Retrofit of FBC Technology for Low Cost Steam Generation

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INTRODUCTION

Steam is an essential raw material for almost all indudstries except for Engineering Industries, to increase the efficiency of the Plants. Most of the Textile, Chemical, Paper, Sugar and Solvent Extraction industries have steam requirement varying from 1 T/h to 25 T/h. These industries use either Lancashire, B & W Cross tube or Marine Boilers. Many of these boilers are hand fired and the rest have the mechanical stokers (chain or reciprocating type). These boilers are originally designed for high calorific value, low ash content coals. But in reality today, the coal available has got high ash content; shale and calorific value as low as 3500 kcal/kg. Added to this the cost of coal varies from Rs. 500 to Rs. 800/- per tonne depending on location. Under these conditions, as the boilers mentioned above operate only with an efficieney varying from 40 to 65% and give only 45 to 60% of rated output, the steam cost becomes prohibitively high and some industries even become sick due to the increased energy cost,

Not mueh attention has been paid till recently in improving the efficiency of these small capacity boilers. Improvement in efficiency & Productivity of these boilers will benefit both industry and nation. Hence, cethar vessels Ltd. entered in this field to offer most fuel efficient "CETHAR—FLUIDIX" Boilers, an answer for this energy crisis This paper describes the ways of improving the efficiency of existing boilers by adopting Fluidised Bed Combustion and also deals with the Principles and Advantages of Fluidised Bed Combustion as applicable to Indian Coals and Agro Fuels.

PRINCIPLE OF FLUIDISED BED COMBUSTION :

When air passes upward at low velocities through a mass of finely divided solid particles (such as ash, crushed refractory, sand or limestone) the particles are not disturbed. As air flow is gradually increased, the particles become suspended. Further increase in the air flow gives rise to bubble formation and vigorous turbulance. The bed of solid particles has the same characteristics as a boiling liquid and thus the bed is termed "Fluidised Bed. Combustion" (FBC).

The fluidised bed combustion provides the following necessary requirements for efficient combustion.

1. Large surface area per unit mass of fuel (minus 6 mm particles are used—much larger surface area than stoker but less than pulverised coal combustor).
2. Long time of contact or large residence time (residence time many times greater than that of pulverised coal firing and stoker firing).
3. High relative speed between air and fuel (turbulance). With these features and large bed thermal storage, the fluidised bed combustion boiler is able to burn a wide variety of fuels including washery rejects having 73% inerts (Ash and moisture).

ADVANTAGES OF FLUIDISED BED COMBUSTION BOILERS

* Ability to burn low grade fuels.
* High efficiency.
* Ability to burn fines.
* Flexibity to burn agro waste fuel.
* No manual ash removal—ash removal easier–lesser manpower.
* No manual fuel feeding—less manpower.
* No slagging in the furnace, no soot blowing.
* Less excess air, higher CO_2 in flue gas.

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* Simple in operation, Quick startup, fast response.
* Less maintenance cost
* 100% depreciation.

ABILITY TO BURN LOW GRADE FUEL :

In the grate type boiler, the grate area limits the quantity of fuel to be fired. With inferior quality of fuel, the coal quantity increases for the same steam output. This results in reduction in steam output as the grate area is fixed and hence the efficiency. FBC boilers would give the rated steam output even with inferior quality fuel. The boiler can fire coals with ash content as high as 62% and having calorific value as low as 2500 kcal/kg.

High Efficiency:

Because of the efficient fluidised bed combustion, FBC boilers can burn fuel with a combustion efficiency of over 95% irrespective of ash content. FBC boilers are guaranteed to operate with overall efficiency of 82±2%.

Ability to burn fines :

The stoker fired boilers can't accept fines. In case of hand fired stokers, the space between grate bars is of the order of 12 mm, which eause the fines to fall through. In case of chain grate stokers excess fines in the coal makes the air flow through the bed difficult and the air enters in the furnance at a location where it is not realiy required. On the other hand FBC boilers can accept fines. These fines are kept in a fluidised state and burn well. This brings an additional saving in fuel cost, as there is no necessity to separate out fines and sell them at a lower price. The cost of the labour involved in separating the fines is completely eliminated.

Flexibility to burn Agro Waste fuel :

In the conventional stoker type boilers, when agricultural wastes such as Rice Husk, Groundnut Shell, Wood Chips etc., have to be burnt, a separate furnace is required from which the flue gas is led into the boiler. With FBC boilers, there is no need for a separate furnace hence it is possible to feed these agricultural wastes either independently or in combination with coal into the same furnance.

No manual ash removal—ash removal easier—less manpower :

In FBC boilers the temperature of the furnace is below 900°C. Due to this the ash does not fuse and form clinkers. Therefore removal of ash is easier as the ash flows like liquid from the combustion chamber. Hence less manpower.

In conventional boilers, the temperature of the furnace is above 1100°C and this leads to the formation of ash clinkers and makes ash removal difficult.

No Manual fuel feeding - Less manpower :

At FBC boilers employ a mechanical feeding arrangement, the fuel fed to the boiler is steady and it is not dependent on operator's skills and consequently the pressure will remain more or less steady with varying steam drawal rate. Such constant steam pressure will improve the process capability and in few cases would reduce the steam requirement also.

No slagging in the furnace, no soot blowing :

In FBC boilers, volatilisation of alkali components in ash does not take place, Because of this, ash is non-sticky and friable. This means no slagging in the furnace and no soot blowing is required.

Less excess air higher CO_2 in flue gas :

In FBC boilers, air is admitted at the right location the boiler can operate with 20 - 25% excess air only (CO_2 in flue gas will be of the order of 14—15% at full load) Hence this boiler becomes more efficient.

Simple operation, Quick start-up, Fast response :

FBC operation is very simple. The start-up and response to changing loads will be comparable to that of oil fired boilers. FBC boiler can be started from cold to full load, within an hour.

Low maintenance cost :

In the FBC boiler, the amount of refractory employed is very less. There are no moving parts in the high temperature zones. Because of this maintenance cost is virtually nil.

100% Depreciation :

As FBC boilers are energy saving device and because of their high efficiency, 100% depreciation is allowed by Government of India.

Size of boiler is compact :

The FBC boiler because of its requirement of smaller combustor and higher heat transfer rate available within the fluidised Bed, requires much smaller boiler surface and layout area than any other boiler.

Less SO_2 emmision and ability to burn high sulphur Coal :

FBC boiler will accept any percentage of sulphur content present in coal. The sulphur present in coal will combine with calcium/magnesium oxides available in the coal ash to form calcium sulphates at the low temperature combustiln. However, if the sulphur content is very high, limeston can be added into the bed in proportion to sulphur present to capture the sulpnur.

EFFICIENCY IMPROVEMENT OF EXISTING BOILERS :

In India, thousands of boilers of fixed grate, travelling grate stoker and pulsating grate firing are available which are operating with low thermal efficiency. These boilers are basically designed for coal of very high calorific value, and their furnace size is selected on the basis of loading on grate in kg/h/m². With the present high ash content low calorific value coal, these boilers are not giving the rated output and the designed effiiecncy. On the contrary in a fluidised bed combustion, heat release rate/² area is the governing factor and to release this quantity of heat, required fuel can be fired irrespective of the calorific value of fuel. Hence the only possibility of increasing the efficiency of the exiting boilers, is to convert the above boilers into fluidised Bed combustion firing.

The above conversion to FBC can be implemented by modifing the existing furnace and slightly altering the pressure parts of the existing boiler. The following paragraphs give the details of conversion of Babcock & Wilcox boilers, Four drum water tube boiler Marine shell boiler, Lancashire boiler which are most common types of boilers abundantly used in India.

The following changes have to be made for conversion of any type of boiler :

01. F.D. Fan has to be changed as high pressure air is required, for fluidised bed. Existing F.D. fan can't supply air at the required pressure.

02. P.A. Fan is required to feed coal pneumatically into Fluidised bed.

03. variable speed rotary airlock feeders to feed coal pneumatically into the furnace through a mixing nozzle. The variable speed is achieved using Dyno Drive and is required to vary the fuel feed to match the varying steam demand and varying fuel quality.

04. Distributor plate for distribution of fluidising air.

05. Air box and duct are designed for better aerodynamic flow and less pressure drop. Flow measurement devices and dampers are provided to measure and control the flow.

06. A mechanical Dust collector is provided to reduce the outlet dust concentration.

PERFORMANCE OF BOILER AFTER CONVERSION :

Present efficiency	: Around 60%
Steam output	: 40-60% of orgional capacity
Efficiency after conversion	: 70-80%
Steam output after conversion	: Equal to original capacity.

I Conversion of Babcock & Wilcox into FBC (Fig. 1)

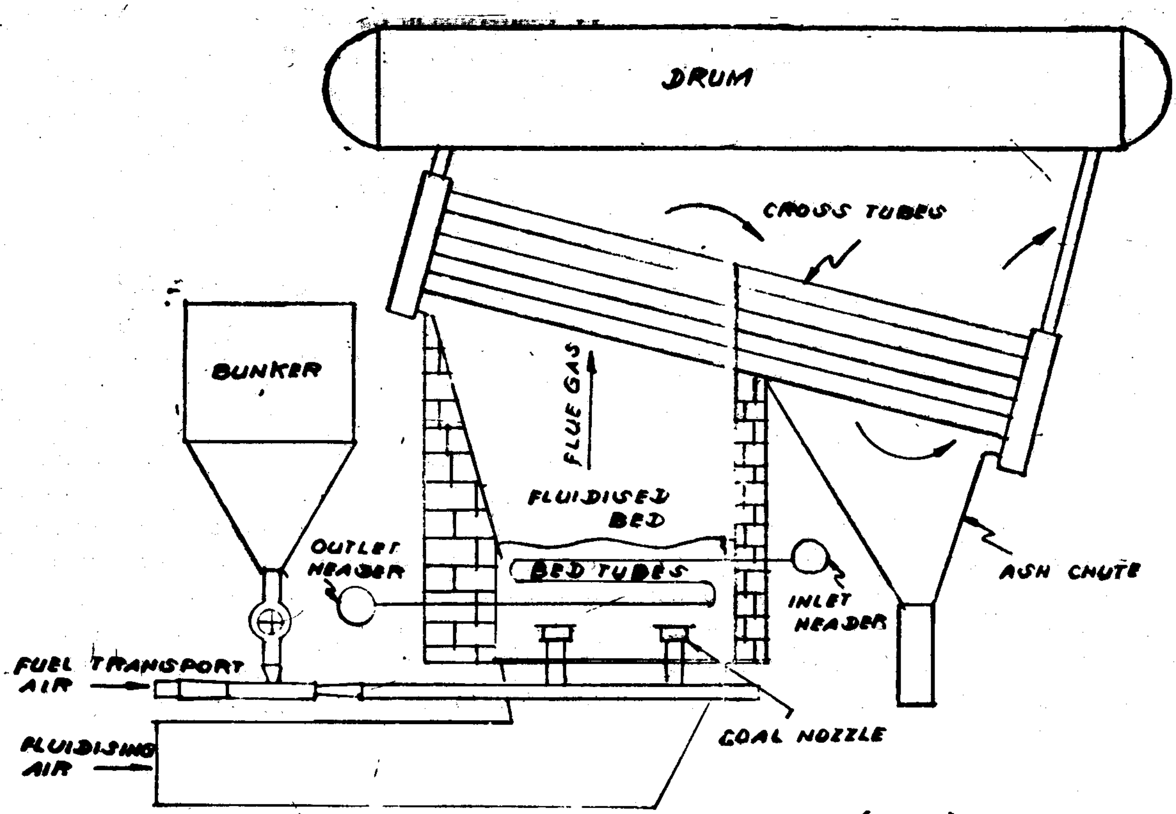
Boiler type	: Water tube boiler with 45 size connecting bottom rectangular water header and supper steam header. Steam/water drum is placed above the tubes.
Type of furnace	: Normally travelling grate stoker.
Coal size	: ¾" to 2" size
No. of passes	: The boiler will be having more than one pass on the flue gas side for heat recovery purpose.

Conversion into FBC :

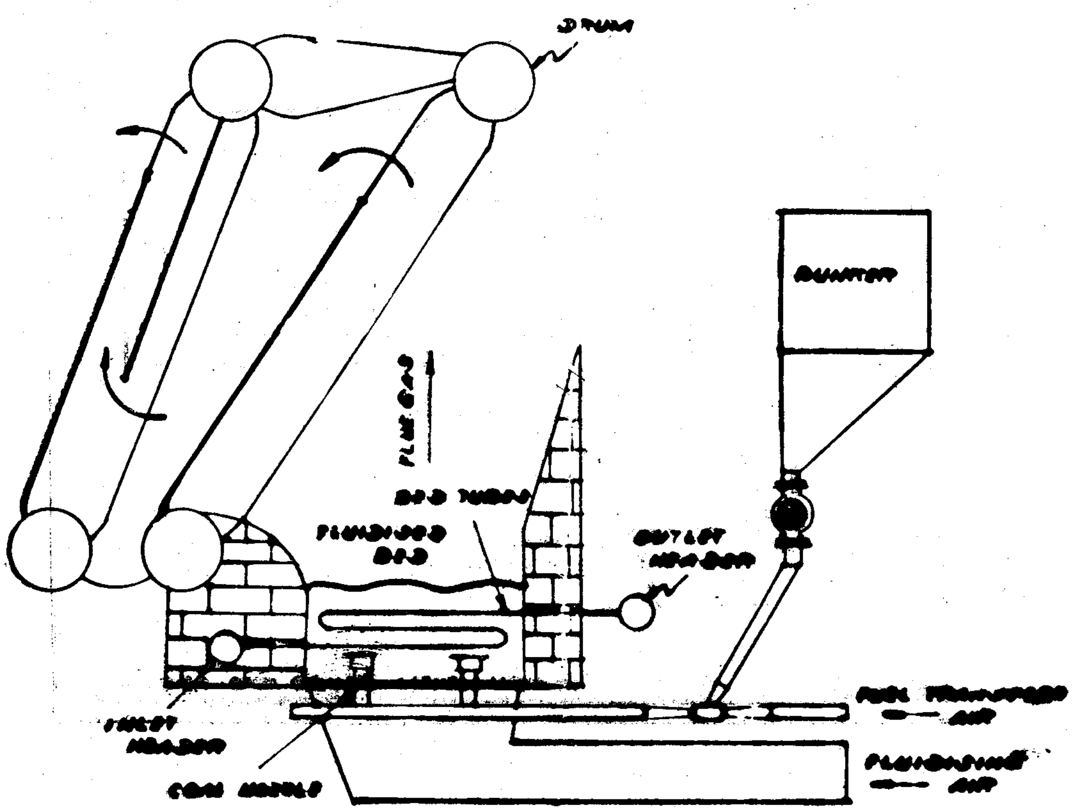
The FBC furnace can be installed after removing the moving grate from its location. The area required for fluidised bed will be much smaller than the area required for moving grate furnace. Hence considerable area has to be covered by Refractory bricks to get smaller furnace. The last row of tubes are removed and converted as inbed tubes as shown in the sketch. This is essential to keep the fluidised bed to operate around 800—900°C by absorbing heat through bed coils. The fuel is fed pueumatically through rotary air lock feeder and air fuel mixing venture.

II Conversion of Four drum water tube boiler into FBC (Fig. 2)

Boirle type	: Water tube boiler with 4 drums and bank tubes.
Furnace	: Normally pulsating grate for coal firing and external twin horse shoe furnace for Bagasse firing. The boiler is basically designed for bagasse which operates with very high excess air. The heat transfer is not effictively utilised with coal firing.



CONVERSION OF B&W BOILER INTO FBC (FIG. 1)



CONVERSION OF FOUR DRUM BOILER INTO FBC (FIG.2)

Conversion into FBC :

The last row of tubes in the lower drum are connected through downcomers to the bottom water header. The bed tubes are taken from the bottom header and is connected to another steam drum. One row of riser tubes will be taken from steam header and connected to top drum.

III. Conversion of Marine Shell boiler into FBC (Fig. 3)

The Marine boilers are generally of horizontal shell type. It consists of normally one or two bigger size flue tubes where the fuel is fired. The flue gases leaving the flue pass through the horizontal fire tubes placed in the next pass.

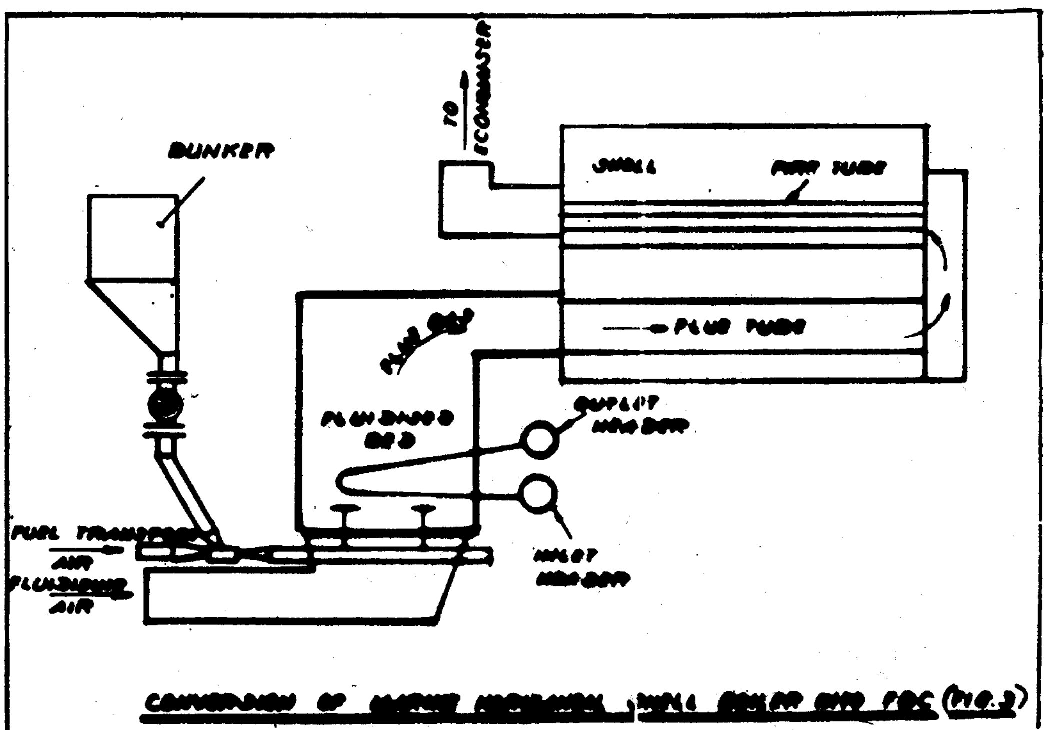
The conversion of the above boiler is effected by constructing an external FBC refractory furnace next to boiler with necessary inbed tubes. An opening to be made in the existing shell bottom and top for connecting downcomer and riser tubes to complete the water circuit required for natural circulation.

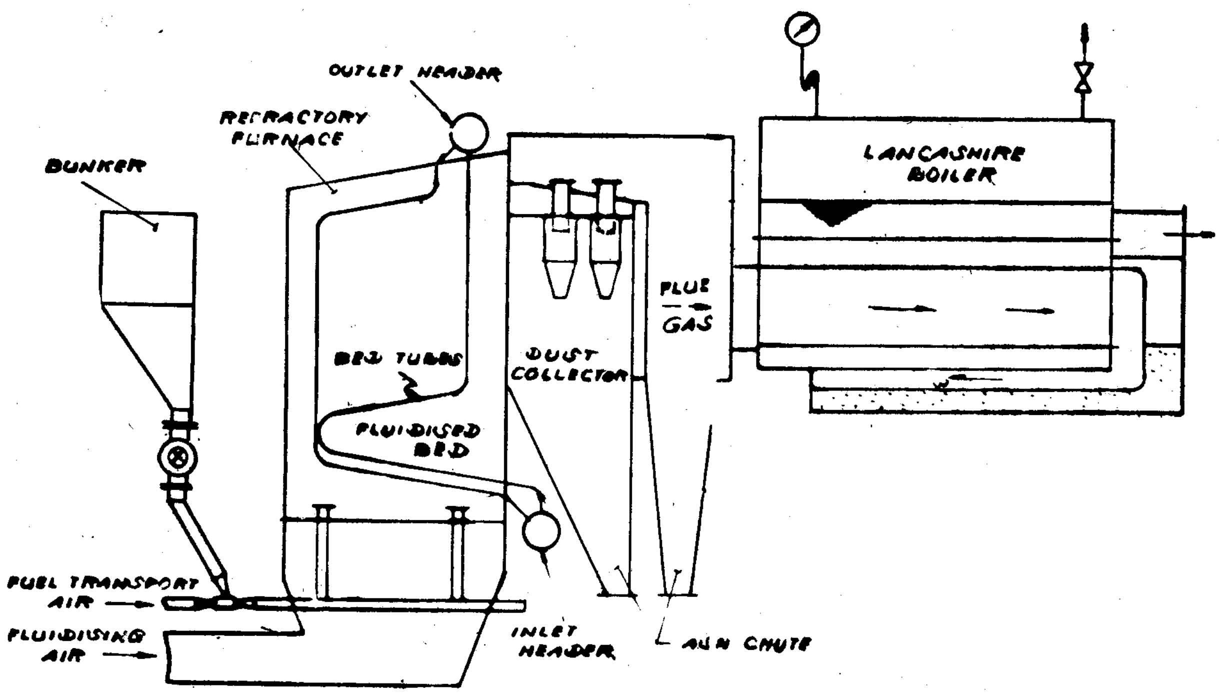
IV Conversion of Lancashire boiler into FBC (Fig. 4)

Boiler type	:	Twin flue fixed grate, firing
Size	:	The evoporation capacity is fixed by length and diameter of the boiler.
	:	Normal size—30′×8′
Present efficiency	:	Around 40%

Conversioa into FBC :

The boiler is having twin flue tube which acts as a combustion chamber. The flue gas leaving the flue tubes are made to pass around the shell twice for heat recovery The FBC combustor will be located externally and the hot flue gases at 900°C will be taken into the twin flue ofLancashire boiler. The bed temperature in the furnace is maintained around 800-900°C by placing bed coils. An opening at the lower portion of end plate is to be made for downcomer connection and a similar opening at the top for riser connection. The water will flow through the downcomer into bed tubes. The steam water mixture generated in the bed tubes will flow to the shell through riser tubes.





CONVERSION OF LANCASHIRE BOILER INTO FBC (FIG. 4)

Enhancing the evaporation capacity :

While converting the old inefficient boilers into FBC, it is possible to increase the evoporation capacity of the boiler. To achieve the increase in evoporation rate, the folloowing points are to be verified.

1. Condition of boiler tubes and surfaces.
2. Will the present feed pump be able to give the additional feed water requirement ?
3. Will the present safety valve relieve the additional steam output.

Economics of FBC Boilers

Fuel Coal	**FBC Boiler**	**Conventional Boiler**
1. Saving due to improved Efficiency :		
Steam output, t/h (Nett)	10	10
Heat output, x 10^6 kcal/h	6.3	6.3
Efficiency, %	82	65
Heat input, x 10^6 kcal/h	7.68	9 69
High heating value of coal, kcal/kg	3800	3800
Coal requirement, kg/h	2022	2551
Coal requirement/year (24 hrs x 330 days) T/h	16014	20404
Coal saving, T/year	4190	
Saving, per year in Rs. (Coal cost Rs. 550/t)	23,04,500/—	

2. Saving due to use of fines : It is assumed that the coal normally received will have fines to the extent of 20% minimum. These fines are seived out before using in grater/stoker fired boilers and sold for 60% of original coal cost (ie. for Rs. 330/-.

Steam output	: 10 T/h
Coal required/year	: 20204 T/year (for Conventional boiler)
Fines generated/year	: 4040 T/year.
Differential cost, Rs.	: 550-330=220
Saving in utilising fines, Rs.	: 8,88,800/—
Total saving in coal, Rs.	: 31,93 300/—

FACTORS TO BE CONSIDERED FOR CONVERSION

While it is technically feasible to convert any boiler into FBC firing system, the practicability and success of conversion depends on the following factors.

1. Willingness to accept a new system on the part of working level people.
2. Space required for coal bunker.
3. Space required for incorporating ash removal system.
4. Space for adding dust collector.

While the management may decide to go in for conversion of the existing boiler into FBC system based on the economics, the very success of the system could be hampered by unwillingness on the part of the staff at the working level. Generally, people resist a change. In this case the skills expected of the boiler operator is different than the one which he may be possessing. In some cases it could lead to retrenchment/transfer to some other sections of few employees. To overcome these problems we should take these people into confidence right from the start and slowly make them realise the advantage of the conversion.

CHANGES IN COAL HANDLING SYSTEM

Most of the small capacity boilers are hand fired. The practice adopted in most places is to get coal by trolleys and heap in front of the boiler, from which the required coal is showeled into the grade. With fluidised bed combustion system crushed coal is fed pneumatically into the furnace. This needs a bunker and associated structures. Unless the required space is available in front of the boiler, this could become difficult to expensive.

Further, in case only of the many boilers in the battery is converted into FBC, coal size required for the two categories of boilers being different, additional equipment/expenditure is involved. In such cases a long range policy decision as to whether in furture all the boilers are to be converted into FBC or not could reduce the expenditure.

CHANGES IN ASH HANDLING SYSTEM

With grate fired boilers most of the ash is removed from the grate in the form of clinkers. Removal of ash from other clinkers, even when provided, is done few times in a year, or just during annual inspection only. But on conversion to FBC, 50 to 70% of the ash will go as fly ash (because of the small particle size used in FBC). Further, the quantity of ash to be removed from the converted boiler could be high due to the following :—

a. As the capacity is nearly doubled in most cases the fuel input is increased.
b. With conversion to FBC, this boiler gets the coal with highest ash percentage.

This ash has to be continuously removed from the various hoppers. This could become expensive if sufficient head room is not available below these hoppers.

EXPERIENCE IN RETROFITTING

Step Grate Furnace :

We had convereted a step grate furnance at M/s. Sanjivani Sakaheri Shekhar Karhana, Kopargaon into Fluidised Bed system to fire Baggasse and coal. This is an operation with coal since July '87. Output and efficiency of the system is as predicted and no problem has been encountered with ash removal from the existing hoppers.

Lancashire Boiler :

A 30′ x 8′ Lancashire boiler has been converted into Fluidised Bed combustion system at M/s. New Rajur Mills, Ahmedabad. While the combustion is good, accumalation of ash in the main flues of the boiler, makes it difficult to run the boiler continuously for more than a week. Another problem, which has not been realised before conversion is the fact that when there is a battery of Lancashir boilers, any modification in the flue as path of one of the boiler without shutting down the other boilers is not possible. Certain modifications were further done to add a high temperature Mechanical Dust Collector. Adding the cost of all equipments, the cost of such conversion became very near to the new boiler cost.

CONCLUSION

The authors have presented in the above paragraphs the status of FBC technology in the country and the likely benefits to the industry and the nation by retrofitting FBC in existing boile s. The views expressed are that of the authors and not necessarily that of the organisation to which they belong.