Root Cause Analysis of Performance Anomalies in Soot Blowers of Chemical Recovery Boiler

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Abstract— The Chemical Recovery boiler is the profit-earning section of the Paper Industry. By properly reutilizing the resources used in various sections of the industry, the net consumption of resources like wood, water and steam can be reduced. Soot blower is one of the major components required for the proper functioning of the boiler. Several issues like Nozzle rupturing, Steam leakage, Lance tube bending and corrosion are frequently reported among the 28 soot blowers of Seshasayee paper and boards limited, Pallipalayam, procured from Clyde Bergemann Inc., Atlanta, usa. This project concentrates on the analysis of root causes of these problems and aims at eliminating them. Also, we have suggested a few corrective measures to be taken to increase the operating efficiency of the soot blowers and the boiler.

Key words: Chemical Recovery boiler, Nozzle, Lance tube, Soot blower

I. INTRODUCTION

A. Industry Profile

Seshasayee Paper and Boards Limited (SPB), the flagship company belonging to ‘ESVIN GROUP’, operates an integrated pulp, paper board mill at pallipalayam, erode-638 007, Tamilnadu, India.

SPB, incorporated in June 1960, was promoted by Seshasayee Brothers (Pvt.) Limited in association with a foreign collaborator M/s. Parson and Whittemore, South East Asia Inc., USA. After commencement of commercial production, having fulfilled their performance guarantee obligations, the foreign collaborator withdraw in 1960. Main promoters of the Company to the ESVIN group headed by Mr. N. Gopalaratnam. SPB commenced commercial production in December 1962, on commissioning a 20000 TPA integrated facility comprising a pulp Mill and two paper Machines (PM-1 and PM-2) capable of producing, writing, printing, Kraft and poster varieties of paper. 1)

1) Expansion/Modernization Project

The Company embarked on an Expansions / Modernization Project to enhance its production capacity from 60000 tonnes per annum, to 115,000 tonnes per annum and to upgrade some of the existing facilities, at an estimated cost of Rs. 1890 millions. The said Expansion / Modernizations Project were completed in December 2000. After successful trials, the commercial production out of the new Paper Machine commenced on July 1, 2000. The current installed capacity of the Company stands at 1, 15, 000 tonnes per annum.

2) Raw Materials

The Company’s paper plant was originally designed for using bagasse, as the primary raw material mixed with 20% bamboo fibre. Bagasse was being obatined from nearby sugar mill on substitution basis using oil fired boilers. With sharp increase in oil prices in 1970-71, the Company shifted over to the use of hardwood, at the time of its expansions undertaken in 1978. Raw material mix underwent a substantial change, with bamboo and hardwood forming 60% and 40% respectively, of its raw material consumption. In 1981, it added one more digester to increase the share of the hardwood in the furnish mix to 80% and restricting bamboo use to only 20%. With the commissioning of more wood based industries in Tamil Nadu, their was again an apprehension about availability of hardwood.

As a Long term Strategy, the company at this time dedicated on restructuring used of bagasse which was seen to be the most reliable source of fibre for the entire Industry. In 1984, the Company promoted ponni sugars and Chemicals Limited, as the captive source for bagasse supply. It added bagasse handling systems modernised PM-1 and PM-2, to shift over to the use of bagasse. The furnish mix for the existing Paper Machines of the Company is 55% bagasse and 45% hardwood 3)

3) Exports Performance

SPB’s export is nearly 20% of its production and is a significant exporter in the Indian Paper Industry. Due to its excellent export performance, SPB has been awarded ‘Golden Export House’ status.

B. Chemical Recovery Boiler

Recovery boiler is the part of kraft process of pulping where chemical for white liquor are recovered and reformed from black liquor, which contains lignin from previously processed wood. The black liquor is burned, generating heat, which is used in the process and in making electricity, much as in a conventional steam power plant. The invention of the recovery boiler by G.H.Tomlinson in the early 1930s was a milestone in the advancement of the kraft process. 1)

1) Description

The chemical recovery boiler at SPB Ltd is a single drum, finned tube, top-supported natural circulation, drainable water tube boiler. The recovery boiler has two main functions. On one hand, it generates steam from the heat energy liberated upon combustion of the organic constituents of black liquor burned in the boiler, where the recovery boiler serves as a steam boiler. On the other hand, the chemical from pulp digesting-sulphur and sodium are recovered from the black liquor, the recovery boiler then serving as a chemical reactor. This double function makes the design of a recovery boiler rather complex and the operation of such a boiler much more complicated than for instance, a power plant boiler burning conventional fuels in the boiler. When viewing the recovery boiler as a chemical reactor, its construction is quite unique. In the recovery boiler furnace, to a great extent in the same space and at the same time, a number of entirely separate physiochemical process take place.
2) Specifications

<table>
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<tr>
<th>Details</th>
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<td>Type of boiler</td>
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<td>Manufacture</td>
<td>ENMAS ANDRITZ Pvt. Ltd</td>
</tr>
<tr>
<td>Type of spray</td>
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<tr>
<td>Boiler capacity</td>
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<td>Evaporation of boiler</td>
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<tr>
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<td>Working pressure</td>
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<td>Black liquor firing rate</td>
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<tr>
<td>Steam flow rate</td>
<td>70 tons/hour</td>
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</table>

Table 1: Specifications of Chemical Recovery Boiler

3) Peripheral Equipment

In addition to the boiler itself, there is a lot of peripheral equipment that is essential to the operation of recovery boiler. This includes:

- Black liquor system
- Spouts and dissolving tank
- Soot blowers
- Electrostatic precipitator

a) Black Liquor System

The only fuel of the recovery boiler is the concentrated black liquor which contains organic wood residue in addition to sodium sulphate from the cooking chemicals added at the digester. High concentration of sulphur requires optimum conditions to avoid the production of sulphur dioxide and reduced sulphur gas emissions. In addition to environmentally clean combustion, reduction of inorganic sulphur must be achieved in the char bed.

The black liquor system includes the equipment for preparing the liquor for firing and introducing into the furnace. In a typical system, the liquor guns are attached manually to a furnace heater (ring heater) through which liquor ready for firing is supplied. The main contents of black liquor are Na₂CO₃, Na₂SO₄, NaOH and Na₂S. Heat energy is partly used to convert the organic compounds used to generate steam.

Semi-concentration black liquor at 70% concentration is supplied to mixing tank where salt cake (Na₂SO₄) is added as makeup chemical and boiler hopper ash is also mixed with black liquor. The black liquor is then heated up to 110°C through the direct heating of the steam and then fired in the boiler through stationary spray guns. The organic is converted into Na₂CO₃, and is further reduced to Na₂S through chain of reactions. All the inorganic flow through cooled spout as molten smelt into dissolver.

b) Spouts and Dissolving Tank

The molten smelt that is produced within the recovery boiler is removed from the furnace through the smelt spouts into a dissolving tank where it is dissolved to from green liquor. The spout openings can be subjected to varying smelt level flows and require some of corrosion production. Spout cooling water systems are designed to minimize the pressure inside the spout while providing on adequate flow of cooling water. The collected cooling water inside is then cooled and pumped back to the head tank. An agitated tank is used to dissolve the smelt stream as it follows out the furnace to prevent the accumulation of molten smelt within the control of the density of the green liquor within the dissolving tank is a key to stabilizing the entire recovery cycle.

c) Soot blowers:

Soot blower is used to remove deposits from the heat transfer surface (super heater, boiler tank and economizer) within the boiler. Soot blower is working a pressure of 42 kg/cm² and temperature is 305°C. It is applicable at 230°C above the drain temperature. Finally steam flow of soot blower is 13tons the soot blower lances are mounted on cars rides outside the boiler. When a soot blower is activated, the lance moves into boiler and rotates. Steam jet located near the front of the lance strike the deposits and blow them off the tube surface. Most soot blower blow continuously as they move into the boiler and then retract. Some are setup to blow while travelling in but to retract quickly with a reduced steam flow on the second part of the cycle. We will discuss in detail about the parts and working of the soot blower in the following sections.

d) Electrostatic Precipitator

The electrostatic precipitator is used to remove the dust from the flue gas leaving the recovery boiler. It is located at end of the train just ahead of the stack. The dust that is removed at the precipitator is primarily sodium sulphate (salt cake) and it is recycled to the black liquor and refried into recovery furnace. Precipitator dust also tends to be enriched in chloride and potassium. If the mill has-plugging problems due to chloride accumulation in the recovery cycle, some of the precipitator dust are dumped in order to purge chloride, some chloride removal process also start with precipitator dust.

C. Process Description

The recovery boiler process has several unit processes:
- Combustion of organic materials in black liquor to generate superheated steam.
- Reduction of inorganic sulphur compounds to sodium sulphide, which exits at the bottom as smelt.
- Production of molten inorganic flow of mainly sodium carbonate and sodium sulphide called smelt, which is later recycled to the digester after being re-dissolved.
- Recovery of inorganic dust from flue gas to save chemicals in ESP (Electro Static Precipitator).

In the recovery boiler furnace to a great extent in the same space and at the same time, a number of entirely separate physiochemical processes take place:
- Feeding of air and mixing it with the furnace gases.
- Feeding the black liquor and dispersing it into droplets.
- Drying of the black liquor droplets.
- Pyrolysis of the black liquor and combustion of the pyrolysis gases.
- Gasification and combustion of the char residue.
- Reduction of the liquor sulphur compounds to sulphide.
- Tapping the molten salt consisting of sodium sulphide and sodium carbonate from the furnace bottom.

I) Chemical Recovery

The inorganic chemicals in the black liquor (sodium, potassium, Sulphur and chlorine) are recovered as a molten salt mixture, called smelt. It consists primarily of Na₂S and Na₂CO₃ with small amount of Na₂SO₄ and other material. The Na₂S, which is necessary for Kraft pulping, requires a local reducing (oxygen deficient) environment. The effectiveness of the recovery boiler in producing this desired chemical (as opposed to Na₂SO₄) is measured by the reduction efficiency. The inorganic chemicals are much...
heavier than the combustion gases and tend to fall toward the hearth. At normal furnace temperature, they are in a molten (liquid) state and can be drained from the boiler through smelt spouts. One feature of recovery boilers is the presence of a char bed on the hearth. The char bed consists of a pile of partially pyrolysis black liquor solids, carbonaceous material and inorganic that accumulates on the hearth.

Not all of the inorganic chemicals proceed directly to the hearth. Some of it forms a fine dust, consisting primarily of Na₂SO₄ with some Na₂CO₃ which flows with the flue gases. This is collected in an electrostatic precipitator and returned to the black liquor being fired. In addition, some inorganic collects on heat transfer surface and is removed by soot blowers. This material either falls directly to the hearth or is collected in ash hoppers and returned to the black liquor.

2) Steam Generation
Superheated steam generation has three basic heat requirements:
- Heating the feed water to the boiling point
- Supplying the latent heat of vaporization
- Heating the steam from saturation to final temperature

Feed water heating takes place in the Economizer, stream temperature rising in the super heater, and evaporation (stream formation) in the generating bank, water walls and screen section. As boiler pressure is increased, the relative heat transfer loads generation are decreased and those for raising feed water and steam temperature are increased.

II. SOOT BLOWER
A. Need for Soot Blowers
The combustion of black liquor causes buildup of combustion deposits (soot, ash and slag) on the boiler’s heat transfer surface. Combustion deposits generally decrease the boiler’s efficiency particularly by reducing heat transfer.

When the combustion deposits accumulate on the boiler tubes, the heat transfer efficiency of the tubes decreases, this in turn decreases the boiler efficiency. To maintain a high level of boiler efficiency, the heat transfer surfaces are periodically cleaned by directing a cleaning medium, e.g., air, steam, water or mixtures thereof against the surface upon which the deposits have accumulated. To avoid or eliminate the negative effects of soot and slag build up on boiler efficiency, the boiler heat transfer surface would need to be essentially free of deposits at all times. Maintaining this level of cleanliness would require virtually continuous cleaning. However this is not practical under actual operating conditions because cleaning is costly and creates wear and tear on boiler surfaces. Injecting the cleaning medium also reduces the boiler’s efficiency and prematurely damages heat transfer surfaces, particularly if they are over-cleaned. Boiler surface and water wall damage resulting from soot blowing is costly because correction may require an unscheduled shutdown.

Accordingly, boiler must be typically maintained reasonable, but less than ideal boiler cleanliness levels. Soot blower operation is regulated to maintain those selected cleanliness level in the boiler. Different areas of the boiler accumulate deposits at various rates cleaning. Most of these soot cleaning devices use steam to dislodge slag and clean surface within a boiler.

B. Terminologies Used
1) Poppet value pressure
The poppet value pressure is the steam pressure measured at the location immediately downstream of the value seat. This is the steam pressure supplied to the feed tube.

2) Nozzle Pressure
The nozzle pressure is often used interchangeably with lance pressure or blowing pressure. It is defined as the steam pressure or blowing pressure supplied to the soot blower nozzles, and is the pressure measured just before the steam enters the nozzle. Note that the nozzle pressure is always lower than the poppet value pressure due to minor losses and the pressure drop in the feed and lance tubes.

3) Impact Pressure (IP) and Peak Impact Pressure (PIP)
The impact pressure is the pressure of the steam when a soot blower jet is brought to a complete stop. Impact pressure is also called pilot tube pressure as it often measured using a pilot tube. PIP is the impact pressure measured along the jet centerline where the pressure is at its peak.

C. Paraphernalia
Soot blower is a device which is designed to blast soot and ash away from the walls of a furnace or similar price of equipment. Soot blower operates at set intervals, with a cleaning cycle that can vary in length, depending on the device and the size of the equipment which needs to be cleaned. Soot blowers function to keep combustion particles from sticking to boiler tube within the boiler tower.

1) Principle
The basic principle of the soot blower is the cleaning of heating surface by multiple impacts of high pressure air, steam or water from opposing nozzles orifices at the end of a translating tube. A travelling lance with nozzle jets penetrates the narrow openings in the boiler tube banks to blast the tubes clean. The tubes must be kept clean to allow optimum boiler output and efficiency. A common applications at oil, coal or multi-fuel source power plants is retractable or rotary soot blowers.
2) Main parts
Soot blower major components the can be divided into two parts:
- Steam carrying components.
- Mechanical and Auxiliary components

a) Steam carrying components:
As the steam enters the soot blower, it is directed through four components in the following order:
- Poppet value
- Feed tube
- Lance tube
- Nozzle

b) Poppet value:
The poppet value serves two purposes:
To open and shut the supply steam to the soot blower
To adjust the blowing pressure of the soot blower
c) Feed tube:
The feed tube is a stationary tube connected to the poppet value with main function is to deliver the steam to the lance tube, refer to Fig. 2. The standard material for feed tube is stainless steel 304 with an outside tube diameter (O.D.) of 23/4 in (70 mm). As the steam exists the feed tube and enter lance tube, it pressurizes the gap between the feed and lance tubes. Non-insulated and non-hardened stainless steel tubes are mainly used as feed tubes at SPB Ltd.
d) Lance tube
The lance is the main components that supplies the soot blower nozzles with high pressure steam and directs the jets towards the boiler tubes. During the cleaning process, the lance extends into the boiler and forms a structure similar to a cantilevered beam. Hence, the lance has to be designed to have sufficient strength to support its own weight in a high temperature environment. The majority of soot blowers installed in recovery boilers at SPB Ltd., are equipped with lance tubes having an outside diameter (O.D.) of 4 in (101.6mm) made of SS 310. The larger lance tube will reduce the pressure drop and increase the nozzle efficiency, thereby improve the jet cleaning power.
e) Nozzle
The main function of a soot blower nozzle is to convert the high pressure steam inside the lance tube into a high-velocity jet. An ideal nozzle is defined as a nozzle that fully expands the blowing medium from the pressure inside the lance tube to the outside ambient pressure thereby, converting the lance pressure completely into velocity (100% efficiency). In order to fully expand the pressure inside the lance and accelerate the steam to a supersonic velocity, a convergent-divergent type of nozzle is used (fig.3). In the convergent section then accelerated to a speed of sound. The divergent section then accelerates it further to a to a speed of speed. The divergent section then accelerates it further to a

f) Mechanical and Auxiliary Components
- Carriage and gear rack
The carriage consists of one electric motor, a gearbox and a packing housing. The electric motor is the main drive that moves the lance tube forward and backward during the cleaning cycle. The motor converts electrical energy into rotation motion, which is then used by the gearbox to rotate and move the lance tube along the gear rank. Since the lance moves together with the carriage, while the feed tube stays stationary, the carriage has to be equipped with a packing set to prevent the steam from leaking through the gap between the feed and lance tubes. The packing set is located inside the packing housing, which is an integral part of the carriage.
- Limit switch
A limit switch is an electromechanical device that sends a signal transmission to the carriage when its mechanical leg is physically pushed by a lever arm. There are two limit switches with one level arm: one is mounted in the rest position and the other is mounted in the reverse position. The lever arm, which is used to trigger the switches, is attached to the carriage and travels together with it.
- Wall box
The main function of a wall box is to prevent the hot flue gas, fume and carry over particles from escaping the boiler through the openings designed for soot blowers operation. This can be achieved by continuously supply the wall box with pressurized air (seal air); hence creating an air wall that prevents the flue gas from leaking through the lance/wall sleeve gap.

D. Performance Goals
The industry management has established certain performance goals which need to be met in the recovery boiler. By keeping these goals as a scale of success for this project, we have progressed on the endeavor.
- Keep the cost of production of steam within Rs.6/ton.
- Increase the power producing capacity of the plant to 10 MW/day
- Maintain the steam production rate of the boiler at 70 tons/hour
  These are the benchmarks that will be used to define, track, and measure project success over.

III. ROOT CAUSE ANALYSIS
A. Objectives
The overall objective of this analysis was to identify and define the root causes impeding effective performance of the soot blowers. The specific objectives are:
- To identify a comprehensive list of issues and the root causes that negatively impact the performance of soot blowers like nozzle damage, steam leakage, etc.
- To provide a basis for developing recommended solutions that address the identified root causes and issues eliminate the negative impacts on performance.

B. Approach and Methodology
The approach for conducting the RCA on soot blower performance anomalies involved collecting data through document reviews and interviews with the engineers and
operations working in the chemical recovery boiler. The data collected where then analyzed to identify the root causes for the problems being encountered in the soot blowers. The methodology used to perform the Root Cause Analysis included the following steps:

1) **Step 1: Define the problem**
   The smooth operation of the soot blowers in the boiler is affected by various reasons as reported by the industry. Despite their efforts to curb them, the complete eradication of the instances remained a challenge.

2) **Step 2: Gather data and evidence**
   Data were gathered to document past shortcomings in performance. These data were predominantly gathered from reviewing documented reports that specifically addressed the repair works undertaken in the soot blowers. The significance and value of the findings in many of these reports were still germane. They were reviewed for continued applicability. The findings from these reports were validated and supplemented with interviews of people directly responsible for soot blowers in the boiler.

3) **Step 3: Identify issues that contribute to the problem**
   On the basis of the data gathered and reviewed through document reviews and interviews, the most significant issues that plague the soot blower performance were identified.

4) **Step 4: Find the root causes**
   Once the common issues negatively affecting soot blowers performance were found, a more through review of the top issues was undertaken to determine the reasons why they continue. The RCA methodologies commonly referred to as the “Ishikawa Diagram” and “Five-Whys” were used. The response obtained in the previous steps were structured to find out the root causes.

5) **Step 5: Develop Recommended Solutions**
   Upon determining the underlying root causes, a series of possible solutions was analyzed in the form of corrective measures aimed at resolving these issues.

6) **Step 6: Implement Recommended Solutions**
   Each corrective measure will be included in a comprehensive and integrated corrective action plan. The implementation of specific corrective measures will be evaluated and reported on a periodic basis.

7) **Step 7: Observe and Measure performance for desired outcome**
   Ensure the commitment and allocation of the necessary resources to continually measure performance against our performance goals. The contents of this report represent completed activity through the first fire steps subsequent efforts will include the development and implementation of corrective actions and the measurement of their effectiveness.

C. **Data Collection**
   During the period of operation, many routine check-ups were made in the boiler and reports were prepared based on them. These company’s soot blower performance details and maintenance and maintenance details given by the company is thoroughly analyzed. A total of 14 company documents and manuals were reviewed and are mentioned in appendix. Some of the most common issues that have effect in the soot blowers were identified.

In addition, a brainstorming session was conducted with the employees working at the soda recovery plant, regarding the performance anomalies in the soot blower, to identify additional issues that may not have been identified through our document reviews.

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<th>Description</th>
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<td>Blowing medium</td>
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<td>Blower design pressure</td>
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<td>Blower design temperature</td>
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<td>Poppet set pressure</td>
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<td>Motor capacity</td>
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<tr>
<td>Lance tube dimensions</td>
<td>101.6 mm (O.D)x 5.6 mm (wall thickness)</td>
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<td>Lance tube material</td>
<td>SS 310 (for 1.5 m from nozzle end) M.S (for the rest 6 m)</td>
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<td>Feed tube dimensions</td>
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<td>Feed tube material</td>
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<td>Lance rotation speed</td>
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Table 2: Soot Blower Specifications

D. **Ishikawa Diagram**

Ishikawa diagram (or fishbone or herringbone or cause and effect diagrams) are causes of a specific event. Common uses of the Ishikawa diagram are product design and quality defect prevention, to identify potential factors causing an overall effect. Each causes are usually grouped into major categories to identify these sources of variation. The categories typically called as 6 M’s are listed here.

- Machine (technology)
- Method (process)
- Material (Includes Raw Material, Consumables and Information)
- Man Power (physical work)
- Measurement (Inspection)
- Milieu /mother nature (Environment)

E. **Five – why’s**

The five –whys are a question-asking method used to explore the cause and effect relationships underlying a particular problem. This further assisted us in defining the root causes of the problems along with the Ishikawa Diagram.

Fig. 3: Ishikawa Diagram

IV. **CORRECTIVE ACTION PLAN**

A. **Results of Analysis**

Upon careful and detailed analysis for rectifying the various problem found in the soot blowers, we arrived at a number
of possible solutions. These results upon successful implementation can substantially eliminate the problems and improve the performance of the soot blowers and in turn boiler itself. They have been explained in the following section.

1) Inclination of soot blowers

Although the steam used for soot blowing generally is superheated, the temperature of the residual steam may drop, causing it to condense inside the piping system. If the piping is not properly designed to drain the condensate, water can accumulate inside the pipe and will be carried by the soot blowing steam to the blower. Following problems are caused by the soot blower jet carrying steam condensate.

- Tube erosion
- Nozzle damage

By design to ensure proper drainage of the condensate, the steam piping system should always be installed with a negative blower slope to allow the condensate to drain out. The condensate from the residual steam, is forced to flow towards the nozzles and exits the lance via small holes located near the tip of the lance. The condensate in the feed and lance tubes not can create a corrosive environment, but may also adversely impact the boiler tube during the cleaning process. The figure illustrates a negative slope with an exaggeration to better clarify the concept. Note that the wall box may move downward due to boiler thermal expansion. Hence, the setup of the housing in a cold condition should for boiler thermal expansion so that proper blower slope can be achieved when the soot blower is operated in a hot condition. Typically the blower slope is set to around -0.4 for proper drainage of the condensate.

![Blower Slope](image)

**Fig. 4: Blower Slope**

a) Scavenging air

Lance tubes are typically made of SS 310, which has good material strength to support its weight at elevated temperature while the lance is inside the boiler. However, it may be susceptible to corrosion if the flue gas from the boiler is allowed to enter the lance tube through the nozzle. The infiltration of flue gases into the lance tube of soot blower has the potential to cause corrosion of soot blower lance tubes. The corrosion is primarily due to the presence of acidic solutions that accumulate in the forward sections of the lance. The acidic condensate is formed by flue gases that contain high concentrations of SO2 together with fume that has low carbonate content. It is important to both provide and maintain a properly functioning air purge system for the lance tubes.

Due to the resulting lack of airflow there was a significant amount of flue gas entering the soot blower. Most of the soot blowers that had no purging air supply had a whitish gas leaking from the flexible steam purge hose at the boiler end of the soot blower. Further investigation confirmed it was not steam. This meant that flue gas was making its way into the blower or wall box and eventually into the hose. To prevent lance tube corrosion it is important that recovery boiler soot blowers are equipped with a scavenging air system.

The scavenging system continuously supplies pressurized air into the feed and lance tubes, even when the soot blower is inactive, to create a barrier that prevents the flue gas entering the lance tube.

It is also recommended to check the proper purge air supply to all individual soot blowers in a system not only at start up but also at regular intervals to ensure its adequacy. In order to ensure the continuous flow of air, It is necessary to make sure that all air lines are blown free of debris prior to being hooked up to equipment.

The following figure shows the steam and air flow in a scavenging air system.

Blue line indicates the purge air introduced to soot blower in the vicinity of the boiler wall from an air header. A portion of the air is sent to the wall box and balance to the lance via the same pipe that carries the steam purge that is used to purge the wall sleeve during the steam cleaning operation of the blower. During the time a check valve at the connection of the steam purge line isolates the low pressure purge air from the high pressure steam.

The proper orifice size must be determined in tests using air pressure valve recommended.

Period checking of the stream purges lines The main function of a wall box is to prevent the hot flue gas, fume and carryover particles from escaping the boiler through the openings designed for soot blower operation. The wall box is also used to direct a small amount of jet stream into the lance and wall sleeve. This jet is used to clean both the lance tube and wall sleeve during soot blower operation.

It is important that the steam supplied to this wall box should be sufficient and is from excessive condensate. Plugging of the wall sleeve may occur if the condensate is mixed with the fume in the wall sleeve of on the surface of the lance tube to form a hard –to – remove material. Also the condensate may react with vicinity air to form rusting on the lance tube surface which reduces its strength. Hence the wall box and the purge line connections should be checked properly for clogging.

b) Feed tube hardening

Due to the extended operation of the soot blower there are instances where the feed tube subjected to cracks. A scratched and rusted feed tube promotes rapid deterioration of the packing performance, and shortens its service life.

Hardening is a surface treatment that is applied to the outer part of the feed tube to make the surface hard and scratch – resistant. A number of hardening techniques are possible. The heat possible one for the feed tube using SS310 material can be analyzed and incorporated accordingly. (Refer Appendix 14)
c) One - way soot blowing
Each section of the boiler has different fouling tendencies. In the area where the rate of deposit accumulation is low (here economizer section) and the soot blower are mainly facing easy – to – remove type of deposits, one – way soot blowing can be utilized to reduce the steam consumption. This strategy uses full blowing steam pressure only in one direction of the travels, either during the insertion or retraction, and used the minimum flow (cooling flow) in the opposite direction. To implement one-way blowing, the mill will need to control the blowing pressure using a control valves and incorporate the control algorithm in the soot blower control system supplied to the soot blower and is not used as a pressure controller.

The following algorithm may be incorporated into the control system to prevent the overheating of the lance tube and damages to the soot blower major components:

Set the minimum amount flow for each soot blower. Note that soot blowers operated in the super heater region may require higher cooling flow than those operated in the boiler bank and economizer regions.

If the control system detects that the steam supplied to the soot blower is below its minimum limit, automatically retract the soot blower and notify the operator.

The soot blower must be taken out of service until the operator acknowledges that the problem has been confirmed.

d) Cooling lance tube with steam
The lance tube is the main components that supplies the soot blower nozzles with high pressure steam and directs the jets toward the boiler tubes. During the cleaning process, the lance extends into the boiler and forms a structure similar to a cantilevered beam. Hence, the lance has to be designed to have sufficient strength to support its own weight in a high temperature environment. The temperature of the steam supplied inside the boiler is around 400C, while the temperature of the steam supplied inside the lance tube is maintained at about 230C. To avoid the overheating of the lance tube during the operation, the steam, which also acts as a cooling medium needs to be supplied continuously to the lance? The minimum amount of the steam required to prevent the overheating of the lance is called minimum cooling flow. The minimum cooling flow of a lance tube depends on the material, the length of the lance tube, the steam and flue gas temperature. The majority of soot blowers installed in recovery boiler are equipped with lance tubes having an outside diameter (O.D) 4 in (101.6 mm). The larger tube will reduce pressure drop and increase the nozzle efficiency, thereby, improve the jet cleaning power.

The temperature and flow of the steam have to be monitored so that it is maintained greater than the minimum necessary steam required for cooling the lance tube, which avoids the bending problem. A bent lance tube may hit boiler tubes and in severe cases, stuck inside the boiler could not be easily retracted. Bent lance tubes increases the load of the motor.

2) Contoured Full Expansion [CFE] Nozzle
The main function of a soot blower nozzle is to convert the high pressure steam inside the lance tube into a high-velocity jet. An ideal nozzle is defined that fully expends the blowing medium from the pressure inside the lance tube to the outside ambient pressure thereby, converting the lance pressure completely into velocity.

On such highly efficient nozzle suggested by Clyde Bergeman Inc Has been installed in some of the soot blowers while replacing the damaged nozzles. It is recommended that all the older nozzle are also replaced with the latest high efficiency CFE nozzles.

CFE nozzle is a new and significantly improved soot blowers nozzle which provides up to twice the cleaning power of a conventional nozzle.

Fig. 5: CFE nozzle with two openings separated by a distance
Higher peak impact pressure [PIP] provided by CFE nozzle ensures lower lance pressure (17 bar) as against a higher lance pressure (25 bar) with conventional nozzles for achieving same PIP & cleaning efficiency. This would be identical to reduction in steam consumption by 20 to 30%. CFE nozzle eliminates the loss of energy due to shock-waves typically produced from the conventional nozzles of the de Laval design. Because of restrictions associated with lance tube size the de Laval design is too short to allow for full expansion.

3) SMART Clean TM technology
Fouling in the boiler has become a dynamic process. Fouling condition may be significantly different from one water tube to another across the boiler. Large amount of ash may from on tubes on super heater side of boiler whole tubes on the economizer side of boiler are relatively clean. Conventional retractable soot blower technology, however, assumes that slag is evenly distributed in the boiler. It cleans all the superheat and economizer tubes with equal intensity, resulting in over cleaning of some tubes and under cleaning of other. This eventually leads to tube leakage or ashes formation.

Modern instrumentation such as super heat fouling monitoring (SHFM) systems are able to locate the exact spot where the slag is accumulated. With the help of these detention systems, plant operators know which area needs to be cleaned more to eliminate the ashes, and which area require less cleaning to avoid tube erosion. Consequently, a smart soot blower, which is able to target and adjust cleaning intensity based on slagging condition, is developed to help power plants to optimize cleaning process, improve boiler reliability and efficiency, reduce operating cost, and increase fuel flexibility.

Further details on this flow advancement are available in the appendix (13) we suggest the implementation of this technology if the industry aim at more efficient functioning of the boiler. However it is advisable to first implement the changes proposed earlier.
and monitor the performance changes before considering this new technology.

B. Summary of Recommendations

The various problems encountered in the soot blowers of chemical recovery boiler have been analyzed for the root cause of their problems and the most likely solutions to them have been summarized here. They have been prioritized based on the most significant ones, which upon implementation can eliminate multiple problems. However we suggest the industry to implement the mandatory changes as effectively as possible.

1) Mandatory
- Inclination of soot blowers set up by an angle of -0.40° (appendix 11)
- Modifying the scavenging air system according to the design specifications mentioned in the report and ensuring its paper functioning by conducting periodic inspection. The minimum air pressure and flow to individual soot blower is 2.5 kpa.
- Periodic inspections of the stream purge line and wall boxes for the formation of condensers and accumulation of ash and paper documentation of the findings.
- Ensuring hardening treatment is done on the feed tubes.

2) Optional
- One way soot-blowing for Economizer regions by using the control valves to vary the stream flow.
- Installation of CFE nozzles in all the soot blowers.
- Implementation of smart clean technology.

V. CONCLUSION

The efficient functioning of any equipment or machinery is guaranteed when it is installed in the industry and operated according to the design conditions recommended by the manufacturers which was formulated after careful and prolonged examination of its performance.

The problems being come across in the operation of soot blowers in the chemical recovery boiler at SPB Ltd is due to the deviation from these guidelines and design regulations. Hence it is suggested that the management should make appropriate change in the soot blowers arrangement as highlighted in this report. Also we suggest the implementation of news advancements which can enhance the efficiency further.

Apart from these the industry should take into considerations about arranging a proper training to the newly recruiting candidates and improving the documenting procedures which will ultimately have a noticeable effect on the organization’s outcome.

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REFERENCES


