CASE STUDY ON EFFICIENCY & AVAILABILITY DETERIORATION IN AN AFBC BOILER

By K.K.Parthiban / Venus Energy Audit System & Sri Devi Boiler Equipment and Spares.

Introduction

This case study is about various operation & maintenance aspects of an AFBC boiler, that led to serious availability issue & efficiency issue. The visit was called for by the management to study the reasons for the following problems faced in the boiler.

1. High fuel consumption in recent times.
2. Severe plugging of air preheater tubes was experienced. The problems continued even after the replacement of the air preheater tubes. Refer photo 1.
3. Spare ID fan had to be started after running the boiler for 10 days.
4. Unburnt levels in ESP ash had been abnormally high.

As we completed the shut down audit, the reasons for the above got revealed. These problems may be experienced in other installations. Hence this audit report is made public for the benefit of the boiler user industries.

About the boiler

- The fluidized bed boiler parameters are 50 TPH, 66 kg/cm2 g, 490 deg C and feed water temperature is 140 deg C.
- The boiler is of single drum design with bed SH, radiant SH, convection SH, economiser, air preheater and ESP.
- The boiler is supposed to have been designed for many load combinations as below.
  100% Indian coal
  100% Imported coal
  70% Lignite + 30% Indian coal
  60% Petcoke + 40% Indian coal
  75% Imported coal + 25% Woodchips
- The design fuel analysis data is as below.

Fuel	unit	Indian coal	Imp.coal	Lignite	Pet-coke	Wood chips
Carbon	%	37.10	56.95	38	86.70	43.71
Hydrogen	%	2.30	5.83	2.80	3.18	5.68
Nitrogen	%	0.70	1.12	0.50	0.39	1.84
Sulphur	%	0.30	**0.90**	**2.00**	**5.94**	-
Moisture	%	8	**12**	**36**	1.08	5.92
Ash	%	45	13	10	0.78	1.72
Oxygen	%	6.60	10.20	10.70	1.93	41.13
GCV	Kcal/Kg	3500	6500	3800	8010	4180

- The highest fuel moisture content is present in the lignite. However GCV is reported to be high. This may not be true GCV.

- The latest fuel combination had been 52% Indian coal + 25% imported coal + 23% Lignite coal. Prior to the visit, locally available lignites were being used based up on the market availability. Imported coal was co-fired in order to limit the moisture content to 20% in the fuel mix. Evidences of sulfur oxides could be seen in the boiler.
- The fuel feeding arrangement is with twin bunker design with rotary feeders. However the fuels are being premixed and fed in both bunkers.
- The boiler is with 2 x 100% FD fans, 2 x100% ID fans and 2 x 100% PA fans.

Boiler history

- The boiler was commissioned eight years back. The performance guarantee test was done by OEM and the log data were available.
- Three years back, a partial gas bypass duct was introduced for economiser to increase the ESP inlet gas temperature. The dampers in the bypass duct between economiser inlet and air preheater inlet was being used to adjust the ESP inlet gas temperature.
- There had been extensive tube plugging in APH and the tubes were replaced about two months back. Hence the boiler is as good as a new one. Yet the fuel consumption was reported to be high.

Summary of Root cause of the problems reported

- There had been combustion issues, causing choking problem of the air preheater and the high fuel consumption.
- There had been air ingress at many places leading to localized corrosion failures in the duct and ESP casing. This had led to draft problem.
- The performance of the ID fans had deteriorated due to failure of sealing ring that maintained the overlap and the annular clearance between the suction cone and the impeller eye.
- There had been fuel flow problems in the fuel feeding and primary air system, causing operational disturbances. The steam pressure fluctuations had caused more fuel consumption.

DETAILED OBSERVATIONS AND DISCUSSIONS

The boiler was under shut down and was available for open inspection. The findings are brought out with photographs below. It should help the readers to catch the point and apply to their installation as applicable.

Combustion issues

The oxygen analyser placed in air preheater inlet had not been working properly. The readings had been erratic. The oxygen analyser had been eroding due to placement at high velocity gas path. It needed to be relocated. The mal-functioning of oxygen analyser had led to operators to disbelieve the oxygen and to follow the air flow meter instead.

1. It was found that the air flow maintained for combustion had been lower as compared to OEM recommendation. The steam flow versus air flow curves were already given by the OEM. These were to be taken as guidelines. Further air adjustments were to be made depending upon CO & O_2 levels in the flue gas.
2. It was found that the air flow maintained for combustion, was lower than the value used during

PG test. In general, high moisture coals and high ash coals would need more air for completing the combustion.

3. Unburnt carbon and unburnt gases led to plugging of air preheater tubes due to carbon soot particles (smut) sticking to the inside of the tubes. LOI analysis of the deposit inside the tubes was found to be 86%. Apart from this ash nature (ash chemistry) and low flue gas temperature would also cause APH plugging. When plugging is experienced, at least three plug / deposit samples should be analyzed in external lab for content. It would make things clear to the plant engineers.

Photo 1- Plugging of airpreheater tubes. Unable to be removed.

Photo 2: Flange leak, Fabric torn at NMEJ at boiler outlet.

Photo 3: Air ingress at Inspection doors. Improper sealing rope placement.

Photo 4: Air ingress in SH inspection door. Improper sealing rope placement.

Photo 5: High velocity at Eco to APH duct is seen here. Bellow protection plate is eroded.

Photo 6: Oxygen analyser is located at high velocity zone. It went out of order frequently.

4. Air ingress was present at the following locations misleading the actual oxygen levels.
   - New gate system provided in the economiser to APH bypass gas duct, was not leak proof. It

was learnt that the damper flap got eroded in the earlier flap damper.

- The boiler outlet expansion bellow was seen sucked in. The fabric was torn due to high temperature. See photo 2. In addition, the flange joints could cause leakages, since the sealing rope fail due to high gas temperature. The seal ropes also fail due to hardening effect over a period.
- Inspection doors at boiler outlet duct, economiser casing, expansion bellow between economiser hopper and APH hopper, were found to be improperly sealed. Refer photos 3 & 4.The doors are to be sealed with flat ropes. The flange joints of expansion bellows should be welded.
- There were signs of air ingress from boiler roof. Refer photo 7. The photo no 8 shows the POP (plaster of paris) application over the SH header and the boiler roof, done at another plant, in order to arrest air ingress. Many boilers have poor sealing at roof panel.

Photo 7- Air ingress marks are seen in SH area.

Photo 8: Sealing by POP helps to seal the roof easily.

Photo 9: SA ports design needs improvement. They are placed close to radiant SH coils.

Photo 10: No SA header pressure gauge.

Photo 11: Better SA port arrangement. Less no and large pipes, on two side walls, provide proper penetration and combing effect.

5. It was seen from log books, that secondary air system had not been used yet. SA system was seen provided a meter below the RSH coil bottom. See photo 9. Secondary air would not be required for firing Indian coal. However it would be required while firing high VM Indonesian coal / lignites. There was no pressure gauge for SA system. See photo 10. It would be required for setting SA flow. The present arrangement differs vastly from the SA system by another boiler maker, which works well. Refer photo 11.
6. Unsteady / troubled fuel feeding leads to excess fuel consumption. There had been improper coal flow in the fuel feeding system of the boiler. There had been steam pressure fluctuations. This would lead to poor turbine heat rate. At times of high coal feed rate during transients, CO generation would be more.

Photo 12- Small hoppers give no view of fuel flow.

Photo 13: Wider feed hoppers for better view.

Photo 14: Multi flap dampers located immediate to PA fan outlet, affect fan performance.

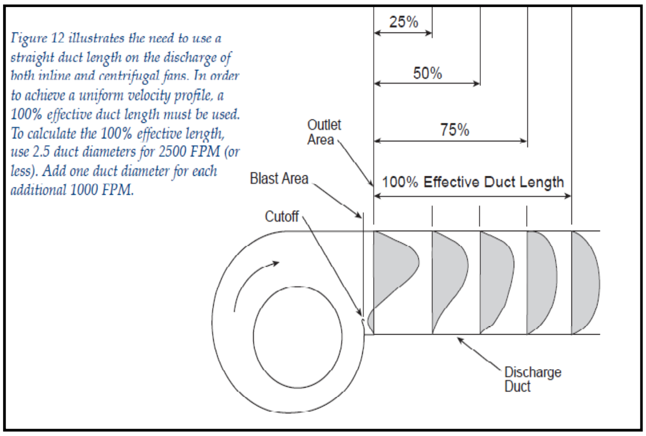


Photo 15: Obstruction free distance required at fan discharge for the best performance of fans.

7. The hoppers above the rotary feeders were too small for inspection of coal flow. Refer photo 12. Photo 13 shows the hoppers modified at another plant. With this wide mouthed hoppers, inspection of coal flow would be easier.
8. Multi flap dampers were found placed immediate to PA fans discharge. This would cause poor performance of the fan. Refer photo 14. It is recommended to replace the multi flap dampers by means of guillotine gate. Photo 15 shows the clear obstruction free distance requirement at fan discharge by fan experts.
9. For wet coals, it is necessary to keep high PA header pressure. This will increase venturi effect at the mixing nozzle. It is necessary to reduce the unnecessary pressure drops in the PA ducting system. Design of ducts should consider aerodynamics in 90 deg turns and in T junctions.

10. When a PA line is de-choked, the fire comes in to the fuel cross. The coal smothers inside fuel cross creating a perpetual choking. Hence once the line is de-choked, the smothered coal must be removed at the earliest, by partial draining of the coal from the vertical pipes below the fuel cross. Proactive cleaning of the fuel cross by partial draining, helps to avoid repeated choking. Compare photos 16 & 17 below.
11. It is suggested to have a static bar screen to filter out coal lumps that travel down from the bunker. The static screen would also help to filter out the corroded steel flakes. One person has to be posted at the feeder floor to remove lumps and foreign materials above this static screen periodically. Refer photo 18.
12. The photograph 19 shows the cleaning arrangement required for rotary feeders in case of high moisture coals. The arrangement should be provided on the return side of the feeder after the coal is dropped into the mixing nozzle. Drag chain feeders do not need this.

Photo 16- Smoke below airbox due to fire inside cross.

Photo 17: Fire removed out of the cross immediately after a de-choking.

Photo 18: Static screen to arrest the lumps / foreign material going to feeder.

Photo 19: Arrangement to clean the feeder before it gets plugged.

Photo 20: High suction desirable for free flow of dust at mixing nozzle.

Photo 21: lumps formed at mixing nozzle chute due to +ve pressure at venturi.

13. The divider chutes below the drag chain feeder may be made of SS 304. This will avoid generation of rust flakes which fall into mixing nozzles. There should be no welding burrs protruding in to the coal flow path.
14. It is seen that old worn out mixing nozzles and new mixing nozzles have been mixed up. This leads to variation in coal transport air flow. This can cause choking of coal.
15. It is advised to replace all mixing nozzles with a new design, in which, the inlet cone is redesigned for improved suction. See photo 20. This will avoid splashing wet coal powder inside the mixing nozzle inlet chute. The splashed coal later forms a lump and falls inside the throat of mixing nozzles. See photo 21.

Draft issues

1. There were no draft measurements available at inlet ID fans. By mistake the draft transmitters meant for this measurement were installed at the ID fan outlet ducts. See photo 22 below. Due to this fact, the actual draft when the air preheater tubes are choked, is not known.
2. The ID fans have been selected for head of 200 mmWC. However the air preheater outlet draft had been -80 mmWC at the maximum. We can consider a pressure drop of 50 mmWC at the maximum across the ESP. Hence there was no limitation with respect to head requirement at the ID fan. But plant engineers did not realize that the draft did not exceed the ID fan design draft.
3. On inspection, it was observed that the sealing ring provided between the suction cone of the ID fan and the impeller failed due to corrosion. Refer photo 23 below. When this happens, there will be recirculation of gases within the ID fan. Hence the second ID fan must have been called for. Since the failure is seen in both ID fans, there would be further limitation to draw the flue gases from the furnace.

Photo 22- Draft transmitters wrongly installed at ID fan discharge.

Photo 23: ID fan impeller eye to suction cone clearance / overlap not OK. Corrosion is the reason.

4. Air preheater outlet duct had been undergoing corrosion due to flue gas condensation phenomenon. The flakes of corroded iron had been falling over the tube sheet and plugging the gas path. Refer photo 24 & 25. Steps are to be taken to avoid condensation.
   a. There is a need to improve the APH outlet gas temperature further to prevent the sulphur condensation.
   b. Combustion has to be completed to avoid carbonic acid formation.
   c. The insulation of the top & side duct wall plates has to be improved.

Photo 24- Plugging of airpreheater tubes.

Photo 25: Corrosion APH top duct plate.

Photo 26: Air ingress at isolation damper flange joints. Light is seen at the flange joints.

Photo 27: Uninsulated isolation dampers at ID fan inlet duct.

Photo 28: Air ingress in ESP inspection door caused corrosion.

Photo 29: Air ingress in fabric joint flanges at ESP inlet.

5. Air ingress was seen in all flange joints. Sealing ropes in flange joints fail over a period due to hardening effect by heat. Leakages develop after this, leading to additional cold air ingress at these joints. The air ingress loads the ID fan. Had there been a draft measurement at ID fan inlet, the plant engineers would have got an idea about the extent of air ingress. Oxygen mapping in flue path would have proved the air ingress. Refer photos 25, 26 & 29. All the flanges below needed seal welding.
    a. Flanges of boiler outlet duct expansion bellow.
    b. Flanges of expansion bellow between economiser ash hopper and air preheater ash hopper.
    c. Flange joints of the duct between economiser ash hopper and air preheater ash hopper.
    d. Flange joints of the nonmetallic expansion bellows provided at ESP inlet and ESP outlet.
    e. Flange joints of the isolation dampers at the outlet of T ducts. (refer photo 27)
6. Proof of air ingress was observed at the ESP casing inspection doors and ESP ash hopper doors. See photo 30. This was due to hardening of sealing rope and absence of the sealing rope. This had resulted in corrosion failures of the ESP casing nearby and air ingress had been in excess. The collecting electrodes nearby the doors were found to be corroded completely.

Photo 30- Corrosion of collecting electrodes in ESP due to localized condensation by air ingress from improperly sealed inspection doors.

Photo 31: Flange leak in ESP double door system. Mineral wool mattress must be packed between inner & outer doors.

Photo 32: Air ingress at ESP hopper inspection doors. Sealing rope is not provided.

Photo 33: Corrosion due to uninsulated duct at fabric expansion bellow at ESP outlet.

7. Condensation from uninsulated areas led to corrosion problems. For example, the duct after the ESP outlet bellow was see corroded and holes were seen in the bottom plate of the duct. Refer photo 33. This is the indication of acidic condensate from flue gas corroding the duct. The following is the list of problematic areas in general and to this plant as well.

a. Flanges of non metallic expansion bellows.
b. Dampers in flue gas duct system & near ID fan.
c. Metallic bellows in flue gas duct system.
d. Uninsulated manhole doors.

8. All non metallic expansion bellows in the flue gas duct system should be replaced with SS multi convulsion bellows. The flanges of the duct should be seal welded. The bellows could then be fully insulated thus avoiding the condensation problem. This action will help to operate the boiler on high moisture - high sulfur coals with least trouble against corrosion.

Photo 34- Fabric joint flanges are sources of flue gas condensation.

Photo 35: Flue gas condensation in uninsulated ducts, bellows and dampers. Removable pad insulation could be used.

Photo 36- Improper inspection door at ESP inlet gas duct as source of water stagnation at top plate of APH - ESP duct. Double door system is needed here as well.

Photo 37- ESP double door systems also need proper sealing. Mineral wool mattress must be packed between the inner and outer doors.

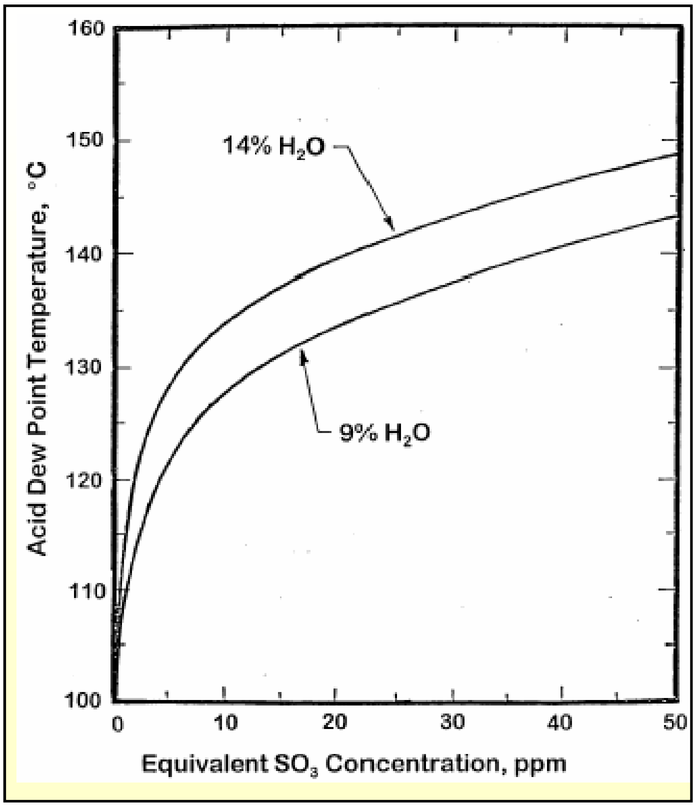
9. There are simple inspection doors at flue gas ducting such as APH inlet, APH outlet, APH intermediate door, ID fan inlet, ID fan outlet. See photo 36. These cause condensation of flue gas inside the gas path. At APH it causes plugging & corrosion. These doors can be provided with double door system as in ESP casing inspection doors. Again insulation must be packed in between the inner & outer doors. See photo 37.
10. In the ESP casing double door system is provided many vendors. Some vendors compromise this. The following should be taken care.
    a. Only flat asbestos rope should be used for sealing at outer doors. Adequate flange holes shall be made at the outer doors.

b. 50 mm thick mineral wool blanket - removable blanket pillows- should be packed in between inner & outer doors.
c. The sealing ropes at the inner door should be replaced every time the doors are opened.
d. Air ingress shall be checked by flame after the assembly of both doors.
e. Provide canopy / rain gutters / folds in cladding to direct the rain water away from entering the insulation cladding.

11. In the ESP ash hopper doors, sealing rope should be provided. See photo 32. Second door is not required. However air ingress shall be checked by flame test.
12. There were left out welding at ESP canopy. Welding / fit up should be complete, in order to avoid water ingress in to ESP casing in the event of rain.
13. ID fans are to be provided with removable insulation bags. ID fans may be provided with shed, so that the insulation / ID fan casing plates will not be damaged due to rain.

<u>Operational modifications required at operating engineer's level</u>

The boiler operational log sheets were reviewed and there were many points related to the boiler operation. An interaction session was held to brief the findings in the visit.



1. The ID fan exit temperature must be above 130 deg C. The design outlet gas temperature is 140 -160 deg C. One must look for condensing water at dead ends such as ID fan suction box drain / casing drain. Refer the graph, which is an important aspect of acid dew point of flue gas. Higher the fuel moisture higher will be the acid dew point. Higher the sulphur content higher will be the acid dew point.
2. Bed temperature should be between 825 & 850 deg C for lignite. This improves the margin between slagging temperature of the bed ash and the operating temperature.
3. SA air pressure should be increased in steps, if it could reduce LOI / CO levels in flue gas. Minimum 300 mmWC pressure is required for the good penetration of secondary air in to the furnace. CO must be measured while fine tuning the SA air pressure.
4. Fluidizing air must be given as long, it improves the bed combustion temperature. Simply maintaining some air flow numbers from the past was not correct. As the APH develops leaks, the number would change.
5. Iron % must be checked regularly in fly ash. It gives an idea about pyrite content of the lignite / imported coal.
6. Iron % must be monitored in bed ash. It should be less than 15%. Iron % is estimated using simple magnet.
7. If bed ash is recycled, the recycle bed material should be free of iron. Iron separating system

must be used. Magnetic separator systems must be installed to remove the iron.

8. Bed ash fusion temperatures must be regularly checked if there is a tendency of the bed to clinker or when small globular clinkers are seen in bed ash.
9. Oxygen sampling points shall be provided at economiser outlet duct, air preheater outlet duct, ID fan suction box. Weekly report shall be generated on the oxygen / CO profile in the boiler. The sampling points at each location should be two numbers, one on the left side and one on right side.
10. CO / O_2 profile shall be regularly checked so that air flow correction can be done. Indicated air flow is not important. It is the completeness of combustion that is important.
11. Portable gas analyzer shall be used on weekly basis to check the field O_2 analyser readings.
12. It is suggested to operate both ID fans to avoid condensation damage caused by stagnant flue gas.
13. It is not correct to hold onto some indicated air flow numbers. As the air preheater tubes fail, it becomes necessary to increase the air flow in order to complete the combustion.
14. It is advised to calibrate the oxygen analyser regularly. It is advised to counter check the oxygen indicated by the insitu analyser, by means of portable analyser. The portable analyser shall also be calibrated on a regular basis, by sending the analyser to the supplier or the calibration agency.
15. The lignites have high sulphur content. Hence while starting the boiler and while stopping the boiler it is advised to operate the boiler on 100% percent Indian coal. This will drastically reduce the corrosion by the sulphur containing fly ash. The boiler will be clear of sulphur deposits, if Indian coal is fired before shutdown. It will result in cleansing of the boiler from sulphur deposits.
16. PA header pressure should be maintained high in case of highly moisture coals. If necessary, the second PA fan shall also be taken into line in order to increase the PA header pressure. PA header pressure can be at the maximum 1300 mmWC.

14\. Ash samples for analysis of LOI should be given at the end of a shift. In two hours, the results should be obtained. The next shift engineer can attempt to adjust the airflow and look for improvement in LOI.

CONCLUSION

Combustion is not merely adhering to some numbers. The best combustion must be established by using a combination of SA and PA. LOI in ash and CO in flue gas together decide the completeness of combustion.

K.K.Parthiban

Dealing with high moisture & high sulfur coals need more attention. No uninsulated areas must be allowed. All flue gas system downstream of economiser are to be protected against air ingress and condensation associated with uninsulated ducts. All Inspection doors downstream of economiser need to be properly closed. The doors must be of double door type.

Never compromise on detailed inspection during annual shut down. The loss of plant availability / plant performance proves costlier than a compromised inspection.