with regard to utilizing high sulphur fuel have been understood and changes to overcome the same have been presented.

The CFB technology has been successfully demonstrated for utilities at the 2x125 MWe power project at Surat. Based on the excellent performance of the units at SLPP, BHEL has bagged order for 2x250MWe CFBC boilers for Neyveli Lignite Corporation, Neyveli, a 1x125MWe CFB Power plant for RRVUNL at GIRAL, Rajasthan, and a 1x75MWe CFB Power plant for GEB, at Kutch, Gujarat. They are under various stages of commissioning. These projects are bound to stimulate utility users to adopt CFB technology for their proposed projects.

NOTATIONS

CFB - circulating fluidized bed, BHEL -Bharat Heavy Electricals Limited, RRVUNL – Rajasthan Rajya Utpadan Nigam Limited, GEB- Gujarat Electricity Board, SLPP – Surat Lignite Power Plant, FBHE – Fluidized Bed Heat Exchanger, MCR – Maximum continuous rating.

REFERENCES

1. Joint Internal BHEL Analysis report with B. Leckner (2007), Chalmers University, Sweden.
2. M. Hupa, Investigation into backpass fouling, Åbo Akademy, Finland. Investigation for BHEL (2010).
3. E. J. Anthony, R. E. Talbot, L. Jia, and D. L. Granatstein, Agglomeration and fouling in three industrial petroleum coke-fired CFBC boilers due to carbonation and sulfation, *Energy & Fuels* (2000) 14, 1021–1027.
4. Prabir Basu, *Combustion and Gasification in Fluidised beds*, CRC eqn 5.7