TIPS TO IMPROVE AVAILABILITY & EFFICIENCY OF YOUR ATMOSPHERIC BUBBLING FLUIDISED BED COMBUSTION BOILERS

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The fluidized bed combustion technology has been now well accepted by the users across the country for different solid fuels. There are installations for mixed fuel firing & even gaseous / liquid fuels co-firing. Across the country there are lot of engineers and boiler operators who have learnt this technology. Yet the technical tips of FBC operation may not have reached all. This is a sincere effort to throw more light to the behavior of FBC to the benefit of boiler users.

A BRUSH UP ON FUNDAMENTALS

WHAT IS FLUIDISED BED?

When air or gas is passed through an inert bed of solid particles such as sand supported on a perforated plate, the air, initially, will seek a path of least resistance and pass upward through the sand. With further increase in the velocity, the air starts bubbling through the bed and the particles attain a state of high turbulence. Under such conditions, the bed assumes the appearance of a fluid and exhibits the properties associated with a fluid and hence the name 'Fluidised Bed'.

MECHANISM OF FLUIDISED BED COMBUSTION

If the sand, in a fluidised state, is heated to the ignition temperature of the fuel and the fuel is injected continuously into the bed, the fuel will burn rapidly and the bed attains a uniform temperature due to effective mixing. This, in short, is fluidised bed combustion.

While it is essential that temperature of bed should be at least equal to ignition temperature of fuel and it should never be allowed to approach ash fusion temperature (1050°C to 1150°C) to avoid melting of ash. This is achieved by extracting heat from the bed by through evaporator tubes immersed in the bed.

If velocity is too low, fluidisation will not occur, and if the gas velocity becomes too high, the particles will be entrained in the gas stream and lost. Hence, to sustain stable operation of the bed, it must be ensured that gas velocity is maintained between minimum fluidisation velocity and particle entrainment velocity.

DESIGN OF FLUIDISED BED

Based on the boiler heat duty, the amount of fuel to be burnt is decided. Based on chemical constituent of fuel, the air required for combustion is calculated. As the combustion takes place in the bed all the heat is released within the bed. The heat is extracted out of the bed by the leaving flue gases and the bed evaporator tubes. The bed cross sectional area is fixed based on the fluidisation velocity which will not exceed 2.8m/s. Once the bed coil area and bed cross sectional area is decided it is clear turndown becomes difficult. Because lower the heat release rate, lower will be the bed temperature. Hence by reducing the bed height, the bed HTA immersed in bed is reduced. Thus the bed temperature is still ensured for steady fuel combustion. Additionally compartmentalisation is done to ensure the minimum fluidization is achieved. The fuel feed and air feed are turned off in the slumped bed.

OVERBED AND UNDERBED FUEL FEEDING ARRANGEMENTS

Any time underbed feeding is superior in terms of combustion efficiency. Underbed is best suited for fuels which have higher carbon content, such as Australian & African coals. The excess air requirement is more in Overbed feeding arrangements. In overbed feeding arrangement elutriation losses would be more. Hence underbed is preferred by many boiler buyers.

FINE TUNING THE FLUIDISED BED COMBUSTION BOILERS

The design of Fluidised bed combustion boiler has lot to do with the fuel type and the fuel conditions. The fuel itself may change since the purchase of the boiler. A design based on certain fuel / fuel combinations is not at its optimum when it comes to other fuels. This is specifically true when the boiler is changed from agro fuels to coal. Similarly change in operating loads may also warrant fine tuning of the boiler operational parameters. There are cases where the boiler is specifically oversized considering the future expansion. In such a case the bed area and bed coil area may have to be covered up until the steam requirement increases. The air requirement and flue gas to be handled becomes less. Use of VFD / use of smaller capacity fans would benefit the user in terms of power saving and operational efficiency. Like this there are lot of possibilities for a review of the original design to present operating conditions.

TIPS FOR IMPROVEMENT IN OPERATIONS / MODIFICATIONS FOR IMPROVEMENT

In the following pages the tips are explained with illustrations as necessary. The tips are based in the operational experience of several make of FBC boilers in India. Some of the tips would certainly benefit some boiler users. There is always a solution born to every problem experienced. In the continual improvement of the design / Operation of the FBC boilers there is always scope for additions to this list.

TIP 1 –Measure and maintain adequate Distributor plate drop

The quality of fluidisation should be good ensuring there are no defluidised zones. This can not be ensured by visual means. The distributor plate pressure drop becomes a vital factor to ensure this. When the DP drop is less than 75 mmWC, the coarse particles begin to settle down at the bed bottom. In an ideal case, DP drop should be 1/3 rd of bed height. Defluidization or settlement of coarse particles will not be visible from top of the bed, as the fine bed material would continue to fluidise. Settling of coarse particles can also damage bed coils. This leads to localised erosion of bed tubes. This can happen even in overfed FBC boilers. Providing studs does not help. Bed coil erosion continues. See figure 1.

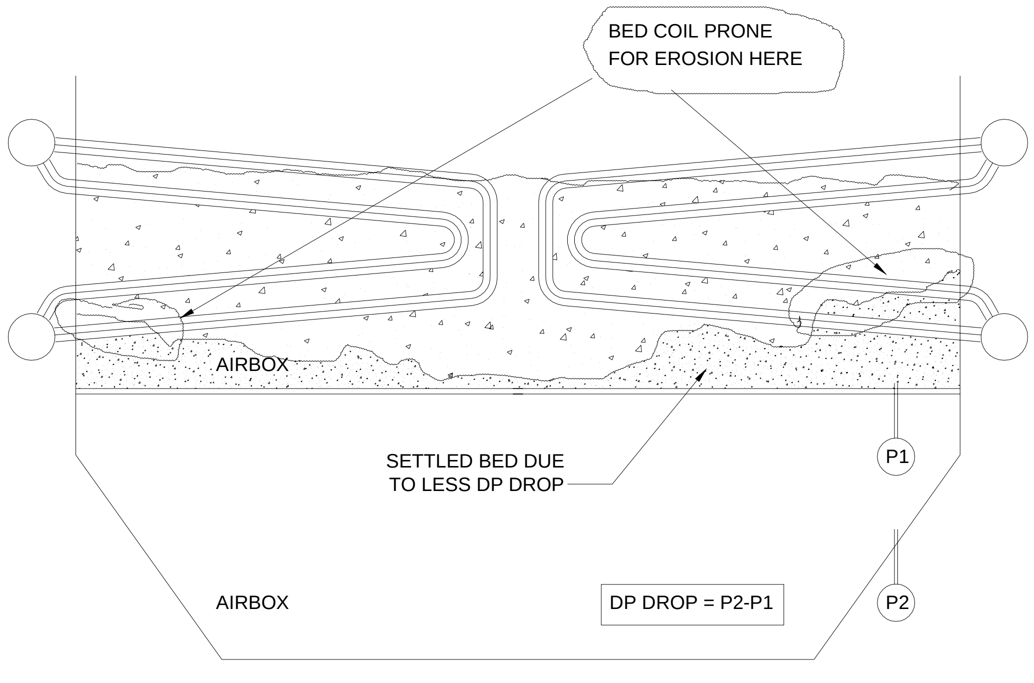

FIG 1: WHEN DP DROP IS LESS BED COARSE PARTICES SETTLE AT BOTTOM OF BED

TIP 2 – Check bed coil pitch for studded bed coils

Studs can increase protection against gross erosion but not localised erosion. Studs decrease the clearance between adjacent bed coils. Spacing of coils is to be specially addressed if studding is opted for. The Increased fluidisation velocity at narrow clearances decreases the life of the bed coils.

TIP 3- Consider reduction of bed size

When the steam demand is less, the bed area becomes oversized. Maintaining a minimum pressure drop for fluidisation would be difficult. The boiler operators continue to maintain high excess air level to avoid bed slumping. In many process boilers this is the case due to oversized boiler (planned considering future steam requirement) See figure 2. It is necessary to reduce the bed area by blocking nozzles and by construction of refractory walls.

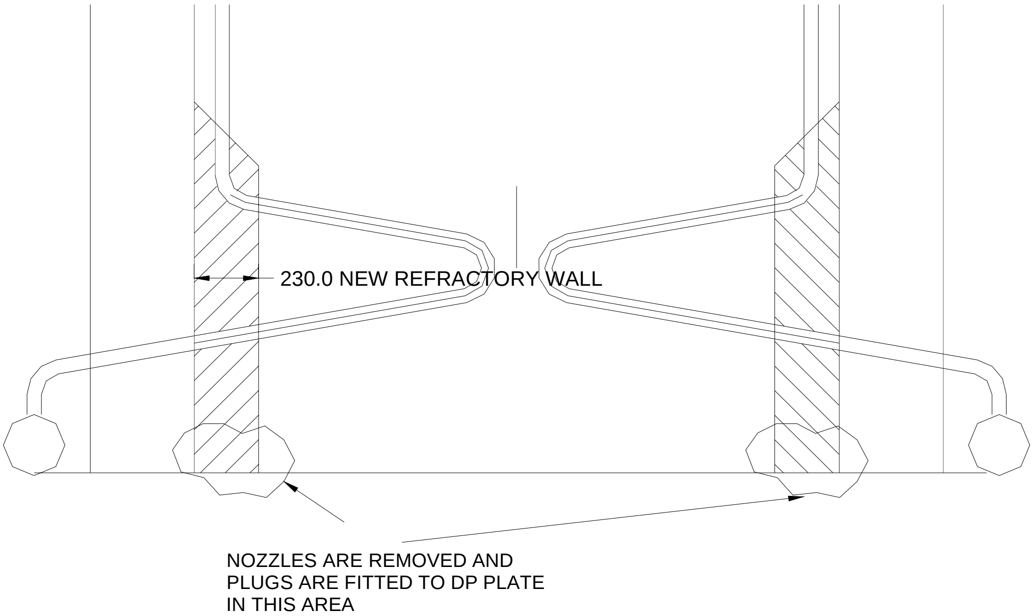

FIGURE 2. BED AREA REDUCTION TO SUIT THE REDUCED STEAM GENERATION REQUIREMENT

TIP 4 - Inadequate instrumentation

Some manufacturers do not provide draft gauges / manometers for indication of bed pressure. In such cases, the operators do not get an idea on bed height. Knowing air box pressure alone does not tell what the bed height is. It may be possible that fluidising air is more and the bed height is less. More fluidising air leads to excess air operation. This affects the bed coil life. See figure 3.

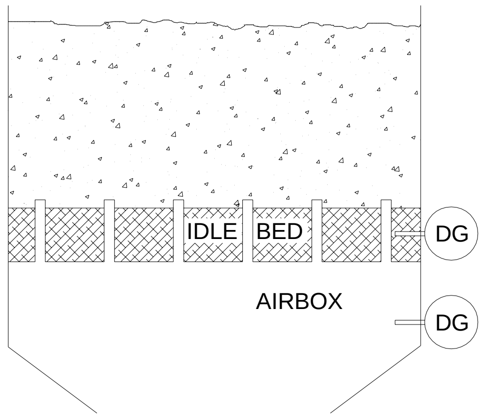

FIG 3: BED HEIGHT & AIRBOX INSTRUMENTATION

TIP 5 - Care of idle bed

At times it may be necessary to reduce the steam production rate. This is done by slumping compartments. Continued operation of slumped bed may result in shallow bed height in the operating compartment and leads to defluidization. This happens particularly when bed size is smaller. The bed height in operating bed becomes less when it spills to adjacent slumped compartment. See figure 4. It becomes necessary to alternately activate the slumped bed to bring the bed height back to normal. There are other reasons as well. See the further tips.

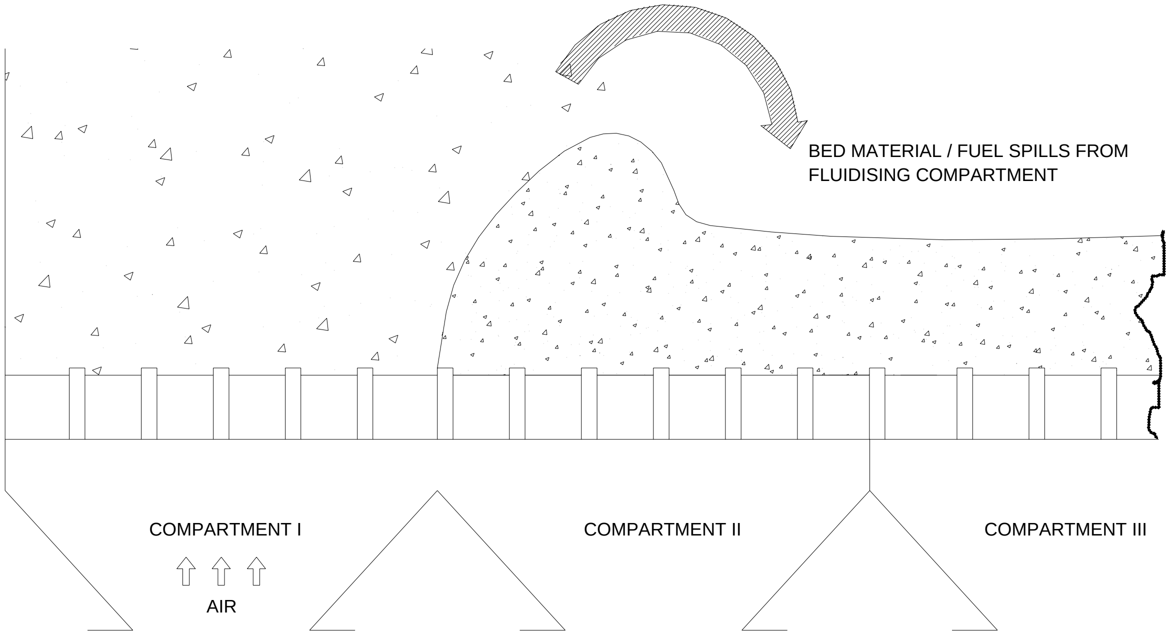

FIGURE 4. BED MATERIAL SPILLAGE TO IDLE COMPARTMENT

TIP 6 Provide additional drain points

Heavy stones and heavy ash particles keep accumulating at the bottom of bed. Larger beds need more ash drain points in order to ensure coarse ash particles, which settle at the bottom can be effectively removed. If drain points are inadequate or if all the available drain points are not used, small clinkers would form and grow big. The ash draining will be effective in open bottom fluidised beds. The ash draining must be kept partially opened to allow gradual discharge of ash from the bed. This way it is found to remove most of the coarse particles that settle at the bottom.

In overbed feeding arrangement coarser particles would settle near fuel feed points. Provide additional ash drain points at these locations to remove the stones / heavy particles.

TIP 7- Care for idle bed

Slumping of the bed is done to meet the steam demand. It is not correct to keep same compartment under slumped condition. In the slumped bed heat transfer to bed coil becomes less. The circulation of water ceases. This may result in high pH corrosion / caustic gouging/ settling of iron oxides / corrosion products in such bed coils, depending on boiler water chemistry. See figure 5, for appearance of tube inside on a caustic gouging failure.

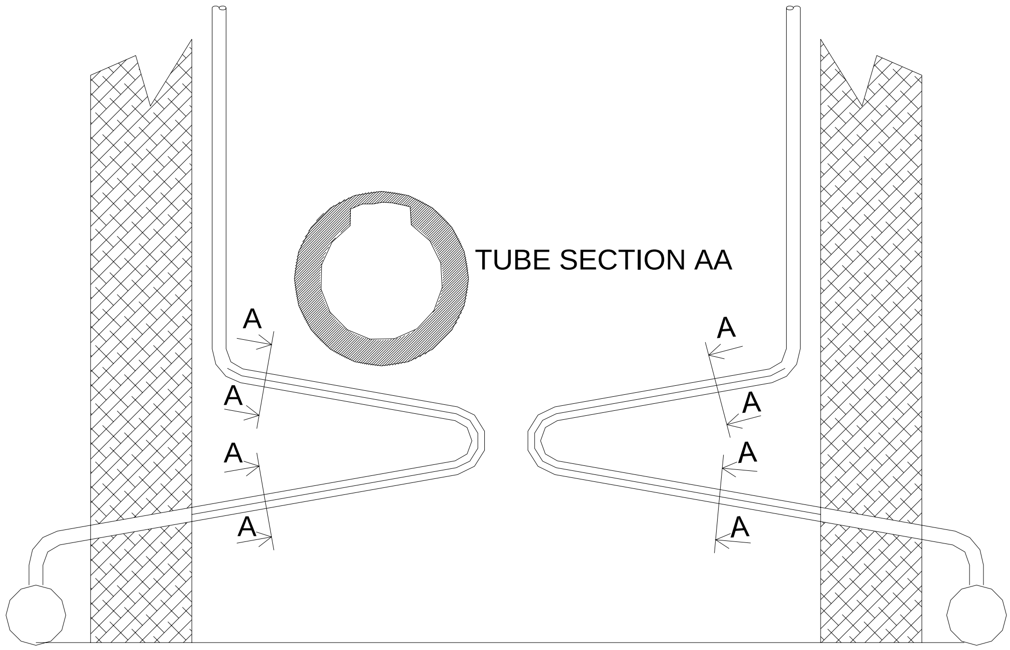

FIGURE 5. CAUSTIC GOUGING ATTACK IN IDLE COMPARTMENT

TIP -8 Use Optimum primary air pressure

Primary air fans are required for underfeed system. The PA fans are selected with 15% - 25 % flow margins. It is necessary to keep the PA header pressure as low as possible so that the suction effect is just the minimum at the throat. The air leakage from the feeder must be taken as a guide. Higher PA header pressure leads to more air flow through the fuel feed points. Higher air flow would erode the bed coils faster. It addition venturi erosion would be faster.

TIP 9 – Care for shutting PA damper in idle bed

In underbed feeding arrangements there is no physical partition above the distributor plate. When a compartment is slumped for load control, particularly for longer duration, it is necessary to close the PA damper in slumped compartments. Leaving the primary air full open in idle compartment would lead to bed coil erosion. It is the tendency of many operators to leave open the PA line dampers, for the fear of line choking. The bed material is continuously thrown at bed coil.

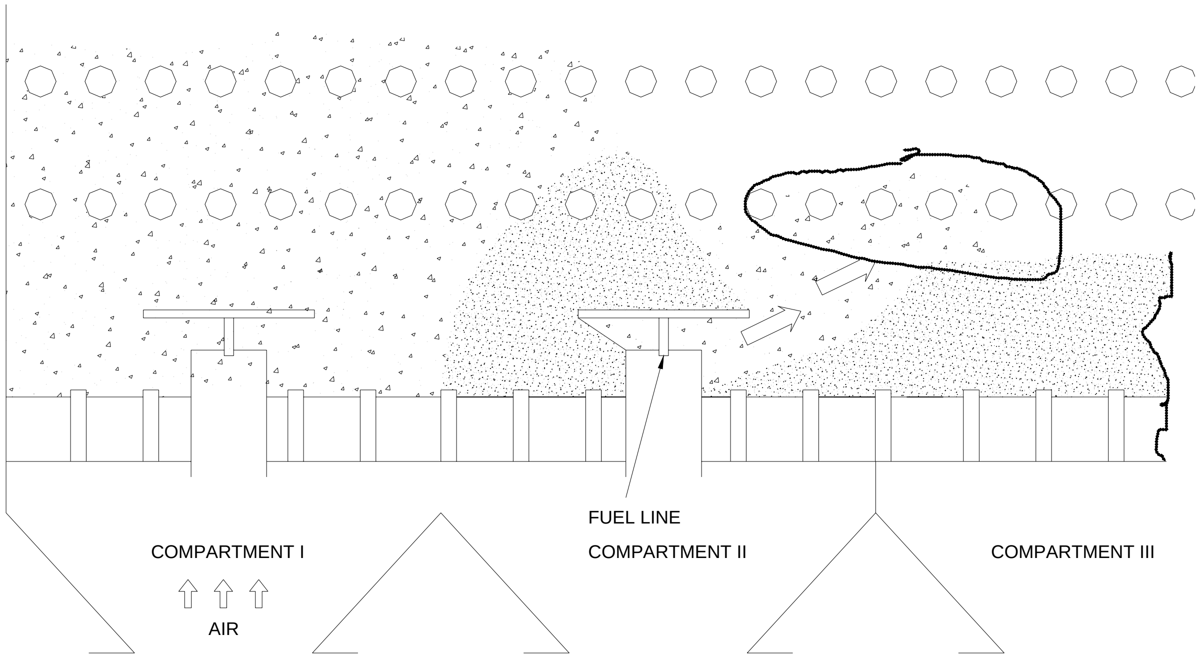

FIGURE 6. FUEL LINE AIR ERODING AWAY BED COIL IN IDLE COMPARTMENT

TIP 10 – Replace the Worn-out venturi / mixing nozzles promptly

In underfeed arrangement the fuel is fed from bottom of the bed. As the pressure at the feed point inside the bed is 400 -500 mmWC, high pressure PA fan with mixing nozzles are used to transport the fuel inside. The air jet velocity at the throat of the mixing nozzle is of the order of 100 – 130 m/s. The fuel particles are accelerated at the mixing chamber and the diffuser ensures the gradual return to normal line velocity. The diffuser erodes over a period (1-2 year). As the pressure drop of mixing nozzle increases more and more air is required for generating suction at the throat. Naturally the erosion rate of bed coil will be more inside the bed.

TIP 11- Care to use the air vent valve in idle compartment

Slumping of a compartment is necessary to take care of load reduction and while start up of the combustor. There can be clinker formation if the fuel spillage is present in the idle compartment. In certain boilers, the fuel feed point may be close to the border of the adjacent compartment. For the clinker to take place there should be air flow in the idle compartment. The compartment dampers may not be leak proof. For this reason, automatic air vent valves are provided in compartment air box, to enable venting the passing air from compartment damper. If the valves are to be manually operated, the same must be done. Needless to say, that the leaky damper will have to be attended.

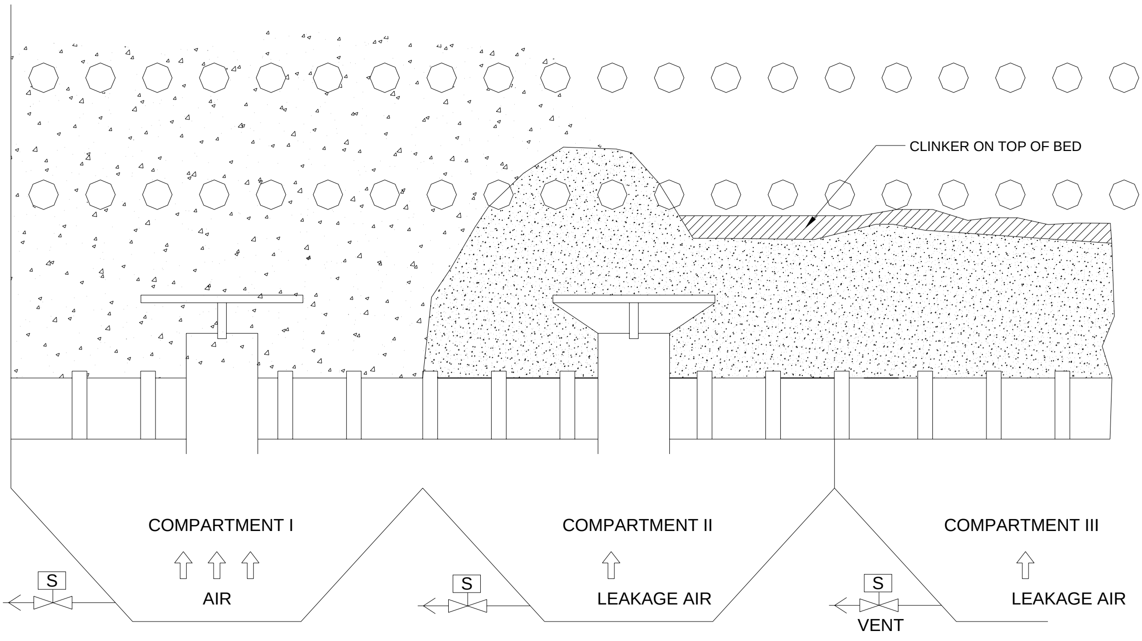

FIGURE 7 : FUEL SPILLAGE AND LEAKAGE AIR IN IDLE COMPARTMENT CAUSING CLINKERS

TIP 12-Avoid continued operation with troubled bed

A fluidised bed may get clinkered when there are disturbances in boiler operation. For example when there is no coal in bunker, the operator momentarily reduces the air flow in order to reduce the bed quenching. At this time, it is likely the bed defludises at some zones. The average particle size is always high compared to start up bed material and hence defluidization chances are more when the air flow is reduced. Once the bed is known to have clinkered, steps are to be taken for immediate removal. This may be possible by increasing the drain rate from the clinkered bed. A bed clinkering can be figured out from the differences between the bottom and top bed temperature readings.

TIP 13- Ensure proper fuel particle size

Improper fuel sizing affects the bed particle size. Improper screen cloth sizing, coarse particle separation in bunker, worn out crusher hammers can lead to oversized fuel particles. Oversized fuel particles are found to accumulate near the fuel feed points leading to defluidization. The air jets upwards once this happens. Bed coils erode locally above the fuel feed point at this time. See figure 8.

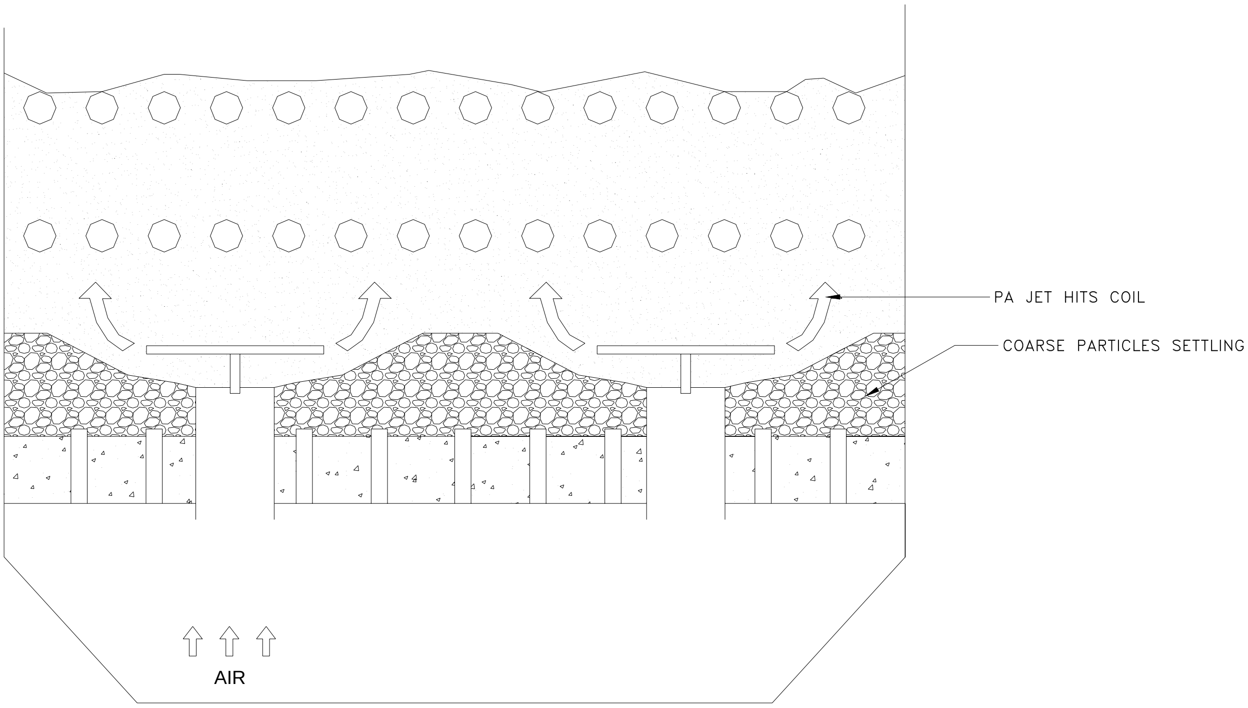

FIGURE 8 : COARSE PARTICLES SETTLING AROUND FUEL NOZZLE AND PA JET HITTING BED COIL

TIP 14 - Attend to Loose air nozzles

Some manufacturers adopt push fit nozzles over the distributor plate. Further a castable refractory is laid over the plate. The castable gets broken during service due to thermal expansion. This leads to leakage at the air nozzle base itself. Such leakages lead to not only bypassing of more air from such locations, but also lead to defluidised zones. This can happen near bed ash drain points.

TIP 15 -Leaky compartment dampers

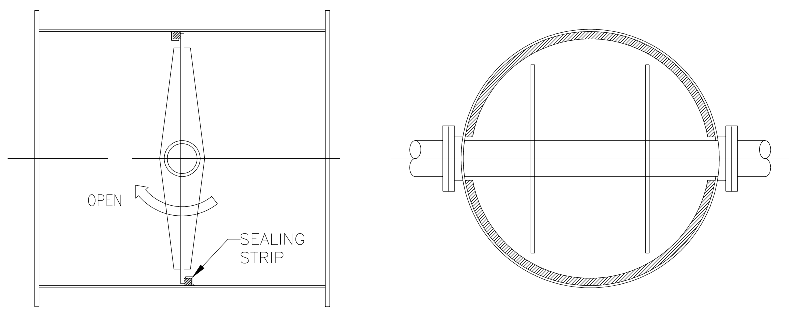

FIGURE 9 : SEALING STRIPS FOR CIRCULAR DAMPERS

Leaky compartment dampers lead to partial fluidisation. Spilled fuel from adjacent operating compartment would lead to clinker formation and further growth. Dampers will need replacement. Butterfly dampers with proper seals would be the ideal choice to solve the clinker problem. In ordinary flap type damper sealing strips would help bring down the leakage. See the figure 9, for the detail of sealing strip which prove useful.

TIP 16- Improper setting of Power cylinder of compartment dampers

Compartment dampers are to be set for closed conditions. At times it is found that the dampers do not close inside where as the power cylinder closes fully at the outside. See figure 10, which points out the defect, which is faced in many cases.

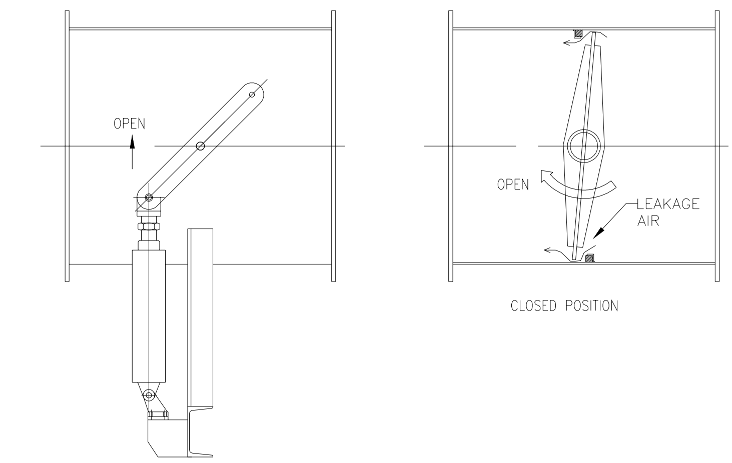

FIGURE10 : IMPROPER POWER CYLINDER ERECTION CAUSES LEAKAGE

TIP -17 Leaky distributor plates

Some manufacturers adopt removable distributor plate design. This is adopted for ease of approach during bed coil maintenance. The leakage between distributor plate and supporting frame would lead to local fluidisation and keeps making clinkers. When the air bypasses at some place it is natural at some other location, the bed has settled. See figure 11. If the erection is improper this could be a serious matter disturbing the fluidised bed operation.

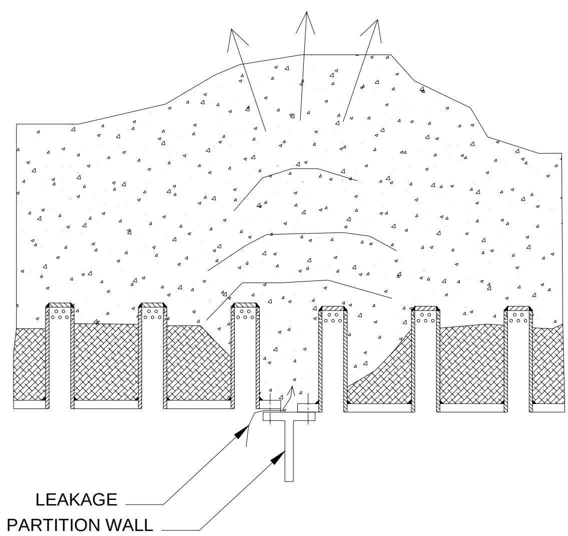

FIGURE 11: LEAKAGE BETWEEN SUPPORT FRAME AND DP PLATE

TIP -18 Replace all failed air nozzles at one go

Air nozzles may be made from cast iron / stainless steel. The nozzles begin to oxidise at the top where it receives radiation and convection heat. Over a period the top opens up. Now the air jets from top hitting the coils above. Some experience cracking of air nozzles along the top row of nozzles. Failed air nozzles allow more air flow and hence the air flow through the good ones would come down (Preferential flow through least resistance path). This leads to defluidised zones.

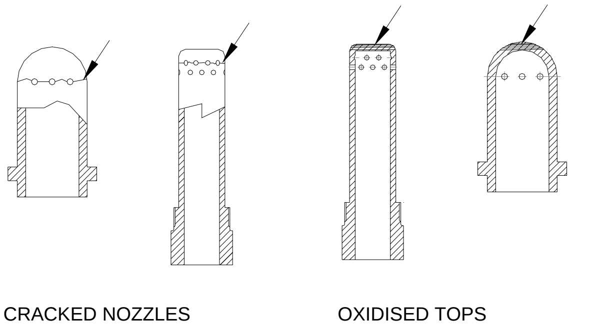

FIGURE 12: FAILED AIR NOZZLES DISTURB FLUIDISATION AND CAUSE BED COIL EROSION

TIP – 19 Do not Operate the boiler with choked PA lines

Primary air lines choke up when oversized fuel is fed or when compartment damper is opened before operating PA damper. Due to this the fuel nozzles get distorted. In running boiler no one can guess what the extent of distortion is. The fuel nozzle cap is distorted the fuel-air mixture may target the bed coil and lead to premature failure. Distorted nozzles are to be replaced immediately. SS fuel nozzles offer better protection when it comes to bed coil life.

TIP 20 -Reduce the chances for start up clinkers

Fluidised beds may be started compartment by compartment. When the first compartment is started one must ensure that there is a good mount of bed material to prevent the fuel spillage to adjacent compartment. The PA pressure should be bare minimum. Excess PA pressure spills more fuel to adjacent compartment. The PA pressure requirement will be less, since the bed height will be less during start up. When the fuel spill is more a border clinker is likely to form. Excess mixing air flow also leads to more spillage. It is necessary to keep the PA air line dampers of adjacent compartments in close condition.

TIP 21- More PA and less fluidizing air

By virtue of design / operating load, bed material settles along the wall side. This leads to throwing of bed material along the wall to the coils. This happens where fuel feed points are close to wall. When the frequent load turn downs are expected the bed plate pressure drop has to be designed for ensuring a minimum bed plate pressure drop of 75 mmWC. Operating at lesser ΔP would lead to pockets of defluidised zones.

TIP 23 -Bed coil to fuel nozzle clearance

The designer has to ensure a minimum clearance of 150 mm from fuel nozzle cap top to bed coil to safeguard the bed coil against erosion. At times due to faulty erection the clearance may be less leading to premature bed coil failure.

TIP 24 –Check the adequacy of instrumentation of fluidised bed

In the absence of bed temperature indications and air box pressure, bed pressure, operation of the fluidised bed is risky. When such instruments are compromised, no one can vouch that the bed is perfectly OK at all places. It may be possible to assess from the bed material drained from ash drain pipe. But the same will not be proper for bigger beds. Failed thermocouples, burnt compensating cables, defective temperature indicators are to be replaced at the earliest opportunity to prevent bed coil erosion.

TIP 25- Review Oversized fuel feeders

In some cases, it is likely that the feeders are over sized. A feeder designed for agro fuel becomes oversized when it comes to changing over to coal. The fuel feeders are to be replaced with a smaller one or additional speed reduction mechanism needs to be added. For a small rpm change the feeder may be dumping excess fuel. The clinker formation possibility is increased due to this. In the recent years many boiler users have started using high GCV imported coal. This may also lead to excess fuel dumping for a small rpm change.

TIP 26- Change the bed coil configuration while replacement

The pitch of the bed coil is a factor for erosion potential. At least one tube gap must be adopted while selecting the pitch. This is a reason for bend erosion in closely pitched hairpin type bed coils. Staggered bed coils would ensure sufficient gap between coils and thus fluidisation becomes more uniform at entire bed. Cross bed tubes are found to be better than the hairpin coils. While planning for replacement of bed coils, consider improvement of bed coil configurations. There are many possibilities for better configurations considering ease of replacement.

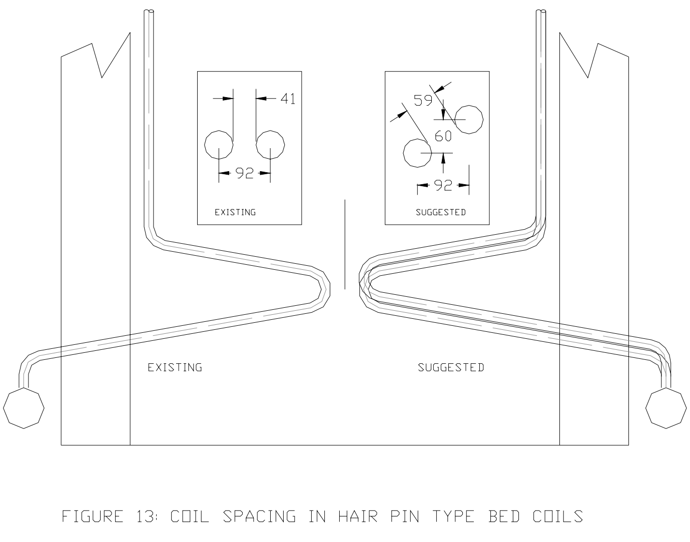

FIGURE 13: COIL SPACING IN HAIR PIN TYPE BED COILS

CONCLUSION

I hope the readers would agree some of the suggestions made here are applicable to their installations. Suggestions are welcome from the readers.