A CASE STUDY ON BOILER TUBE FAILURE AT JPL

Introduction:

JPL has two no of super critical Boilers (Make: Harbin Boiler Company Limited). This boiler adopts low NOx burners with offset tangential combustion, once-through reheat, single furnace, balance draft, dry ash removal, total steel structure frame and total hanging structure. Boiler continuous output is 2115.5T/H at BMCR. SH steam outlet temperature is 571^0C RH steam outlet temperature is 569^0C Feed water temperature is 292.6^0C. These boilers were commissioned in the year 2012 and till date operated for about 22,000 hours of cumulative operation hours.

Boilers are essential and critical component in operation of a power plant and thus we need to ensure preventive, proactive and time based maintenance to ensure maximum availability of the unit.

Operational issues:

JPL has been facing several issues from operation side of the boiler like high ash content in coal, water wall temperature difference between left, right (2^{nd} pass RHS hotter than LHS) etc.,

1. **High ash content coal – ash erosion in tubes and coils**

Our boiler has been designed for 34% ash quality, but sometimes we get coal beyond the design range which results in ash erosion/thinning in boiler tubes.

2. **No. of start-ups /shut downs – Grid Requirement**

In 2016 alone, we have faced 23 No's starts/stops due to SLDC requirement, which imposes heavy cyclic stresses in boiler tubes, especially on high Cr joints which may result in cracking of the same due to creep. Age of the boiler depends on how it was operated but not on simple age of boiler

3. **Water chemistry – High oxide layer formation**

Present regime which is being operated is AVT-O. Super-critical boilers, preferably to be operated in OT cycle as per EPRI for less oxidation in tubes, but due to frequent change in loads from tech min to Full load, starts and stops, boiler chemistry was not put in OT. **Temperature imbalance – Failure in LTRH hanger tubes (RHS)**

Tangential fired boilers have inherent problem of deviation in left and right temperatures after furnace. The difference across left and right in 2^{nd} pass lead to hotter right side at LTRH hanger tubes and leading to failure. SOFA burners balancing done in both units, further fine tuning to be done on day to day basis depending on the velocity of the coal piping, SADC adjustment, wind-box DP, etc.

4. **Differential expansion:**

To allow the free expansion in vertical water wall panel w.r.t header, provision was not provided in the panel, same provided in both units by doing fin modification to allow free expansion. This was done in consultation with OEM as per RCA of vertical water wall header stub cracks in both the boilers.

Design issues:

Apart from the operational issues which are concerning us, we have also issues pertaining from boiler design

1. **Overheating failures:**

About 11 No's failures in LTRH Hanger tubes due to short term overheating failure only on RHS were observed. The failures were observed above the top bank of LTRH coils. The Hanger tubes process is closed circuit leading to short flow of cooling media and failing the least cooled tubes (high temperature area). These were repaired to sustain the temperature

2. **Low quality material in pressure parts:**

Low quality used for material selection in critical locations of pressure parts and observed the Cr content in the Cr steels on lesser side of the ASME range.

   a. TP 347H in place of 347HFG/Super alloys in FSH/FRH
   b. T12 in place of T91 in case of LTRH Hanger tubes

3. **Alignment locking devices are absent in design**

Alignment is the most important factor to avoid erosion in the second pass of the boiler. To compensate the ash erosion in the high velocity of flue gas we used wear protective shields in 2^{nd} pass LTRH/LTSH bends

Erection/commissioning issues:

1. **Erection weld joints quality – 12% RT during project stage**

JPL faced welding joint leakages/failures from the erection welding joints. However, we have carried out 100% RT for Economiser outlet header to coil and repaired the defective joints during opportunity/AOH/reserve shut down

We are also in the process of consulting for non-destructive testing/phased array UT since conventional RT testing during AOH consumes lot of time and also forcing other maintenance works to stop

2. **Non uniform heat distribution**

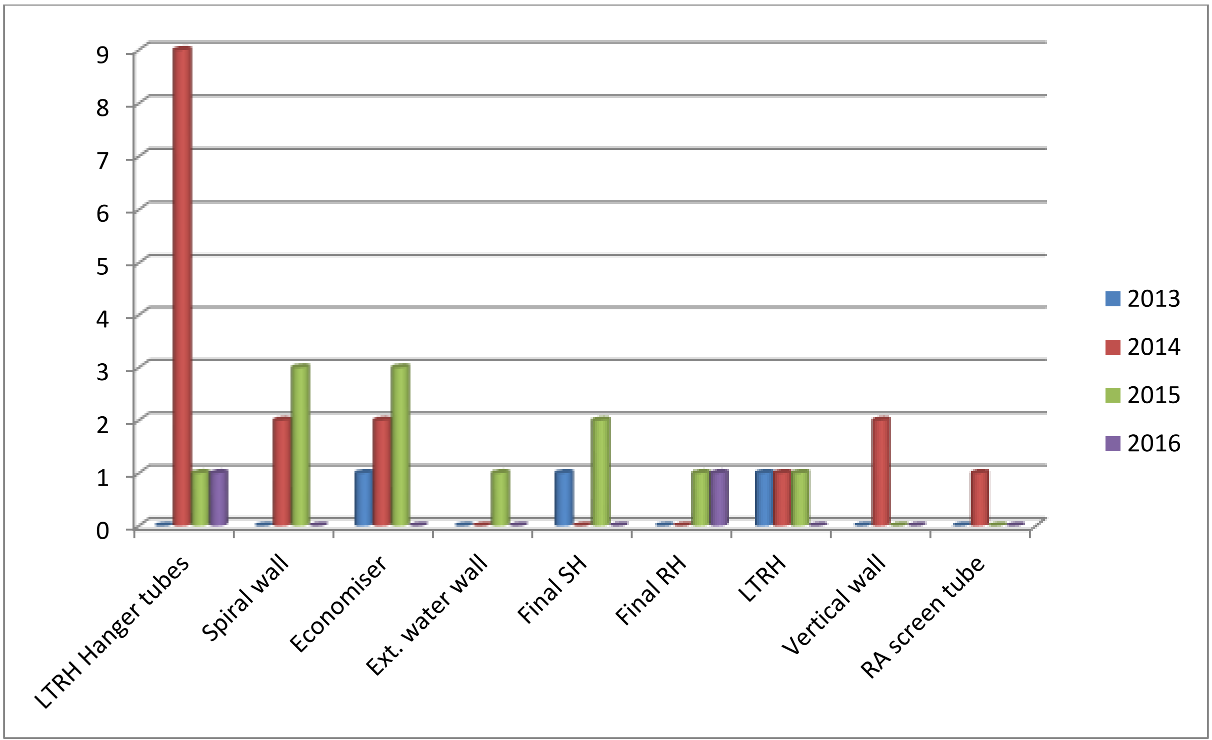
Observed heavy SH and RH spray requirement in one side of boiler. At times it was observed it is not controllable for handling the coal type fed into boiler. At full load the spray requirement reduces only for one side

JPL Boiler tube failures:

As we understand, in a coal based power plants unit availability largely affected by boiler tube leakage (BTL), it is foremost important to pay focused attention for preventive, proactive and time based maintenance for boiler. To ensure maximum reliability and performance we have formulated our strategy for reduction of boiler tube leakage in 2014 through from short, medium and long term action plan. This strategy has helped us immensely in reducing the in EFOR (Equivalent forced outage rate) due to boiler tube leak from 8.6% in 2014 to1.1% in 2016.

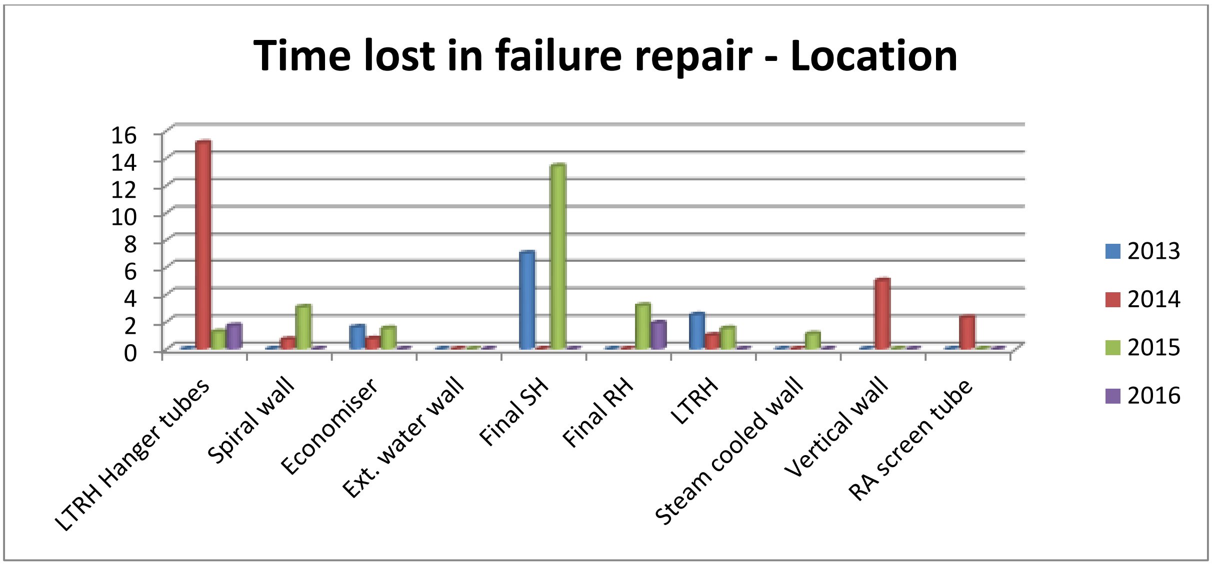
Unit Shut down due to Boiler tube failures from 2013 to 2016(till date) – area/location wise

Location	2013	2014	2015	2016	Total
LTRH Hanger tubes	-	9	1	1	11
Spiral wall	-	2	3	-	5
Economiser	1	2	3	-	6
Ext. water wall	-	-	1	-	1
Final SH	1	-	2	-	3
Final RH	-	-	1	1	2
LTRH	1	1	1	-	3
Vertical wall	-	2	-	-	2
RA screen tube	-	1	-	-	1
Total	3	16	12	2	23



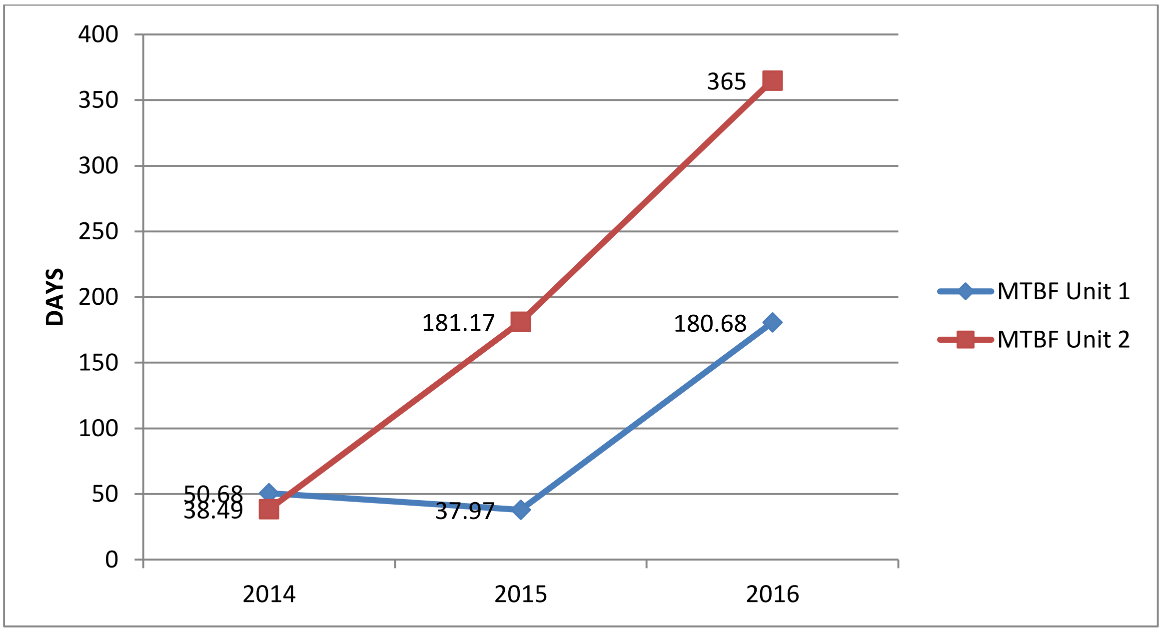
Time lost in each failure – location (days)

Location	2013	2014	2015	2016
LTRH Hanger tubes	-	15.1	1.25	1.7
Spiral wall	-	0.7	3.06	-
Economiser	1.6	0.75	1.5	-
Ext. water wall	-	-	-	-
Final SH	7	-	13.4	-
Final RH	-	-	3.18	1.9
LTRH	2.5	1	1.5	-
Steam cooled wall	-	-	1.1	-
Vertical wall	-	5	-	-
RA screen tube	-	2.3	-	-



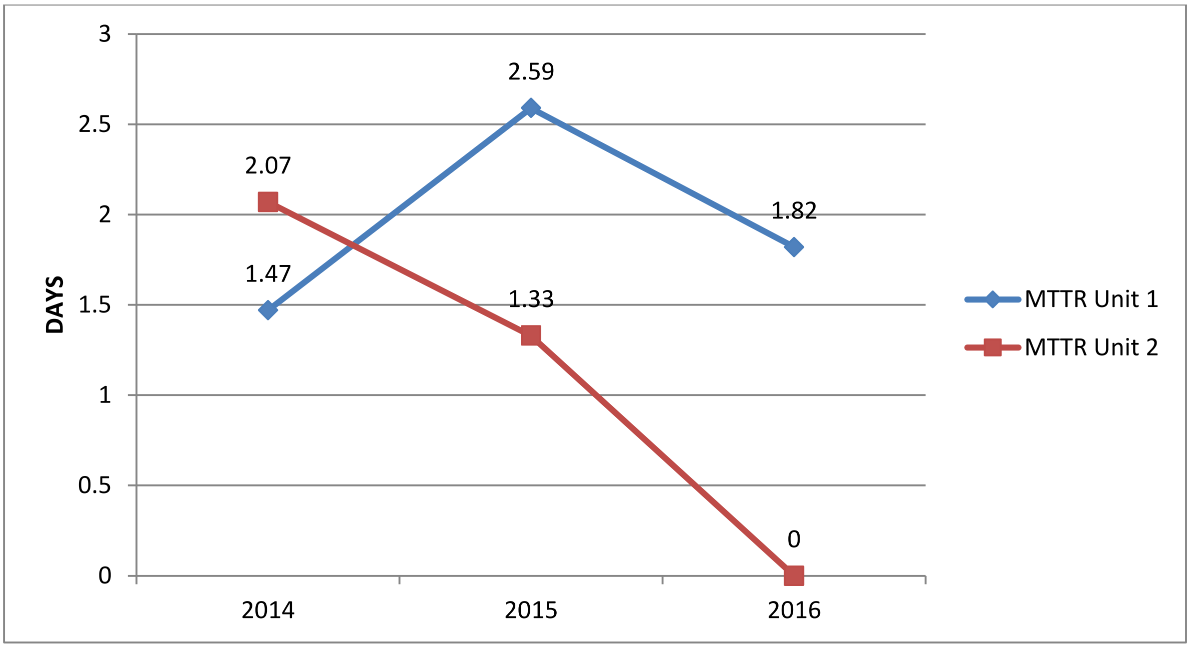
Mean time between failures (days)

MTBF	2014	2015	2016
Unit 1	50.68	37.97	180.68
Unit 2	38.49	181.17	365



Mean time to repair: (days)

MTTR	2014	2015	2016
Unit 1	1.47	2.59	1.82
Unit 2	2.07	1.33	0



Final Super Heater Short term Overheating – Back to back after long shut down and reserve shut down

Observations:

Boilers were kept under wet preservation during reserve shut down and after synchronising the unit failure was noticed within 5 to 6 hrs

These leakages were found twice back to back in FSH, both being fish mouth failures in FSH coil on both sides of boiler

For inspection many of the nearby coils were cut for the investigation and RCA. Observed loose deposits of oxide scales found in bottom loops when inspected through bore-scope

Scales found in FSH were analysed through third party for its chemical composition.

Element	Percentage (%)
Fe	73
Al	5.02
Cr	6.91
Ni	3.36
O2	11.72

Thick loose internal oxide scales were observed on the inside portion of the failed tubes.

It was concluded that, after long term lay up of wet preservation the scales might have peeled off or dislodged and during start up the loose scales have clogged the coil tube leading to failure in the high temperature exposed (High MTM) tubes

The mitigation measure were taken to control the loose oxide scales are as per below mentioned

Operational control:

MS & HRH Steam temperature reduced to keep metal temperatures of FSH/FRH coils in control.

System	MS	HRH
Design Parameters	566 degC	566 degC
In 2015, Revised Parameters to control boiler temperatures(Unit#1)	545 degC	550 degC

Maximum metal temperature of FSH is restricted to <590^{0}C and FRH <600^{0}C

Rate of Change of metal temperature alarms implemented to <1.5 Deg. /min

Startup is closely monitored for temperature excursions

IDF/FDF/PAF second set being started at early stage (to avoid MS temp. mismatch)

Boiler water chemistry treatment to be decided for conversion to OT treatment by appropriate methodology to reduce oxide layer formation in boiler high temperature tubes with changes in operational regimes by expert recommendations

Load ramp up and ramp down rates are being followed stringently and aligned with CCS mode of operation from DCS

During shut down the boiler SH vents are opened at higher temperature to remove any inadvertent moisture to remain in SH and RH tubes (non –drainable).

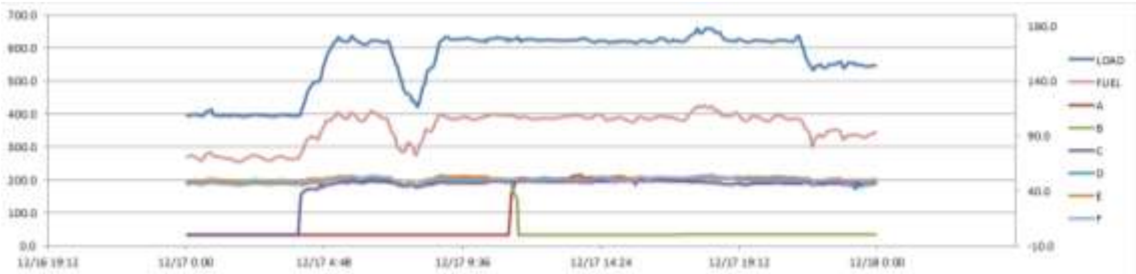
Preservation of boiler changed from wet to dry mode for non – drainable steam circuits for long lay up

Existing TP347H tubes in FSH to be changed to TP347HFG or Shot peened tubes for boiler HT coils on term basis – as per the study it was observed that fine grain structure of base material are proven for reduced oxide layer formation. By shot peening (surface deformation by compression by high speed shots) further reduction of oxide layer is possible

Present status:

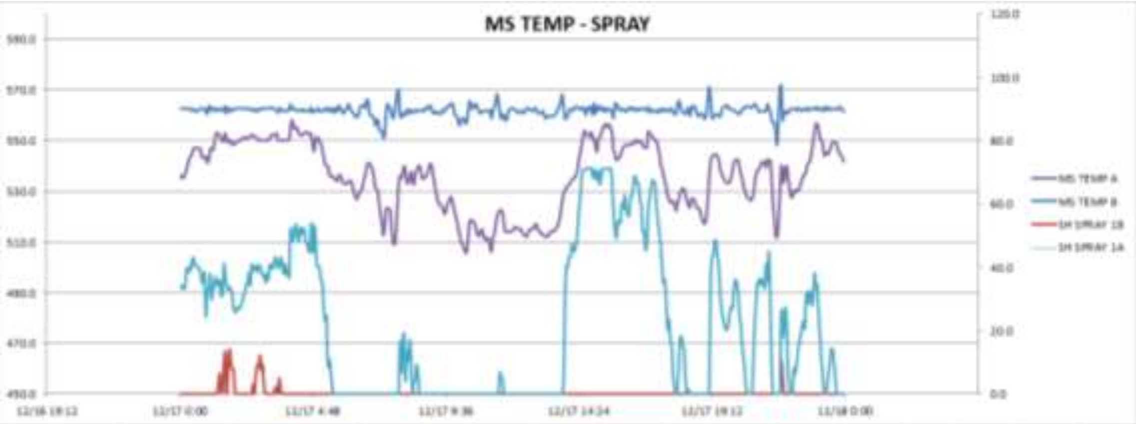
No leakage observed after 01/10/2015

However we are monitoring metal temperatures of FSH coils and FRH coils on daily basis for analysis purpose. (As below)


LOAD
FUEL
A
B
C
D
E
F


FSH - MTM TREND


FRH - MTM TREND



LTRH Hanger tubes short term overheating in RHS of boiler

Observations:

Observed tube leakage in hanger tubes since 2014 and lost time is 30 days of running hours of boiler

Short term overheating in LTRH hanger tubes are only in RHS side of both the units. Overheating failure observed between 2-3 m above LTRH top bank

The study and analysis found that there is high flue gas temperature in the RHS of boiler.

All the tubes were repaired to withstand the temperatures in that location

There is a short circuiting /closed loop steam flow in the second pass hanger tubes with second pass division wall. This might be the reason for starvation and overheating failure of high temperature areas which cannot be withstood

On discussion with OEM (HBC) it was confirmed for newer plants MOC was higher – existing is T12 in place of T91. 30 tubes on RHS planned in MOH 2017 with new upgraded design (T91) and remaining will be replaced on term basis

Present status:

No leakage observed after April 2016