

# CASE STUDIES ON BOILER TUBE EROSION

By K.K.PARTHIBAN, Boiler Consultant

Venus Energy Audit System

Email ID:parthi2006@gmail.com / venus.energy@gmail.com

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## **INTRODUCTION**

Erosion is associated with solid fuel fired boilers. The cause can be defective design, defective erection, improper operation & improper maintenance. Remedies could be available for many cases. This paper discusses some case studies which were diagnosed by author of this paper.

## **CAUSES ATTRIBUTED TO DESIGN**

Solid fuels depending on the amount of ash & type of ash constituents can cause erosion. There can be numerable causes under this heading. To name a few,

### *1. Design with high gas velocities.*

Solid fuels such as coal, rice husk can erode the boiler tubes due to their ash constituents. Using higher gas velocities are found to erode the flue tubes in shell type boiler. Tubes are found to erode within a distance of 150 mm from the tube sheet. The usual protection system for this is the sacrificial tube ferrules. The tube ferrules must fit properly in the tube. The nitrided ferrules are found to last longer as compared to ordinary ferrules. See figure 1.

In water tube boilers, the bank can erode due to high impingement velocity / high gas velocity within the tube bank. When impingement erosion is prevalent, the remedy can be in two ways. One way is to replace the tubes periodically. Another remedy is to again use sacrificial shields. The shields are to be replaced regularly. In many cases it is not advisable to use the sacrificial shields. The shields may get distorted due to overheating and cause more complications.

When the design gas velocity is high, the tube banks erode haphazardly within the bank. See figure 2. Instead of attending to tube failures, remedial measure should be taken to decrease the gas velocity. This can be possible in some cases. Where it is not possible to alter the pitch of the tubes, tubes are surface treated for longer life.

### *2. Design without considering normal dust flow pattern expected within the tube bank*

A tube bank is always with bends & straight lengths. It is natural to have to more gas / ash flow between the casing and the bends. During the fabrication of coils it is not practical to ensure all the coils are made to exact length. Preferential gas flow along the bends is unavoidable. Hence gas baffles are placed above & at appropriate places within the bank to control this. See figure 4.

Wherever the tubes penetrate through the waterwall/ steam cooled wall / steel casing, the tubes are susceptible for erosion due to preferential ash flow along the wall. When the free fall of ash is high the erosion rate is high. Sleeves are to be provided in this area. See figure 5. Figure 6 shows the common failure encountered if tube sleeve is not provided.

### *3. Design without considering the preferential gas flow upstream / downstream of the tube bank*

In shell type boilers, the preferential gas flow occurs when the gas turning takes place. Inadequate

space in the gas reversal chamber for the proper gas turning results in tube failures preferentially. It may be possible to modify the gas reversal chamber in many cases. See figure 3.

In water tube boilers, the superheater / economiser banks may be positioned either vertically or horizontally inside the waterwall / Steam cooled wall / steel casing. We may have tube banks / gas baffles / gas ducts in upstream / downstream of the tube banks. They may cause certain erosion pattern on tube banks. See figure 8-11.

- Tube banks ahead can direct the ash laden gas to preferential locations
- Hanger tubes can direct the ash laden gas to preferential locations.
- Sloped panels / flat ducts can direct the ash to a particular zone of the tube bank.
- Ducts with sharp turns can through the dust to outer portion of the bends
- Improper duct orientation can cause biased gas flow

The remedies include periodical replacement of tubes, alteration of gas ducts. This will involve cold flow studies / CFD analysis. Shields can be used, provided the gas temperature does not distort them.

#### *4. Design without provision for controlling the preferential flow*

In water tube boilers, tube banks have to be positioned in an economical way to optimizing the space requirement. By providing adequate space for flow stabilization, the preferential erosion can be avoided. Sometimes it becomes necessary to place flow dividers ahead of the bank to ensure the gas is distributed uniformly over the bank. See figure 12.

#### *5. Design with narrow clearance between tubes*

Adopting very closely pitched tubes is not welcome for solid fuel fired boilers. Narrow clearances (20 to 30 mm) are not possible to maintain in actual case, though in drawing it looks nice. Clearances come down during erection / operation at site for various reasons such as

- Bow in tube length as received from tube manufacturer
- Bow in tube length caused by transport / erection procedure
- Fuel ash deposition brings down the tube to tube clearances.
- Improper support system ( welded supports )
- Thermal expansion bring down the clearances
- Staggered pitch with narrow clearance makes the tube erode faster than the inline tube arrangement. See figure 7.

It is always preferable to use a minimum of 40 mm clearance for fouling fuels.

#### *6. Design without proper lateral spacers to maintain the longitudinal / transverse pitch of tubes*

Tube banks have to be provided with adequate spacer / hanger to ensure pitch is uniform & tube leaning out is avoided. There are cases wherein only two supports / spacers are envisaged for long coils. A coil assembly with smaller diameter tubes needs more spacers than with large diameter tubes. Spacers are required to maintain the pitch between the tube assemblies as well.

#### *7. Design with possibilities for impingement erosion*

Generally there may be pitch change between the two tube banks. Screen tubes may be placed ahead of boiler bank / SH / Economiser banks. If enough space is not provided, we may experience impingement erosion. Instead of attempting to protect with shields, it is preferable to replace the tubes

in a scheduled manner. See figure 11. It may be possible to rectify the defect in some cases.

#### *8. Failure to provide the sacrificial tube shields near soot blowers*

Sacrificial shields are to be provided for the tubes that are in proximity to the tubes near soot blowers. Designers should place the tubes at an optimum distance away from the soot blower.

#### *9. Improper design of flow dividers*

Improperly designed flow dividers some times cause more havoc than the one without it. Depending on the thickness survey / erosion / polishing pattern, the design of flow dividers would call for a change.

#### *10. Failure to provide proper sealbox at places where the tubes enter inside the gas path*

Seal boxes are required wherever the tubes enter the flue path. The compromise here leads to erosion of tubes due to air ingress surrounding the tubes. When the tubes are hung from the roof panel, the air ingress around the tubes can lead to erosion of tubes. Many boiler design / operating engineers think that covering the openings with refractory is a solution. It is not a solution, as the refractory cracks from the steel support on thermal expansion.

### **CAUSES ATTRIBUTED TO ERECTION**

#### *1. Improper erection methods resulting in irregular pitching of tube banks*

Tube banks are to be erected ensuring the design pitches are achieved while erecting the boiler tube banks. Using gauges while fit up & welding would ensure the clearances are maintained as per design. I have presented a case of failure due to this aspect.

#### *2. Improper / incomplete erection of protective shields / gas baffle*

Failure to erect the gas baffles is a common problem due to stringent erection schedule imposed in the project stage. Failure to overlap the shields is a common problem seen.

#### *3. Incomplete erection of sealbox*

The drawing may specify that the sealbox is to be erected with seal welding. Many engineers fail to read the drawing / fail to ensure the detail is carried out at site. The failure case is dealt in case study section.

### **CAUSES ATTRIBUTED TO OPERATION**

#### *1. Operation of the boiler beyond the design parameters*

The boiler auxiliaries may be designed with certain margin for the various inferior fuels specified at the design stage. It does not mean that the full capacity of the auxiliaries can be used up for generating more steam from the boiler. Many times this can cause high rate of erosion.

#### *2. Operation of the boiler without understanding the fuel characteristics / Operation of the boiler with fuels not designed for*

Of late there is acute shortage of reliable fuel supply. Various grades of coals are imported from

various countries. Operating engineers are left with no option. There are cases where the  $\text{Fe}_2\text{O}_3$  in fuel ash is high enough to cause severe slagging of FBC boiler bed tubes / radiant SH / final SH tubes. The slagged ash / fouled ash choke up the flue path causing erosion of the tubes both in coils & in the waterwall / steam cooled wall. Operating engineers need to understand the effect of various ash constituents with respect to the boiler in hand. Simply firing all types of coal / other fuels would damage the boiler tubes.

### ***CAUSES ATTRIBUTED TO MAINTENANCE***

#### *1. Failure to ensure the design pitching is maintained during tube replacement*

Making use of gauges / fixtures can avoid this mistake. A small review needs to be done with the repairer on this aspect. Simply entrusting the work to even an experienced contractor is not correct. The quality levels demanded at the first supply should be demanded at every repair as well. A review of erection procedure can bring out the proper way to ensure perfection.

#### *2. Failure to observe the pattern of erosion and to take remedial advice from manufacturer.*

Appraising the manufacturer by means of photographs, sketches and operational data can lead to generation of a better design for the present case & future cases. Only in some exceptional cases, the erosion is to be taken as part of boiler life

#### *3. Failure to fit the gas baffles & tube shields / sealing arrangement after the tube replacement*

Unless & until the original design drawing is referred this may not be known to many new comers in the boiler maintenance.

#### *4. Decision to retain the distorted / plugged coils within the flue path.*

It has become a practice to retain the distorted coils / plugged coils in the flue path. This is not a good practice. Many times it is seen that the distorted coils offer sites for ash accumulations and cause the tube erosion.

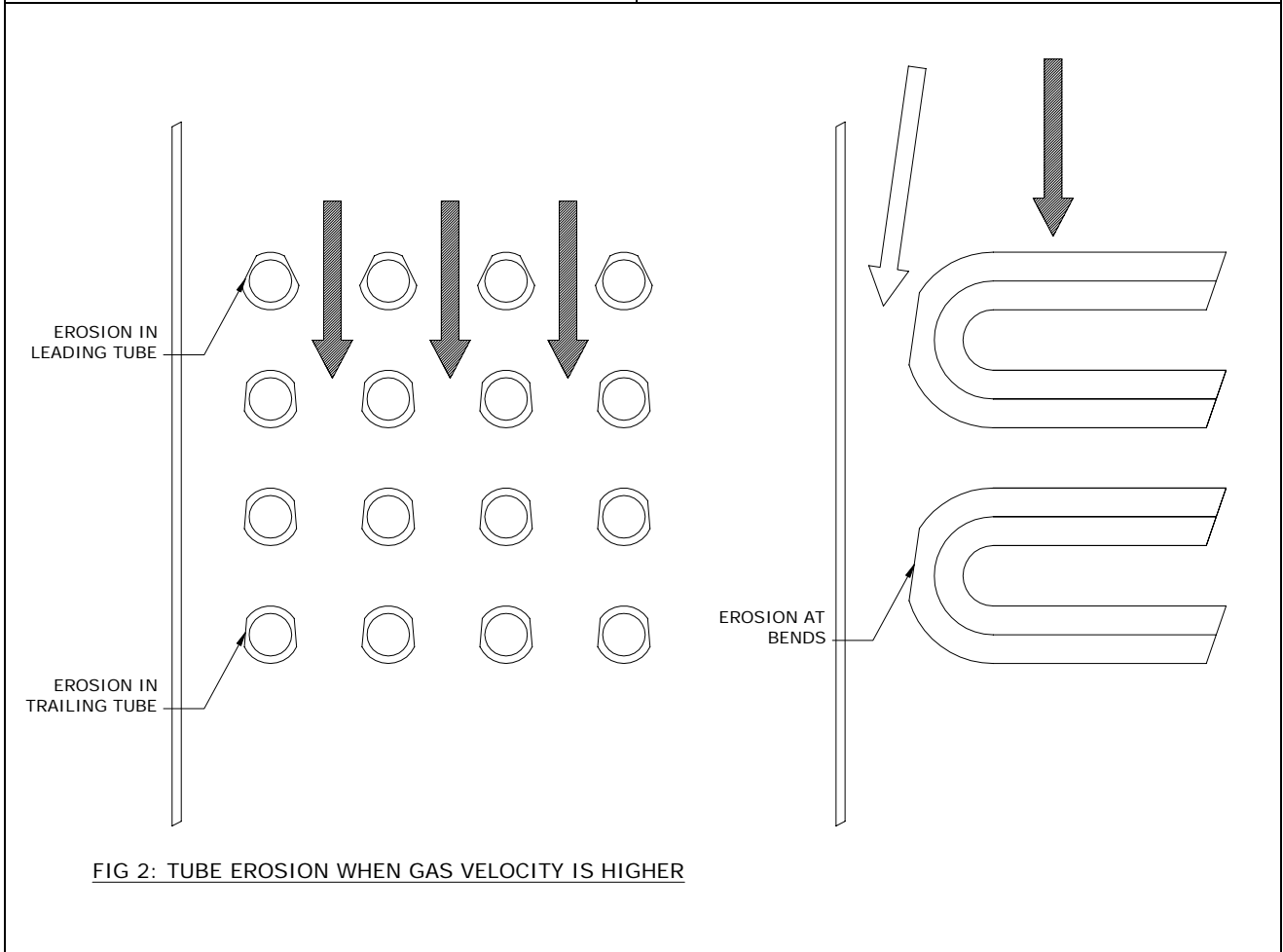
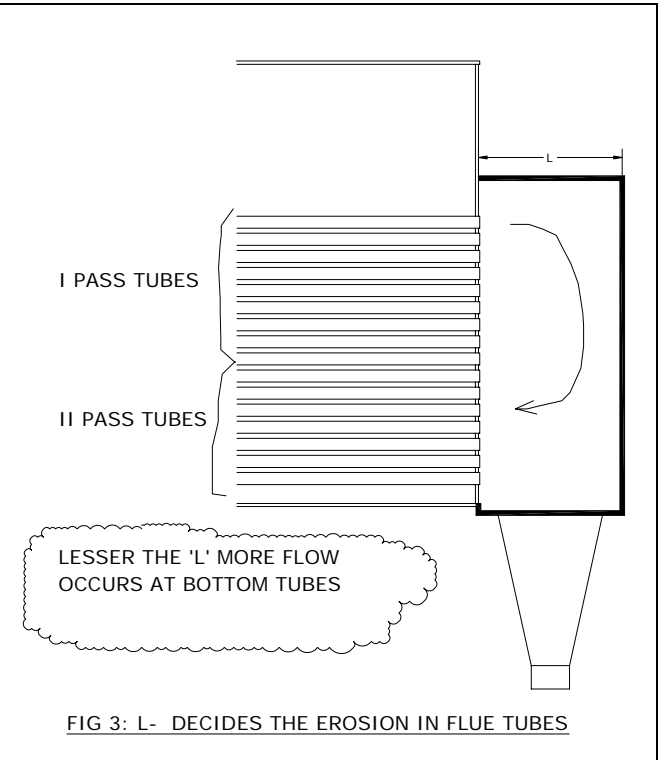
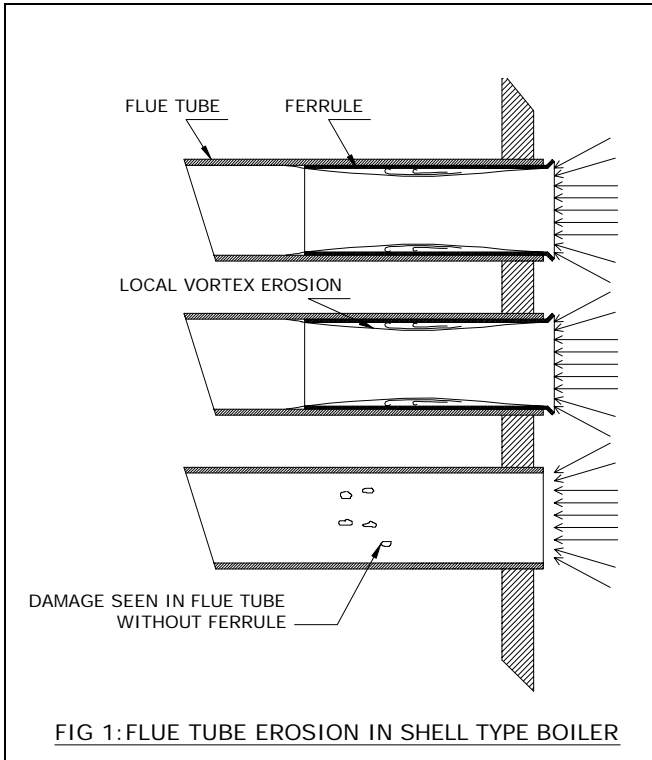
### ***CASE STUDIES***

Numerous cases have been seen in the past and some of them have been highlighted at the end of the paper.

### ***CONCLUSION***

The boiler erosion problems have to be addressed instead of taking it as if it is an incorrigible defect. Some of the defects can be corrected by the mutual involvement of the design engineers & operating engineers by design modification. Adopting certain quality checks during repair can ensure better plant availability.

FIGURES



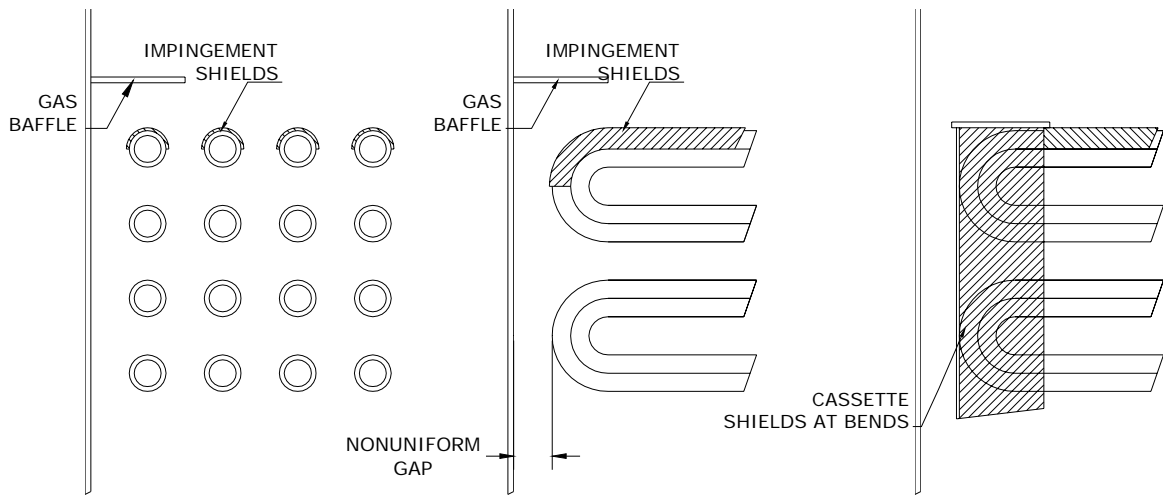


FIG 4: SOME WAYS TO PREVENT PREFERENTIAL GAS FLOW & PROTECTION OF BENDS

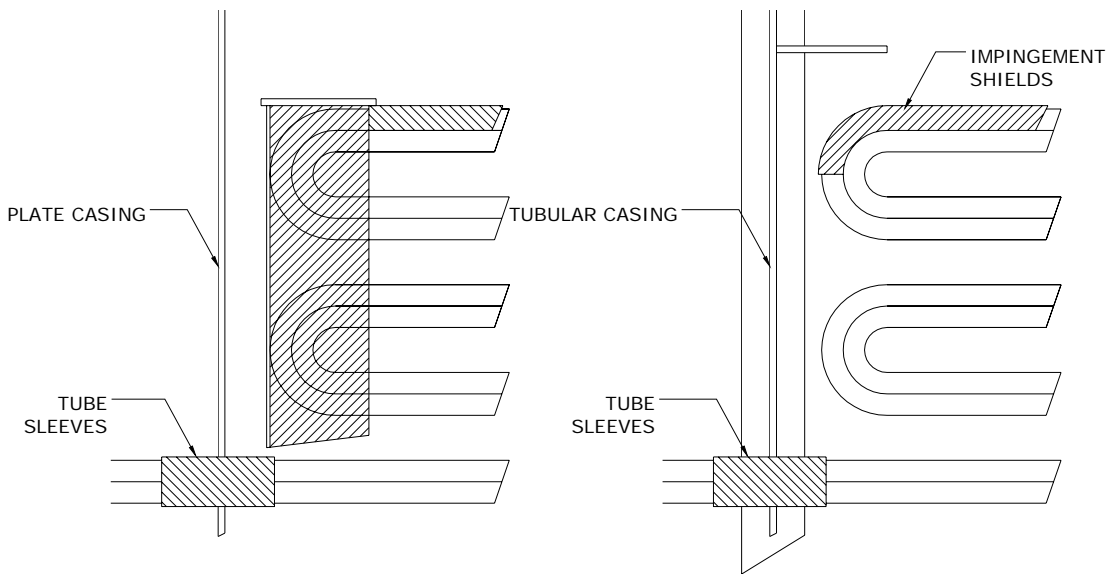


FIG 5: SLEEVE PROTECTION FOR TUBES AT PENETRATIONS

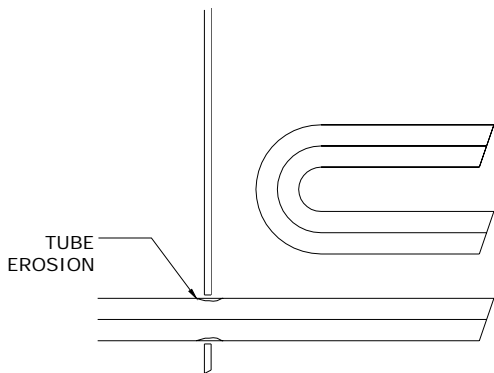


FIG 6: EROSION OF TUBES AT PENETRATIONS SEEN IN UNCLOSED SEAL BOXES & CASES W/O SLEEVE TUBES

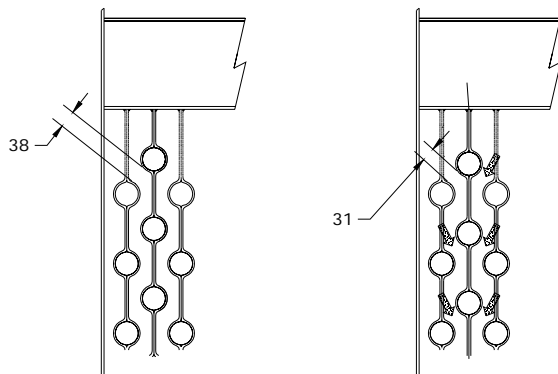


FIG 7: STAGGERED PITCH WITH WELDED SUPPORTS - EFFECT OF PITCH TO VELOCITY

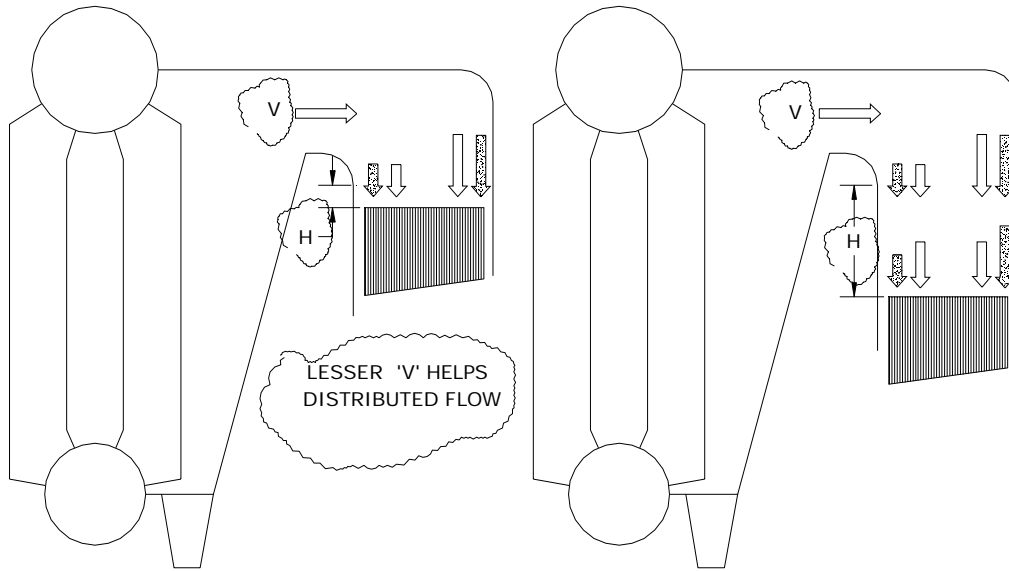


FIG 8 : H-DIMENSION THAT DECIDES EROSION PATTERN

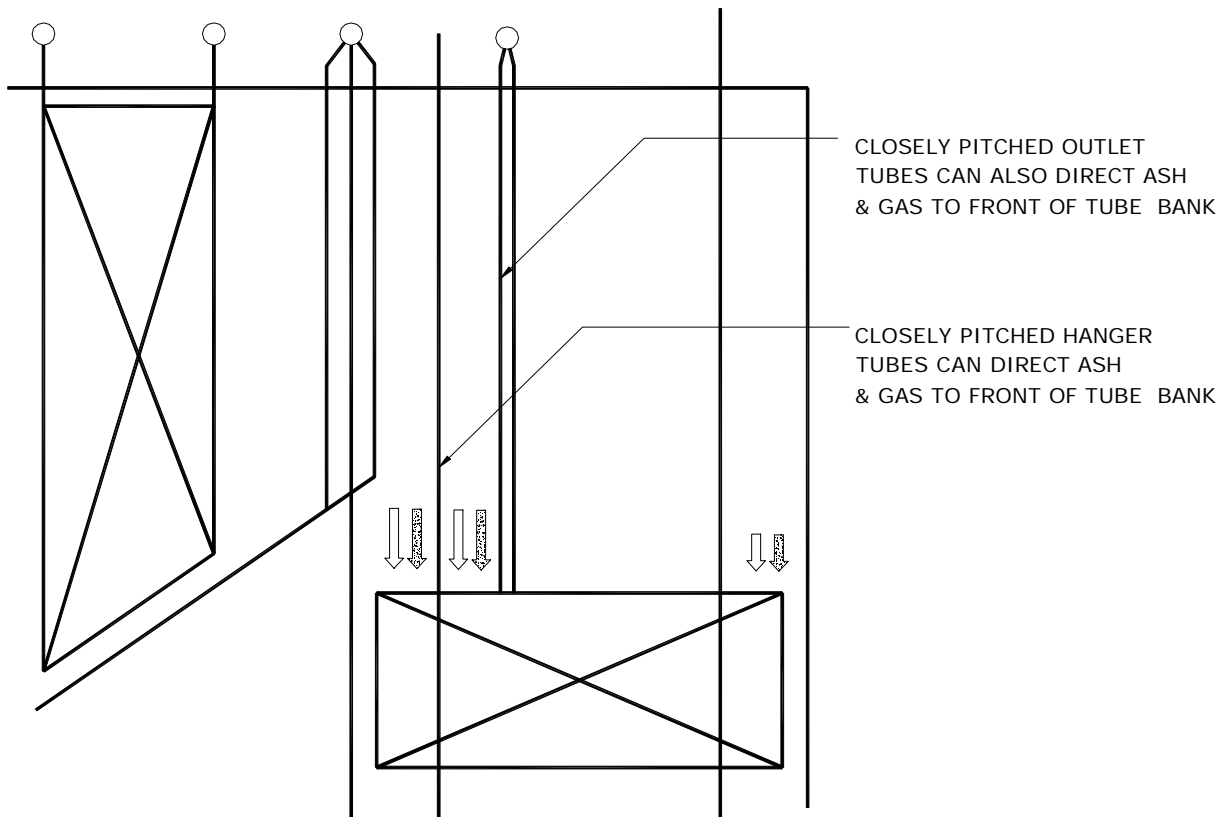


FIG 9 : IF COILS COULD BE ARRANGED FROM SIDE TO SIDE, MOST OF THE PROBLEMS CAN BE AVOIDED

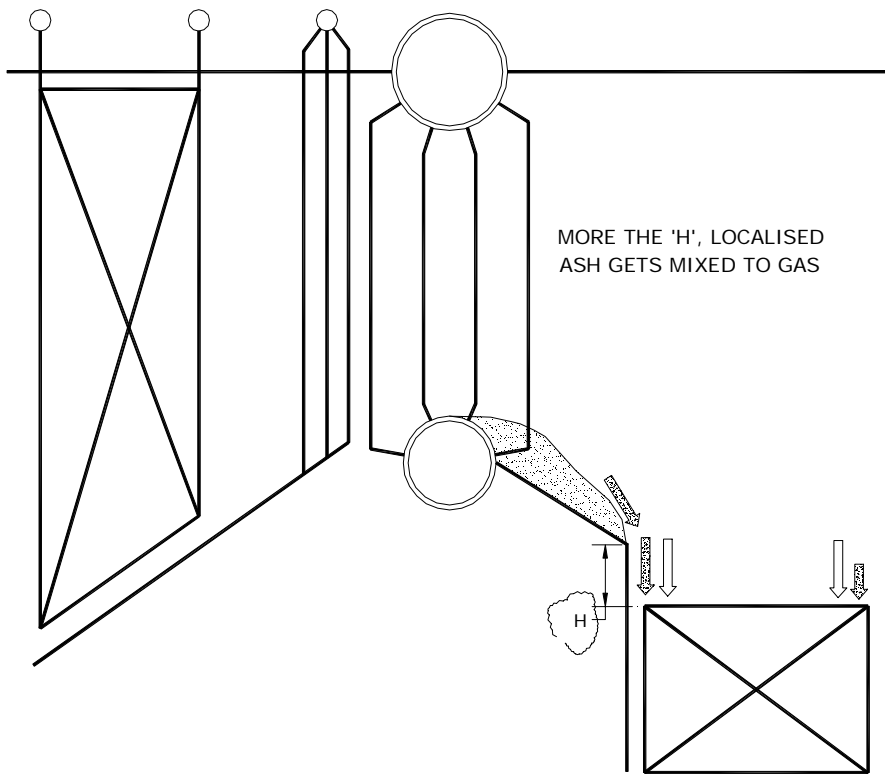


FIG 10 : ASH ACCUMULATIONS AT BOILER BANK CAN DUMP ASH TO NEAREST COILS.

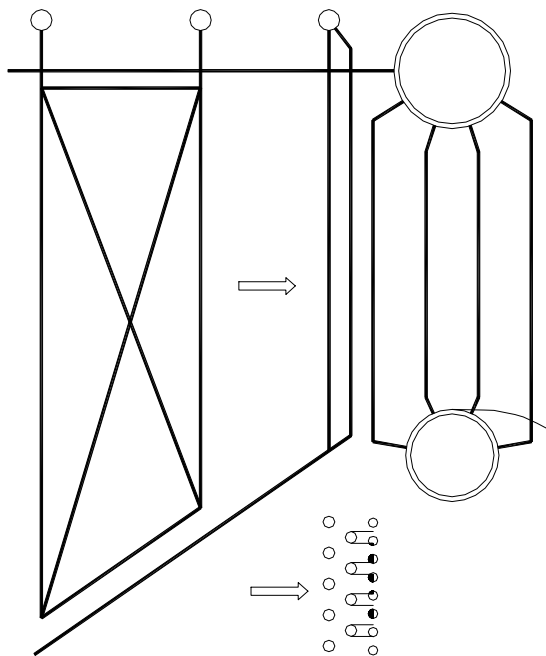


FIG 11: MISMATCH BETWEEN PITCH OF SCREEN TUBES AND TRAILING BANK TUBES CAN GET ERODED

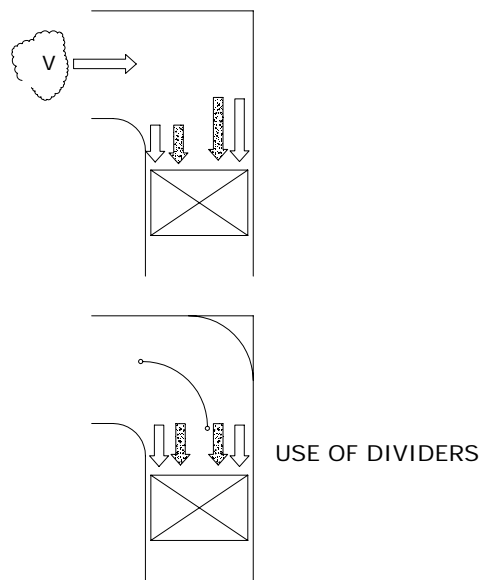
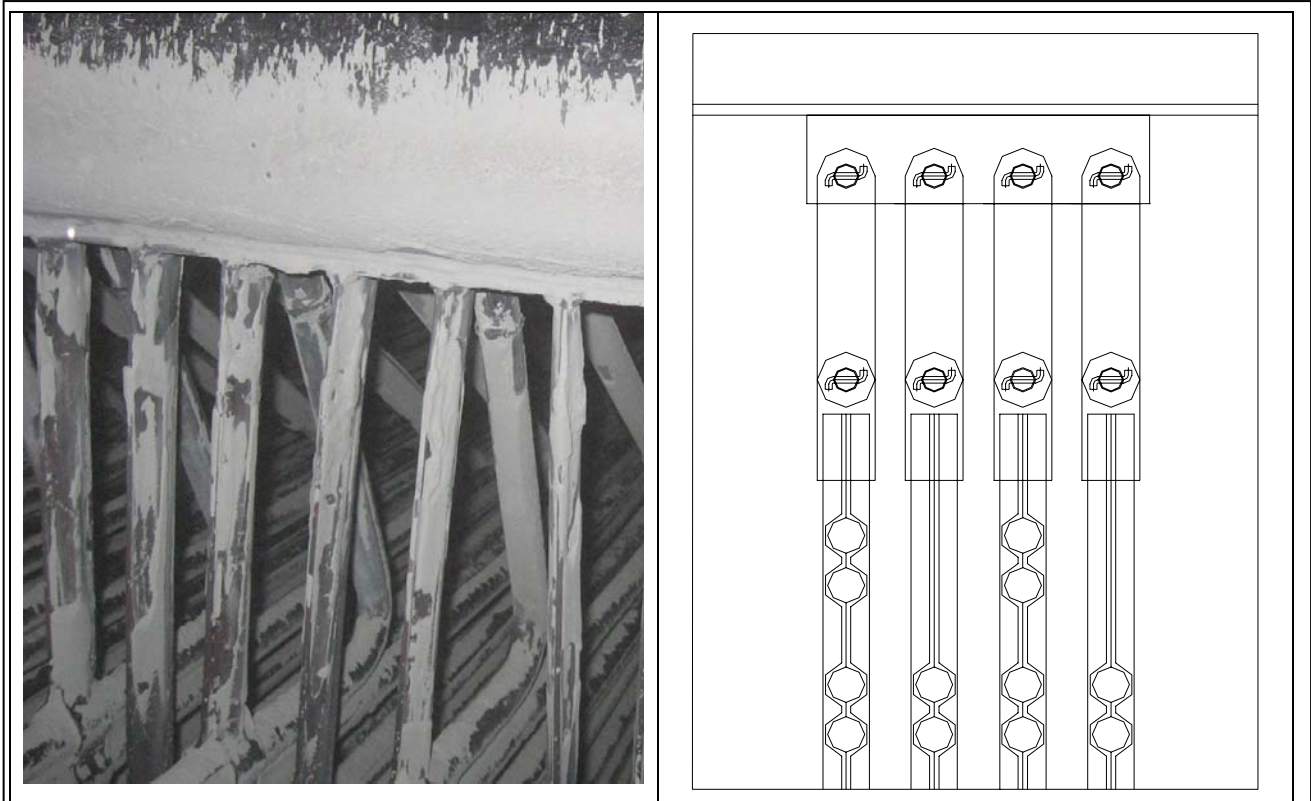


FIG 12: MORE THE 'V', MORE THE PREFERENTIAL FLOW



## CASE STUDIES ON EROSION OF BOILER TUBES

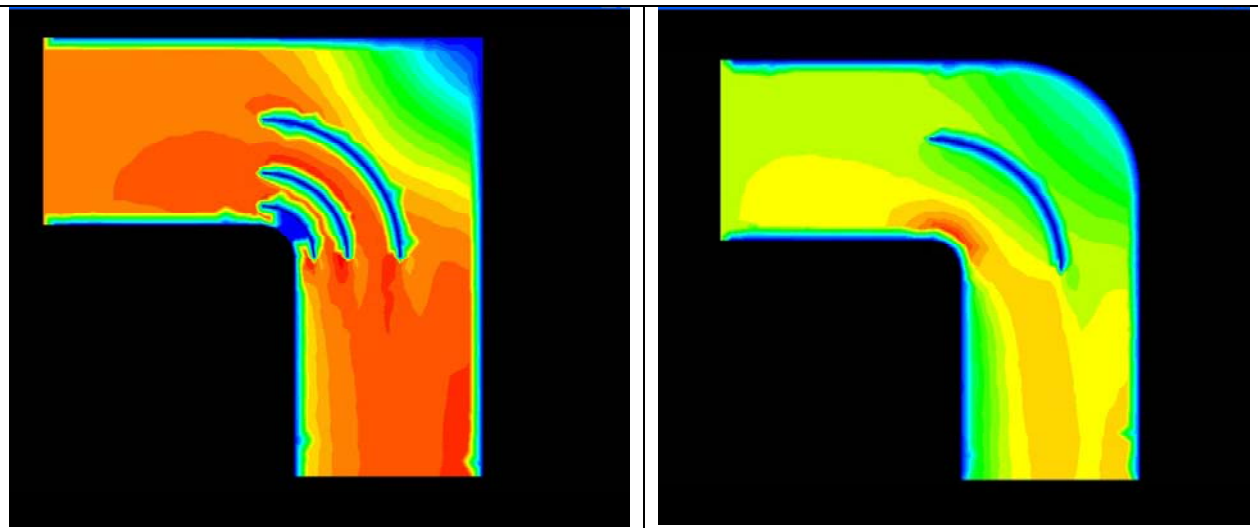


Case 1: Economiser hanger support system is of welded design. Uniform pitch & verticality could not be maintained during erection or repair. Drilled hanger plates & lug plates ensure the pitch. During any repair work alignment & spacing can be again ensured.

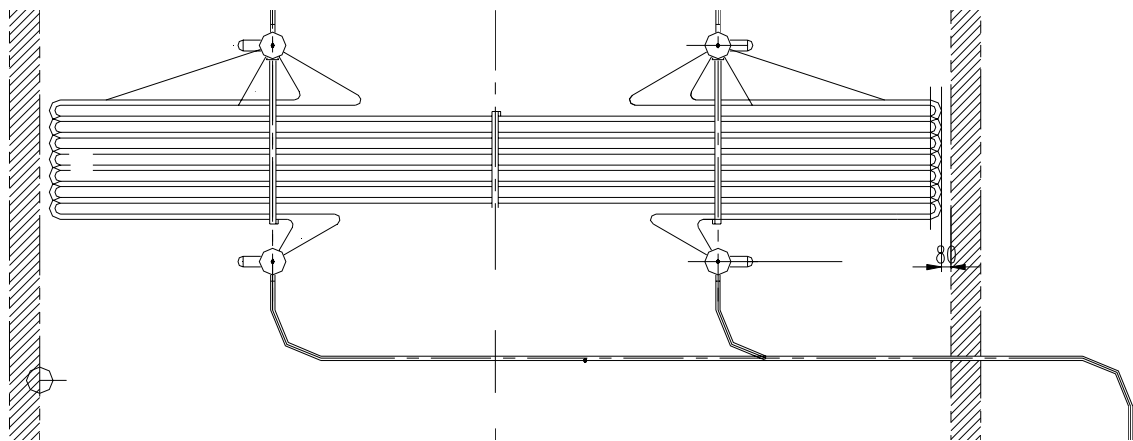


Case 2: A welded support system for an economiser is seen here. The economiser tubes got eroded haphazardly due to non uniform pitch. Staggered pitch needs more care to maintain the longitudinal pitch.





Case 3: In one case the economiser was eroding along the rear wall. The gas baffle arrangement was altered based on the CFD analysis and the erosion pattern was removed.



Case 4: The economiser headers are in the flue path. The economiser tubes are finned type and also staggered. The clearances were so less that the ash could easily trap in to narrow spacing of the tubes. Clogged ash formed during a fouling coal had led to erosion within the bank. Placing headers inside had also led to higher apparent gas velocity.

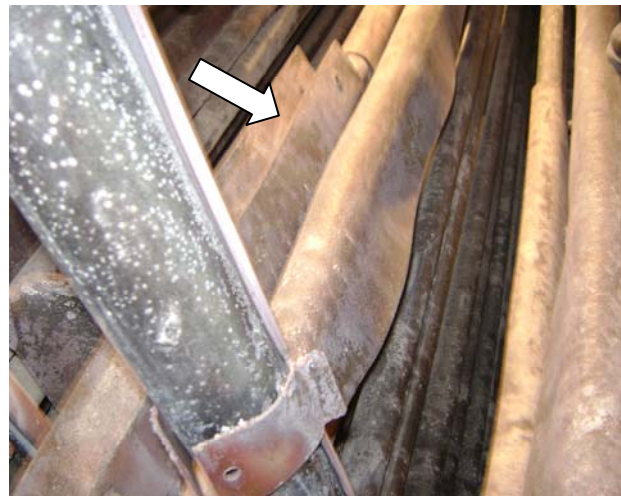
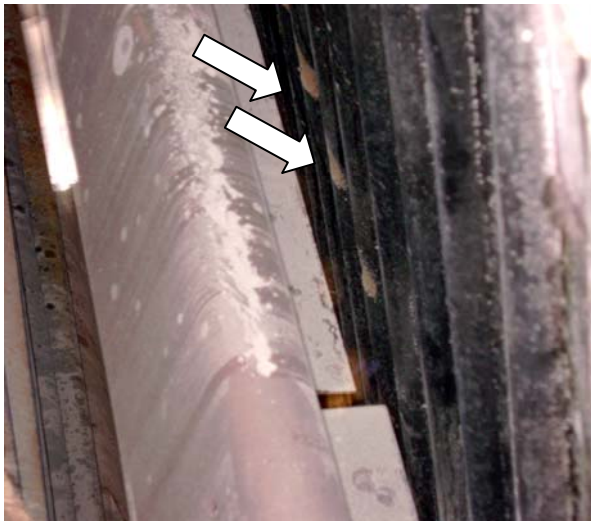




Case 5: The SH coil bends had come close to the casing, that the bends had got eroding. The shields were not placed properly during a maintenance & it led to failure of SH.



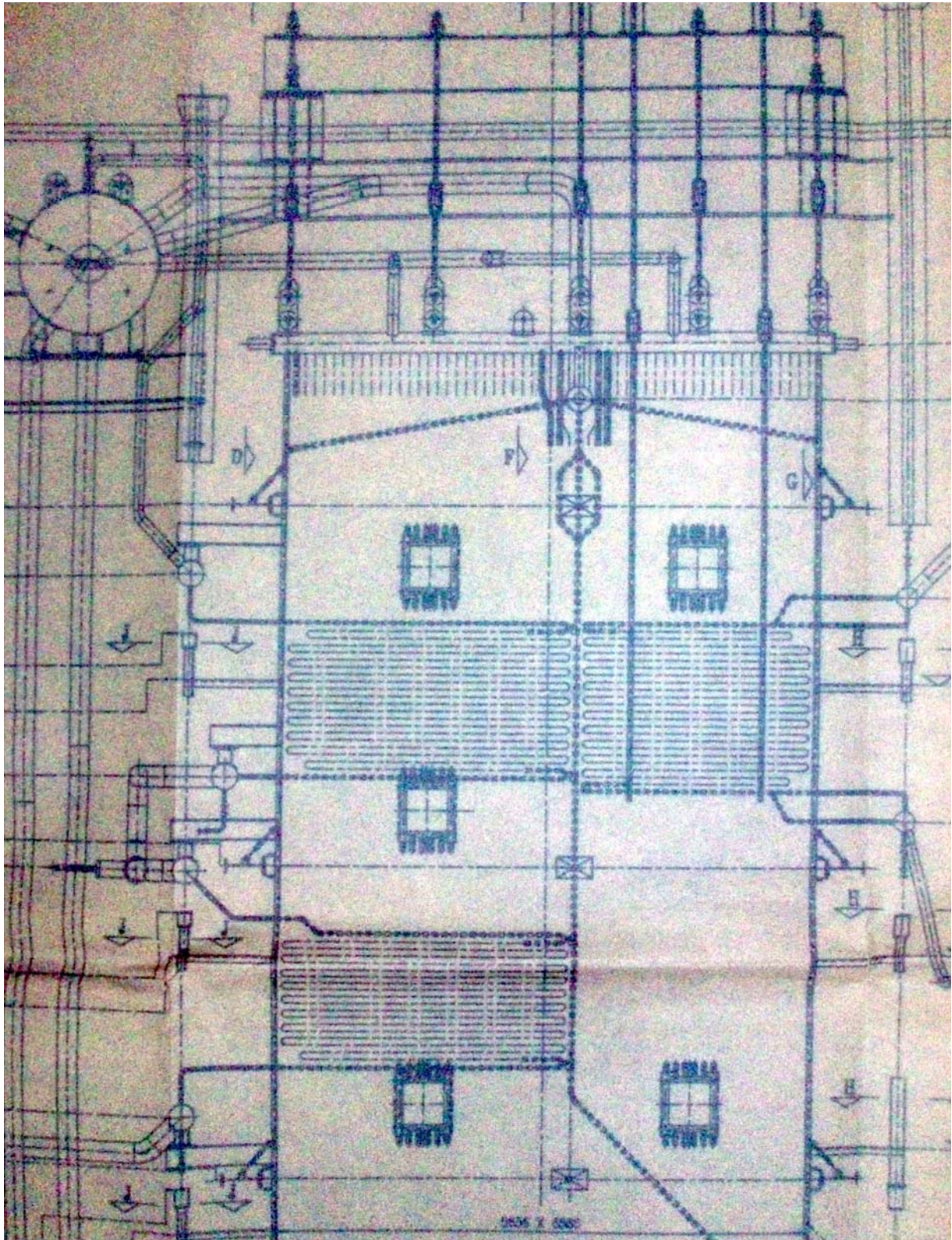
Case 6: The protection shield at bends was not placed properly during maintenance. This had led to a stoppage of the plant. There is a gas baffle to prevent the gas going along the bends.



Case 7: Erosion at the top rows of a convection phenomenon depends on the arrangement of pressure parts layout. A shabby work of shields can lead to poor availability of the boiler. We can see how the shields are disoriented. The waterwall is seen eroded due to shields. The distorted shields have led to multiple failures within the bank. Simply all the shields were removed and all tubes were replaced in a scheduled manner.

Planned replacement of tubes can improve the availability of the boiler than simply resorting to shields. Shields & baffles are to be engineered depending on various parameters, such as present velocity & temperature profile, tube to tube clearances.





Case 8: This boiler suffered erosion of tubes all over in the first pass whereas in the second pass suffered no erosion though the design gas velocities were same. The small window opening had caused increase in the ash concentration in 1 pass and the mild vibration prevalent due to support system had led to erosion of convection SH tubes.