NTPC PMI
The Learning Tree

एनटीपीसी NTPC

पावर मैनेजमेंट इंस्टिट्यूट
POWER MANAGEMENT INSTITUTE

STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE

THROUGH DIAGNOSIS OF PROCESS PARAMETERS

A COMPILATION OF REPORTS BY NTPC

FOR INTERNAL CIRCULATION AT NTPC ONLY

PREFACE

PMI, Noida has organized an on-line training workshop "Diagnosis of Boiler Performance through Process parameters" from 17th-21th Aug 2020 for senior O&M executives from our various power stations. The theme of the training was to identifying the root cause of existing performance issues by measuring and analyzing the process parameters available in daily life of an operation engineer. A total of 78 executives took part in the workshop.

This training was conducted in association with India Boiler dot Com, Vadodara on the specially designed and integrated learning portal www.steamingopps.com, which includes discussion forums also. The 05-day workshop was followed by assigning different research topics to different teams relevant to their working fields. Teams learned different analytical tools and implemented them in analyzing the identified complex situations to arrive on solutions. Additional support was extended from PMI, faculty members and senior colleagues from O&M to complete the assignments in 75 days.

Eight teams come up with best reports which were compiled from faculty and PMI team. We are now pleased to publish the hard works of different teams in the form of this book containing 08 reports. The enthusiasm and valour with which the station executives have put their efforts towards this study at current difficult pandemic time is highly appreciable and I offer my heartiest congratulations to all the team members.

I am grateful to Sh. D. Sarkar, Executive Director (Operation Services) and Sh. D. S. Rao, Executive Director (PMI), who appreciated the work and written 'Foreword' for this book.

I am sure that the fruit of team's hard work in the form of this book will help all our colleagues at different power stations. Best wishes.

Anoop Kumar

(Anoop Kumar)
Course Director and Faculty Member
Power Management Institute

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कार्यकारी निदेशक (प्र०से०)
DEBASIS SARKAR
Executive Director (OS)

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भारत सरकार का उद्यम
NTPC Limited
A Government of India Enterprise
(Formerly National Thermal Power Corporation Ltd.)
नोएडा कार्यालय / NOIDA OFFICE

Foreword

I am very happy to know about this wonderful initiative taken by our colleagues from PMI and O&M team. I would also like to congratulate all team members who continuously utilised the learning from training, did an extensive research work and generated reports in the pandemic times. That is the Team NTPC can do spirit.

We know that, these days, the survival of thermal power plant is being challenged by the renewable integration and compliance of new environmental norms . With so many players in the power business now, a time has come when we can sell our power only, if it is at a competitive rate. We have to, therefore, continuously audit our systems and take immediate actions to correct even the smallest of performance gaps to stay competitive. With continuously changing schedule, continual fine tuning of our operation is now a necessity.

"Continuous monitoring of key process parameters, analysis of the smallest of deviation and taking decisive action at the earliest possible time" are need of the time and going to be the key to our success.

We all are very proud of our O&M competence. I am sure that initiatives of publishing an e–book in a compendium form will reinforce our O&M competence.

My best wishes to all of you.

ED (OS)

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Executive Director-(PMI)

Foreword

"…..It's not just learning that's important. It's learning what to do with what you learn and learning why you learn things that matters" – **Norton Juster**.

I am very happy that our O&M executives who have attended the Workshop on "Diagnosis of Boiler Performance through Process Parameters (17-21 August, 2020)" have truly justified/lived by the above mentioned quote.

It is heartening to note that the workshop which PMI has arranged through on-line platform has encouraged the participants to apply the training inputs to real-time applications in plants, with enthusiastic support & motivation from our senior colleagues. Eight teams from different stations have prepared a detailed report, which we have decided to publish.

The works of our colleague deserve high praise as the complete exercise was conducted at a time when we all are struggling to cope up with the crisis brought by the pandemic. I appreciate the contribution from India Boiler doc com, Vadodara who have extended their support and guidance during the entire period.

I am sure these reports would help and motivate all O&M fraternity, particularly our young executives, to adopt this approach in their work.

With best wishes.

Executive Director - PMI

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Reports on Study and Analysis of Boiler System Performance through Diagnosis of Process Parameters

STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE THROUGH DIAGNOSIS OF PROCESS PARAMETERS

AT

NTPC-GADARWARA

Submitted by:

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Under the guidance of

SHRI ANSUMAN SEN SHARMA
India Boiler Dot Com

STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR UNIT 1 AT GADARWARA TPS

SUB INDEX

FOREWARD

In the current scenario, the power sector is facing many challenges. Flexible operation of conventional generation sources has reaffirmed the role of boiler system performance to minimise the heat losses. Study and diagnosis of process parameters of boiler is quite critical in efficient operation of power plant units.

It gives me immense pleasure and delight to know that PMI, Noida has come out with an analytical training module on, "**STUDY AND ANALYSIS OF BOILER PERFORMANCE THROUGH DIAGNOSIS OF PROCESS PARAMETERS**" in collaboration with India Boiler Dot Com.

I convey my warm wishes to the Gadarwara Team for completion of this project and hope that learning from this project will go a long way in generating awareness on boiler efficiency aspects thereby ensuring an improved overall performance of the power plants.

Probal Mundle
General Manager (Operation)

1.0 Objective: - Identification of performance irregularities in Boiler system through diagnosis of process parameters. Study and analysis of process parameters of Unit-1 boiler system was carried out after the completion of the training workshop by M/s India Boiler Dot Com on "Diagnosis of Boiler Performance through Process Parameters".

2.0 Methodology:

A. Recording process parameters and computing performance matrices

B. Identification of irregularities

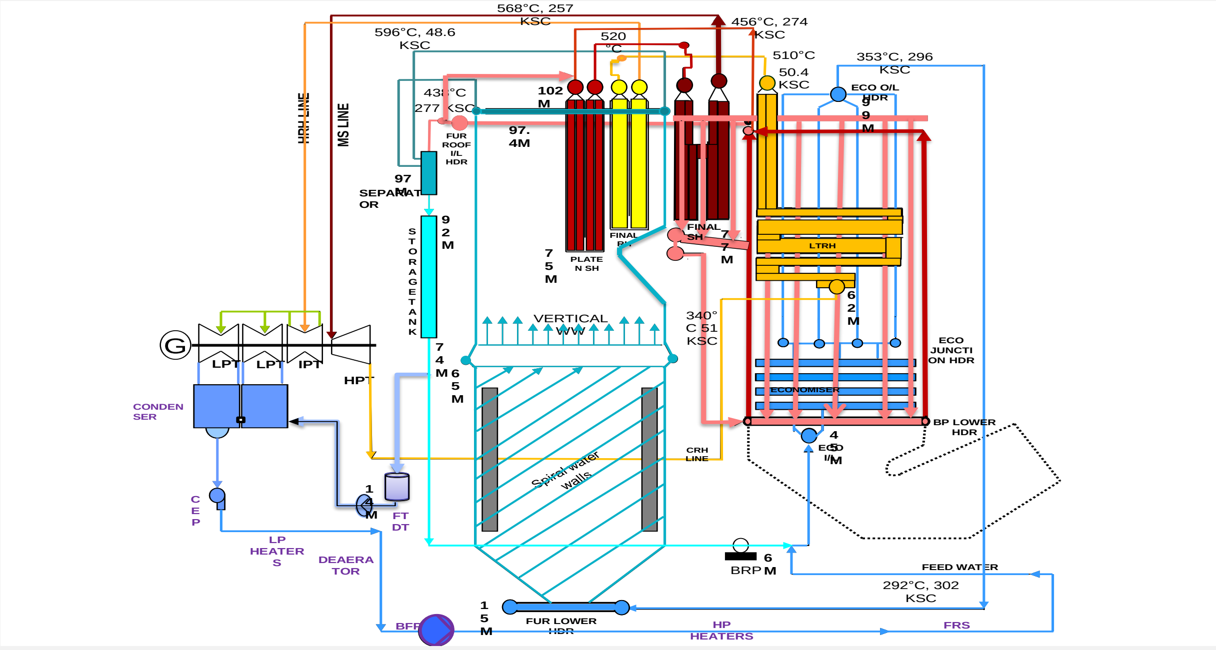
C. Diagnosis of possible root causes

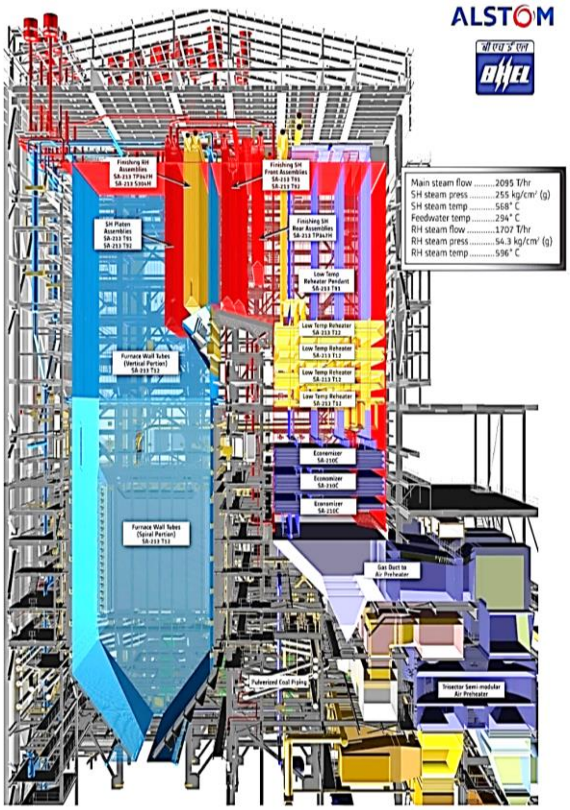
D. Conducting trial after minor changes of process conditions to validate

E. Conclusion and suggestions

3.0 Overview of the Unit-1 NTPC Gadarwara Boiler System:

Boiler: Alstom 800 MW
Design Steam Parameter: Main Steam- 257 KSC, 568^{o}C
HRH – 56.14 KSC, 596^{o}C
Fuel Firing Equipment:
Coal: Tilting Tangential, 36 No. Mill type: Bowl Mill HP 1203
Oil burner –LDO 20 No
SOFA- 5 Compartments
Design Coal: 538 TPH (CV 3200 kcal/kg), Best coal-423 TPH (4000 Kcal/kg)





800 MW BOILER

- **Total air: 2808 t/hr**
- **MS flow: 2335 t/hr**
- **MS pressure: 257 ksc**
- **MS temp: 568 deg C**
- **HRH pressure: 56.14 ksc**
- **HRH temp: 596 deg C**
- **Feed water flow: 2241 t/hr**
- **SH spray flow: 93 t/hr**
- **RH spray flow: 0 t/hr**
- **Coal flow: 538 t/hr of GCV: 3200 kcal/kg**
- **Mills in service: 8/9**
- **O2 in flue gas: 3.6%**

Fig 1: NTPC Gadarwara Unit-1 Boiler

4.0 Performance Parameters on 31.08.2020:

Load (MW)	T_g (°C)	O_{2in} (%)	O_{2out} (%)	T_{airin} (°C)	AL (%)	$T_{gcorrect}$ (°C)	$T_{gdesign}$ (°C)
766	131	3.25	4.62	37.5	0.0753	137.74	125

Air leakage (AL) = (O2out - O2in) x 0.9/ (21 - O2Out)

T_g: APH gas outlet temperature

Tgcorrect =Tg +AL x Cpa x (Tg - Tair in)/ Cpg

where C_{pa}=0.23 & C_{pg}=0.24

Fuel CV kcal/kg	Fuel flow TPH	Air flow TPH	UB_{FA}%	UB_{BA}%	CO%	CO_2%	Aa	Ta	PA Flow TPH	PA/ Coal
3599	482	2850	0.14	0.87	0.0004	15.10	5.91	27	1100	2.28

Aa = Air flow /Fuel flow

Coal Proximate Analysis:

FC (%)	VM (%)	A (%)	Mw (%)
28.5	**20.6**	**31.5**	**19.4**

FC-fixed carbon, VM-Volatile matter, A- Ash Content, M_w- moisture content.

Fuel Analysis:

C	H	N	S	O	A_a	M_G
0.364	0.017	0.017	0.005	0.088	5.91	6.248

Aa = Air flow /Fuel flow = 2850/482 = 5.91 kg/ kg of fuel

A = 0.315kg/ kg of fuel

M_w = 0.194 kg/ kg of fuel

FC = 0.285 kg/ kg of fuel

Mass of Dry Flue gas per Kg of fuel

Mg = (Aa + 1) – (A+9H + Mw) = (5.91 + 1) – (0.315 + 9* 0.017 + 0.194) = 6.248kg/ kg of fuel

C = $(0.97*FC+0.7*(VM+0.1*A)-M_w*(0.6-0.01*M_w))/100$

H = $(0.036*FC+0.086*(VM-0.1*A)–0.0035*M_w*M_w*(1-0.02*M))/100$

N = (2.10-0.020*VM)/100, S = Taken as 0.5%, O = 1–((C+H+N+S+$(A+M_w)$/100)

4.1 Performance Matrices calculations:

Theo Air (%)	Ideal EA (%)	Actual EA (%)	Mg	L1	L5	L6	TCL
4.46	18.31	32.63	6.25	166.091	0.054	7.283	173.4

Excess Air (IDEAL) = 100 * $O_2/(21-0_2)$

Min theoretical air = (2.67 C + 8H – O + S) * 100/23

Excess Air (Actual) =100 * { (Air flow/fuel flow) – Theoretical Air } / Theoretical Air

Loss analysis

Heat lost with dry flue gas through chimney (L1) = mg x Cg x (Tg - Ta)

L1 = Mg x Cg x (Tg – Ta) Kcal/ kg of fuel

Heat Lost due to incomplete combustion (L5) = {CO% / (CO% + CO2%)} x Cx 5654kcal/ kg of fuel

L5 = C x {CO% / (CO% + CO2%)} x 5654kcal/ kg of fuel

Heat lost due to un-burnt (L6) = Mash x {0.9 x (UBFA%/ 100) + 0.1 x (UBBA%/ 100)} x 8084

(L6) = Mash x {0.9 x (UBFA%/ 100) + 0.1 x (UBBA%/ 100)} x 8084 Kcal/Kg of fuel

Observations:

i) APH outlet O_2 looks less. The correctness of this measurement is required to be checked by local measurement. If it is incorrect, then the corrected gas temperature at APH outlet would be also incorrect. Excess air measured from O_2 (Ideal EA) is significantly less than that measured from total air to coal ratio (Actual EA)

ii) Air to fuel ratio looks high. This is contributing largely towards the high dry gas loss (L1). We need to conduct few air optimization trials. It has been observed that during ramp up of system O_2 value falls down sharply. Fuel-air controls tuning is needed to be checked.

iii) PA to coal ratio appears to be significantly high. This was on account of the biasing given to each mill to attain the Mill O/L temperature, which is coming below OEM specified temperature with rated PA flow (specially during wet coal conditions). Moisture in coal is around 19%, which is more than design moisture. We need to check for CAD passing and also observe for coal pipe chocking by reducing PA flow to rated quantity.

iv) Un-burnt losses look well under control although quantity of PA is high.

4.2 Mill Performance Parameters:

Date	Load (MW)	Mill	Mill DP(mm WC)	Coal Flow (TPH)	PA Flow (TPH)	PA to Fuel Ratio	(+) 50 Mesh(%)	(-)200 Mesh(%)
31.08.2020	766	C	406.4	70.8	141.2	2.0	0.3	71.2
		D	390	70.7	152.1	2.2	0.1	87.4
		E	386	70.9	154.6	2.2	0.1	76.1
		F	378	70.5	149.3	2.1	0.1	87.0
		G	398	71.0	155.2	2.2	0.1	71.2
		H	376	69.1	156.0	2.3	0.1	82.0
		J	332	61.3	142.7	2.3	0.1	76.9

Observations:

i) High PA to coal ratio in almost all mills.
ii) Coal fineness looks quite healthy except for Mill C & G. We need to check the results for individual coal pipes to identify imbalance of coal fineness distribution in the coal pipes.

4.3 Gas, Water and Steam Side Temperatures:

Flue Gas Temperature(^{o}C)	Actual	Design
Furnace	-	-
Platen SH O/L(RH inlet)	810/749	996
Final SH inlet	783/714	879
LTRH inlet/ FEGT	654/636	728
Eco I/L	443/440	504
Eco O/L	339/341	333
APH O/L	150/115	125
ESP I/L	150/115	124
ESP O/L	121/123	122

Water Side Temperature(^{o}C)	Actual	Design
LP Heater Inlet	45	
LP Heater Outlet	149	
DA Outlet	190	188
HP Heater Inlet	189	190
HP Heater Outlet	291	290
Eco Outlet	342	347
Separator Outlet	414	422
Steam Side(^{o}C)	**Actual**	**Design**
Platen SH u/s	432	427
Platen SH d/s	496/488	516
FSH Spray u/s	488/499	495

FSH Spray d/s	438/439	496
SH Outlet	568	568
LTRH inlet	350	347
LTRH outlet	452/462	499/499
RH spray d/s	462/452	499/499
HRH	555	596

Observations:

i) Furnace dilution can be noted from the gas temperatures

ii) Inlet gas temperature to the economizer is around 60^{o}C less than design temperature. Temperature drop across economizer is around 70^{o}C less than the design temperature drop. Whereas water side heat pick up in the economizer is same as design heat pick up. This confirms high mass flow of gas through the economizer and indicates high excess air.

iii) LTRH inlet gas temperature is nearly 90^{o}C less than design due to furnace dilution. But flue gas side temperature drop almost matches the design temperature drop and the mass flow is evidently more. Still the heat pick up across LTRH is almost 50^{o}C less than rated. **This clearly indicates we have inadequate heating surface area in LTRH. Though heat pick up across FRH is same as design heat pick up, final RH temperature is around 40^{o}C less**

iv) Heat pick up across platen super heater, which picks up heat primarily through radiant heat transfer is almost 30^{o}C less than the design, which is expected due to lower gas temperature. **But the heat pick up at the final super heater is almost 60^{o}C more than the design, which is causing higher MS attemperation spray.**

v) Considerable Cooling of gas is taking place across ESP, which indicates possible leakages in the expansion joint and duct.

Note: Unit#1 COD was with effect from June 2019, boiler PG Test yet not done, and issues related to boiler performance are being taken up with BHEL.

4.4 APH Performance Parameters:

APH	Inlet Gas Temp (°C)	Outlet Gas Temp (°C)	Outlet Gas Temp (°C) (Design)	Inlet Air Temp (°C)	Outlet Air Temp (°C)	Outlet Air Temp (°C) (Design)
PAPH-A	331	150	125	42	303	311
PAPH-B	330	143		42		
SAPH-A	336	115		33		
SAPH-B	334	118		33		

Gas Side Damper Position:

PAPH A	SAPH A	PAPH B	SAPH B
50/ 50	100	49/ 49.7	100

Observation:

i) The PAPH side gas outlet temperature is significantly higher though PAPH gas side damper is throttled and less gas flow is going through PAPH. Both gas mass flow and temperature drop is higher but still SAPH outlet air temperature is lower than design. This could be due to high SA mass flow and also possibility of CAD passing.

4.5 Diagnosis Of Parameters And Preliminary Conclusion:

i) Very high use of excess air. This could be due to our effort to increase the heat pick up in the LTRH area. But the gain in LTRH is coming at the cost of high heat pick up in the final super heater.

ii) High PA flow to all mills to attain higher mill outlet temperature. This is detrimental to combustion optimization philosophy. This could lead to delayed combustion. However, due to the use of high excess air, the gas temperatures are not indicative, but final super heater heat pick up is much higher though inlet gas temperature as measured is lower than design. It is essential to conduct a furnace temperature mapping at various elevations through optical/ acoustic pyrometer.

iii) High dry flue gas loss resulting due the above issue

iv) Mill Fineness is good. But individual coal pipe fineness is required to be measured to check for balanced flow through all four corners. Fineness of Mill C and G need improvement. Good fineness could be the reason for low un-burnt loss in FA, though the PA is higher.

v) We need to observe the system response by reducing the total air by reducing the PA quantity. We need to reduce the O_2 set point for that during trial and observe.

5.0 Performance Trial On 07.09.2020 After Reducing PA Quantity

A trial was conducted on 7th September 2020 after reducing the PA quantity to mill C, E, F, H and J to nearly the rated quantity and the parameters were monitored once again. Total around 200 T of PA flow was reduced, same quantity of SA flow got increase in auto and the total air to fuel Ratio has increased from 5.54 to 5.63 as compared to the data on 31st August. The CV of coal was a little more (3718 kcal/ kg as compared to 3599 kcal/ kg as on 31st August) and so was the load (775 MW as against 766 MW)

5.1: Comparison of Controllable Losses:

Heat losses in kcal/ kg	**31.08.2020**	**07.09.2020**
Heat lost with dry flue gas through chimney	166.09	158.58
Heat Lost due to incomplete combustion	0.05	0.07
Heat lost due to un-burnt	7.23	9.47
Total Controllable losses	173.37	168.12
GCV of coal	3599	3718
% Loss	4.82	4.52

Observation:

Marginal change in the total controllable losses, which is expected as the total air quantity was not reduced.

5.2 Mill Performance Comparison:

Date	Mill	Mill Bowl DP (mmWC)	Coal Flow (TPH)	PA Flow (TPH)	PA to Fuel Ratio	Fineness (+) 50 Mesh(%)	Fineness (-)200 Mesh(%)
31.08.2020	C	406.4	70.8	141.2	2.0	0.3	71.2
	D	390	70.7	152.1	2.2	0.1	87.4
	E	386	70.9	154.6	2.2	0.1	76.1
	F	378	70.5	149.3	2.1	0.1	87.0
	G	398	71.0	155.2	2.2	0.1	71.2
	H	376	69.1	156.0	2.3	0.1	82.0
	J	332	61.3	142.7	2.3	0.1	76.9
07.09.2020	C	318	69.0	118.0	1.7	0.3	65.1
	D	327	69.0	142.0	2.1	0.1	70.7
	E	329	69.0	113.0	1.6	0.1	76.9
	F	307	69.0	119.0	1.7	0.1	70.8
	G	342	69.0	140.0	2.0	0.1	78.7
	H	330	69.0	113.0	1.6	0.2	72.1
	J	316	65.0	118.0	1.8	0.1	74.2

Date	Mill	Mill Bowl DP (mmWC)	Coal Flow (TPH)	PA Flow (TPH)	Mil inlet Temp (°C)	Mill outlet Temp (°C)	PAPH Outlet Air Temp(°C)
07.09.2020	C	318	69.0	118.0	287	75	310
	D	327	69.0	142.0	277	68	
	E	329	69.0	113.0	287	70	
	F	307	69.0	119.0	286	70	
	G	342	69.0	140.0	245	63	
	H	330	69.0	113.0	285	65	
	J	316	65.0	118.0	290	69	

Observations: The difference between APH outlet air temperature and Mill inlet temperature indicated passing of CAD. The passing is significantly more in Mill D and G. It can be observed the mill outlet temperature of D and G is also less despite the PA flow was significantly higher as compared to other mills. This confirms the low mill outlet temperature is caused by CAD passing.

Note: Coal mill capacity test is going on with OEM (BHEL), deficiencies, if any, shall be taken up with BHEL.

6.0 Coal Fineness In Individual Coal Pipes As Measured On 11.09.2020 :

Mill	Coal Flow (TPH)	PA Flow (TPH)	(+) 50 Mesh (%)	(-) 200 Mesh (%)
B1	68.9	132.7	0.1	72.6
B2				
B3			0.1	75.7
B4			0.1	68
D1	68.7	150.2	0.1	68.9
D2			0.1	80.6
D3			0.1	73.2
D4			0.1	80.6
E1	68.7	148.2	0.1	84.7
E2			0.1	84.3
E3			0.1	76.4
E4			0.1	84.7
F1	68.1	141.8	0.1	79.1
F2			0.1	66.6
F3			0.1	77
F4			0.1	80
G1	68.6	147.7	0.1	85.5
G2			0.1	77.4
G3			0.2	75.7
G4			0.1	87.2
H1	68.2	143.9	0.1	70
H2			0.1	80
H3			0.1	82.6
H4			0.1	80.6

Observations:

There is significant difference in fineness for Mill B, D, F & H in all coal pipes. This shows the Synchronization of classifier blade angles and lengths are required to be checked for these two mills.

7.0 SADC Position Comparison:

Mill	18.08.2020		07.09.2020	
	Fuel air damper (%)	Auxiliary damper (%)	Fuel air damper (%)	Auxiliary damper (%)
A	18	63	--	--
B	32	62.0	20	75
C	25	61	20	75
D	38	62.0	20	75
E	--	--	20	75
F	29	62	--	--
G	18	63	20	75
H	--	--	20	75
J	17	62.0	--	--

Observations:

With coal air damper at 20%; 75% opening of auxiliary air damper to achieve wind box DP of nearly 80 mmWC. We need to check by reducing the SA by some margin as the total air needs to be reduced.

8.0 APH Performance Comparison:

18.08.2020	I/L Gas Temp (^{o}C)	O/L Gas Temp (^{o}C)	O/L Gas Temp (^{o}C) (Design)	I/L Air Temp (^{o}C)	O/L Air Temp (^{o}C)	O/L Air Temp (^{o}C) (Design)
PAPH A	350	182.17	125	45	298	324
PAPH B	351	174.78	125	46	293	324
SAPH A	373	150.16	125	38	343	326
SAPH B	351	140.34	125	38	333	326
07.09.2020						
PAPH A	358	182.3	125	45	310	324
PAPH B	352	164.6	125	46	300	324
SAPH A	391	155.7	125	38	349	326
SAPH B	358	148.3	125	38	326	326

Observations:

In both cases the SAPH side damper was 75% and PAPH side damper was 100% open. Though the PA flow on 07.09.2020 was reduced, PAPH O/L gas temperature has not increased. PA temperature has improved marginally, but still less than design temperature. We therefore need to throttle the SAPH side gas damper further and check the result.

These positions have to change as per PAPH and SAPH flue gas outlet temp and that is changing with total fuel flow quantity. Overall study and tuning is being done with OEM

9.0 Comparison Of APH Parameters At Full Load And Part Load:

Date: 07.09.2020; Load: 775 MW; Coal flow: 465; PA flow: 900; SA flow: 1600

APH	Inlet Gas Temp (°C)	Outlet Gas Temp (°C)	Outlet Gas Temp (°C) (Design)	Inlet Air Temp (°C)	Outlet Air Temp (°C)	Outlet Air Temp (°C) (Design)	SADC(%)
PAPH-A	337	144	125	40	308	311	45/45
PAPH-B	337	141		40	308		60/60
SAPH-A	336	124		32	294		100/100
SAPH-B	336	122		32	288		100/100

Date: 07.09.2020; Load: 454 MW; Coal flow: 348; PA flow: 720; SA flow: 950

APH	Inlet Gas Temp (°C)	Outlet Gas Temp (°C)	Outlet Gas Temp (°C) (Design)	Inlet Air Temp (°C)	Outlet Air Temp (°C)	Outlet Air Temp (°C) (Design)	SADC(%)
PAPH-A	304	105	125	40	272	277	75/75
PAPH-B	305	113		40	275		100/100
SAPH-A	304	121		32	275		40/40
SAPH-B	304	132		33	284		40/40

Observations:

At part load, primary air flow is proportionately more as compared to secondary air from that at full load. That is the reason why the SAPH side gas damper is required to be throttled instead of PAPH side gas damper that is getting throttled at full load. We may notice indication of lesser CAD passing at part load too. But we need to keep PAPH A side damper full open, or else it is unnecessary increasing the ID fan load.

10.0 Performance Trial on 29th September 2020

Another trial conducted on 29.09.2020 at load 778 MW where the PA was increased marginally and compared with parameters recorded on 07.09.2020 parameters recorded at load 775 MW.

10.1 Comparison of Controllable Losses:

Heat losses in kcal/ kg	07.09.2020	29.09.2020
Heat lost with dry flue gas through chimney	158.58	168.25
Heat Lost due to incomplete combustion	0.07	0.14
Heat lost due to un-burnt	9.47	9.99
Total Controllable losses	168.12	178.38
GCV of coal	3718	3849
% Loss	4.52	4.63

Observations: It shows only a marginal increase in the total controllable losses.

10.2 Mill Parameters Comparison:

Date	Mill	Mill Bowl DP	Coal (TPH)	PA (TPH)	PA to Fuel Ratio	(+) 50 Mesh %	(-) 200Mesh%	UC% (BA)	UC% (FA)	Mill Reject GCV (kcal/kg)
07.09.2020	C	318	69.0	118.0	1.7	0.3	65.1	1.02	0.16	1382
	D	327	69.0	142.0	2.1	0.1	70.7			
	E	329	69.0	113.0	1.6	0.1	76.9			
	F	307	69.0	119.0	1.7	0.1	70.8			
	G	342	69.0	140.0	2.0	0.1	78.7			
	H	330	69.0	113.0	1.6	0.2	72.1			
	J	316	65.0	118.0	1.8	0.1	74.2			
29.09.2020	B	360	66.6	140.2	2.1	0.06	73.2	1.04	0.25	870
	C	396	66.9	138.1	2.1	0.16	65.6			
	D	345	68.3	148.9	2.2	0.13	71.9			

	E	385	66.6	159.1	2.4	0.07	84.4			
	G	329	66.9	154.5	2.3	0.09	75.2			
	H	378	65.1	149.9	2.3	0.08	75.0			
	J	357	63.5	137.6	2.2	0.07	73.4			

Observations:

We can observe that while we have increased the PA flow, the GCV of Mill reject has decreased by 37%, but at the same time the un-burnt in the fly ash has increased by 56%. When we consider that almost 30% of the total fuel mass is collected as fly ash, it is not difficult to realize that the loss due to increase in mill reject is absolutely insignificant.

10.3 APH Parameters Comparison:

On 7th September 2020:

APH	Inlet Gas Temp (°C)	Outlet Gas Temp (°C)	Outlet Gas Temp (°C) (Design)	Inlet Air Temp (°C)	Outlet Air Temp (°C)	Outlet Air Temp (°C) (Design)	Damper(%)
PAPH-A	335	129	125	41	310	311	45
PAPH-B	337	133		42	310		75
SAPH-A	335	132		34	294		100
SAPH-B	336	127		34	303		100
Average		130.25					

On 29th September 2020:

APH	Inlet Gas Temp (°C)	Outlet Gas Temp (°C)	Outlet Gas Temp (°C) (Design)	Inlet Air Temp (°C)	Outlet Air Temp (°C)	Outlet Air Temp (°C) (Design)	Damper (%)
PAPH-A	337	144	125	40	308	311	45
PAPH-B	337	141		40	308		60
SAPH-A	336	124		32	294		100
SAPH-B	336	122		32	288		100
Average		132.75					

Observations:

Marginal increase in the average APH outlet gas temperature can be observed.

10.4 Flue Gas Temperature Comparison:

Location Temp(°c)	7th Sept 2020	29th Sept 2020	Design Temp(°c)
Platen SH O/L	832/736	828/718	996
Final SH inlet	802/709	793/688	879
LTRH inlet/ FEGT	653/630	648/645	728
Eco I/L	432/428	429/436	504
Eco O/L	337/339	335/337	333
APH O/L	130.25	132.75	125

10.5 Steam Side Temperatures Comparison:

Location Temp(°c)	7th Sept 2020	29th Sept 2020	Design Temp(°c)
Platen SH u/s	434	443	427
Platen SH d/s	498/505	525/507	516
FSH Spray u/s	498/506	525/507	495
FSH Spray d/s	491/500	503/499	496
SH Outlet	568	569	568
LTRRH inlet	341	345	347
LTRH Outlet	459/448	457/447	499/499
RH spray d/s	457/488	456/447	499/499
HRH	543	556	596

Observations:

No significant difference in the gas temperature, apart from a little indication of dilution. HRH temperature gain can be observed, but super heater heat pick up and MS attemperation has also increased.

11.0 Final Conclusion and Suggestions:

1. The correctness of online O_2 measurement at APH inlet and outlet should be verified with field measurement.
2. It appears that the LTRH has been provided with less surface area than required, which is leading to low RH temperature. We are using higher excess air to increase the heat pick up in the LTRH area, but this also leading to higher heat pick up in the final super heater, leading to higher attemperation and metal temperature excursion along with higher dry flue gas loss. Since we have 347H metallurgy in the final super heater, we should check for exfoliation of oxides and chance of blockages across the bends and also should go for Replica study of the platen super heater components to assess creep damages.
3. The PA flow is high along with the total air. A trial with reduction of PA flow is required to be carried out after modification of the control loop, so that the total air flow also gets reduced. During the trial we shall compare the increase in loss due to decrease in RH temperature (which is expected) against reduction of dry gas and fly ash un-burnt losses. We shall also check whether the SH spray and metal temperatures are decreasing during this condition.
4. CAD is passing, particularly for mill D&G, which shall be rectified at the earliest opportunity. Due to inadvertent cold mill inlet temperature, mill outlet temperature is also going down. PA flow should be such that it supports the combustion process by the way of maintaining SA/PA ratio and fuel to air ratio. PA flow should not be increased to increase the mill

outlet temperature only it is also to be seen that it does not create combustion imbalance inside the furnace.

5. Classifiers of mill B, D, F & H should be checked for blade synchronization
6. At times, both SAPH and PAPH side gas dampers are being throttled, which should be avoided to reduce ID load
7. Duct/ expansion joint leakage in the ESP area is suspected. O_2% may be measured at ESP inlet and outlet to confirm the same.

12.0 Acknowledgement:

We, members of Team #7, GwSTPS, express our sincere gratitude towards Shri Ansuman Sen Sharma for continuous guidance every step for completion of the project report. This would not have been possible without splendid coordination of Sri Anoop Kumar from PMI and Shri Susovan Sen Sharma from India Boiler Dot Com.

Study and Analysis of Boiler system performance through

Diagnosis of process parameters

AT

NTPC - KORBA

Submitted by

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Under the guidance of

Shri Ansuman Sen Sharma
India Boiler dot com

ACKNOWLEDGEMENT

We wish to express our heartfelt gratitude to the all the seniors who have played a crucial role in this project, without their active cooperation the preparation of this project could not have been completed within the specified time limit.

We are thankful to respected **Shri Ansuman Sen Sharma, India Boiler dot com & Sri Anoop Kumar from PMI** for motivating & supporting us throughout this project with utmost cooperation and patience for helping us for completion of this project with complete focus and attention.

STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR STAGE 2, UNIT 4 BY KORBA TPS

SUB INDEX

Diagnosis of Boiler through process parameters

Objective: - Identification of performance irregularities in Boiler system through Diagnosis of process parameters. Study and analysis of process parameters of stage_2, unit 4 (500MW) boiler system at base load was carried out after the completion of the training workshop for this purpose.

Methodology:

A. **Recording process parameters and computing performance matrices**
B. **Identification of irregularities**
C. **Diagnosis of possible root causes**
D. **Conducting trial after minor changes of process conditions to validate**
E. **Conclusion and suggestions**

KSTPS stages :

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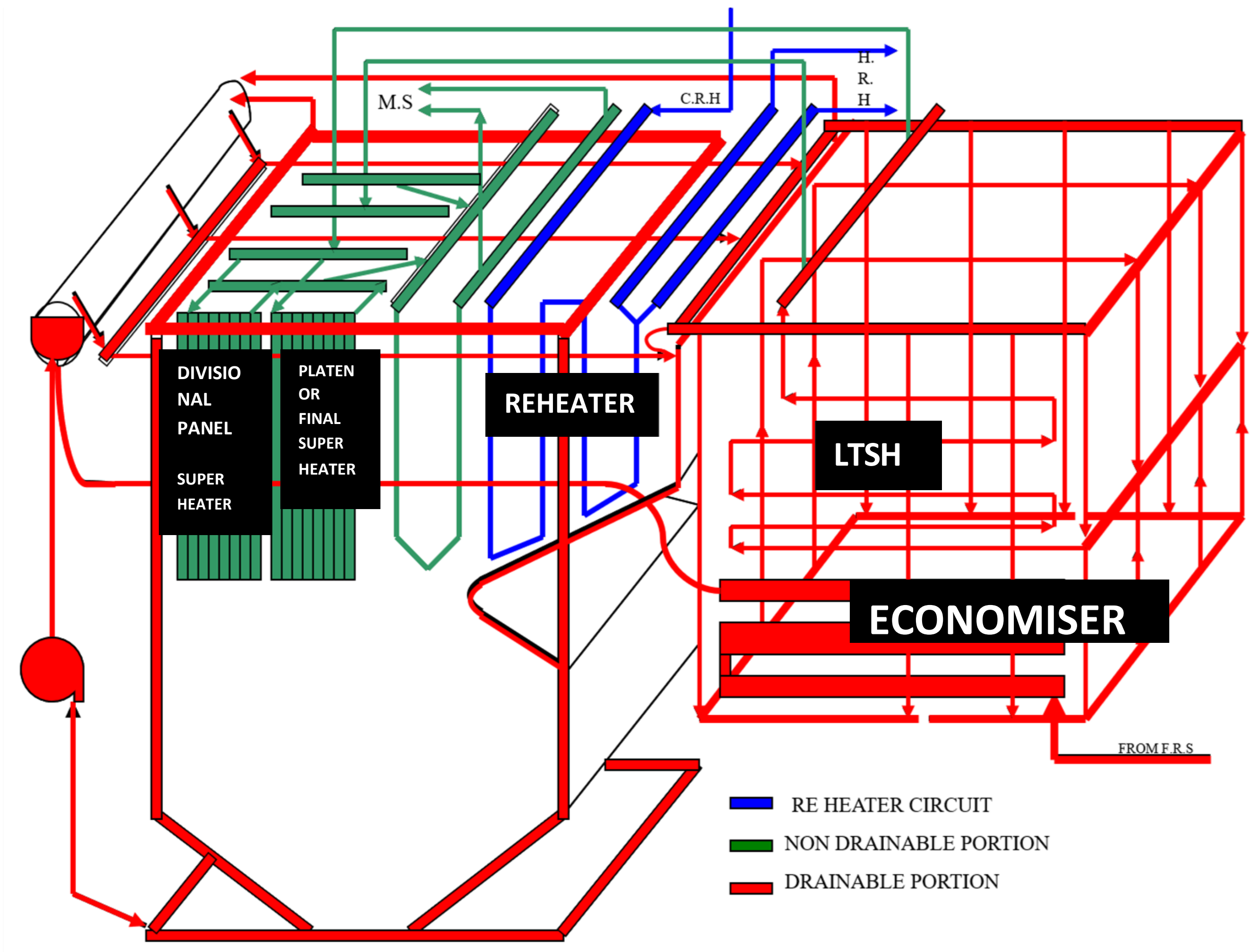
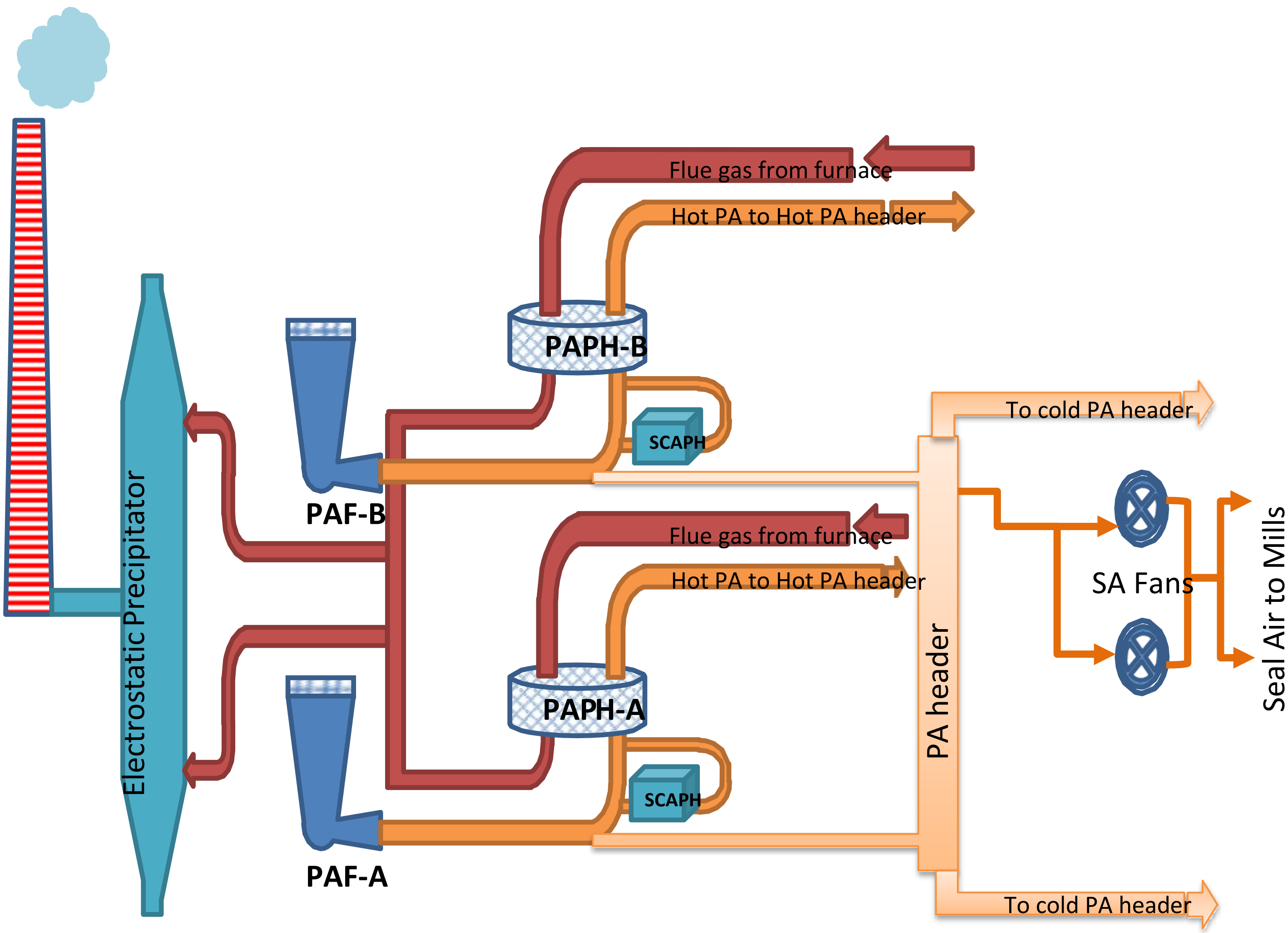
STAGE 1	STAGE 2	STAGE 3
• 200MW x 3 units • MANUFACTURER : BHEL • BALANCED DRAFT, DIRECT FIRED. • NATURAL CIRCULATION SINGLE DRUM • TANGENTIAL FIRING • TOTAL : 6 MILLS	• **500 MW x 3 units** • MANUFACTURER : BHEL • BALANCED DRAFT, DIRECT FIRED. • TANGENTIAL FIRING • CONTROLLED CIRCULATION SINGLE DRUM • TOTAL : 9 MILLS	• 500 MW x 1 units • MANUFACTURER : BHEL • BALANCED DRAFT, DIRECT FIRED. • TANGENTIAL FIRING • CONTROLLED CIRCULATION SINGLE DRUM • TOTAL : 10 MILLS

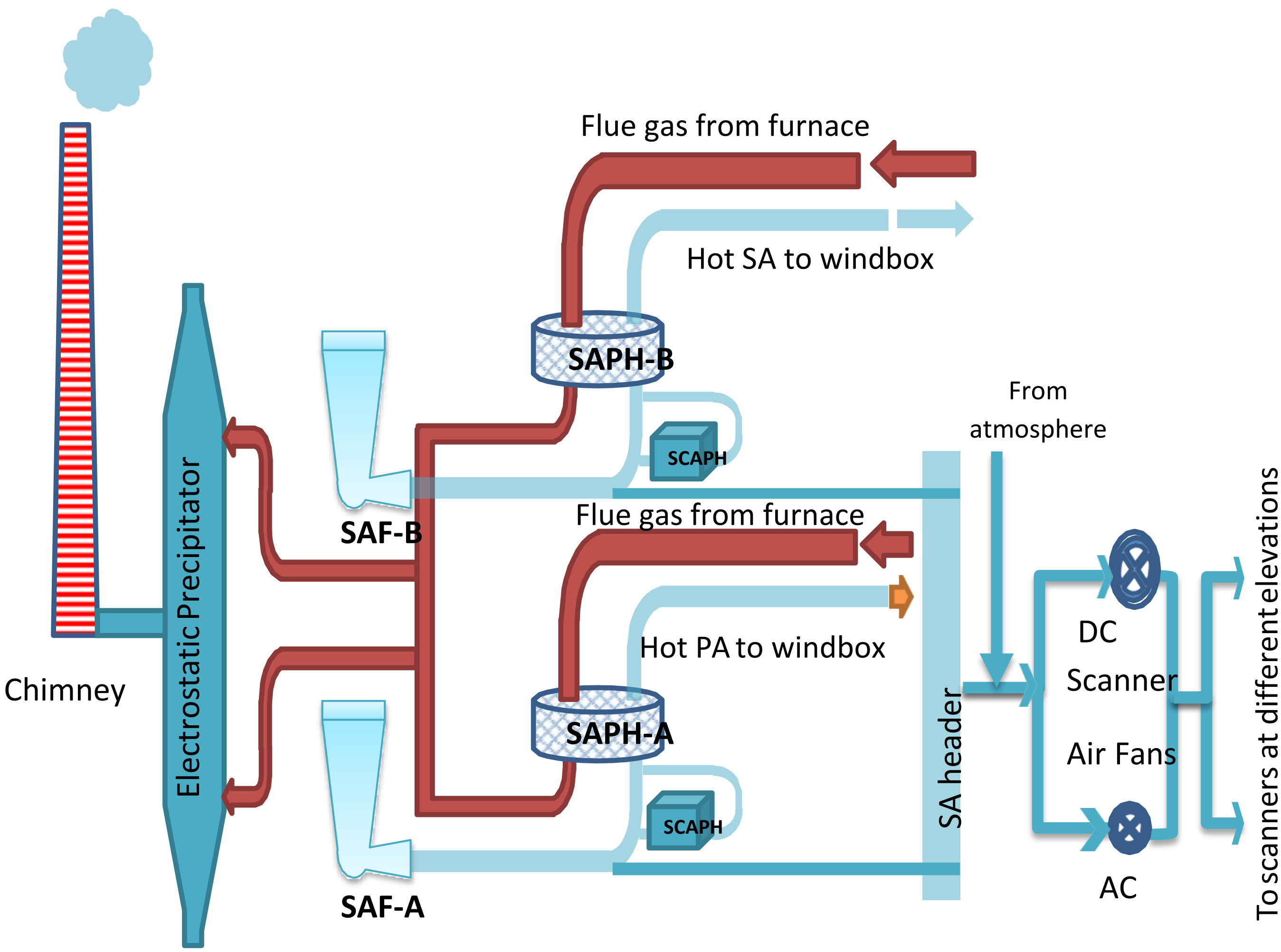
Over view of Boiler internal arrangement (Stage 2 & 3)



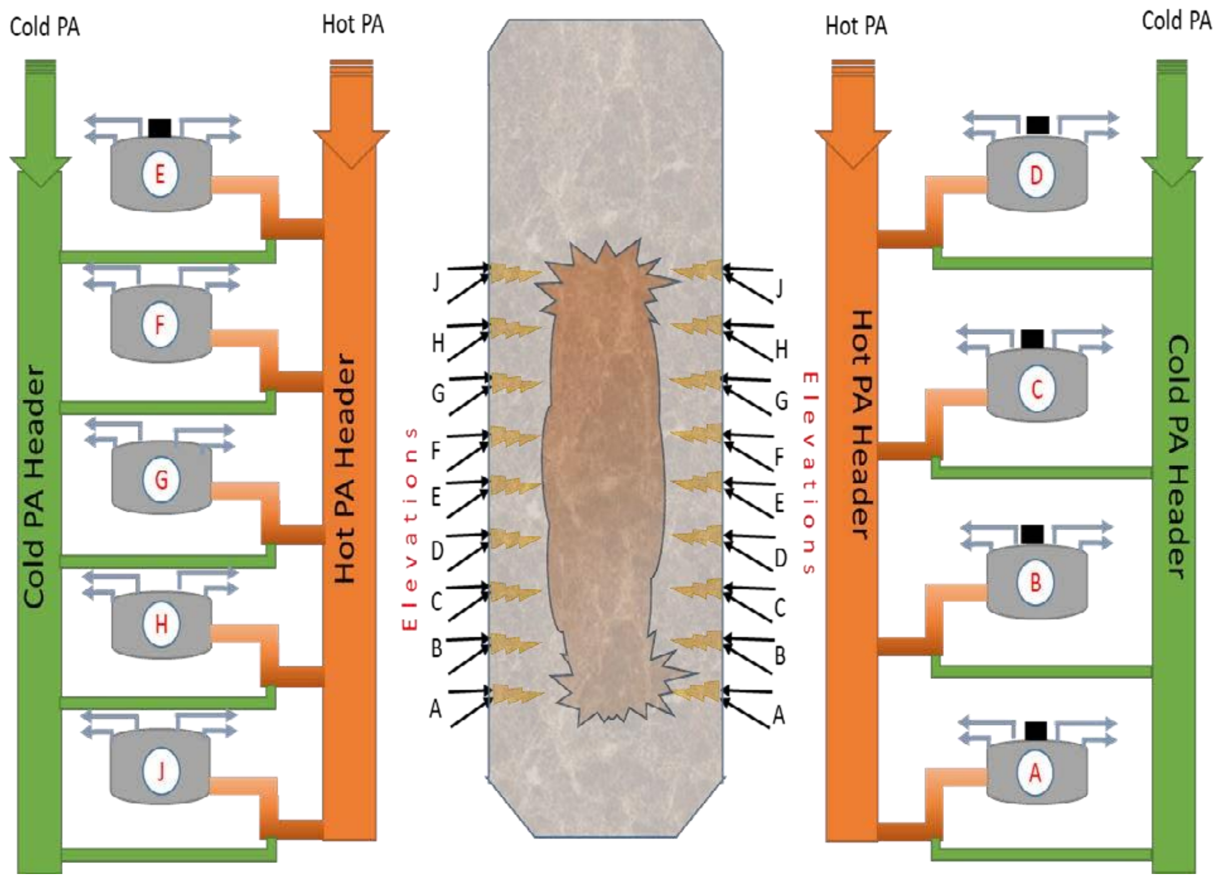
Primary air flow arrangement : (Stage 2 & 3)



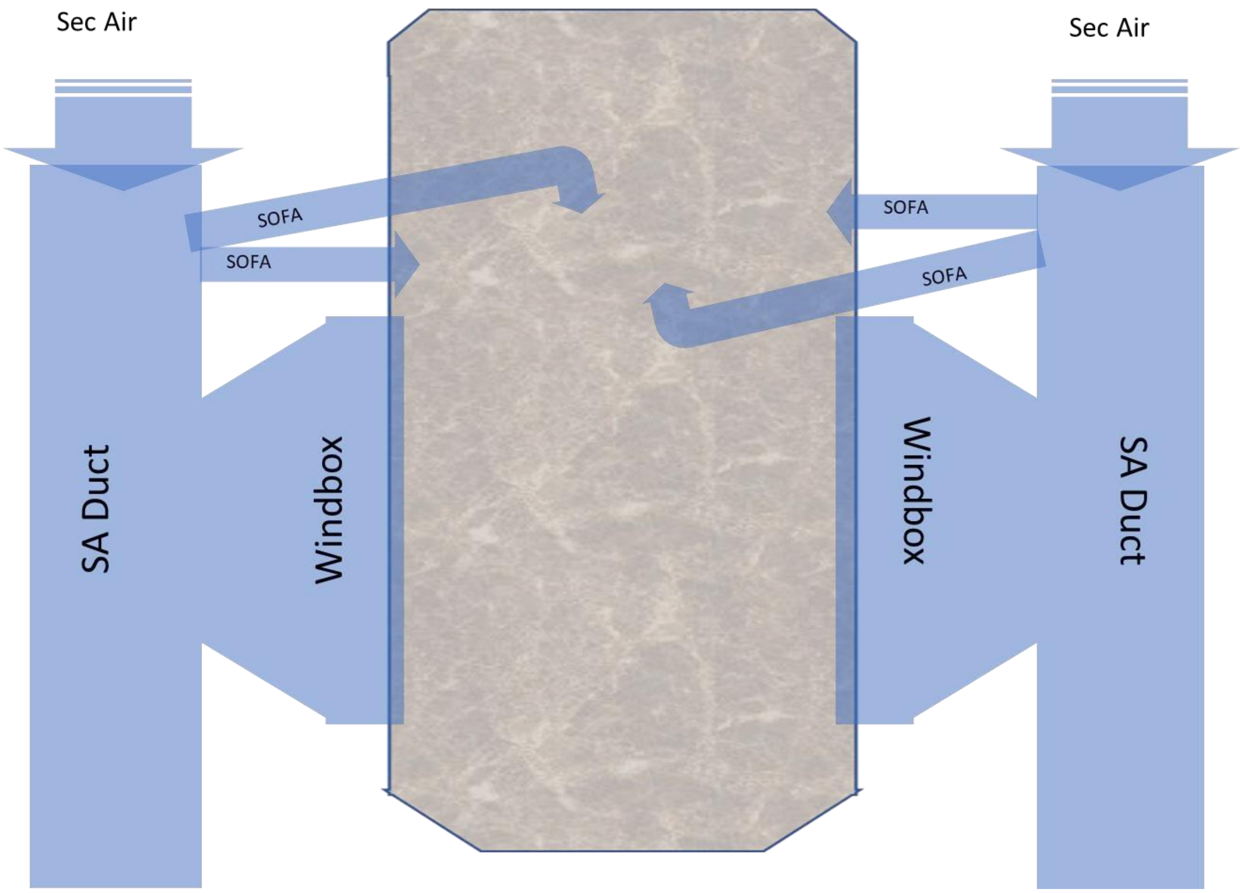
Secondary air flow arrangement : (Stage 2 & 3)



Furnace : (Stage 2 & 3)



SA Duct & Wind box : (Stage 2 & 3)



Formulae Used :

- APH leakage % = (O2out- O2in)*0.9*100/(21-O2out)
- $T_{gas\ out\ no\ lkg} = T_{gas\ out} + (AL\%*C_{pa}*(T_{gas\ out} - T_{air\ in})/(C_{pg}*100))$
- X ratio = $(T_{gas\ in} - T_{gas\ out\ no\ lkg}) / (T_{airout} - T_{air\ in})$
- Gas side efficiency = $(T_{gas\ in} - T_{gas\ out\ no\ lkg})*100/(T_{gas\ in} - T_{air\ in})$
- Heat lost with dry flue gas through chimney L1= Mg x Cg x (Tg - Ta)
- Heat Lost due to incomplete combustion L2 = C x {CO% / (CO% + CO2%)} x 5654 kcal/ kg of fuel
- Heat lost due to un-burnt L3= Mash x {0.8 x (UBFA%/ 100) + 0.2 x (UBBA%/ 100)}x 8084 kcal/ kg of fuel

C pa = 0.23 kcal/ kg oC C pg = 0.24 kcal/ kg oC

Mg = (Aa + 1) – (A + 9H + Mw)

Aa = (FD flow + PA flow)/ Fuel flow

H = 0.036FC + 0.086 (VM - 0.1xA) - 0.0035Mw 2 (1- 0.02Mw)

- Minimum Theoretical Air required for complete combustion = [2.67C + 8H - O + S] x 100/23
- C = [0.97FC+ 0.7(VM+0.1A) - Mw(0.6 - 0.01M)]/ 100
- H = [0.036C + 0.086 (VM - 0.1xA) – 0.0035Mw 2 (1-0.02M)]/ 100
- N = [2.10 - 0.020 VM]/ 100
- Minimum Theoretical Air required for complete combustion = [2.67C + 8H - O + S] x 100/23
- Excess Air from measured O_2% ; EA% = 100 x O/ (21 - O) (Ideal)
- Excess Air from measured Air to Fuel Ratio
  EA% = 100 x [(Air Flow/ Fuel Flow) – Theoretical Air]/ Theoretical air (Actual)

Fuel analysis:

DATE	Fuel CV	FC	VM	A	Mw	C	H	N	S	O
10-Oct	3546	25.77	23.66	45.91	4.75	0.42	0.0249	0.016	0.003	0.027
18-Oct	3600	26	24	45	5	0.42	0.0253	0.016	0.003	0.031

VM % in coal	Safe Mill o/l temp
16 - 20	105 -110 ^{0}C
20 - 24	90 -95 ^{0}C
24 - 26	85 -90 ^{0}C
> 24	65 -85 ^{0}C

KSTPS Coal VM % lies in this range.
Hence mill o/l temp set-point can be maintained higher than current operating temp set-point.

Before Optimization Unit data for Total controllable losses calculation:

Unit	date	load	T_g	O_{2in}	O_{2out}	T_{airin}	AL	$T_{gcorrect}$	$T_{gdesign}$
4	10-oct	500	132	3.25	8.34	37	36 %	165	135

Unit	Fuel CV	Fuel flow	Air flow	$UB_{FA\%}$	$UB_{BA\%}$	CO%	CO_2%	Aa	Ta
4	3546	391	1696	0.5	1.6	0.007	10.6	4.338	27

Unit	Theoretical Air	Ideal EA	Actual EA	Mg	L1	L2	L3	TCL
4	5.6538	18.31	-23.28	4.6063	152.50	1.5494	26.72	180.8

Before Optimization Observations :

i) Exit gas temperature is very high which is leading to high dry flue gas loss

ii) High APH horizontal seal leakage

iii) Both fly ash and bottom ash un-burnt requires control.

iv) Un-burnt losses appear to be within OEM limit. We can try to reduce the fly ash un-burnt percentage by a margin though (< 0.1 %) to match the best practices.

v) Excess air as measured from actual air is in negative, indicating **incorrect air flow measurement**. The dry gas loss could actually be much higher than what we are getting now.

vi) Huge opportunity in reduction of total controllable losses if we can reduce the exit gas temperature as well as air flow quantity.

Mill performance parameters & PA flow analysis 10.10.2020:

MILL	LOAD %	COAL FLOW	AIR FLOW	DESIGN AIR	AIR I/L	MILL O/L	-200 MESH	FAD %	AUX DAMP %	WB FUR DP 1	WB FURN DP 2	CAD OPENING
A	82.85	58	104	95	231	80	81.0	25	40	30	32	80
B	82.85	58	107	95	228	79.5	86.6	25	40	30	32	35
C									40	30	32	
D	80	56	102	93.84	242	81	81.7	25	40	30	32	45
E	81.42	57	101	94.41	228	79	83.5	25	40	30	32	20
F									40	30	32	
G	82.85	58	103	95	236	79	87.9	25	40	30	32	30
H	72.85	51	107	91	210	77	90.6	25	40	30	32	30
J	72.85	51	110	91	183	78	91.5	25	40	30	32	50

NOX 175-225 PPM

MAX METAL TEMP	
LTSH	425
PLATEN	560
RH LEFT	572
RH RIGHT	574

Observations on mill performance 10.10.2020:

1. Very High PA to coal ratio in mills, higher than design value. Higher PA flow could be one of the causes leading to higher FA un-burnt.
2. Fineness of all mills is very good. We may think of reducing the fineness of upper mills to 76-80% @ -200 mesh to control metal temperature excursions.
3. We need to check the results for individual coal pipes to identify imbalance of coal fineness distribution in the coal pipes.
4. **All mills having high CAD opening , one of the primary reasons behind high exit gas temperature**
5. As coal VM% is around 25, we can also explore the possibility of increasing the mill outlet temperature set point to 90 to reduce CAD opening
6. All mills are having Higher FAD openings & high Aux damp openings & low wind-box DP

U4 Heat transfer analysis 10.10.2020 :

GAS SIDE	ACTUAL (FULL LOAD)	Fur pr	DESIGN	DES Fur pr
FURNACE		-2		
PLATEN SH I/L	856/713	bad	1091	-4
RH I/L	726/710	-13	990	-5
LTSH I/L	730/700	-25	705	-17
ECO I/L	480/459	bad	529	-31
ECO O/L	395/380	bad	366	-63
APH I/L	359/350/371/370	-92	366	
PAPH / SAPH O/L	95/112/165/156	-170	135	-180
ESP I/L	155/164/152/163			-236
ESP O/L	140/145			

WATER SIDE	ACTUAL(FULL LOAD)	DESIGN
LP HTR I/L	52	46.1
LP HTR O/L	129	125.2
D/A O/L	171/168	164.6
HP HTR I/L	171/169	166.5
HP HTR O/L	256	253.4
ECO O/L	332/332	304
DRUM O/L (BCW SUCCTION MANNIFOLD)	357/354	348.9

STEAM SIDE	ACTUAL (FULL LOAD)	DESIGN
LTSH O/L	410/408	406
DIVISIONAL PANEL SH I/L AFTER SPRAY	377/400	400
1ST STAGE SPRAY	80	22.5
MS	544/539	540
CRH BEFORE SPRAY	350/350	343
CRH AFTER SPRAY	290/290	
RH SPRAY	35	0
HRH	532/530	540

Observations :

i) Despite platen SH inlet gas temperatures are lower than design, we are getting high LTSH inlet gas temperature, which could mean deposits in the furnace SH or RH zone. DP is also on higher side. Less number of LRSB are available in UNIT 4.

ii) RHI/L temperatures are showing less than LTSH I/L gas temperatures means faulty temperature measure points in RH I/L.

iii) The gas side temperature drop across LTSH is around 74 ^{o}C more than the design. The steam side heat pick up across LTSH is evidently high. Modification done by BHEL to avoid excursion in metal temperature.They decreased two banks of LTSH and added one bank in ECONOMISER but still LTSH heat pick up is more than the design.

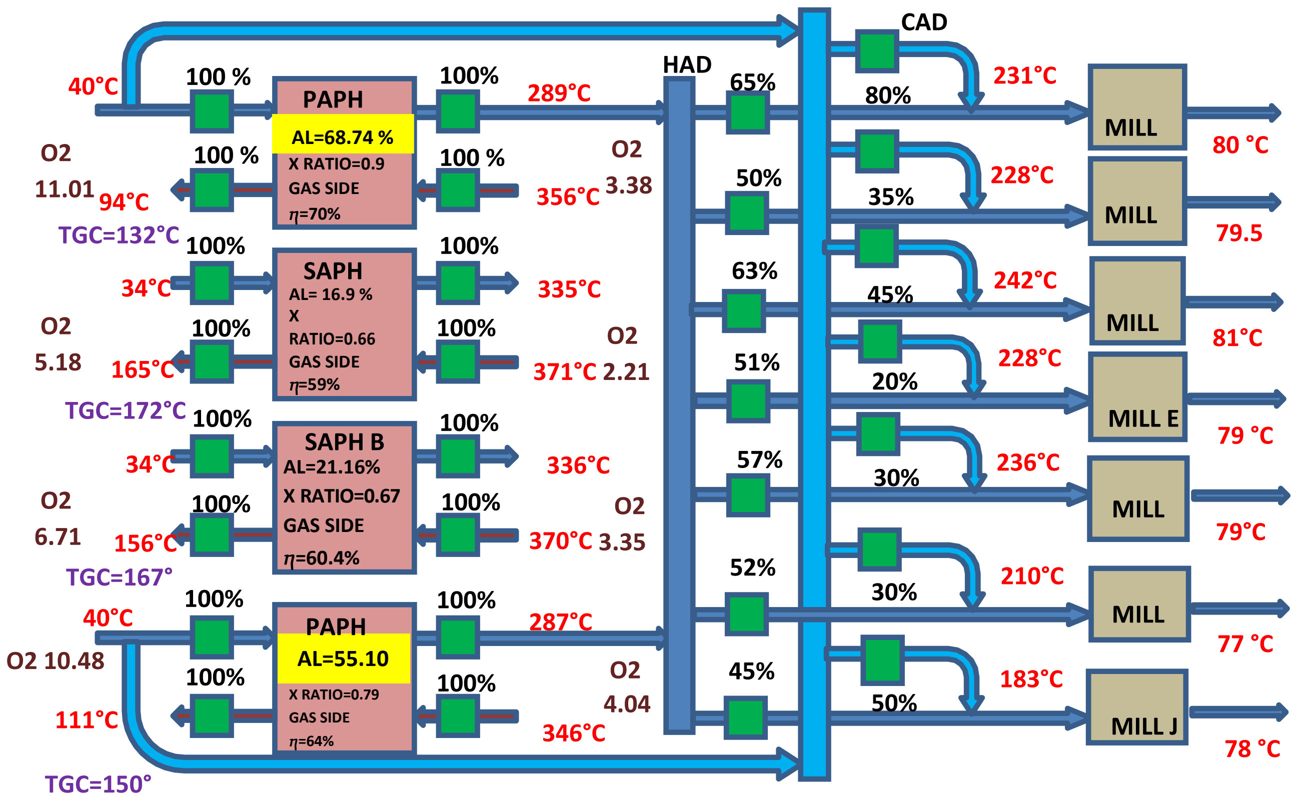
iv) MS attemperation spray is high, which could be due to higher heat pick up in the LTSH. Wall blowing would not be able to correct this condition.

v) Gas temperature drop across economizer is low, whereas economizer heat pick up is high. This is again clearly indicating higher mass flow and therefore higher excess air.

vi) There is significant cooling of gas taking place between Economizer outlet and APH inlet, which indicates duct leakage. Field O_2 should be checked to confirm. Ducts to be inspected properly to arrest those ingresses. This could one of the reasons leading to ID saturation which is creating significant limitations during operation at full load.

vii) ESP inlet temperatures appear to be faulty. This should be corrected to identify Expansion joint/ duct leakage in the ESP area .

APH Performance data U4 10.10.2020:



GAS SIDE DAMPER POSITION			
PAPH A	SAPH A	PAPH B	SAPH B
100	100	100	100

APH PERFORMANCE	I/L GAS	O/L GAS without correction	O/L DESIGN	AIR I/L	AIR O/L	AIR O/L DESIGN
PAPH A	356/356/355/356	95/93/93/95	135	40	288/291/290/288	343
PAPH B	346/346/347/347	108/110/112/114	135	40	286/286/287/288	343
SAPH A	368/367/368/382	165/165/164/165	135	34	335/336/335/333	325
SAPH B	380/368/366/367	160/145/145/175	135	34	335/335/336/336	325

Observations:

i) The SAPH side gas outlet temperature is contributing more towards high gas exit temperature. However, we can't throttle SAPH gas O/L dampers because of ID fan saturation and vibration issues in ID fans

ii) PAPH air outlet temperature is less than rated temperature, but still we need to keep the CAD opened to control mill outlet temperature. Throttling the gas side damper to increase PA outlet temperature is in direct contradiction as a result. **This is a strong indication that we have high PA flow**

iii) Gas side efficiency is low; gas side DP needs to be monitored for basket fouling identification.

Diagnosis of parameters and preliminary conclusion:

i) Air flow measurement could be faulty. All parameters are indicating we have high Air flow. We need to conduct a trial by reducing the total air flow by reducing PA flow marginally in each mill and observe the feedback from the system.

ii) High APH outlet temperature leading to high dry gas loss

iii) There is significant opportunity to reduce the dry gas loss as well as fly ash un-burnt loss, which we may achieve by reducing PA flow along with total air flow.

iv) Reduction of PA should also reduce the CAD opening, thus reducing the exit gas temperature

v) LTSH heat pick up is high. This could be due to higher heating surface area provided in LTSH combined with high mass flow of gas. This should be confirmed from studying past records. If it gets confirmed, then we may need to go for a replica study of the LTSH components to assess the creep damage.

vi) FAD opening looks higher. We can try with reducing the FAD to 20% and observe if that improves the furnace wind box DP, or not.

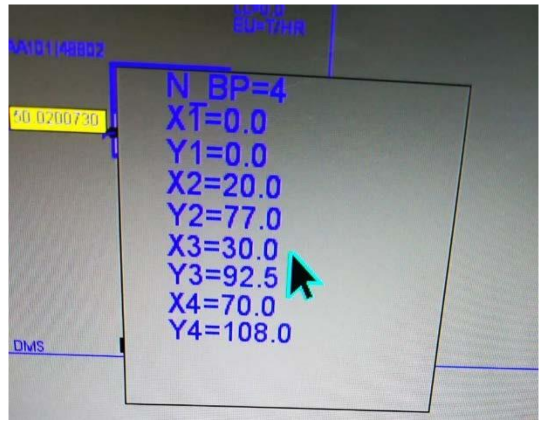
vii) Possibility of duct side leakage between Economizer and APH should be checked.

viii) ESP inlet gas temperature measurement , should be corrected.

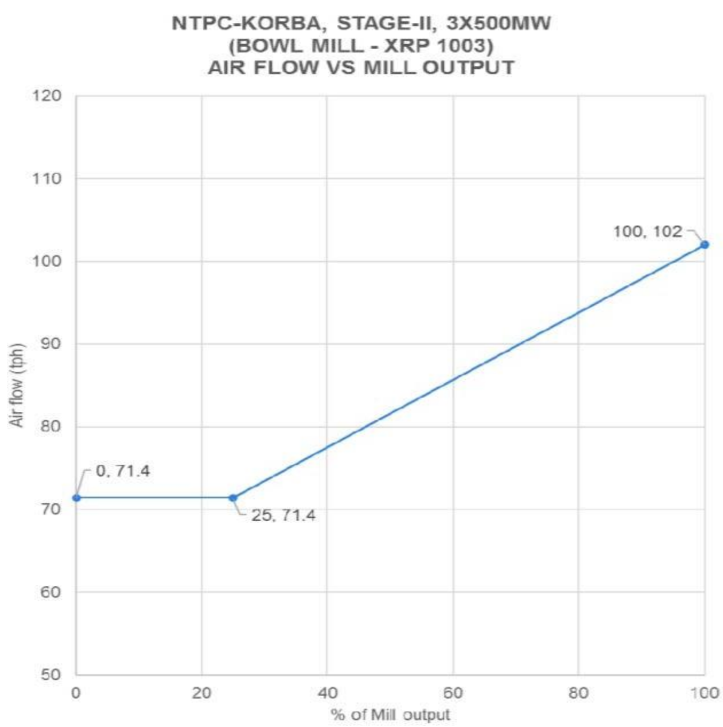
Optimization of Unit 4:

On the basis of our observation and diagnosis, we have conducted a trial on 18.10.2020 at base load after changing/ modifying following few system parameters:

1. PA flow through all mills tried to maintain design air by changing it in logic with the exact design curve.
2. Mill o/l temps are increased to 89 deg to all mills
3. FAD of all mills are reduced from 25% to 10 %
4. Varying aux damp positions upper mills have higher openings than lower mills
5. Mill fineness of upper mills are tried to maintain lesser than lower mills fineness



Before



After

After optimization data Unit 4 at 18.10.2020 :

Unit	date	load	T_g	O_{2in}	O_{2out}	T_{airin}	AL	$T_{gcorrect}$	$T_{gdesign}$
4	18-Oct	500	122.5	2.2	7.3	37	33.5%	150	135

Unit	Fuel CV	Fuel flow	Air flow	$UB_{FA\%}$	$UB_{BA\%}$	CO%	CO_2%	Aa	Ta
4	3600	391	1655	0.3	1.6	0.007	10.64	4.24	29

MILL	LOAD %	COAL FLOW	AIR FLOW	DESIGN AIR	AIR I/L	MILL O/L	-200 MESH	FAD %	AUX DAMP %	WB FUR DP 1	WB FURN DP 2	CAD OPENING
A	84.28	59	96	95.58	256	89	88.3	10	15	65	70	23
B	84.28	59	96	95.58	262	88	91.4	10	15	65	70	02
C	74.25	52	92	91.5	245	89	91.4	10	15	65	70	08
D	82.85	58	95	94.65	250	89	87.1	0	15	65	70	25
E	82.85	58	95	94.65	260	89	81.0	10	15	65	70	0
F												
G												
H	82.85	58	95	94.65	250	89	91.7	10	20	65	70	10
J	70	49	90	89.8	252	89	91.5	10	20	65	70	15

Unit	date	load	T_g	O_{2in}	O_{2out}	T_{airin}	AL	$T_{gcorrect}$	$T_{gdesign}$	L1	L5	L6	TCL
4	18TH - OCT	500	122.5	2.2	7.3	37	33.5%	150	135	133.2	1.54	20.37	155.5

Observations:

As expected, we could see a significant reduction in CAD opening and APH outlet gas temperature, as well as some reduction in fly ash un-burnt. We have made a comparative study of losses on these two days as under:

Descriptions	10.10.2020	18.10.2020
Heat lost with dry flue gas through chimney (Kcal/kg)	152.5	133.2
Heat Lost due to incomplete combustion (Kcal/kg)	1.55	1.54
Heat lost due to un-burnt (Kcal/kg)	26.72	20.37
Total Controllable losses (Kcal/kg)	180.8	155.5
GCV of coal	3546	3600
% Loss	5.1	4.32

Cost Benefit Analysis:

After optimization controllable losses decreases to 155.5 kcal/kg from previous 180.8 Kcal/kg.

- Coal price 1756 RS/ Ton & coal 391 T/Hr was consuming in 500 MW on the day 10TH oct & 391 T/Hr was consuming for 500 MW on the day 18th Oct.
- % of TCL w.r.t GCV= 5.1 & 4.32 .
- So coal saved on that day = {(5.1-4.32)/100}*24*391*1000= 73195.2 Kg.
- So the cost saving for unit 4 on 18th Oct was = 73195.2*1756 / 1000 = Rs. 128530.77
- Apprx. cost savings in one Year = 128530.77*365 = Rs. 46913731.4 (**Rupees 4.7 cr Apprx**.)
- Also there is **APC reduction of 200 KW** in draft power which amounts to Rs 200*24*365*1.5 = Rs. 2628000.
  - **Total Annual cost savings : Rs 4.95 crores (approx)**

After Optimization Comparisons:

APH performance:

10.10.2020	I/L Gas	O/L Gas	O/L Gas (Design)	I/L Air	O/L Air	O/L Air (Design)
PAPH A	356/356/355/356	95/93/93/95	135	40	288/291/290/288	343
PAPH B	346/346/347/347	108/110/112/114	135	40	286/286/287/288	343
SAPH A	368/367/368/382	165/165/164/165	135	34	335/336/335/333	325
SAPH B	380/368/366/367	160/145/145/175	135	34	335/335/336/336	325
18.10.2020						
PAPH A	361/361/359/361	95/90/90/93	135	40	300/301/300/299	343
PAPH B	346/346/347/347	102/104/107/111	135	40	294/295/296/297	343
SAPH A	361/364/365/370	147/143/142/143	135	34	324/323/321/320	325
SAPH B	367/361/363/364	135/120/121/148	135	34	319/319/321/322	325

Mill Parameters :

Mill	10.10.2020				18.10.2020			
	Air I/L temp.	Air Flow	Mill O/L temp	CAD %	Air I/L temp.	Air Flow	Mill O/L temp	CAD %
A	231	104	80	80	256	96	89	23
B	228	107	79.5	35	262	96	88	2
C					245	92	89	8
D	242	102	81	45	250	95	89	25
E	228	101	79	20	260	95	89	0
F								
G	236	103	79	30				
H	210	107	77	30	250	95	89	10
J	183	110	78	50	252	90	89	15

SADC:

Mill	10.10.2020			18.10.2020		
	Fuel air damper	Auxiliary damper	Wind box DP	Fuel air damper	Auxiliary damper	Wind box DP
A	25	40	30	10	15	70
B	25	40	30	10	15	70
C		40	30	10	15	70
D	25	40	30	0	15	70
E	25	40	30	10	15	70
F		40	30		20	70
G	25	40	30		20	70
H	25	40	30	10	20	70
J	25	40	30	10	20	70

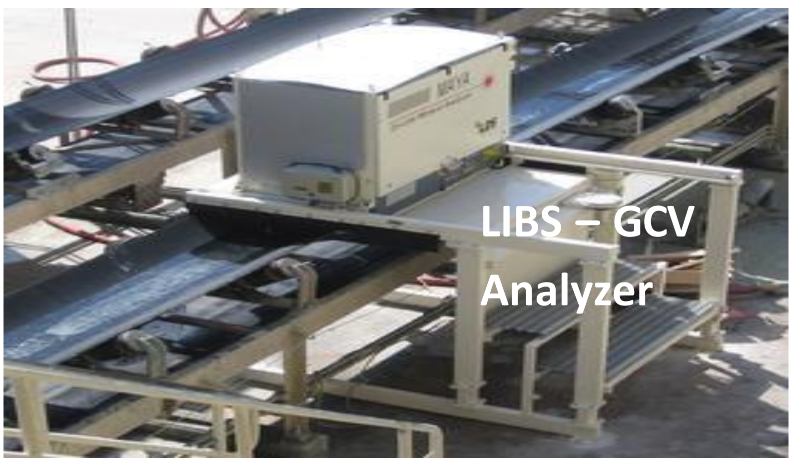
Observations: We could observe marked improvement in APH and mill performance as well as in wind box furnace DP. PAPH outlet air temperature has improved and CAD opening has reduced, resulting in reduction of APH outlet gas temperature. Further improvement in APH performance is possible by throttling the SAPH gas side damper if ID margin improves.

Suggestions

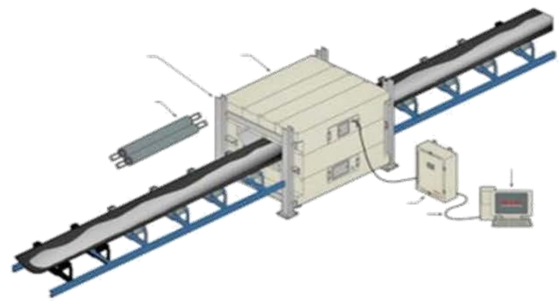
- Our total Air flow measurement should be corrected because it showing less than the actual.
- High priority should be given to leakage identification in the duct and arresting the same to reduce ID load.
- APH seal leakage should be attended during next available opportunity.
- In order to improve combustion we can **throttle SADC** in such a way that opening of upper elevation is more as compared to lower one and so on.
- We can have **mills of variable fines** such that higher fineness for the mills at lower elevations.
- We need to closely monitor LTSH inlet gas temperature and gas side DP across furnace SH and RH and operate LRSBs of those location, instead of operating wall blowers to reduce spray.
- We can maintain our upper mill fineness in the range of 76%-80% in -200 mesh
- In order to reduce PA flow proper pulveriser **throat clearance** to be checked.
- Chemistry should give the **all pipes fineness** of every mill in their report.
- There should be provision for furnace temperature mapping to identify for Flame unbalancing or shifting
- We also introduce some **new modern technologies** that can be applied for better online monitoring and to get optimisation results.

SOME NEW TECHNOLOGIES FOR COMBUSTION OPTIMIZATION

Online Element Analyser:



1. If we know present VM we can optimise mill O/L temperatures.
2. If we know present ferrous and SiO_2 content, we always be prepared for controlling slagging & fouling.



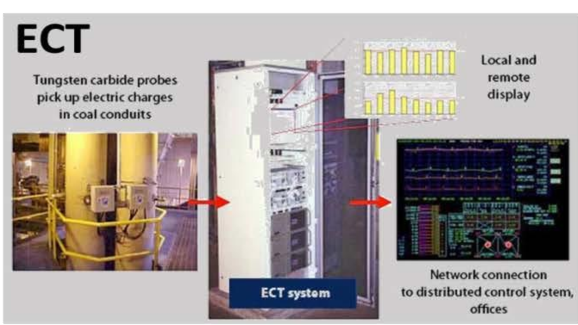
proximate and ultimate analysis

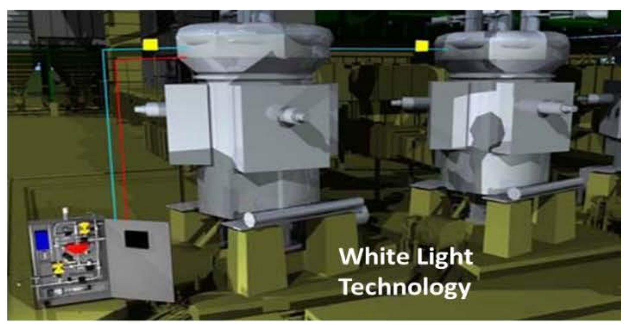
Iron (Fe)
- Aluminium (Al)
- Silicon (Si)
- Potassium (K)
- Sulfur (S)
- Calcium (Ca)
- Magnesium (Mg)

Carbon
- Hydrogen
- Nitrogen
- Oxygen
- Sulfur

- Ash
- Volatiles
- Fixed carbon
- Calorific Value

Online Coal Pipe Distributions:





Laser technology

Case Study of High Unburnt :

Can be identify quickly by online coal pipe distributions:

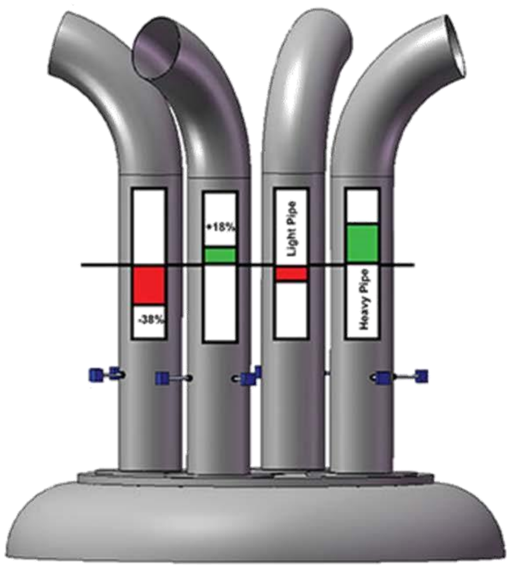
Unburnt Carbon					
Date	Unit	Bottom Ash		Fly Ash	
		Limit	Actual	Limit	Actual
27.08.20	#1	< 3.5	4.7	< 0.5	0.7
	#2		2.6		0.3
	#3		2.5		0.4
	#4	3.0	1.7	<0.5	0.4
	#5		2.2		0.3
	#6		1.5		0.3
	#7		1.5		0.5

High unburnt found in bottom ash is spite of fineness of all mills are good.

After chemistry taking samples of all pipes of all bottom mills root cause found in mill A, different fineness in different .pipes.

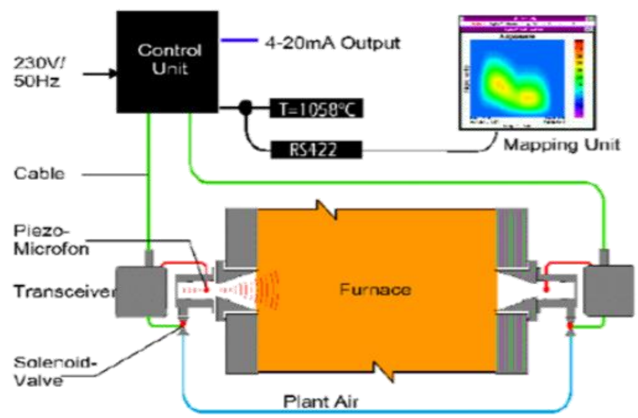
Unit-1					
Date: 28/08/2020					
Mill	50	-100	-200	Coal flow	Air flow
	Limit ≤1.0	≥ 90.0	≥ 70.0	in (MT/ Hr)	
B	0.3	91.0	76.7	34	56
C	0.2	92.3	80.2	30	57
D	0.2	93.2	80.8	34	56
A (Cor.1)	0.7	91.9	77.9	32	55
A (Cor.2)	1.6	78.4	60.4	32	55
A (Cor.3)	0.8	88.5	67.6	32	55
A (Cor.4)	4.2	90.9	83.5	32	55

Adjustable orifices:



Optimisation velocity and correct air flow distribution

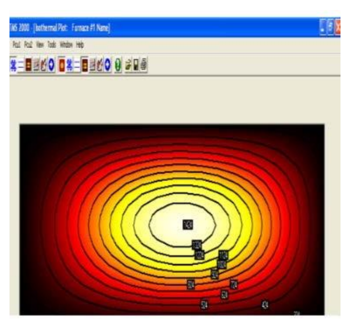
Acoustic pyrometer for FEGT measurement:



We don't have any FEGT temp measurements system .we have temperature measurements after Platen SH I/L

FEGT or furnace temperature monitoring is very important to monitor

1. Flame shifting
2. Slagging controlling

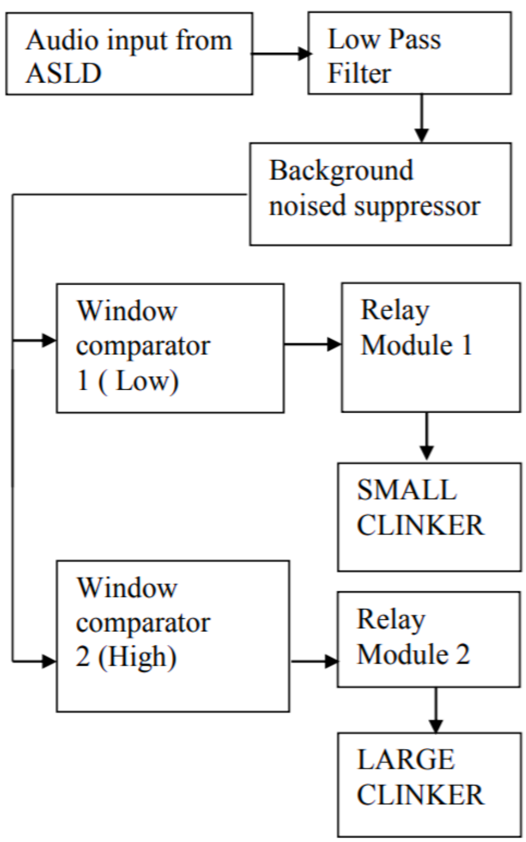


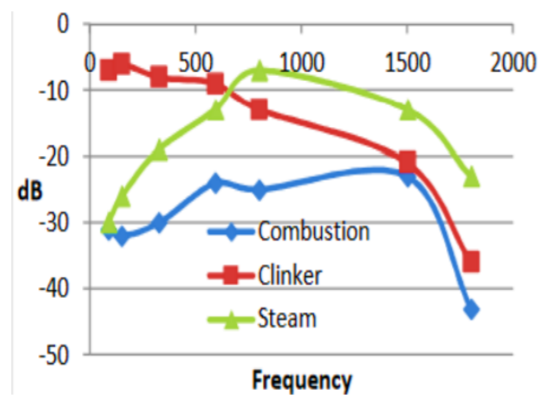
Early detection of clinkering by ASLD :

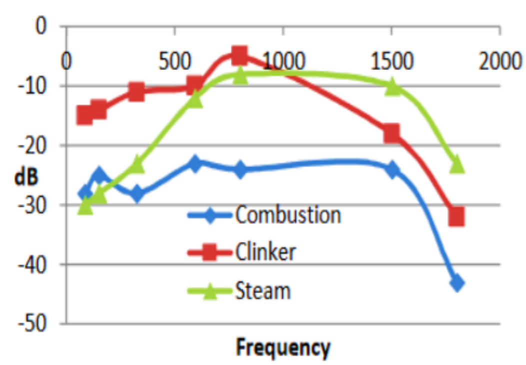
We can use ASLD with some filter & suppressor to detect clinkering early .

It can help to prevent

- Hopper choking,
- Ash build up,
- Scrapper failure
- Clinker grinder failure







Different Types of Gas Analysers :

For Optimizing combustion & Emission control we have to know after combustion Gases percentage with accuracy

- Raman Analysers
- Cavity Ring-Down Spectroscopy (CRDS) – The High Sensitivity Gas Analyzer
- TDLAS – Leading Segment of Laser-Based Gas Analyzers

Benefits of TDLAS :

Low cost, ease of maintenance high detection accuracy, as well as the ease of operation. For instance, traditional gas analyzers such as Zirconia, Paramagnetic and so forth require frequent calibration and maintenance in critical process environments.

Study and Analysis of Boiler System Performance Through Diagnosis of Process Parameters

AT

NTPC – Vindhyachal (Stage-II, U#8)

Submitted by

Shri Ritesh Agarwal , Sr Manager (EEMG), NTPC VSTPP

Under the guidance of

Shri Ansuman Sen Sharma

India Boiler dot com

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STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR STAGE 2, UNIT 8 BY VINDHYACHAL TPS

SUB INDEX

2.0. Objective: - Identification of performance irregularities in Boiler system through Diagnosis of process parameter. Study and analysis of process parameters of Stage-II, Unit# 8, VSTPP boiler system was carried out after the completion of the training workshop for this purpose.

- Some of the issues which are already identified are:
- ID capacity saturation
- High SH/ RH spray
- Metal Temperature excursion
- Low HRH temperature at part load
- Slagging and clinkering

3.0. Methodology:

A. **Recording process parameters and computing performance matrices**

B. **Identification of irregularities**

C. **Diagnosis of possible root causes**

D. **Conducting trial after minor changes of process conditions to validate**

E. **Conclusion and suggestions**

4.0. Overview of the system:

Vindhyachal project of NTPC is the largest Thermal Power Project of India. The station is located in Singrauli District of Madhya Pradesh and is nearly 200 Kms. from Varanasi. Total approved capacity of the station is 4760 MW. The project has been constructed in five stages. Stage I consists of six units of 210 MW each, stage II, III & IV consists of two Units of 500 MW each ,while one unit of 500MW is there in 5th stage.

This project was carried out in stage-II, Unit #8 of VSTPP .The various technical specifications of boiler are as indicated in Table 1.

Table1. Technical specifications of boiler at VSTPP, Stage- II, U#8

1	Boiler make	BHEL 500 MW (C.E.Design.)
2	Boiler Type	Controlled circulation with Rifled Tubing, Dry bottom, Radiant Reheat, Single drum, Top Supported, Balanced draft furnace
3	Main Steam Pr.	176.2 Ksc
4	Main steam Temp.	540 ^{o}C
5	HRH steam Pr.	41.4 Ksc
6	HRH steam Temp.	540 ^{o}C
7	Design Coal	301 T/H
8	Design Total Air	1575T/H

9	Mill type	Pressurised, double ended Ball Tube Mills (BBD 4772)
10	No. of Mills / Boiler	5
11	No. of Mills in service for Design Coal	4

General Arrangement of Superheater & Reheater in Boiler at Stage-II, U#8 VSTPP.

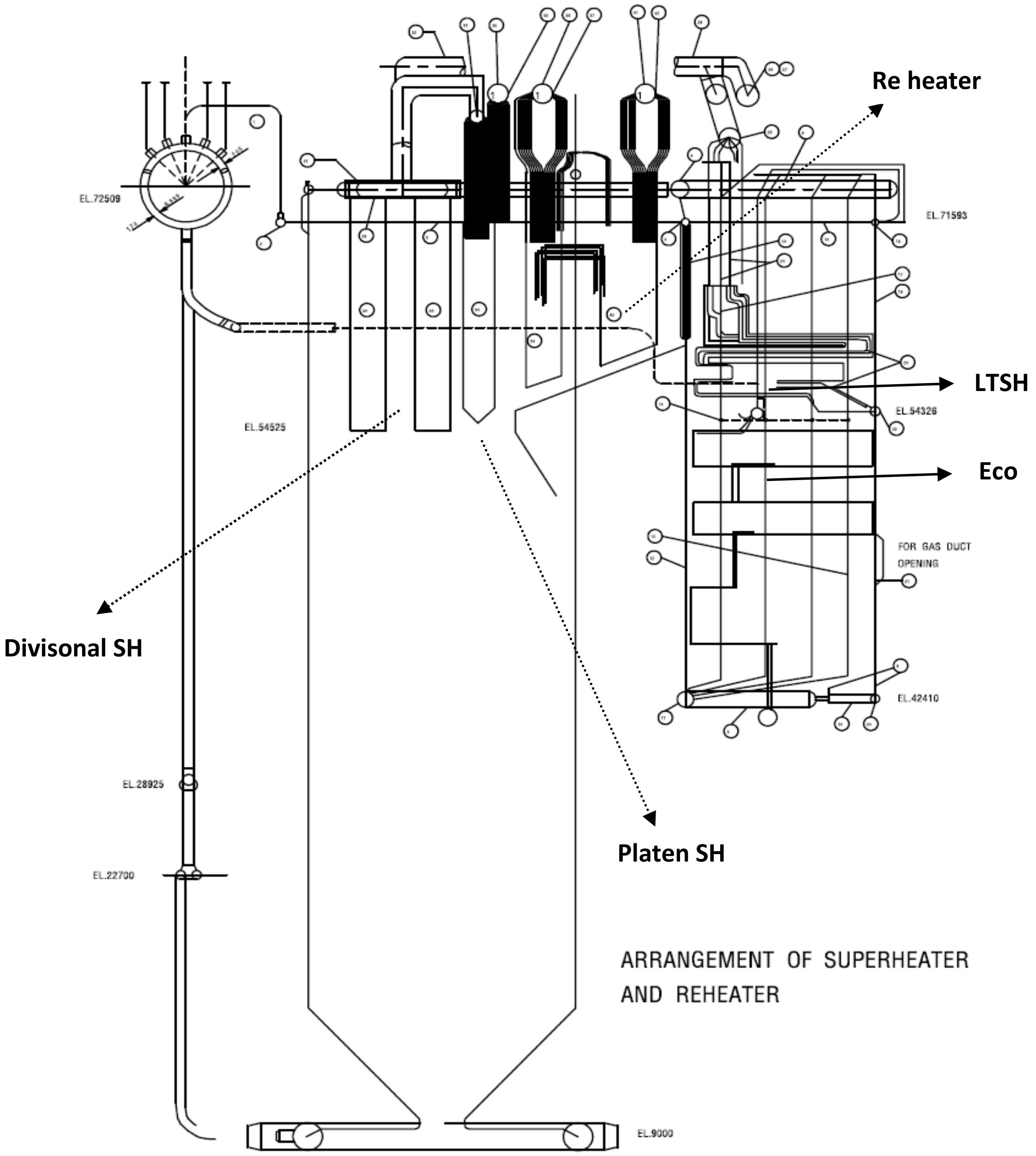

Fig 1 General Arrangement of Superheater & Reheater in Boiler at Stage-II, U#8 VSTPP.

As indicated in Figure 1, steam from drum firstly enters Low temperature super heater (LTSH), followed by Divisonal Super Heater, and then finally Platen Super heater . Between LTSH and Divisional Panel S/H there is system of Super heater Attemperation.

Reheater assembly consists of two sections Radiant Front Platen and Convective Rear Pendant .Reheater attemperation system is provided for emergency temperature control in CRH line.

Fuel Firing Equipment:

The various technical details of coal, HFO,LDO burners are indicated in following Table 2,3,4 respectively

Table 2.Coal Burner Details

1	Type	Tilting Tangential
2	No. of coal burners feed by each mill	8
3	No. of elevation of burners	10
4	Total no. of coal burners	40

Table 3 .HFO Burner Details

1	Type	Tilting Tangential, Corner fired
2	No. of oil guns	20 (4 per elevation)
3	Oil Gun	Parallel pipe design, steam atomised
4	Location of oil guns	Auxiliary air nozzles, AB, CD, EF, GH,JK

Table 4. LDO Burner Details

1	Atomiser Type	External mixed, constant pressure, compresed air atomised.
2	No. of oil guns	4 at AB elevation

As indicated in Fig 2. Secondary over fire dampers (SOFA) consists of two compartments (OFA-U) overfire air upper and over fire air lower dampers (OFA- L).

INTRODUCTION OF BALL & TUBE MILL:

These mills are consisting of a Tube shaped shell containing balls (Fig 2). The BBD 4772 Mills are direct firing type Mills with shell size of 4.7 mtrs. dia and 7.2 mtrs length. These are slow speed Mills and the shell rotates horizontally at 16rpm. The Mills consist of two perfectly symmetrical grinding circuits provided in each end of the Mill shell. Raw Coal from R.C. feeders fall through a chute, pass through a mixing box and the feed pipe. The raw Coal enters into the Mill by means of the Screw Conveyors provided in each end. By-pass air entering the Mixing Box dries the Raw Coal before its entry into the Mill. The screw conveyors push the Raw Coal into the Mill shell for Pulverization. Coal is pulverized mainly by impact and attrition. Balls getting lifted by the Mill shell liners due to rotation fall after reaching a particular height on the Coal and perform pulverization.

Hot Primary air enters the Mill through Screw Conveyor central Tube and lifts the pulverized fuel. The pulverized fuel moves through the annular space between fixed Trunion Tube and rotating Hot Air Tube on its way to the classifier. Coal laden air passes through the double cone static classifiers with adjustable classifier vanes for segregation to produce pulverized fuel of desired fineness. The finer particles move to the burners for combustion in the Boiler and the coarse particles come back into the raw Coal feed pipe for further grinding. The shell always contains Coal (raw and pulverized).

Primary air directly proportional to the Boiler load demand is passed through the Mill. To ensure and maintain sufficient velocity of pulverized fuel and to avoid settling in P.F. pipes, an additional quantity of primary air known as the by-pass air tapped from the primary air duct is fed into the mixing box on raw Coal circuit. Tube Mill output is controlled by regulating the primary air flow, while responding to Boiler load demand. Variation of Boiler load is very fast and is well comparable with oil firing response as it is achieved by varying the air flow through Mill. This is the biggest advantage of the Tube Mills. Fineness obtained with these Mills are very high, which is of the order of 85-90% through 200 mesh sieve and less than 0.5% is retained on the 50 mesh sieve. The unburnt Carbon in bottom ash is 1.8% - 1.9 % and that in fly ash is 0.18% - 0.1

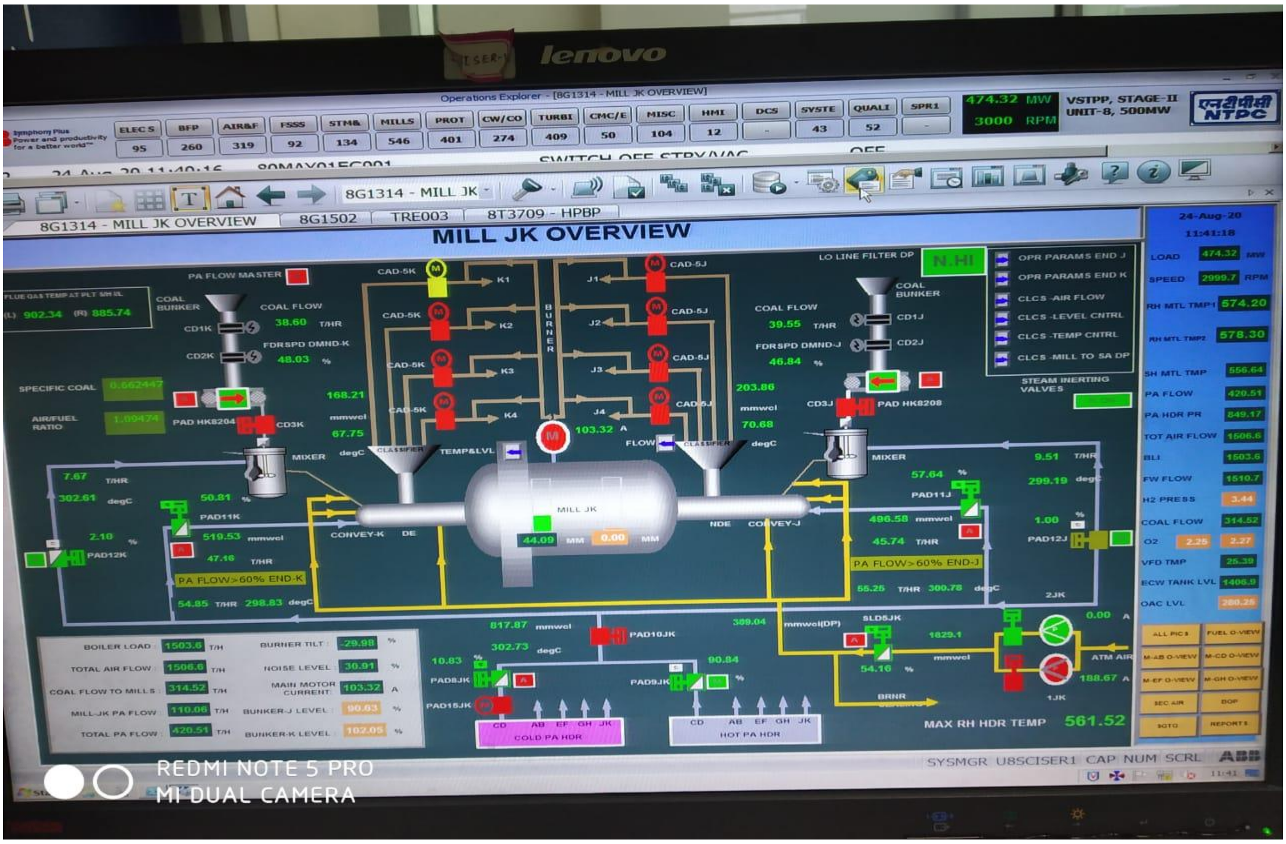

Fig 2. Ball and Tube Mill arrangement as per DCS image

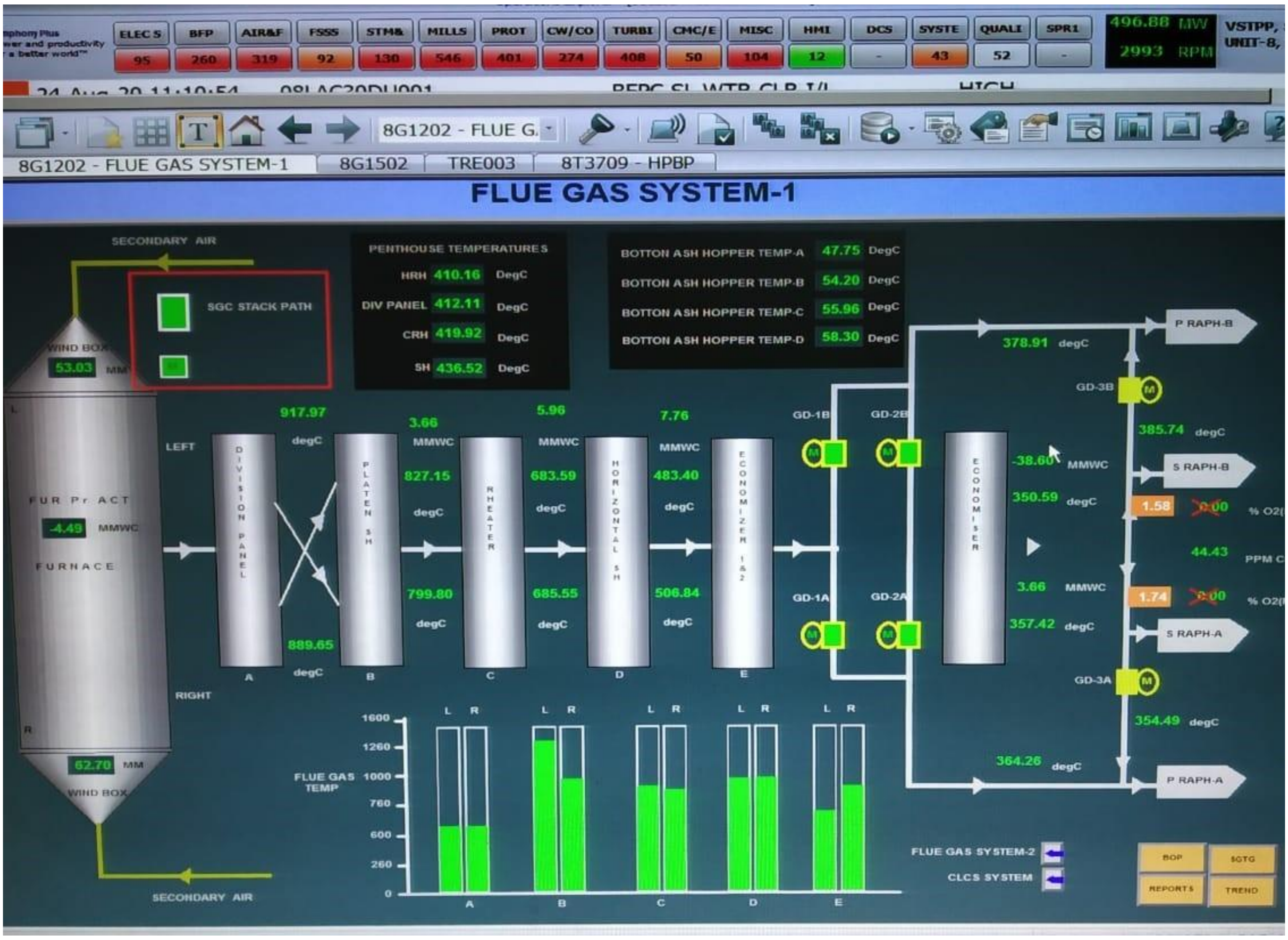

Fig3. Flue Gas Circuit Arrangement at VSTPP , Stage-II, Unit-8 ,BHEL make 500 MW unit

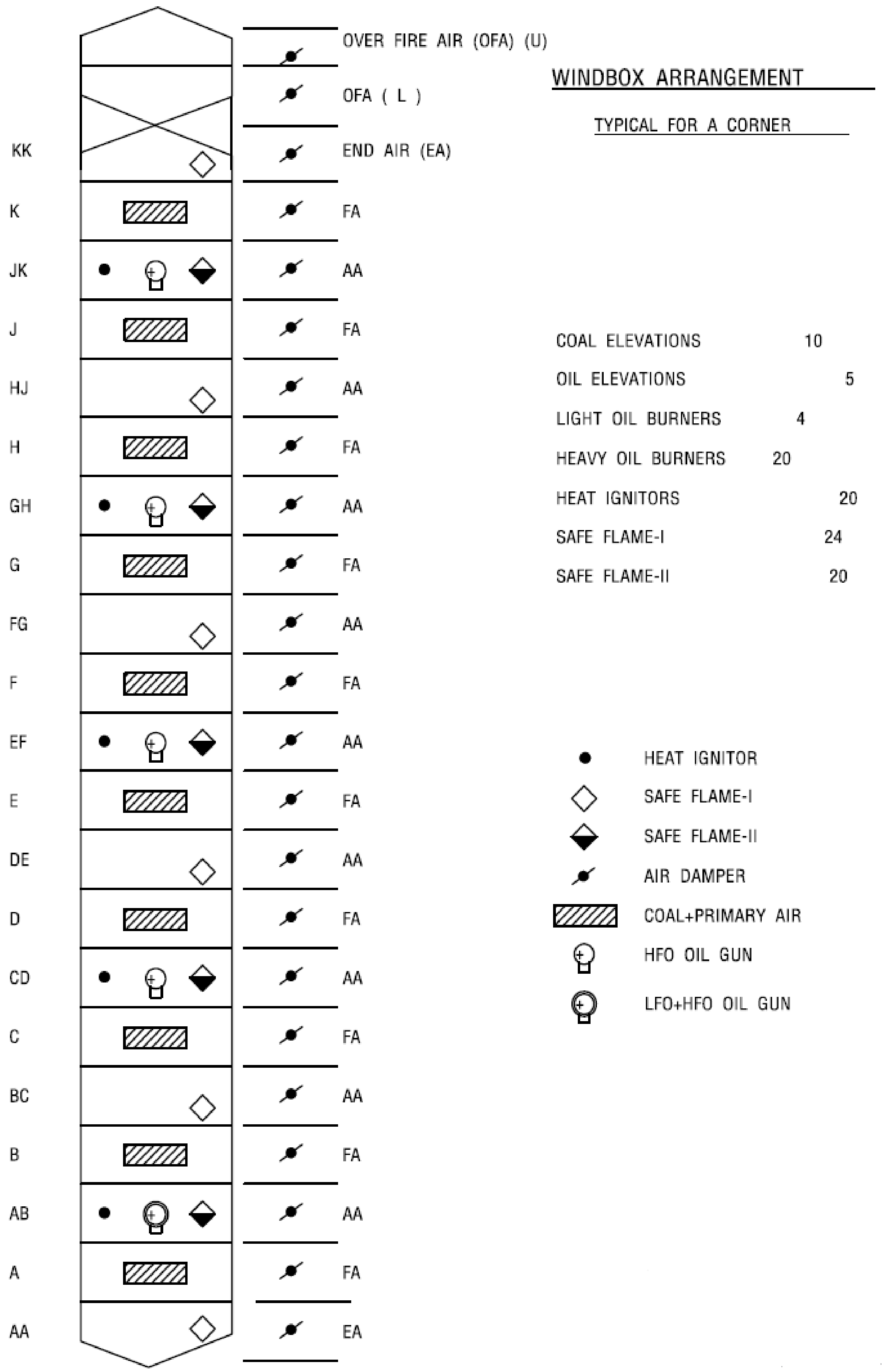

Fig 4. Windbox Arrangement for VSTPP Stage -II, U#8

5.0 Recording process parameters and computing performance matrices

Table 5. Performance Parameters recorded on 21.08.2020 at 479 MW load:

Load	T_g	O_{2in}	O_{2out}	T_{airin}	AL	$T_{gcorrect}$	$T_{gdesign}$
479	152.5	3.4	6.4	38	0.1849	172.79238	134

Fuel CV	Fuel flow	Air flow	$UB_{FA\%}$	$UB_{BA\%}$	CO%	CO_2%	Aa	Ta
3510	335	1592	0.17	2.2	NA	12.86	4.752	38

Table 6. Coal Proximate Analysis:

FC	VM	A	Mw	C
24.4	27	32.7	16.2	0.37761

Table 7. Performance Matrices calculations

Theoretical Air	Ideal EA	Actual EA	Mg	L1	L5	L6	TCL
4.79689	19.3182	-0.931	5.0564	163.575	--	15.22638	178.8

A. Observations:

i) Air leakage percentage is high indicating heavy horizontal seal leakage

ii) Exit gas temperature is significantly high, which needs diagnosis.

iii) Excess air as calculated from actual air (Ideal EA) is coming less than even theoretical air. PA and SA flow measurement is doubtful. Air to coal ratio (Aa) would be more than what we are getting now. This would increase Dry gas loss (L1) significantly. We need to check other parameters to confirm high excess air. Higher excess air also increases load on ID, which already has capacity saturation problem.

iv) Fly ash Un-burnt losses look well under control, however, bottom ash un-burnt needs to be addressed.

Table 8. Mill performance parameters recorded at 495 MW load

Mill	Elevation	Coal flow (T/H)	Air Flow (T/H)	PA/ Coal	Air I/L (C)	Mill O/L (C)	Mill DP (mmwc)
AB	A	48	54	1.13	290	62.8	406
	B	47	54	1.15		64.3	474

CD	C	37	49	1.32	293.95	66.2	415
	D	37	49	1.32		66.7	450
EF	E	44	51	1.16	288.09	64.8	376
	F	41.5	51	1.23		65.7	338
JK	J	40.6	48	1.18	303	70.6	295
	K	40	48	1.2		67.7	353

Table 9. Mill Fineness report as on 24.08.2020

	+50	-200			+50	-200			+50	-200			+50	-200
A1	1.2	78.8		C1	0.4	94.2		E1	1.8	79.8		J1	0.6	87.4
A2	0.2	94.6		C2	0.3	93.7		E2	3.4	77.6		J2	1.4	69.6
A3	0.2	89.4		C3	0.4	91.8		E3	5.6	71.4		J3	0.2	92.6
A4	0.4	88.2		C4	0.2	94.8		E4	2.8	80.0		J4	0.4	82.0
B1	0.2	93.6		D1	0.5	89.5		F1	0.3	92.3		K1	0.4	92.0
B2	0.2	95.6		D2	0.2	96.0		F2	0.2	93.6		K2	0.3	92.3
B3	0.3	88.3		D3	1.6	79.2		F3	0.3	90.3		K3	1.0	84.8
B4	0.4	92.4		D4	2.0	74.8		F4	0.2	96.2		K4	0.2	93.6

Fig 5. Corner wise coal fineness sample collection in progress using cyclone separator .

Observations:

i) High PA to coal ratio in CD mill. The other mills appear to have rated PA flow, but the flow measurement could be incorrect. D elevation coal pipes have been found problematic and coal lifting is an issue. If the flow measurement is incorrect, then this could lead to delayed combustion.

ii) Coal fineness looks quite healthy. But corner A1, D3, E1, J2 and K3 have improper fineness. There could be a problem of corner balancing, which may lead to horizontal shift of flame ball inside the furnace. Both classifier health check and coal pipe balancing are to be carried out.

Table 10. Dirty Air Flow Test Report conducted on 14.07.2020

Mill	Parameter	Unit	C 1	C 2	C 3	C 4	Average
A	Fuel-Air Mixture Velocity	m/ s	29.05	26.88	30.97	31.45	29.59
	Deviation from average velocity	%	-1.82	-9.14	4.67	6.29	
B	Fuel-Air Mixture Velocity	m/ s	29.13	28.45	29.50	28.96	29.01
	Deviation from average velocity	%	0.41	-1.93	1.68	-0.16	
C	Fuel-Air Mixture Velocity	m/ s	25.80	26.19	28.66	27.96	26.65
	Deviation from average velocity	%	-3.20	-1.74	0.04	4.91	
D	Fuel-Air Mixture Velocity	m/ s	27.15	27.17	NA	26.34	26.88
	Deviation from average velocity	%	0.97	1.07	NA	-2.04	
E	Fuel-Air Mixture Velocity	m/ s	27.73	28.53	NA	27.48	27.92
	Deviation from average velocity	%	-0.65	2.21	NA	-1.56	
F	Fuel-Air Mixture Velocity	m/ s	26.38	28.19	27.59	26.99	27.29
	Deviation from average velocity	%	-3.34	3.31	1.12	-1.08	
J	Fuel-Air Mixture Velocity	m/ s	28.99	28.03	30.24	27.78	28.76
	Deviation from average velocity	%	0.81	-2.55	5.15	-3.41	
K	Fuel-Air Mixture Velocity	m/ s	29.27	28.25	27.79	28.31	28.40
	Deviation from average velocity	%	3.04	-0.54	-2.16	-0.33	

Dirty air test showing lower average velocity in C and D mill and deviation more than +/- 5% in A and J mill. These coal pipes are required to be checked.

A. Gas, water and steam side Temperatures at 495 MW Unit Load

Table 11. Gas Side Temperatures versus Design Values

Flue Gas side (On-line)	Design (C)	Actual (C)	Actual (C)
Divisional SH O/L	1142	922.8	882.8
Platen SH Inlet	1142	922.8	882.8
Platen SH O/L	1040	825.2	797.8
Eco I/L	570	483	506
Eco O/L	368	350.5	356.4
PAPH A O/L	134	130.03	
PAPH B O/L	134	127.9	
SAPH A O/L		186	
SAPH B O/L		188.96	
ESP I/L		188.72	188.48
ESP O/L		152	159

Table 12.Furnace Temperature mapping at 495 MW load:

Level	Temperature at Corner			
	1	2	3	4
AB - 21.3M	1015	1288	1085	1228
CD - 25.3M	1108	1120	1105	1150
EF - 28.3M	1012	1148	1106	1014
GH - 31.3M	1108	1141	1133	1231
JK - 34.3M	1280	N/O	1283	1308
37.5M	1205	1283	1292	1228
40.3M	1225	1324	1325	1293
43.5M	1313	N/O	1230	1248
46.5M	1231	1251	1270	1170

Fig 6.Furnace Temperature Mapping in progress using Infrared Pyrometer

Table 13. Water side Temperatures versus Design Values

Water Side Temperature	Design (C)	Actual (C)
LP Heater Inlet	48.4	53.47
LP Heater Outlet	124.2	123.29
DA outlet	165.5	166.7
HP Heater inlet	165.5	170.17
Hp heater outlet	253.4	257
Eco Outlet	318	304.44

Table 14 . Water side Temperatures versus Design Values

Steam side Temperature	Design (C)	Actual (L)	Actual (R)
Primary SH outlet (LTSH outlet)	393	415.04	433.59
First stage Spray Downstream		397	390

MS	540	531.45	534.38
CRH	336	345.7	346.68
RH spray Downstream		281.62	264.55
HRH	540	544	542.65

B. Observations:

i) Furnace dilution can be noted from the gas temperatures near Divisional SH outlet and Platen SH outlet. This indicates higher excess air.

ii) Inlet gas temperature to the economizer is around 80^{o}C less than design temperature. Temperature drop across economizer is around 60^{o}C less than the design temperature drop. Whereas water side temperature pick up in the economizer is only 15oC less than the design heat pick up. This is only possible of the mass flow of gas across the economizer is high, which again suggests high excess air.

iii) LTSH inlet gas temperature is nearly 200^{o}C less than design due to furnace dilution. But LTSH outlet steam temperature is nearly 30^{o}C more than the design temperature, which is resulting higher attemperation spray. This also supports the condition of high gas mass flow.

iv) Furnace temperature mapping indicates horizontal shift of the flame ball at elevation AB and EF. Temperature recorded at 43.5 and 46.5 m elevation at four corners are higher indicating a vertical shift of the fire ball too (Delayed combustion). Whereas the on-line gas temperature measured at inlet to Divisional Super heater shows dilution. There is a possibility that we may have a vertical shift of the fire ball, could be due to higher primary air (which is not showing in the flow measurement) as well as higher fuel air, but it is getting masked in the on-line gas temperature measurement due to furnace dilution

v) Significant gas cooling is taking place across ESP, indicating heavy leakages possibly at the expansion joint, or in the duct. In light of ID capacity saturation problem, this requires serious attention.

Table 15. APH performance parameters:

	Inlet gas (C)	Outlet gas (C)	Outlet gas Design (C)	Inlet air (C)	Outlet air (C)	Outlet Air Design (C)
PAPH A	362.3	128.4	134	49.3	290.77	345
SAPH A	349.61	185.5	134	33.3	348.14	341
PAPH B	377.9	128.17	134	49.3	323.73	345
SAPH B	386.72	188.96	134	33.4	359.86	341

Table 16. Gas side Damper position:

PAPH A	SAPH A	PAPH B	SAPH B
100	100	100	100

Table 17. Performance of Air Pre-Heater & Duct

	Design PAPH/SAPH	PAPH # A	PAPH # B	SAPH # A	SAPH # B
APH Gas Side Efficiency		63.6	72.8	53.0	57.4
Air Preheater X-Ratio	0.73/0.73	0.84	0.87	0.58	0.68
Flue Gas Temperature at APH outlet.	146.4/142.4	159.9	130.7	199.1	194.7
Air Heater Leakage	12.9% / 4.3%	37.6	20.9	9.7	10.7

RAH Inlet (Test Valve)					
	PAPH/SAPH	PAPH # A	SAPH # A	PAPH # B	SAPH # B
O_2 (%)	3.50%	2.65	3.15	3.0	2.75
Pressure (mmwc)	-66	-86	-93	-86	-91
RAH Outlet (Test Valve)					
O_2 (%)	5.7% / 4.3%	8.0	4.80	6.2	4.7
Pressure (mmwc)		-191	-216	-203	-217
Dp (mmWC)		105	123	117	126
APH Air Inlet Temp.		44	33	44	33
APH Air Outlet Temp.		315.7	353.2	336.6	350.1

A. Observations:

i) The SAPH side gas outlet temperature is significantly higher and the PAPH side air temperature is less than design. Since the coal moisture is high and we are getting low mill outlet temperature, SAPH side gas side damper should be throttled, but it cannot be done due to ID saturation.

ii) That the mass flow of gas is less through PAPH is also getting confirmed from the higher X ratio we are getting at the PAPH side

iii) Flue gas side DP is more across SAPH and the gas side efficiency is lower, which suggest APH basket chocking

B. Diagnosis of parameters and preliminary conclusion:

i) All the parameters are suggesting that we are using high excess air, though the measurement contradicts it. It is essential therefore to crosscheck the air flow measurement.

ii) The indication of delayed combustion could be an indication that our PA flow measurement is incorrect and we are using more primary air than desired. The possibility of delayed combustion could be the reason behind metal temperature excursions.

iii) High mass flow of gas is increasing the LTSH heat pick up in the convection pass

iv) There is also a strong indication of horizontal shift of fire ball in the furnace. Due to the uneven heat distribution, this could result both in low RH temperature and metal temperature excursion at some location. The corner flow balancing should be recommended.

v) Due to the use of higher excess air and heavy APH seal leakage and also leakage in the ESP area, the ID load is increasing

vi) If we can achieve some margin in ID capacity by attending some of the leakages in the ESP area, APH performance can be improved by operating the SAPH gas side damper. This by itself can save us a lot of money through reduction of dry flue gas loss

vii) We need to conduct a trial and observe the system response by reducing the PA and also the quantity of total air. We need to reduce the O_2 set point for that during trial. This would also reduce the load on ID, increasing the margin further.

viii) APH seal leakage arresting should be a priority during next opportunity for annual overhauling

6.0 Details of Trial Conducted

Extensive survey of complete flue gas duct circuit was carried out from Economizer outlet to ID fan Outlet by joint team of EEMG, Operation and BMD executives. Using a cloth tied to a long rod all critical approachable areas like manholes, expansion joints, bends were inspected for any cracks ,hissing sound and air ingress.

Later the defects identified were attended by BMD online wherever possible by erection of scaffolding as shown in figures. This exercise was repeated several times over a month. It resulted in creation of margin in ID fan , after which throttling of SAPH A/B outlet dampers was done in next phase of trial.

VSTPP , U#8, on 04.10.2020 , at 08:30 hrs SAPH A/B flue gas side outlet damper throttling was carried out from 100% to 65% in gradual steps of 5% and its impact on APH Flue gas outlet temperature was studied.

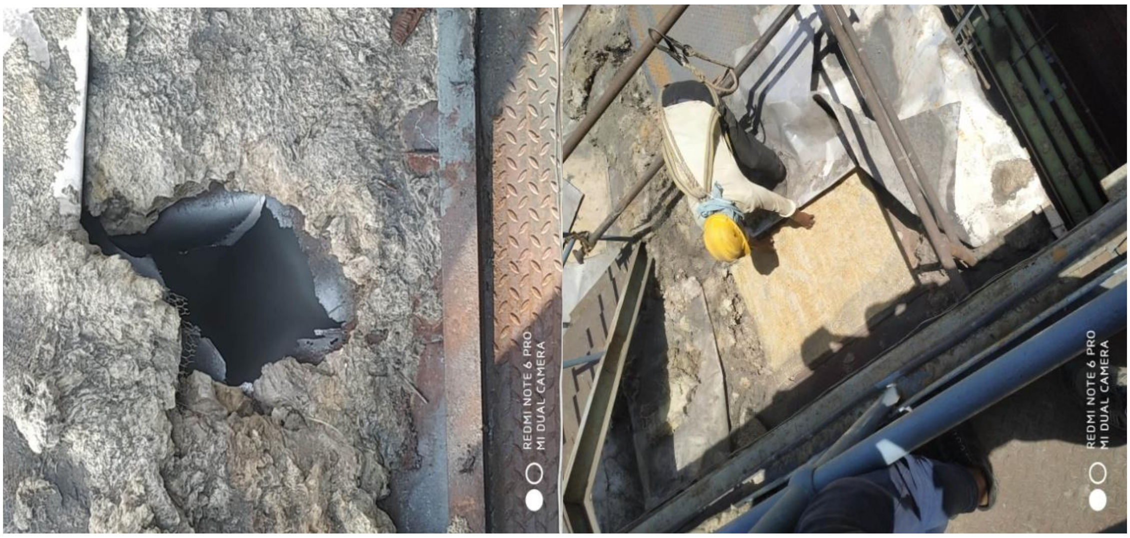

Fig 7. Air Ingress Point at Flue gas duct ,ESP Inlet Top ,(Right) attended online by metallic sheets and insulation mattress and cladding is restored.

Fig 8.Ingress Point found in checking

Fig 9. Approach made with scaffolding

Fig10. **Ingress cracks located**

Fig 11. Air Ingress points plugged

SAPH B damper Actual Value (AV)was reduced to 65.09% as indicated in Fig . SAPH A flue gas outlet damper was having demand feed back mismatch and its position was 82.06% at demand of 65%. No change was made in PAPH A/B flue gas outlet dampers. Further , throttling could not be carried out due to restriction from ID fan current values .

Due to high demand feedback mismatch in SAPH A flue gas outlet damper, it remained almost full open. Throttling of SAPH B outlet damper resulted in reduced flue gas flow through it, while flue gas flow increased through all three remaining APH. The same is reflected in reduced flue gas temperature at SAPH-B outlet ,while in all other APH the flue gas outlet temperature increased due to increased mass flow of flue gas.

Status Before SAPH FG O/L Damper Throttling (04.10.2020,08:30 hrs)				
Parameter	**SAPH-A**	**SAPH- B**	**PAPH- A**	**PAPH- B**
Flue Gas Outlet Damper Position (%)	**100%**	**100%**	**100%**	**100%**
Flue Gas outlet Temperature(C)	**176.76**	**184.81**	**124.51**	**119.14**
Average Flue Gas outlet Temperature (C)	**151.30**			
Dry Flue Gas Loss (Kcal/ Kg coal)	**160.5**			

Status After SAPH FG O/L Damper Throttling ((04.10.2020,08:43 hrs)				
Parameter	**SAPH A**	**SAPH B**	**PAPH A**	**PAPH B**
Flue Gas Outlet Damper Position (%)	**82 %**	**65%**	**100%**	**100%**
Flue Gas outlet Temperature (C)	**179.69**	**174.56**	**125.98**	**121.34**
Average Flue Gas outlet Temperature (C)	**150.39**			
Average Flue Gas outlet Temperature Reduction (C)	**0.91**			
Dry Flue Gas Loss (Kcal/ Kg coal)	**156.3**			
Dry Flue Gas Reduction(Kcal/ Kg coal)	**4.2**			
Annual Monetary Gain (Lakhs)	**64.7**			

*****Assuming cost of coal Rs 2000/Ton, GCV =3500 Kcal/Kg , Coal Cons =340 T/H, Average Running Hrs. = 8000 hrs

* Coal properties are assumed to be constant for the one hour study period.

In tube mills , required PA flow through the mill for a particular quantity of coal , is a function of the ball ,liner condition inside the mills. In Mill CD liner replacement ,ball sorting is required for reducing the quantity of primary air. These jobs will be taken during upcoming overhauling in Mill CD along with other mills. Therefore trial by reducing quantity of Primary Air in mills is not possible without sacrificing unit load .

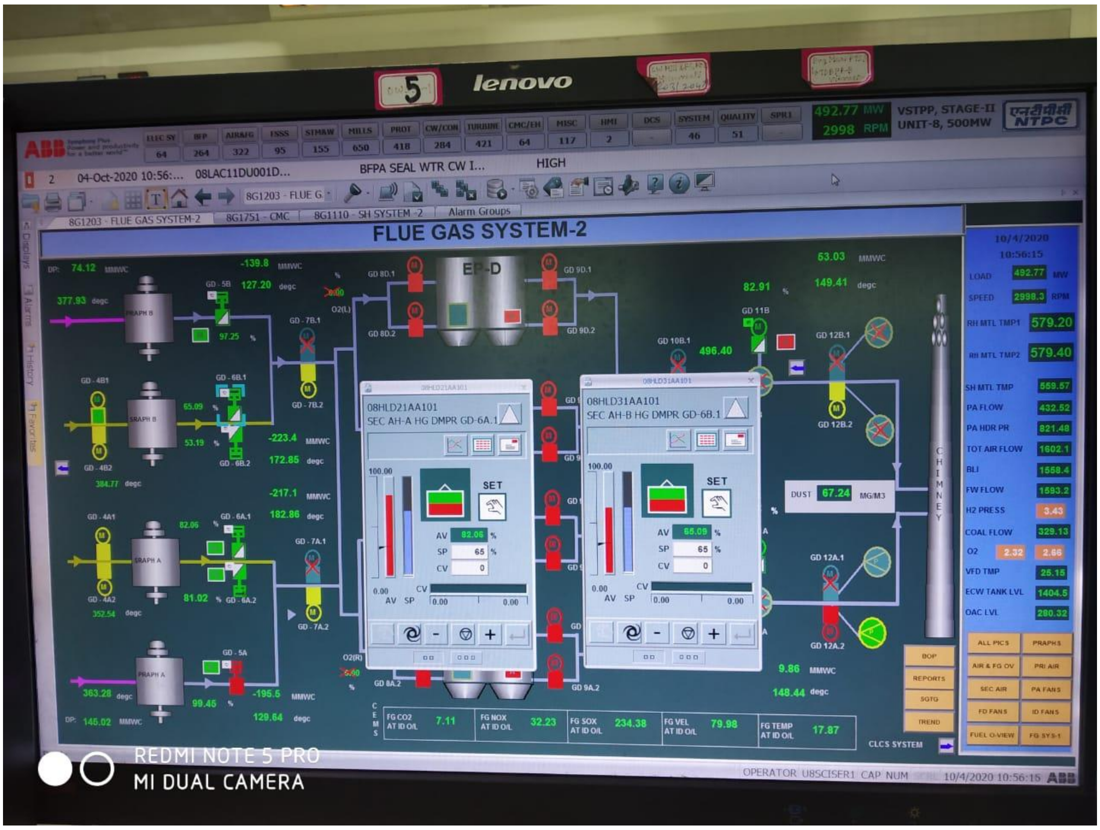

Fig 12. SAPH A/B Flue Gas Outlet Damper Throttling DCS Image .

Fig 13.Trend of Flue Gas Outlet Temperature post throttling

7.0 . Road Map and Future Action Plan

Installation of online coal flow / fineness measurement and control

Optimization of the combustion process inside coalfired boilers can be achieved by installation of online coal flow measurement and control and online coal fineness measurement . The system automatically balances the coal flow from pipe to pipe and monitors continuously the flow behaviour. In combination with the online measurement of particle fineness the combustion efficiency, unburnt carbon and fouling are continuously optimized.

The coal flow measuring system is designed to work continuously in closed-loop. It can be easily integrated into an existing monitoring & control environment. The controller adjusts the valves automatically so as to maintain constant air-fuel rations at the burner levels. Additionally, the mill and the classifier are adjusted according to the readings of the coal flow and the size spectrum.

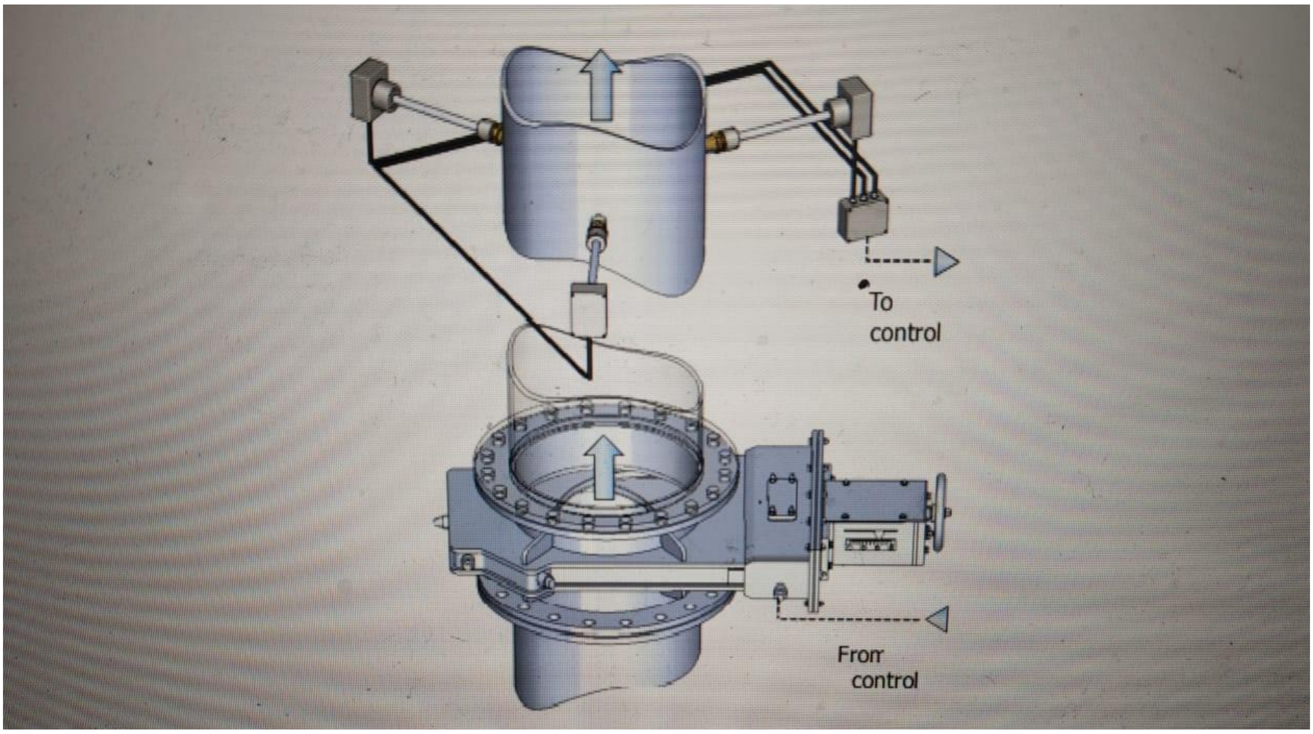

Fig 14. Closed Loop Control Set Up with adjustable Orificing Valve

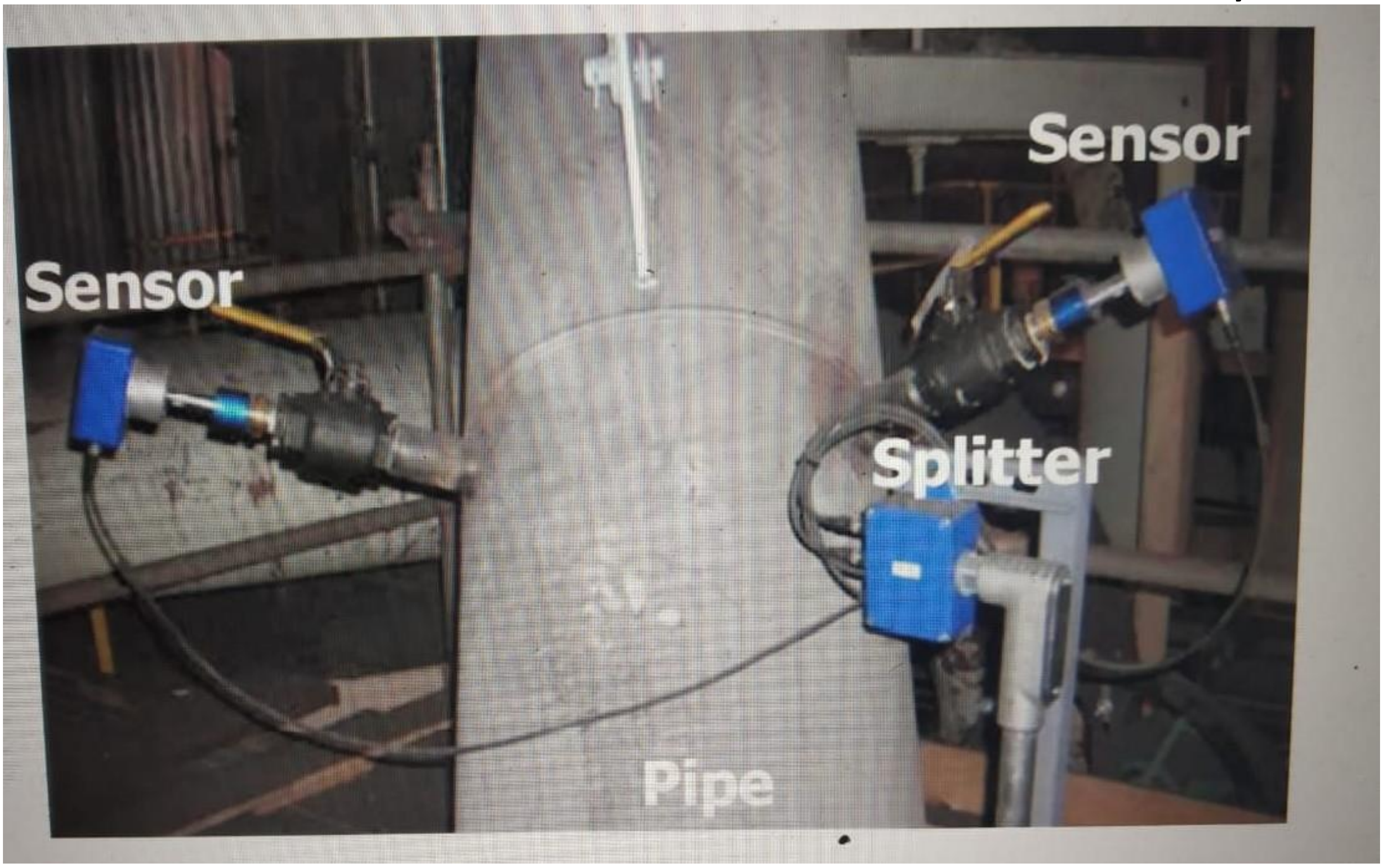

Fig 15. Configuration of Microwave sensors at a pipe.

Cost Benefit Analysis for installation of EU Tech Coal Flow Monitor in U#8

Table 18. Benefit Analysis

S.No	Parameters	Units	Design	Data Recorded during Monthly Unit Efficiency Test					
1	Test Date			10 Apr	25 May	23 Jun	24Jul	20 Aug	23 Sep
2	Unit Load	MW	500	491.2	482.5	494.5	494.5	497.0	490.2
3	SH spray	T/H	0	76.4	41.8	36.6	78.1	46.6	55.4
4	HR Loss (SH spray)	kcal/kWh		3.1	1.7	1.5	3.1	1.9	2.2
5	RH spray	T/H	0	36.8	29.2	38.1	49.2	31.7	34.4
6	HR Loss (RH spray)	kcal/kWh		8.8	7.0	9.1	11.8	7.6	8.3
7	HRH Temp	C	537	532.1	528.3	529.5	531.7	531.2	525.5
8	HR Loss(HRH temp)	kcal/kWh		2.9	5.1	4.4	3.1	3.4	6.8
9	Cumulative HR Loss	kcal/Kwh		14.8	13.8	15.0	18.1	12.9	17.3
10	Average HR Loss	kcal/Kwh		15.3					
11	Monetary Loss	Rs		1,30,010					
12	Annual Monetary Loss	Lakhs		475					

13	Average BTL Annually	Nos		4					
14	Annual BTL cost	Lakhs		200					

*1 kcal/Kwh is equivalent in monetary terms to Rs 8,500 daily for a pithead station like NTPC VSTPP

* Cost of one BTL is taken as 50 Lakhs.(It includes Generation loss, DSM Loss, Start Up Oil cost ,DM water cost)

*Assuming 25% reduction in monetary heat rate loss on account of SH/RH spray & HRH temp loss ,and 25% reduction in BTL cost ,cumulative benefit comes out to be Rs 168.75 Lakhs.

Table 19. **Cost Analysis**

1	EU coal sizer mobile	Lakhs	79.9
2	EU coal flow mobile	Lakhs	61.1
3	Total Cost	Lakhs	141
4	Payback period	Years	0.83

8.0. Conclusion

In units with delayed overhauling , draft power optimization can be achieved by thorough flue gas duct inspection and online attending of air ingress locations. Various unit efficiency testing revealed that achieving individual coal pipe balancing is the key for reduction of attemperation sprays and achieving optimum combustion.

Long term road map involves optimization of the combustion process inside coalfired boilers by installation of online coal flow measurement and control and online coal fineness measurement .Cost benefit reveals that payback period is less than a year under conservative estimate. Initial pilot project can be carried out by installation of one mobile EU coal sizer and coal flow mobile and further analysing the gains .

These systems can go a long way in reduction of clinkering ,boiler tube leakages, achieving design attemperation , HRH temperatures. Generation loss due to high flue gas temperature at divisional Super heater outlet can also be avoided due to shifting of fire ball (whenever bottom mills are under maintenance).

Study and Analysis of Boiler system performance through Diagnosis of process parameters

AT

NTPC - Rihand

Submitted by

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STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR STAGE 3, UNIT 5 BY RIHAND TPS

SUB INDEX

Diagnosis of Boiler through process parameters

Objective: - Identification of performance irregularities in Boiler system through Diagnosis of process parameters. Study and analysis of process parameters of stage_3_, unit 5, (2X 500MW) boiler system was carried out after the completion of the training workshop for this purpose.

Methodology:

A. **Recording process parameters and computing performance matrices**
B. **Identification of irregularities**
C. **Diagnosis of possible root causes**
D. **Conducting trial after minor changes of process conditions to validate**
E. **Conclusion and suggestions**

Introduction:

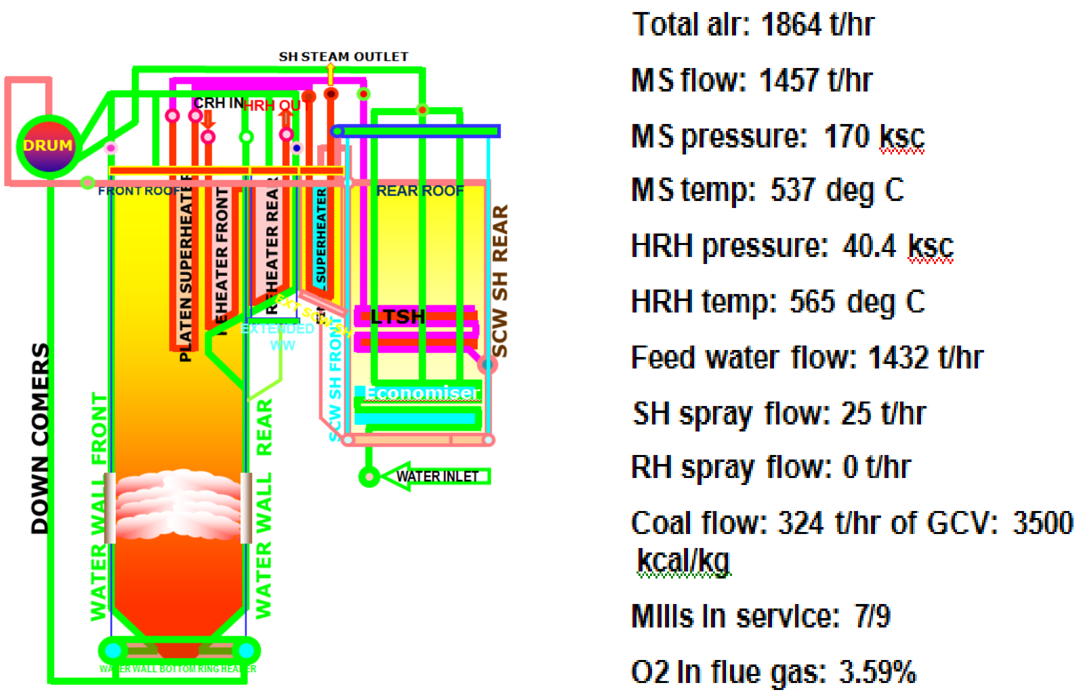
A steam power plant consists of a boiler, steam turbine and generator, and other auxiliaries. The boiler generates steam at high pressure and high temperature. The steam turbine converts the heat energy of steam into mechanical energy. The generator then converts the mechanical energy into electric power.

We can find out any deviation from design by monitoring the Boiler process parameters. Any deviation in the process parameter indicates that there is a certain problem in the system and there may be a deviation from the field condition. The objective is to identify the parameters that have deviated from the prevailing field condition and diagnose the problem with reasonable accuracy and to take the necessary actions to improve the efficiency of the boiler.

An analysis of the flue gases leaving the boiler is invaluable as an index of complete, economical combustion. Combustion should be completed before the gases leave the furnace. The presence of carbon monoxide (CO) in the flue gas indicates incomplete combustion. The best percentage of excess air is to be used to ensure complete combustion will depend upon the nature of the fuel, design of the fuel burning equipment as well as other factors. The most desirable excess air for different rates of evaporation must be established for the particular installation.

Overview of the system:

Fig.1 Over view of Boiler internal arrangement.



Typical schematic Diagram of power plant:

A. Parameters recorded for Exit gas temperature on 18.08.2020:

In the initial phase, we have conducted a test in Rihand stage-3 unit 5 for recording of boiler process parameter for analysis point. We have recorded oxygen % and temperature at Eco out let, APH inlet and outlet for finding the excess air and % APH seal leakage. At the same time by the coordination from chemistry coal sample has been taken from running coal feeders & for calculation of unburnt carbon loss, Bottom ash and fly ash sample were taken.

Load	Equipment	Tg(FGET)	O_2 in	O_2 Out	T air in	Air Heater lkg	Tg(Correct)	Tg(Design)
493	**PAPH A**	160	4.8	7.6	42	18.81	182.17	125
	PAPH B	153	4.4	7.4	44	19.85	174.78	125
	SAPH A	139	3.7	5.6	35	11.10	150.16	125
	SAPH B	131	3.8	5.5	36	9.87	140.34	125
	Average	146	4.2	6.5	39	14.61	161.9	125

Coal Proximate Analysis:

M	A	VM	FC	GCV
16	29.48	23.35	31.17	4111

B. Observations:

I. Exit gas temperature is very high which is leading to high dry flue gas loss.
II. High APH seal leakage

A. Parameters recorded for controllable losses:

Load	Coal flow	Air flow	Air/ coal	$Tg_{(Correct)}$	T Air	UB% (FA)	UB% (BA)	CO %	CO_2 %
493	261	1709	6.55	161.9	39.27	0.3	0.6	6	14.5

Factors influencing Performance of Boiler:-

Flue gas

- Dry flue Gas Loss
- Loss due to moisture in fuel
- Loss due to Hydrogen in Fuel
- Loss due to moisture in air
- Loss due to Carbon monoxide
- Loss due to sensible heat in Fly ash

Ash

- Loss due to Unburnt Carbon
- Loss due to sensible heat in Fly ash
- Loss due to sensible heat in Bottom Ash

The various losses associated with the operation of a boiler are given below.

- Heat lost with dry flue gas through chimney

  = mg x Cg x (Tg - Ta) kcal/ kg of fuel
- Heat loss due to moisture formed by combustion of Hydrogen in fuel

  = 9H x {584 + 0.45 x (Tg - Ta)} kcal/ kg of fuel
- Heat loss due to moisture present in fuel

  = Mw x {584 + 0.45 x (Tg - Ta)} kcal/ kg of fuel
- Heat loss due to moisture present in combustion air

  = Ma x FH x 0.45 x (Tg - Ta)} kcal/ kg of fuel
- Heat Lost due to incomplete combustion

  = C x {CO% / (CO% + CO2%)} x 5654 kcal/ kg of fuel
- Heat lost due to un-burnt

  = M_{ash} x {0.8 x (UB_{FA}%/ 100) + 0.2 x (UB_{BA}%/ 100)} x 8084 kcal/ kg of fuel

- Sensible Heat lost due to fly ash = 0.8 x Mash x 0.2 x (Tg - Ta) kcal/ kg of fuel
- Sensible Heat lost due to bottom ash = 0.2 x Mash x 0.2 x (Tash - Ta) kcal/ kg of fuel
- Heat Lost due to radiation and convection: Based on ABMA curve, radiation losses is assumed as 0.4% for power station boiler.

Conversion formula for proximate analysis to ultimate analysis:-

%C = 0.97C + 0.7 (VM + 0.1A) - M (0.6- 0.01M)
%H2 = 0.036C + 0.086 (VM- 0.1xA) - 0.0035M2 (1- 0.02M)
%N2 = 2.10 - 0.020 VM
Where C = % of fixed carbon
A = % of ash
VM = % of volatile matter
M = % of moisture

One way of assessing and improving the performance is to ensure that minimum heat is lost in the system.
These are the controllable losses by the given below formula we can calculate it and control it.

1. **Heat lost with dry flue gas through chimney**
2. Heat Lost due to incomplete combustion
3. Heat lost due to un-burnt

Mass of dry flue gas Mg = (Aa + 1) – (A + 9H + Mw)
Aa = (FD flow + PA flow)/ Fuel flow

H = 0.036FC + 0.086 (VM - 0.1xA) -0.0035Mw2 (1- 0.02Mw)

A, Mw and VM are ash, moisture and volatile matter from the proximate analysis Respectively in kg per kg of fuel.

Performance Matrices calculations: By using the above controllable losses formula we can calculate losses by captured boiler process parameter.

Descriptions	**Kcal/ kg of coal**
Heat lost with dry flue gas through chimney	202.70
Heat Lost due to incomplete combustion	0.10
Heat lost due to un-burnt	8.58
Total Controllable losses	211.38

Excess air as calculated from O_2 at Eco out: 22.09%

Excess air as measured from actual air to fuel ratio: 26.45%

B. Observations:

- Very high dry flue gas loss. We should try to reduce it to less than 150 kcal/ kg of coal
- Air/ coal ratio appears to be quite high, which could be the reason behind high dry flue gas loss
- Un-burnt losses appear to be within limit. We can try to reduce the fly ash un-burnt percentage by a little margin though (< 0.1 %) to match the best practices.

A. Mill performance parameters:

Mill	Load	Coal flow	Air flow	PA/ coal	Des. Air/ coal	Air I/L temp.	Mill O/L temp	Mill DP	APH O/L Air temp	CAD
A		40	95	2.375		257	76	161		0%
B		45	102	2.27		274	69	223		0%
C		47	97	2.06		263	72	192		0%
D	518	45	107	2.38	92.7/46.7 = 1.98	262	64	141	296	0%
F		47	108	2.30		257	64	176		0%
G		45	98	2.18		280	81	211		0%
J		45	101	2.24		293	75	189		0%

B. Observations:

i) High PA to coal ratio in A, B, D, F and J mill. This was on account of the biasing given to each mill to attain the Mill O/L temperature.

ii) The Mill air inlet temperature of A, B, C, D and F mill is decreasing by 30-40 degree despite the CAD is full close. **This clearly indicates we have CAD passing.**

iii) It is detrimental to the combustion condition if we increase PA quantity to increase Mill O/L temperature. No significant issues were observed when we are operating with low Mill O/L temperature.

A. Mill Fineness Report:

Mill	CP1		CP2		CP3		CP4	
	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh
A	70	0.6	70	0.6	70	0.6	70	0.6
B	71	0.5	71	0.5	71	0.5	71	0.5
C	73	0.4	73	0.4	73	0.4	73	0.4
D	72	1.1	72	1.1	72	1.1	72	1.1
F	70	0.8	70	0.8	70	0.8	70	0.8
G	71	0.9	71	0.9	71	0.9	71	0.9
J	74	0.6	74	0.6	74	0.6	74	0.6

B. Observations:

i) All four coal pipes of individual Mill are showing similar fines, which means; samples from all four coal pipes are mixed to get average sieve analysis. We need to check the results for individual coal pipes to identify imbalance of coal flow in the coal pipes.

ii) Both - 200 and + 50 Mesh size looks poor. We need to target >75% for – 200 Mesh and < 0.1% for + 50 Mesh**.**

A. SADC position:

Mill	Fuel air damper(CAD)	Auxiliary damper	Wind box DP
A	18	63	75
B	18	62	
C	18	61	
D	19	62	
F	19	62	
G	18	63	
H	14	62	

B. Observations:

i) Coal Air Damper of mills is ok. Maximum opening at full load of feeder is 20%.

ii) Wind Box DP is reasonable even with high Auxiliary Air Damper opening. This could be because of higher quantity of SA flow through wind box.

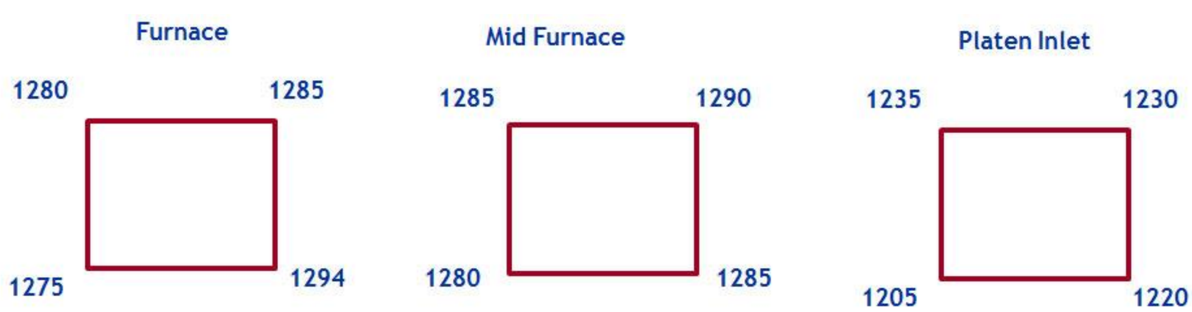
A. Gas, water and steam side Temperatures

Flue gas side	Actual	Design
Furnace		
Platen SH inlet	-	1111
Final SH inlet	990	1009
FEGT	778	
ECO inlet	515	535
ECO outlet	330	349
APH outlet	161.9	125

Water side	Actual	Design
LP Heater inlet	55	49.5
LP Heater outlet	131	125.7
DA outlet	168	163.5
HP Heater inlet	171	163.5
HP Heater outlet	250	253
ECO outlet	315	317
Drum/ separator outlet	346	361

Steam side	Actual	Design
After LTSH	419/412	
MS spray	26/33	25
Before divisional	397/402	
MS	540/538	537
Before CRH d/s	343/346	337
RH spray	14/11	0
After CRH d/s	332/330	
HRH	553/554	565

Furnace temperature Profile measured with IR pyrometer:



B. Observations:

i) Online gas temperatures at FSH inlet and in the second pass appear to be in line and so are the waterside temperatures. But the furnace temperature profile created with IR pyrometer measurement shows irregularities at the mid-furnace (around 42 m elevation) and platen inlet (around 52 meter elevation). Horizontal positioning of the fireball appears to be correct, but there is an indication of vertical shift towards upper part of the furnace.

ii) MS attemperation spray is high, which supports the temperatures as observed.

iii) RH temperature is low, but spray is high on due to RH spray valve passing.

iv) Economizer outlet (APH inlet) gas temperature is less than rated, whereas APH outlet gas temperature is high, which indicates the problem could be due to performance issues in the APH and due to higher use of excess air.

A. APH performance parameters:

	I/L Gas	O/L Gas	O/L Gas (Design)	I/L Air	O/L Air	O/L Air (Design)
PAPH A	350	182.17	125	45	298	324
PAPH B	351	174.78	125	46	293	324
SAPH A	373	150.16	125	38	343	326
SAPH B	351	140.34	125	38	333	326

Gas side Damper position:

PAPH A	SAPH A	PAPH B	SAPH B
100	75/75	100	75/75

B. Observations:

i) The PAPH side gas outlet temperature is contributing more towards high gas exit temperature

ii) PAPH air outlet temperature is less than rated temperature. This could be due to high PA flow

iii) SAPH side gas damper could be throttled a little more as SAPH outlet air temperature is more than rated temperature

iv) Gas side efficiency is low; gas side DP needs to be monitored for basket fouling identification

C. Diagnosis of parameters and preliminary conclusion:

i) APH horizontal seal leakage can be seen.

ii) Heavy passing of the Cold Air Damper.

iii) Very high exit gas temperature could be because use of high excess air, passing of coal air damper as well as APH fouling.

iv) High dry flue gas loss resulting due the above issue.

v) Mill Fineness is poor. +50 mesh size should be brought down to less than 0.2% while -200 mesh size should be targeted at more than 75% .

vi) Coal air and PA quantity to mills are high.

vii) Furnace temperature profile indicates possibility of vertical shift of the fireball towards upper furnace area.

viii) MS spray is high, which could be the result of the vertical shift of fireball.

ix) RH spray valve passing is depressing RH temperature. Burner Tilting is being kept at less than 50% to increase RH temperature. This is further creating higher heat pick-up in the SH area leading to more spray. This condition could be very critical as it may lead to SH tube failures, if not controlled.

D. A trial was conducted on 7th September 2020 after reducing the PA quantity to each mill to nearly the rated quantity and the parameters were monitored once again. The total air to coal ratio was reduced to 5.93 instead of 6.54. Coal fineness was measured individually at four coal pipes in one of the mills.

The comparative parameters are as under:

Controllable losses:

Heat losses in kcal/ kg of fuel	18.08.2020	07.09.2020
Heat lost with dry flue gas through chimney	202.70	166.00
Heat Lost due to incomplete combustion	0.10	0.17
Heat lost due to un-burnt	8.58	9.19
Total Controllable losses	211.38	175.36
GCV of fuel	4111	3622
% Loss	5.14%	4.84%

Marginal improvement in total controllable losses

Mill parameter:

Mill	18.08.2020		07.09.2020	
	Air I/L temp.	Mill O/L temp	Air I/L temp.	Mill O/L temp
A	257	76	--	--
B	274	69	278	66
C	263	72	263	65
D	262	64	290	60
E	--	--	274	64
F	257	64	--	--

G	280	81	286	73
H	--	--	297	65
J	293	75	--	--

The air inlet temperature has improved and the mill o/l temperature has reduced marginally.

Coal fineness in individual coal pipes of Mill B

Date	CP1		CP2		CP3		CP4	
	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh
18.08.2020	71	0.5	71	0.5	71	0.5	71	0.5
07.09.2020	68	0.5	74	0.3	72	1.3	76	0.3

There is significant difference in fineness between Coal pipe 1 and 3. The Synchronization of classifier blade angles and lengths are required to be checked.

SADC position:

Mill	18.08.2020		07.09.2020	
	Fuel air damper	Auxiliary damper	Fuel air damper	Auxiliary damper
A	18	63	--	--
B	18	62.0	20	75
C	18	61	20	75
D	19	62.0	20	75
E	--	--	20	75
F	19	62	--	--
G	18	63	20	75
H	--	--	20	75
J	14	62.0	**--**	**--**

With coal air damper at 20%; 75% opening of auxiliary air damper to achieve wind box DP of nearly 80 mmWC. We need to check by reducing the SA by some margin as the total air needs to be reduced

APH performance:

18.08.2020	I/L Gas	O/L Gas	O/L Gas (Design)	I/L Air	O/L Air	O/L Air (Design)	Gas damper
PAPH A	350	182.17	125	45	298	324	100
PAPH B	351	174.78	125	46	293	324	100
SAPH A	373	150.16	125	38	343	326	75
SAPH B	351	140.34	125	38	333	326	75

07.09.2020							
PAPH A	358	182.3	125	45	310	324	100
PAPH B	352	164.6	125	45	300	324	100
SAPH A	391	155.7	125	37	349	326	75
SAPH B	358	148.3	125	38	326	326	75

In both cases the SAPH side damper was 75% and PAPH side damper was 100% open. Though the PA flow on 07.09.2020 was reduced, PAPH O/L gas temperature has not increased. PA temperature has improved marginally, but still less than design temperature. We therefore need to throttle the SAPH side gas damper further and check the result.

During the IBR shutdown in September 2020, the CAD passing was partially attended. On 30th September a fresh set of parameters were recorded after reducing the PA and SA by a small margin. Let us compare the parameters recorded on 30.09.2020 at 514 MW load with coal flow 322 TPH, Air flow 1724 TPH and GCV of fuel 3412 kcal/ kg against that recorded on 31.08.20202 at 518 MW load with coal flow 313 TPH, air flow 1717 TPH and GCV of fuel 3741 kcal/ kg:

Mill parameters on 31.08.2020

Mill	Load	Coal flow	Air flow	Des. Air/ coal	Air I/L temp.	Mill O/L temp	Mill DP
A	518	40	95	92.7/46.7	257	76	161
B		45	102	92.7/46.7	274	69	223
C		47	97	92.7/46.7	263	72	192
D		45	107	92.7/46.7	262	64	141
F		47	108	92.7/46.7	257	64	176
G		45	98	92.7/46.7	280	81	211
J		45	101	92.7/46.7	293	75	189

Mill parameters on 30.09.2020

Mill	Load	Coal flow	Air flow	Des. Air/ coal	Air I/L temp.	Mill O/L temp	Mill DP
A	514	45	101	92.7/46.7	269	75	205
B		45	101	92.7/46.7	266	68	231
C		46	99	92.7/46.7	248	73	182
E		45	102	92.7/46.7	282	75	201
F		47	102	92.7/46.7	255	64	193
G		45	101	92.7/46.7	281	86	226
J		45	101	92.7/46.7	287	78	188

It can be observed that there is no considerable gain in the mill inlet temperature which shows the CAD passing could not be corrected.

Controllable losses:

Heat losses in kcal/ kg of fuel	31.08.2020	30.09.2020
Heat lost with dry flue gas through chimney	162.54	160.48
Heat Lost due to incomplete combustion	0.14	0.07
Heat lost due to un-burnt	6.63	10.14
Total Controllable losses	169.31	170.69
GCV of fuel	3741	3412
% Loss	**4.52%**	**5.00%**

No significant change in the controllable loses, in fact a little increase can be observed. The total air is required to be reduced further.

Furnace temperature mapping:

On 31.08.2020

Furnace Elevation	Corner 1	Corner 2	Corner 3	Corner 4
3m above top burner	1275	1280	1285	1295
Mid furnace	1280	1285	1290	1285
Platen SH inlet	1205	1235	1230	1220

On 30.09.2020

Furnace Elevation	Corner 1	Corner 2	Corner 3	Corner 4
3m above top burner	1295	1285	1299	1295
Mid furnace	1251	1240	1255	1271
Platen SH inlet	1153	1190	1192	1172

Platen inlet gas temperatures have come down by small margin

On line gas temperatures:

Location	31.08	30.09	Design
Final SH inlet	990	940	1009
FEGT	778	765	
ECO inlet	515	516	535
ECO outlet	330	340	349
APH outlet	141	142	125

Waterside temperatures:

Location	31.08	30.09	Design
LP Heater inlet	55	55	49.5
LP Heater outlet	131	131	125.7
DA outlet	168	166	163.5
HP Heater inlet	171	170	163.5
HP Heater outlet	250	252	253
ECO outlet	315	313	317
Drum/ separator outlet	346	346	361

Steam side temperature:

Location	31.08	30.09	Design
After LTSH	419/412	420/410	
MS spray	16/23.5	36/52	25
Before divisional	397/402	389/ 392	
MS	543/539	545/ 545	537
CRH d/s	347/348	349/352	337
RH spray d/s	14/15	15/19	0
HRH	558/559	565	565

SH spray and MS temperature have increased

On 31.08.2020

	I/L Gas	O/L Gas	O/L Gas (Design)	I/L Air	O/L Air	O/L Air (Design)	Damper position
PAPH A	350	147	125	45	298	324	100
PAPH B	351	137	125	46	293	324	100
SAPH A	373	141	125	38	343	326	75
SAPH B	351	139	125	38	333	326	75
	Avg	**141**					

On 30.09.2020

	I/L Gas	O/L Gas	O/L Gas (Design)	I/L Air	O/L Air	O/L Air (Design)	Damper position
PAPH A	351	140	125	45	296	324	100
PAPH B	350	126	125	44	285	324	100
SAPH A	365	154	125	37	345	326	65
SAPH B	360	148	125	36	330	326	65
	Avg	**142**					

No significant change in APH parameters

E. Conclusion and suggestions

Unit 5 was taken under short shut down on 23.09.2020, during which many defects were attended.

I. To some extent Mill CAD passing was attended, but still some passing was observed. By doing so mill inlet temp slightly increased. CAD passing will be attended during OH for increasing MILL outlet temp.

II. APH hot washing done during short shut down. By doing so APH DP across flue gas and Air significantly reduced.

III. RH spray valve passing is attended and Slight improvement was observed in RH O/l Temperature. During OH RH spray passing will be attended to increase RH temp. upto design value.

IV. Though the dry flue gas losses is slightly decreased but total controllable losses is increased due to increase of unburnt carbon losses. Both bottom and fly ash unburnt carbon % is closely monitored through isokinetic sampling .Regular mill maintenance is done for unburnt carbon loss deduction.

V. O_2 optimisation is regularly done to reduce dry flue gas losses.O2 mapping from Eco. Outlet to ID outlet to reduce draft power.

VI. PA to coal ratio was earlier 2.3, now with optimisation it has been reduced to 2.0.

A REPORT ON

STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE THROUGH DIAGNOSIS OF PROCESS PARAMETER

BONGAIGAON THERMAL POWER STATION (3 X 250 MW)
SALAKATI, ASSAM

SUBMITTED BY

Shri. H. BENJAMIN MAWIKHANLAL SIMTE
MGR (OPERATION)

UNDER THE GUIDANCE OF

Shri. ANSUMAN SEN SHARMA

India Boiler dot com
www.steamingopps.com .

ACKNOWLEDGEMENT

I express my sincere thanks to **Shri Anoop Kumar**, PMI for organising this training, giving us the opportunity to learn and better understand boiler performance with a different approach.

I express my deep sense of gratitude to respected **Shri Ansuman Sen Sharma of India Boiler Dot Com,** for his zeal in sharing the knowledge and encouraging us all the way with regular follow up and ensuring us his availability and cooperation throughout the journey and without whom this would not have been possible.

I also wish to find mention to thank

1. Shri Akhil Mandal, Sr.Mgr Operation
2. Shri Kamal Kant, Sr. Mgr, Operation
3. Shri Murali Mohan Macha, Sr. Mgr Operation
4. Shri Pradeep Das, Sr. Mgr - Chemistry
5. Shri Aloke Sarkar, Officer- Chemistry

for their support in providing inputs and help when necessary.

PREFACE

As a new era is dawning in the power sector in the form of a competitive power market and generating power stations now faces various challenges in the form of flexi operation and reducing cost of power generation. These challenges demands reducing inefficiencies in a generating plant and to maintain the health of the plant and machineries. Study and analysis of process parameters, assessing the performance and timely implementing necessary corrective action is of utmost importance to meet the challenges.

I am very much pleased to know that training **on "STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE THROUGH DIAGNOSIS OF PROCESS PARAMETERS"** was arranged by PMI, Noida in collaboration with India Boiler Dot Com with the intention to meet the challenges.

And it was my pleasure to notice that**, Mr. H. BENJAMIN MAWIKHANLAL SIMTE** was attending the said training and his interest in tracking the process parameters, focussing on the improvement of boiler performance by optimizing process parameters especially in assessing proper combustion and high reject in pulverizers. His sharing of knowledge, hardwork and ready to learn attitude is quite commendable. I wish the learning put forward in this report will spread awareness in BgTPP regarding Boiler efficiency assessment through analysis of process parameters and also the performance of the plant at large.

AKHIL MANDAL
SR. MANAGER (OPERATION)
(Shift Charge – B Group, BgTPP)

STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR UNIT 1 BY BONGAIGAON TPS

SUB INDEX

1. Overview of System:

Bongaigaon Thermal Power Station (3X250 MW) located at Salakati, Kokrajhar District, situated in the Bodoland Territorial Council Region of Assam.

The steam generator is a Drum type (Natural circulation), Two pass, convection pass design, 3 Stage Super Heating (LTSH-Horizontal and Pendant, Platen Super heater, Spaced Final Super heater) Single Reheat, Radiant Furnace, Dry Bottom, Balanced Draft Furnace, Top Supported, Tilting Tangential Fired Pulverised coal system with all necessary auxiliaries along with FGD system.

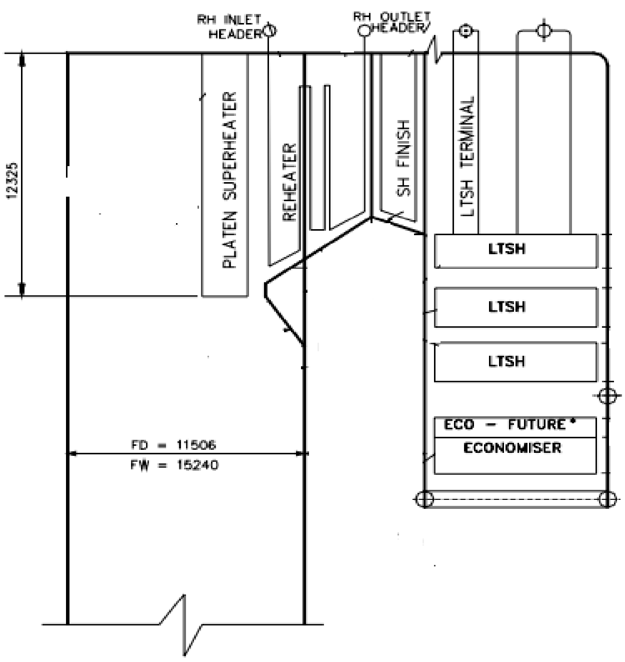


Fig 1: Boiler Heat Exchanger arrangement

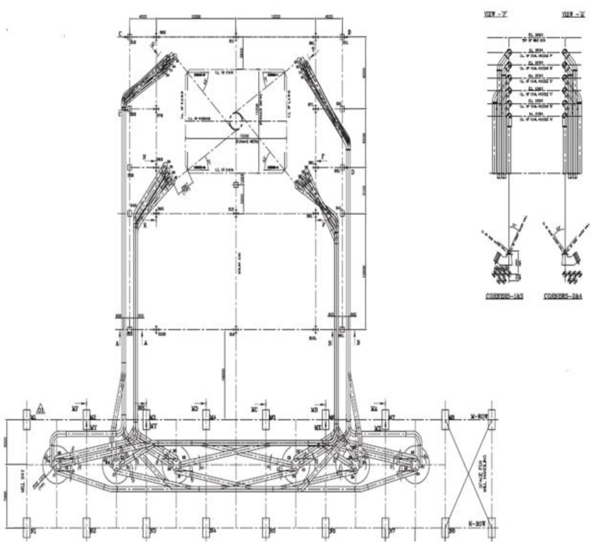


Fig. 2: Typical Coal piping and tangential firing

2. INTRODUCTION:

Performance of boiler has two parts:
1. Conversion of chemical energy of the fuel in to heat energy through combustion of fuel.
2. Transfer of the released heat into water and steam.

How well do we get these two activities carried out in the boiler would decide how good the boiler performance is. Since both activities involve dealing with heat energy, one way of assessing and improving performance would be to ensure that minimum heat is lost from the system.

Let us take a look at various boiler losses first and try to understand which parts of these losses are controllable:

- **Heat lost with dry flue gas through chimney (L1)** = **mg x Cg x (Tg - Ta)**
  Heat is lost through chimney of a boiler in many ways. This is by far the largest heat loss (nearly 50 – 60% of the total heat loss) and ***can be controlled*** to some extent.

- **Heat lost with vapour:** This is another loss though chimney and on some part ***we do not have any control***. This loss is due the presence of moisture in the flue gas. Moisture takes away heat from the flue gas and leave with the flue gas as superheated steam at the exit gas temperature. Since moisture can be present in flue gas from different sources, this loss is further specified as
  - Heat loss due to moisture formed by combustion of Hydrogen in fuel
    (L2) = 9H x {584 + 0.45 x (Tg – Ta)} kcal/ kg of fuel
  - Heat loss due to moisture present in fuel,
    (L3) = Mw x {584 + 0.45 x (Tg - Ta)} kcal/ kg of fuel
  - Heat loss due to moisture present in combustion air
    (L4) = Ma x FH x 0.45 x (Tg - Ta)} kcal/ kg of fuel

- **Heat Lost due to incomplete combustion (L5) = {CO% / (CO% + CO2%)} x Cx 5654kcal/ kg of fuel**
  If we use inadequate air for combustion, part of Carbon gets partially oxidized resulting CO in flue gas and a large part of the heat value of Carbon is carried away by the CO without getting released. Heat lost per kg of carbon forming CO

is considered to be 5654 kcal/ kg. To find out the mass of carbon forming CO in flue gas, we need to measure percentage volume of CO and CO2 in flue gas and the mass of Carbon in fuel. Since the total mass of Carbon is converted into CO and CO2, mass of CO can be calculated by multiplying Carbon mass with proportionate volume of CO. So mass of carbon forming CO = {CO% / (CO% + CO2%)} x C**.** This loss is ***controllable*** by using adequate air for combustion.

- **Heat lost due to un-burnt (L6) = Mash x {0.8 x (UBFA%/ 100) + 0.2 x (UBBA%/ 100)} x 8084** , where Mash is the mass of ash in 1 kg of fuel burnt, UBFA% and UBBA% are the un-burnt percentage in fly ash and bottom ash respectively. When we find un-burnt carbon in the fly ash or bottom ash, it means we are having an improper combustion and total heat value of the un-burnt carbon is lost. We ***can control this loss*** by ensuring proper combustion of fuel.

- **Loss due to sensible heat in ash (L7): Fly Ash = (0.8 x Mash) x 0.20 x (Tg – Ta) kcal/ kg of fuel**
  Bottom Ash = **(0.1 x Mash) x 0.20 x (Tash – Ta) kcal/ kg of fuel,** Where Tash is the bottom ash temperature

- **Heat Lost due to radiation and convection (L8):**
  To be taken from the curve given by ABMA, approximately 0.4% There would be other losses like Blow-down loss, SWAS water loss, Mill reject loss, etc. which are usually ***not taken in to consideration*** while assessing the performance of a boiler.

And looking at the different major heat losses in a Boiler, it may be noted that there are 3 major losses that can be controlled through our process parameters which are:

- **Heat lost with dry flue gas through chimney (L1)**
- **Heat Lost due to incomplete combustion (L5)**
- **Heat lost due to un-burnt (L6)**

The parameter readings given in this report was taken for Unit#1 on 12/09/2020, 16:00 Hrs at 140 MW load

3. OBSERVATION AND ANALYSIS OF PROCESS PARAMETERS

3.1 FUEL ANALYSIS (*from proximate analysis*) :

FC	VM	A	Mw	C	H	N	S	O	Aa	Mg
40	25	23	12	0.5215	0.0159	0.016	0.003	0.0936	7.1259	7.633

Aa = Air flow /Fuel flow

= 571/ 80.13 = 7.1259 kg/ kg of fuel

A = 0.23 kg/ kg of fuel

M_w = 0.12 kg/ kg of fuel

FC = 0.4 kg/ kg of fuel

Using Empirical formula:

C = $(0.97*FC+0.7*(VM+0.1*A)-M_w*(0.6-0.01*M_w))/100$

= {(0.97*0.4)+(0.7*(0.25+(0.1*0.23))-0.12*(0.6-(0.01*0.12))}/100=**0.5215**

H = $(0.036*FC+0.086*(VM-0.1*A)–0.0035*M_w*M_w*(1-0.02*M))/100$

= [(0.036*0.005442) + {0.086*(0.25- (0.1*0.23)} - { 0.0035*(0.12*0.12)} * {1 - (0.02*0.12) }] /100

= **0.0159**

N = (2.10-0.020*VM)/100

= { 2.1 - (0.02 * 0.25)} / 100 = **0.016**

S = Taken as 3% = **0.003**

O = $1–((C+H+N+S+(A+M_w)/100)$

= { 1 - (0.5215 + 0.0159+ 0.016 + 0.003 + 0.12 + 0.23)} = **0.0936**

Mass of Dry Flue gas per Kg of fuel

Mg = (Aa + 1) – (A+ 9H + Mw)

= (7.1259 + 1) – (0.23 + 9 * 0.0159 + 0.12) **= 7.633 Kg/Kg of fuel**

3.2 CALCULATION OF EXCESS AIR :

Most of the combustion processes, the required Oxygen is not supplied as pure Oxygen but supplied as air from the atmosphere through our PA & FD fan. Air contains 21 mol percent O_2 and 79 mol percent of N_2. The minimum amount of air which supplies the required amount of oxygen for complete combustion of fuel is called **theoretical air**. The amount of air in excess of the theoretical air is called excess air. It is usually expressed in terms of the as percent excess air. Amount of air less than theoretical air is called deficiency of air. Air that is excess or air that is deficient leads to improper combustion.

The theoretical amount of air required for complete combustion can be obtained from the Proximate analysis of the coal.

FC	VM	A	Mw	C	H	N	S	O	Aa	Mg
40	25	23	12	0.5215	0.0159	0.016	0.003	0.0936	7.1259	7.633

O2 at ECO O/L	Ideal EA	Theoretical Air	Actual EA
3.96	26.83	6.212	14.71

Min Theoretical Air = (2.67 C + 8H – O + S) * 100/23 = (2.67 * 0.5215 + 8 0.0159 – 0.094 + 0.003) * (100/23) = 6.212 kg/ kg of coal

Excess Air (IDEAL) = 100 * O_2/(21-0_2)   : Where O_2 is the value at Eco O/L

= 100 * 3.96/(21-3.96) = 23.24% (LHS) & **30.43%** (RHS with O_2 = 4.9)

Excess Air (Actual) = 100 * { (Air flow/fuel flow) – Theoretical Air } / Theoretical Air

= 100 * (7.1259 – 6.212) / 6.212 = **14.71%**

OBSERVATION :

- **EA ideal is greater than EA actual – this could be due improper combustion or leakage from Dog house / Penthouse. But looking at the low excess air percentage that is being calculated from actual air flow, it appears there could be some problem with air flow measurement. The actual air flow could be more than what it shows. This will get verified from the furnace gas temperature and heat pick up in the convection pass. If gas temperature is less in the radiant zone and the heat pick up is more in the convection zone, then that would be a confirmation that the flow measurement must be incorrect.**

- **Air fuel ration need to be optimized / Air ingress to be checked (ATT / Furnace pressurization test)**

3.3 CALCULATION OF CORRECTED APH O/L GAS TEMPERATURE (Tg corrected)

One particular parameter that is affecting five out of eight heat losses is Tg (Boiler flue gas exit temperature measured at APH outlet). Therefore, quite naturally, Tg becomes the Diagnosis of Boiler Performance through Process Parameters **5** most important performance parameter of the boiler.
Effective monitoring of this parameter is of utmost importance. Design exit temperature can be a good reference for monitoring. The Tg has to be first corrected to no leakage exit temperature before we compare with the design exit temperature.

First, we need to measure the O2% both at inlet and outlet of APH and use the following empirical formula to calculate Air leakage (AL);

Air Leakage = (O_2out - O_2in) x 0.9/ (21 - O_2Out) ***Design: 8%***

APH - A	APH - B
AL = (5.6-3.9)*0.9 /(21-5.6)	AL = (6.5-4.9) *0.9 / (21-6.5)
= 0.09935	= 0.09931

Tg corrected: APH - A = 158 + 0.09584 * 0.23 * (158 - 34) / 0.24 = 169.385

APH - B = 153 + 0.09931 * 0.23 * (153 – 34.5) / 0.24 = 164.2779

And the corrected gas temperature can be calculated as

Tgcorrect =Tg +AL x Cpa x (Tg - Tair in)/ Cpg ;
where, AL is Air leakage and the values of Cpa and Cpg can be assumed as 0.23 and 0.24 kcal/ kg oC respectively.

	Load	T_g	$O_{2\ in}$	$O_{2\ out}$	$T_{air\ in}$	AL	$T_{g\ correct}$	Design $T_{g\ correct}$
APH A	140	158	3.96	5.6	34	0.09584	169.3895	156
APH B	140	153	4.9	6.5	34.5	0.09931	164.2779	156

Avg Tg = (169.8 + 164.27)/2 = 166.8337 Avg Ta = (34 + 34.5)/2 = 34.25

**Online O_2 reading is not correct. Values taken are of offline readings. Online Trx calibration required.*

OBSERVATION :

- **APH Exit gas temperature is high as compared to the design values leading to high dry Flue gas loss**

3.4 PERFORMANCE MATRIX CALCULATIONS:

Fuel CV	Fuel flow	Air flow	Air/Fuel	$UB_{FA\%}$	$UB_{BA\%}$	CO%	CO_2%	Aa	Ta
4992	80.13	571	7.12592	0.8	2.41	0.006	10.64	7.125	34

L1 : Heat lost with dry flue gas through chimney (L1)

L1 = Mg x Cg x (Tg – Ta) Kcal/ kg of fuel

= 7.56 * 0.24 * (166.833 – 34.25) = 242.882 Kcal/Kg of fuel

L5 : Heat Lost due to incomplete combustion (L5)

L5 = C x {CO% / (CO% + CO2%)} x 5654kcal/ kg of fuel

= 0.521 * { 0.006 / (0.006 + 10.64)} * 5654 = 1.661 Kcal/Kg of fuel

L6 : Heat lost due to un-burnt (L6)

(L6) = Mash x {0.9 x (UBFA%/ 100) + 0.1 x (UBBA%/ 100)} x 8084 Kcal/Kg of fuel

= { 0.3045 * (0.8 * 0.0053) + 0.2 * 0.0268 } * 8084 = 20.861 Kcal /Kg of fuel

Descriptions	Kcal/ kg of coal
Heat lost with dry flue gas through chimney	242.882
Heat Lost due to incomplete combustion	1.661
Heat lost due to un-burnt	20.861
Total Controllable losses	265.404

B. OBSERVATIONS:

- **Heat loss with dry flue gas loss is high on account of high exit gas temperature. It actually shows less than what it is, as we suspect an incorrect air flow measurement, using which we have computed the dry gas loss. It would be even higher if we get the corrected air flow.**

- **Higher Un-burnt FA% of 0.8%.**
  Even though it is within the allowable limit of 1%, the best practices UB fly ash of about 0.1% can be achieved, which can lead to considerable saving.
- **In order to control the above two losses, we need to address the combustion condition of the system**

Opportunities for saving:

We see that, if the design Tg corrected value of 156 ^{o}C could be maintained, (AL 9%, just for calculation purpose) then the dry flue gas loss can be brought down to;

L1 = Mg x Cg x (Tg – Ta) Kcal**/** kg of fuel

= 7.56 * 0.24 * (156– 34.25)

= 223.036 Kcal/Kg of fuel

Which amounts to a potential saving of 19.846 Kcal/Kg of fuel, which in monetary terms is valued at **₹ 1.3 Crs** per year (approx)

Yii2 Grid Export (PDF) | Grid Export | Generated: Thu, 15-Oct-2020 12:32 pm UTC

Results ::	Input Values ::
Dry Gas Loss (DGL) :: 266.367782359 Un-Burnt Loss (UBL) :: 19.3648178 CO Loss (COL) :: 1.55154517699 Total Controllable Losses (TCL) :: 287.284145336 Saving Potential by reducing Total Controllable Losses (TCL) by just 1 kcal/ kg :: Annual savings :: Rs. 653907.69	Tm (%) : 12 A (%) : 23 VM (%) : 25 FC (%) : 40 S (%) : 0.003 F (TPH) : 80 SA (TPH) : 311 PA (TPH) : 260 C (Rs./T) : 5313 GCV (kcal/kg) : 4992 UFA (%) : 0.8 UBA (%) : 2.41 CO (%) : 0.006 CO2 (%) : 10.64 Tgasout (%) : 166.83 Ta (%) : 34.25 O2in (%) : 4 O2out (%) : 6

*Fig 3: *Typical calculation of tentative annual cost for reducing controllable loss by 1 Kcal/Kg using Losses Assessment Tool provided by **India Boiler Dot Com** at portal www.steamingopps.com .*

By back calculation it is observed that, in order to maintain the design corrected APH O/L temperature of 156 ^{o}C with the same condition, we are required to maintain **146 ^{o}C** at APH O/L.

In case we achieve 0.1% Unburnt FA , the potential saving according to our data would be **₹ 68,08,612.44** per annum.

Yii2 Grid Export (PDF) Grid Export Generated: Thu, 15-Oct-2020 12:09 pm UTC

Previous Result ::	Input Values ::
Annual savings by reducing fly ash un-burnt by 0.1% :: Rs. 972658.92	A (%Age of Ash in Fuel) : 23 F (Fuel Fired in TPH) : 80 C (Cost of fuel in Rs./T) : 5313 GCV (Gross Calorific Value of fuel in kcal/kg) : 4992

Fig 4: Tentative Annual savings by reducing Fly Ash UB by 0.1% calculation Losses Assessment Tool provided by ***India Boiler Dot Co*** *at portal* *www.steamingopps.com .*

(L6) = Mash x {0.9 x (UBFA%/ 100) + 0.1 x (UBBA%/ 100)} x 8084 Kcal/Kg of fuel

= { 0.3045 * (0.1 * 0.0053) + 0.2 * 0.0268 } * 8084

= 10.4493 Kcal /Kg of fuel

If the above assumptions/ targets could be achieved, then the total saving in monetary terms would be, ₹ 1.98 Cr (approx.) per year. *(1.3 + 0.68)*

<u>3.5 APH PERFORMANCE</u> :

Parameters for APH Performance

UNIT-1	AIR			GAS			GAS SIDE EFFICIENCY	X - RATIO
	INLET	OUTLET		INLET	OUTLET			
		ACTUAL	DESIGN		ACTUAL	DESIGN		
PA Side A	39	289	322	337	158	156	55.179	0.6621
SA Side A	29	284	323					
Average	**34**	**286.5**						
PA Side B	38	292	322	339	153	156	57.379	0.6759
SA Side B	31	294	323					
Average	**34.5**	**293**						

OBSERVATION :

- **APH Gas side Efficiency is less than the design 0.61 % indicating in efficient heat transfer**
- **The X- Ratio is close to the design value of 0.68.**

3.6 TWO MAJOR FACTORS AFFECTING BOILER PERFORMANCE

- **Improper combustion**
- **Performance of Heat Exchangers**

3.6a) IMPROPER COMBUSTION:

Parameters for combustion assessment:

LOAD	COAL FLOW	PA FLOW	SA FLOW	UB% FA	UB% BA	O2%	PI SH I/L T	FEGT	Tg Correct
140	80.13	262	308	0.8	2.41	4.19 / 3.8	N/A	498	168

The various reasons for Improper combustion are:

- Pulveriser performance & higher primary air
- Deficient / excess amount of air flow
- Failure to oxidize the entire combustible material in fuel, we get the unburnt in FA or BA
- Due to unbalance retention & reaction time in the combustion zone.

Pulverizer Performance:

MILL	LOAD	COAL FLOW	AIR FLOW	DESIGN	ACTUAL	Air I/L	Mill O/L	Mill DP	HAD	CAD
A	140	24.92	65.69	2.52	2.64	213	76.72	68	26	33
B	140	0								
C	140	18.4	64.5	3.27	3.51	208	84	61	26	24
D	140	18.5	65.4	3.27	3.54	180	75	90	20	29
E	140	18.53	65.27	3.27	3.52	194	78	92	24	22
F	140									

Coal pipe fineness

COAL PIPE 1		COAL PIPE 2		COAL PIPE 3		COAL PIPE 4	
-200 mesh	+50 mesh	-200 mesh	+50 mesh	-200 mesh	+50 mesh	-200 mesh	+50 mesh
73.96	0.1	76.73	0.12	79.42	0.1	77.51	0.1
77.34	0.1	74.51	0.1	76.42	0.12	73.04	0.14
70.24	0.54	74.61	0.1	76.33	0.1	71.61	0.1
77.85	0.1	72.4	0.15	75.27	0.1	78.8	0.1

APH outlet air temperature:

APH	ACTUAL	DESIGN
PA SIDE - A	289	322

PA SIDE - B	292	322
SA SIDE - A	284	323
SA SIDE - B	294	323

OBSERVATION :

- **Higher Primary Air/Fuel ratio in all Mills**
- **Though the fineness is good, distribution of coal fineness in all corners are not even/equal. Health of classifier needs to be checked.**
- **APH outlet air temperature is significantly less than design but the more CAD opening to control mill outlet temperature. It is quite evident that it is caused by high mass flow of PA through APH and the mill.**

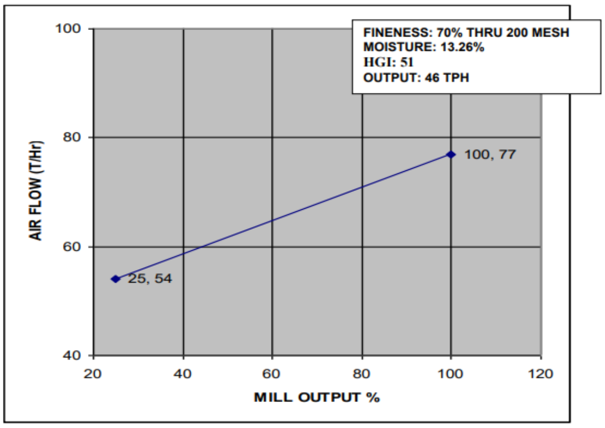
In order to improve combustion inside the furnace the following activities may be considered:

- **Raw coal size from feeder to mill** : Desirable 20mm to 50 mm
  (*Coal sieving machine for 20-50 mm not available with chemistry*)
- **Pulveriser Blue printing :**
- **Coal size distribution**
  Ensuring 75% through -200 mesh and 0.1 % through +50 mesh
- **Grinding area**
  Machine in good condition, Same spring tension in all rollers, correct bowl angle, correct roller gap, correct throat clearance.
- **Classifier area**
  Classifier adjustment for same distribution of coal pipe fineness to all corners, synchronising blade angles and length, maintain inverted cone to classifier cone clearance, good mechanical condition of classifier blades are required.

- **Primary Air optimization**
- The Primary Air in our case is much higher than required as evident in the Air/Fuel ratio.
- Oxygen rich condition during primary combustion increases possibility of SOx & NOx formation.
- Higher Primary Air will proportionately reduce Secondary Air, as quantity of total air is controlled by O_2 % at Eco O/L.
- We need to optimize PA flow by reducing CAD opening and maintaining the right amount of PA flow to mill loading as per the graph given below

FLUE GAS EMISSION (mg/m3)

AIR FLOW
VS
MILL OUTPUT



REF: BONGAIGAON/3x250MW/ 2009 REV. 02 DATE: 31.05.12

NTPC Bongaigaon

Nox	Sox	CO
241	443	59.98

The main constrains in our unit in controlling excess PA flow are;

- Sluggish operation of HAD & CAD – Fine tuning of HAD & CAD are required for precise control of Mill O/L temperatures and PA flow to mills.
- Mill reject open to atmosphere - unaccounted PA flow escapes through mill reject to atmosphere. This is one of the primary reasons behind high PA flow through APH
- Maximum PA flow through the Mill reject to atmosphere is 10 T/hr, which is affecting the APH performance

➢ **Secondary Air optimization**

For an effective combustion to take place, we need the 3 T's of combustion -Time, Temperature & Turbulence. The un-burnt combustion can also burn in the second pass if the oxygen does not come in contact with them in the right place. For this the third T-Turbulence place a vital role. Turbulence is the mixing of air and fuel to ensure contact of oxygen with the combustible in the fuel.
Also, our coal contains more Volatile matter, the retention time of the coal particles will be very less and hence the requirement for optimizing Secondary Air flow.
The relation between the reaction time and retention time of the coal particles with respect to the coal particle size as given in the table below:

	Retention Time	Reaction Time
More Finer coal particles	Less	Less
More VM in coal	Less	Less

We need to adjust SADC to maintain more opening of the Fuel Air Dampers in higher elevation coal burners to create more turbulence and provide complete combustion of the fuel, also avoiding delayed combustion.

- **Coal Fineness Optimization**

We should try to adjust the coal fineness to various elevations of coal burners as given below to avoid delayed combustion. Less fine particles at higher elevations.

BURNER ELEVATION	COAL PIPE FINENESS < 200 MESH
F	75 %
E	75 %
D	75-80 %
C	75-80 %
B	80-85 %
A	80-85 %

- **Burners Balancing**

Ensuring proper balancing of Burners in a tangentially fired pulveriser system is important for proper fire ball formation and heat transfer inside the furnace. For proper balancing of burners we should try to ensure;

- Same coal flow to all coal pipe corners
- Same air flow (mass and velocity) in all coal pipes corners
- Same coal fineness to all coal pipe corners

Parameters for checking unbalanced burners				
Furnace elevation	Cr-1	Cr-2	Cr-3	Cr-4
3m above top elevation	N/A	N/A	N/A	N/A
Mid furnace	N/A	N/A	N/A	N/A
Platen SH inlet	N/A	N/A	N/A	N/A

OBSERVATIONS:

- **As already mentioned before, we don’t have the same coal particle size flowing through the four corners of any elevation.**
- **Since we did not have the parameters available with us as in the table above to asses our burner performance, it is important that we give importance to it and try to get a complete picture of the unbalanced burners/improper combustion inside the furnace by exploring new technologies such as;**

- Installation of online monitoring such as **EU coal sizer mobile** which will provide instant online reading of - Coal particle size distribution, Air flow, Coal mass flow, Air -Fuel ratio, fuel analysis.
- Installation of Online Furnace monitoring and flame analysis system (Eg. **EUvis , EU Flame**) for combustion homogenization, flame ball positioning. Erosion, slagging and fouling.
- Using ASLD to monitor slagging and clinkering in the initial stage.

Also installing adjustable Orifice in our coal pipes and using Tunable Diode Laser Spectrometer for reliable real time CO, CO2 and O2 measurement such as In-situ gas analyser TDLS8000 (YOKOGAWA make).

3.6b) PERFORMANCE OF HEAT EXCHANGERS

Under the conditions of incomplete combustion, unburnt carbon particles get deposited on the fireside of the tubes. This is called fouling and it greatly reduces heat transfer efficiency of the boiler. As the layer of soot builds up, the stack temperature increases and boiler efficiency reduces. So, it is very much essential to check the heat transfer characteristics in the high temperature zones of the boiler system such as superheater, reheater and heat recovery system like economizer and air preheaters. The design & actual temperature profile across various heat exchangers is as follows;

FOR HEAT TRANSFER DIAGNOSIS

Flue Gas side (Design vs Actual)

	DESIGN		140 MW	
	250 MW	150 MW	LHS	RHS
Furnace	1200	1100	N/A	N/A
Pl SH I/L	1125	1082	N/A	N/A
Final SH I/L	722	649	527	566
FEGT	682	556	487	509
ECO I/L	435	409	374	383
ECO O/L	377	345	337	339
APH O/L	160	156	158	153
ESP O/L			130	131

Steam side (Design vs Actual)			140 MW	
	DESIGN		ACTUAL	
	250 MW	150 MW	LHS	RHS
LTSH O/L	411	406	411	405
SH spray			215	211
Pl SH D/S	401	379	385	396
MS	540	540	538	542
CRH	344	351	339	335
RH spray				
HRH	540	540	521	522

Water side (Design Vs Actual)		
AREA	**DESIGN 150 MW**	**ACTUAL 140 MW**
LPH I/L	66.7	66
LPH O/L	107	108
DA O/L	144.6	144
HPH I/L	147.7	147
HPH O/L	222.7	221
ECO O/L	249	415
DRUM O/L	344	344

Metal Temperature				
DRUM	LTSH	Pl SH	FSH	RH
325	460	511	548	531

OBSERVATIONS:

- Looking at the flue gas side process parameters above, we find there are some variations in the design and actual parameters. And it is obvious that we got our Eco O/L temperature close to our design values, but the Final SH I/L, FEGT and ECO I/L temperatures are lower than the design parameters **which suggest use of higher excess air.**
- Since the actual Furnace temperature and Pl SH I/L temperature are not available with us it is difficult to pin point the causes for lower temperatures than design or where the problems lies.
- One point of interest is the lower gas side ΔT between the Eco I/L and Eco O/L temperature which is about 40 ^{0}C compared to the Design ΔT of 64 ^{0}C, which should reflect in the Eco O/L temperature as well. But the Eco O/L temperature readings shows Trx 1- 415 & Trx 2 – Nan/ Bad value. **Here, If we get the required heat pick up in the economizer that would again confirm higher mass flow of flue gas resulting from high excess air.**
- Performance of heat exchangers is difficult to analyse due to insufficient data except for APH which is already done before.
- Seeing we don't have sufficient data, we need to operate top 3 mills as recommended by Technical diary for low load operations below 200 MW to get the design Flue gas temperatures across various heat transfer banks.

But this is also limited due to various reasons such as high reject in Mill E, Maintenance and other day to day issues in Mills such as oil leakage, coal pipe leakage, abnormal sound etc.

- It is recommended to maintain and run machine as per recommendations of OEM and commissioning of all LRSB.

4. MILL REJECT:

MILL	GCV (Kcal/Kg)
A	2152
C	2469
D	1675
E	2368
Avg	2166

Mill Reject on 12.09.2020 = 44.8 T (10 Tractors)

1 Tractor = 3.5 m^3 X 1.28 = 4.48 T

(* Data provided by Operation,General)

REJECT LOSS CALCULATION

Reject Lost / hr = 44.8/24 = 1.87 T/hr

Coal flow / hr = 80.1 T/hr

Reject is 2.23 % of coal i.e., 0.0223 in 1 Kg of coal.
Reject loss in terms of GCV = 0.0223 x 211

= 50 Kcal/Kg of coal

Calculating the expected reject loss as per design (0.5% of coal flow)
Reject Loss = 0.005*80.1

= 400 Kg/Hr

Which is 0.005 in 1 Kg of coal
Reject loss in terms of GCV = 0.005 x 1000 ***(*Taking reject GCV – 1000 Kcal/Kg)***

= 5 Kcal/Kg of coal

Total Reject loss = (50 – 5) = 45 Kcal/Kg of coal

Which amounts to ₹ 2.94 Crs (approx.) per annum.

OBSERVATION :

- **Mill rejection loss is too high**
- **Probable causes may be because of the non-availability of Mill Reject System and improper Mill throat clearance**

5. CONCLUSION :

- ➢ **Controllable Losses**
- **Loss with to dry flue gas amounts to ₹ 1.3 Crs per year (approx.)**
- **Loss due to unburnt amounts to ₹ 0.68 Crs per year (approx.)**
- **Loss through reject amounts to ₹ 2.94 Crs per year (approx.)**
- **Total controllable loss in terms of money is ₹ 4.92 Crs per year (approx.)**

Taking into account the various process parameters and observations above, there are various issues which we can do to reduce our cost of power generation to a huge margin over the years, which includes;

- ➢ **AIR FLOW**
- We need to verify the correctness of air flow measurement, there is a possibility of high air ingress in the system.
- More CAD opening while maintaining Primary side and Secondary air side AH O/L temperature lower than the design O/L temperature is an indication of higher PA mass flow.
- It should be our target to bring down the PA/Coal flow ratio to the design values.

- ➢ **MILL REJECT**
- Commissioning of Mill Rejection in all units and putting them into service. This will reduce mill reject and may also reduce the PA mass flow too.
- Maintaining the optimum Mill throat clearance, which is also one main reason for higher mill reject.

- ➢ **BURNER BALANCING**

- Uneven distribution of coal fineness to the four coal pipes in all the mills, which may be because of unhealthy classifier blade which needs to be checked.
- Temperature of all corners at specific elevations as provided in Table (*Parameters for checking unbalanced burners*) to identify the proper balancing of burners.

➢ **CORRECT AND RELIABLE IMPORTANT PARAMETERS**

- Eco O/L temperature has to be provided in OWS – This is important for identification of improper heat transfer in Economizer.
- Pl. SH I/L temperature needs to be provided in OWS – This is important for identification of improper heat transfer in Gas side Heat exchangers and excess air flow.
- Temperatures required for burner balancing needs to be provided.
- Faulty online APH O/L O_2 readings needs to be attended.

➢ **APH PERFORMANCE**

- Improper heat transfer in APH needs to be addressed.

***Due to various unavoidable circumstances, Trial of the suggestions could not be taken.**

Study and Analysis of Stage-1, Unit 3 Boiler Performance Through Diagnosis Of Process Parameters

AT

NTPC - Ramagundam

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STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR STAGE 1, UNIT 3 BY RAMAGUNDAM TPS

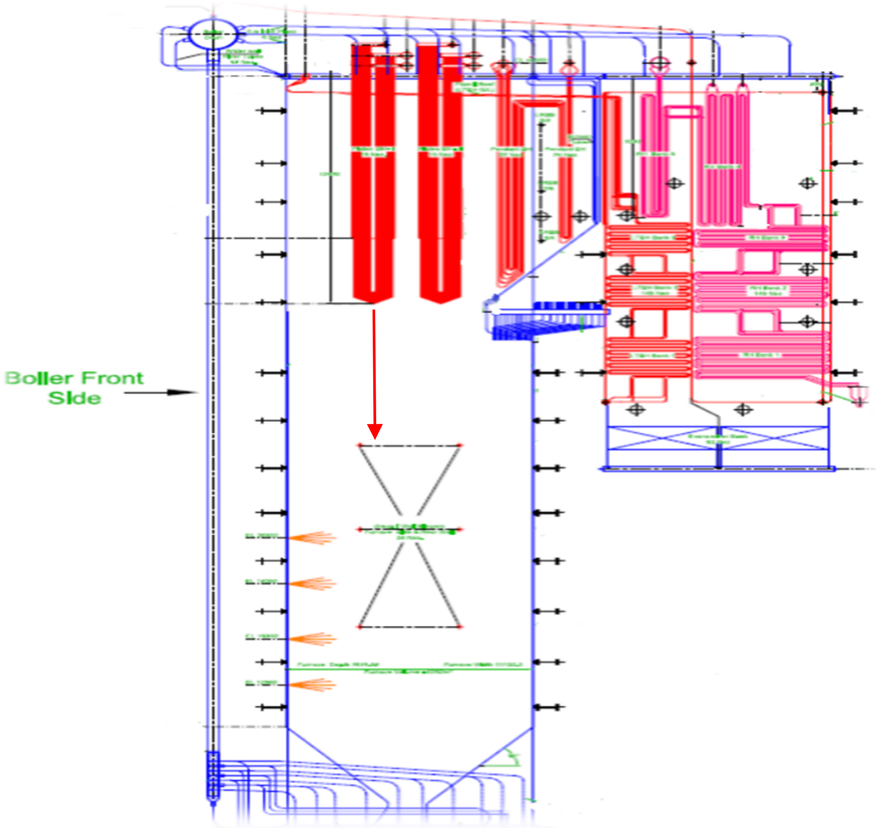
SUB INDEX

1.0 Introduction

The Boiler System consists of various sub systems like fuel system, draft system, flue gas system, feedwater system etc. In each sub-system there are various components performing a certain job. Each component has various physical parameters like pressure, temperature, flow etc. are measured and most of the parameters are available online in the DCS. Based on these parameters each component in the system has a defined objective to fulfil. Practically due to various field limitations the working of the components tends to deviate from ideal condition which again reflects in the parameters. A deviation in the parameter indicates that there is a certain problem in the system and there is a deviation from the field condition. The objective is to identify the parameter that has deviated from the prevailing field condition and diagnose the problem with reasonable accuracy and to take the necessary actions to improve the efficiency of the boiler.

1.1 Ramagundam Stage-1 Boiler

In line with the objective the study has been carried out in RSTPS stage-1 unit 3 -200 MW Boiler which is of B&W design, natural circulation radiation type and mainly composed of large combustion chamber, a drum, Eco Banks, SH1, SH2 and SH3 & the RSH and RH bank. It is completely suspended from the structural steelwork and the expansions take place in downward direction. There are 2 main structural sections -The furnace in the front part and the cage in the rear. The furnace is formed by the 4 walls of the combustion chamber and contains the suspended plates SH1 & SH2. The side walls of the cage are formed by the Eco tubes, while the front and rear walls are formed by the feed tubes SH1, the cage contain the banks of the horizontal SH1, the SH3 & the RSH and the Eco coils.



2.0 Assessing and improving the performance Through Process Parameters

The performance of the boiler depends on two parts i.e. Conversion of chemical energy of the fuel into heat energy through combustion of fuel and transfer of the released heat into steam and water. To check whether the above two activities are carried out to the maximum extent, we require various parameters at each stage of the process including the fuel characteristics, firing method, steam pressure etc. and review with the Boiler design data to find out the probable root cause of the deviation. On 1st September,2020 the Data required for evaluating the Boiler performance has been collected, calculated, irregularities in the system have been identified & diagnosis of probable root cause have been carried out.

3.0 Total Losses in The Boiler

One way of assessing and improving the performance is to ensure that minimum heat is lost in the system. The heat lost in the Boiler i.e. Boiler losses are of various types like L1-Heat lost through dry flue gas through chimney ,L2-Heat Lost with vapor, L3- Heat loss due to moisture present in the fuel, L4-Heat Loss due to moisture present in combustible air ,L5- Heat lost due to incomplete combustion,L6-Heat lost due to Un-Burnt, L7-Heat lost due to sensible heat in ash & L8- Heat lost due to radiation & convection . The Boiler flue gas exit temperature is the only parameter which is common in 5 out of the 8 losses. Thereby the Boiler Flue Gas exit temperature after APH ($T_{g\ corrected}$) is the parameter that needs an effective monitoring.

3.1 Corrected Exit Gas Temperature ($T_{g\ corrected}$)

The exit gas temperature (T_g) has to be first corrected to no leakage exit temperature before comparing with the design exit temperature. To measure the leakage % we need to measure the O2% both at inlet and outlet of the APH by using the empirical formulae

$$AL = \frac{(O_{2out} - O_{2in}) \times 0.9}{(21 - O_{2Out})}$$

and the corrected gas temperature can be calculated as

$$T_{g\ (corrected)} = T_g + AL \times C_{PA} \times (T_g - T_{air\ in})/C_{PG}$$

Where C_{PA} & C_{PG} can be assumed as 0.23 & 0.24 kcal/Kg ^{0}C

As per the Data collected the Air Leakage & corrected exit gas temperature are as follows

Date: 01.09.2020

Load	Tg-APH Exit Gas Temp		O_2 in		O_2 out		T_{air} in	Air/Fuel Ratio
	APH-A	APH-B	APH-A	APH-B	APH-A	APH-B		
183	171	170	3.4	3.6	5.2	5.4	41	
	AL-Air Leakage		$T_{g(corrected)}$		Tg design	Fuel Flow	Air Flow	
	APH-A	APH-B	APH-A	APH-B				
	0.1025	**0.1038**	**183.77**	**182.84**	150	127	652	5.13

From the analysis it can be emphasized that the APH outlet temperature is maintaining very high i.e 183^{0}C against the design value of 150^{0}C. This leads to the increased Boiler losses. The probable reason for high exit gas temperature is due to any of the following reasons

1. Improper heat transfer across APH (Low gas side efficiency) due to APH basket fouling
2. High CAD opening /Passing
3. Superheater fouling
4. Improper heat transfer in the radiation zone due to high excess air

3.2 Controllable Boiler Losses

Other than the Boiler Flue Gas exit temperature the other controllable parameters are M_g, CO, CO2, UB_{FA} & $UB_{BA.}$ By controlling these parameters, the Boiler Losses L1-Heat lost through dry flue gas through chimney, L5- Heat lost due to incomplete combustion & L6-Heat lost due to Un-Burnt can be controlled. All these losses can be controlled by proper combustion inside the boiler.

4.0 Losses Due to Improper Combustion

The performance of boiler has two specific aspects: Combustion of fuel and heat transfer to water and steam. Combustion is the chemical reaction of carbon, hydrogen, Sulphur & hydrocarbons present in the fuel with oxygen from air. If the reaction is successfully converted inside the furnace, the total chemical energy will be converted to heat energy. But in most of the systems 100% complete combustion will not take place. The reasons for Incomplete combustion are

1. Inadequate amount of air flow
2. Excess amount of air flow
3. Failure to oxidize the entire combustible material in fuel, we get the unburnt in FA or BA
4. Due to unbalance retention & reaction time in the combustion zone.

4.1 Calculation of the Air required for Complete Combustion

In most of the combustion processes the required Oxygen is not supplied as pure Oxygen but is supplied as air. The minimum amount of air which supplies the required amount of oxygen for complete combustion of fuel is called theoretical air. The amount of air in excess of the theoretical air is called excess air. It is usually expressed in terms of the as percent excess air. Amount of air less than theoretical air is called deficiency of air. Air that is excess or air that is deficient leads to improper combustion.

The theoretical amount of air required for complete combustion can be obtained from the Proximate analysis of the coal. The Proximate analysis of the coal that is fired in unit 3 NTPC Ramagundam as on 01.09.2020 is as follows

Coal Sample Analysis	Ash	Moisture	Volatile Matter	Fixed Carbon	Calorific Value	Fuel Flow	Air Flow
	32.5	12.18	23.68	31.64	3856	127	652

From the Coal sample analysis, the theoretical amount of air that is required for complete combustion can be calculated from the below empirical formulae’s

C = (0.97*FC+0.7*(VM+0.1*Ash)-Moisture*(0.6-0.01*Moisture))/100
H = (0.036*FC+0.086*(VM-0.1*Ash) -(0.0035*Moisture*Moisture) *(1-0.02*Moisture))/100
N = (2.1-0.02*VM)/100
O = 1-(C+H+N) -(Ash + Moisture)/100

Theoretical Air = (2.67*C+8*H-O)/0.23
Estimated Air (Ideal) = (100 * O2 at APH I/L)/ (21- O2 at APH I/L)
Estimated Air (Actual) = (100* Air/Fuel - Theoretical Air)/ Theoretical Air

Calculation of the Total amount of Air Required for Complete Combustion

Coal Sample Analysis	Ash	Moisture	Volatile Matter	Fixed Carbon	Calorific Value	Fuel Flow	Air Flow
	32.5	12.18	23.68	31.64	3856	127	652
	C	H	N	O	Theoretical Air	Ea Actual	Ea Ideal
	0.4372	0.025	0.0163	0.0747	5.6208	**-8.663**	20.69

From the analysis the total amount of air being fired for combustion is very less than the theoretical air that is required. The deviation is so high that there is a need of checking the total air flow measurement. Both PA & SA flow measurement to be checked for correctness.

Total Unburnt in Bottom Ash & Fly Ash

Incomplete Combustion Data	**Load**	**Air flow**	**Ta**	**UB%FA**	**UB%BA**	**CO%**	**CO2%**
	183	652	41	**0.84**	1.86	0.00338	15.7

The un-burnt in fly ash is found to be very high i.e. 0.84%, failure to oxidize the entire combustible element in fuel will be collected along with the fly and bottom ash. As major amount of ash is fly ash a minute increase in unburnt in fly ash will have tremendous effect on Boiler Losses which need to be taken seriously & the value has to be brought down to less than 0.1%. The reason behind high un-burnt in the fly ash could be improper fines & improper SA/PA ratio.

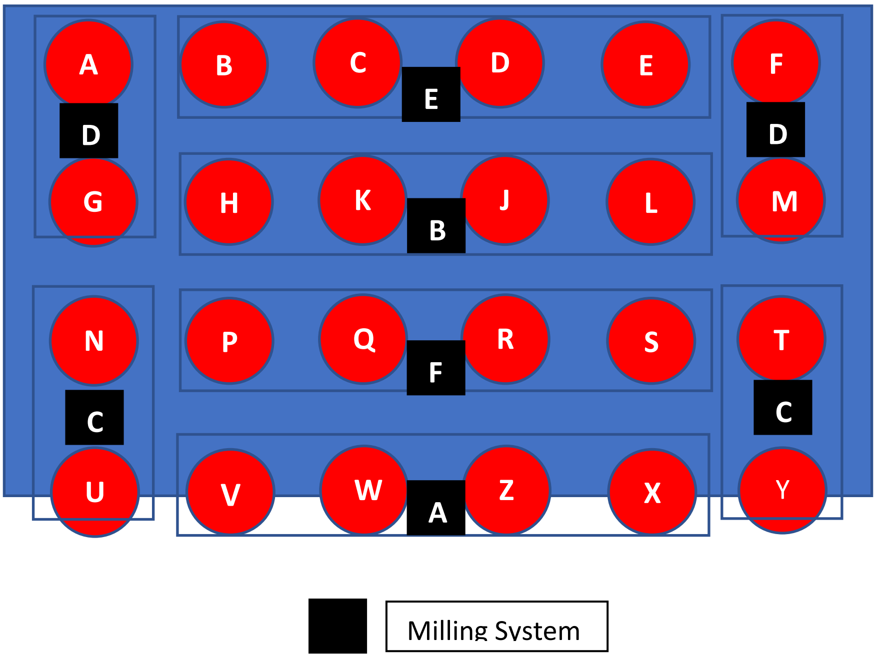
Total Controllable Losses

Total Controllable Losses	Mg	Tg	L1	L5	L6	TCL
	5.461764	**183.3059**	186.5378	0.532026	27.42901	**214.4989**

The Total controllable losses are 214 kcal/kg which are found to be very high. There is an opportunity to bring down the controllable losses which can lead to huge savings.

5.0 Milling System Performance

In Stage-1 units the Mills are of Ball & Race with each mill having a maximum loading capacity of 27T/Hr. Raw coal enters the top of the pulverizer through the raw coal feed pipe. The raw coal is pulverized in-between the ball and the two races which provide the grinding surfaces. Hot air is forced through the bottom of the pulverizer to remove unwanted moisture and transport the coal dust up through the top of the pulverizer chamber through 4 coal pipes into the burners. All the burners are on the front side of the boiler distributed in 4 elevations with 6 burners in each elevation. On the Bottom elevation we have the burners -VWZX of Mill A & Burner -U&Y of Mill C. In this way the 24 coal pipes from 6 mills are distributed on the Boiler front as shown in the below diagram.



For an effective combustion to take we need 3 T's-Time, Temperature & Turbulence. The unburnt combustion can also burn in the second pass if the oxygen is not coming in contact with them in the right place. For this the third

T-Turbulence place a vital role. Turbulence is the mixing of air and fuel to ensure contact of oxygen with the combustible in the fuel. Combustion will start only if there is sufficient amount of ignition energy. The turbulence depends on the manner in which air is added into the furnace. Air is added in four different paths.

1. Primary Air: The role of primary air is to lift the coal particles from the mill to burner at various elevations. Since the total air quantity is fixed and depends on the O2 at the APH I/L, any increase in primary air will reduce the secondary air i.e air being added into the wind box.
2. Secondary Air: Secondary air is the air that is added into the wind box. The role of this air is to ensure complete combustion. This air is added again in three different paths which are controllable through SADC.
   a. Coal Air: This is added through the burner. The role of this air is to get the flame sufficiently away from the burner.
   b. Auxiliary Air: This is added from either side of the burner to keep the fuel sandwiched between them. This air catches the fuel while it travels up through the furnace.
   c. Tertiary air through OFD: This part of air primarily ensures reducing condition during the initial part of the combustion and sequential air distribution to control NOx formation

Data regarding Milling System Performance

Mill	COAL FLOW	AIR FLOW	Actual Air/Coal	Design Air/Coal	AIR I/L	MILL O/L	MILL DP	-200 MESH	+50 MESH	HAD/ CAD	WB Box
B	25.6	49	1.91406	1.807	241	84	628	74.4	0.2	100/0	30
C	25.7	50	1.94553	1.807	226	74	720	74.3	0.5	100/0	30
D	25.9	49	1.89189	1.807	240	74	630	73.1	0.4	100/0	30
E	23.2	46	1.98276	1.913	213	81	664	73.0	0.3	100/10	30
F	26	49	1.88462	1.807	245	83	610	72.7	0.2	100/0	30

From the milling system data, it can be analyzed that the reason for poor combustion is poor coal fineness, high PA flow and very low wind box pressure. With reference to the above data the following observations are made

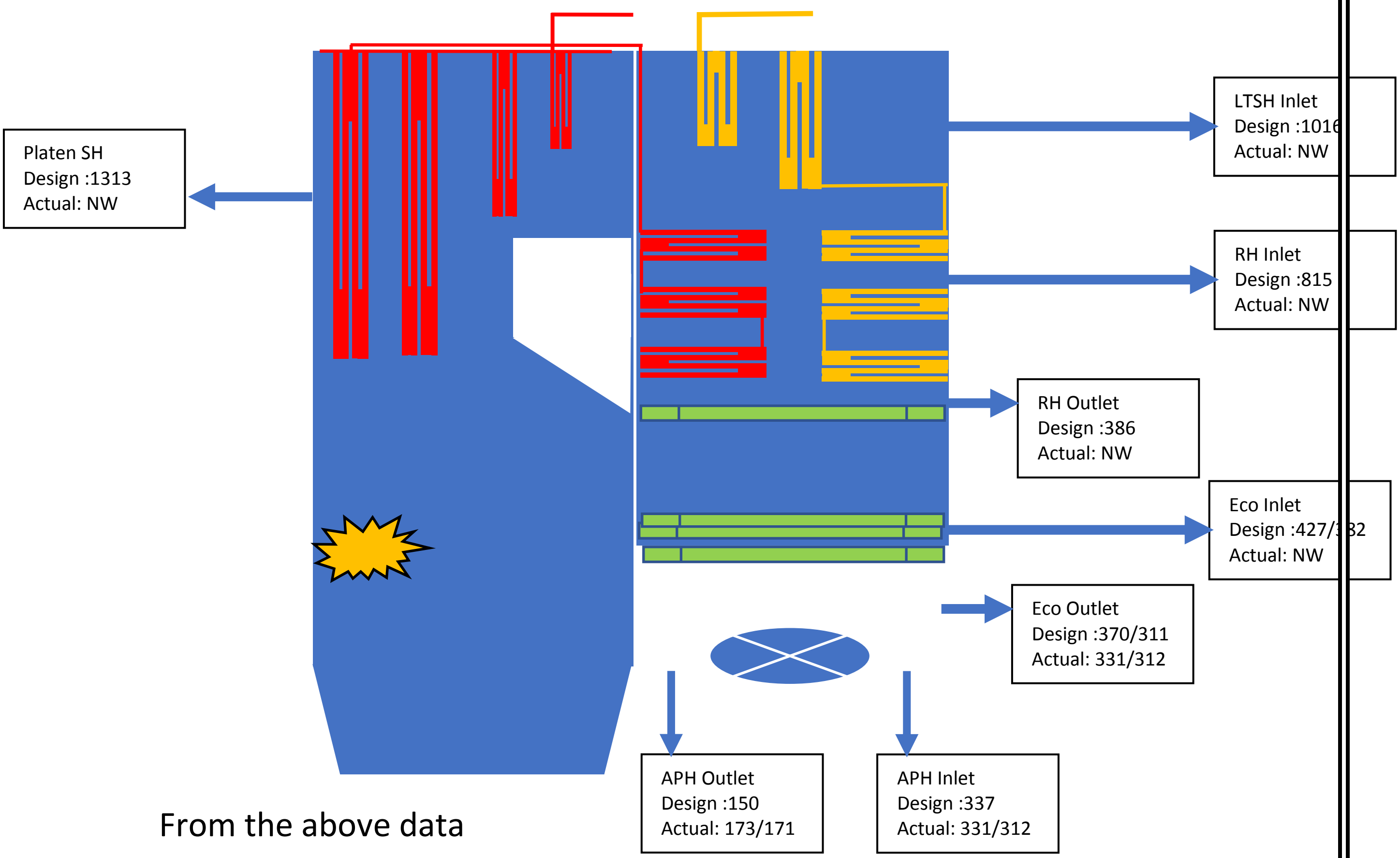
1. Primary air flow is kept slightly higher than the designed air flow. On reducing the primary air to the designed value, a loss of 4-5MW in generation is observed.
2. One of the reasons for high PA flow might be the coal delivered to each burner is not distributed equally in each coal pipe. To analyze this dirty air velocity test to be conducted across all the coal pipes.

3. The wind box pressure is maintaining very low i.e. 30 mmwc against the design value of 60mmwc. At lower load it is further going down to 10 mmwc. To increase the wind box pressure secondary air has to be increased but there is no margin in the ID fan loading.
4. Air Preheater air O/L temperature is maintaining low 250^{o}C against the design value of 280 ^{o}C. Even with the reduced APH Air O/L temperature the CAD of Mill E is operated to reduce the Mill O/L temperature. This can happen only when the mass air flow is very high. So, it can be analyzed that the primary air flow is very high compared to the measured value which needs to be corrected.
5. Comparing the performance of Mill B & D for the same loading of 26Tons & air flow of 49 Tons, for the same inlet temperature of 240 ^{o}C the mill outlet temperature varied by 10 ^{o}C due to the difference in mass flow rate.
6. To determine the coal flow distribution in each pulverized coal pipe the sample of coal fines across each coal pipe is to be collected, but the provision to take samples is not available.
7. It is suspected that CAD of Mill C & E are passing as their Air I/L temperature is maintaining low i.e. 226^{o}C & 213 ^{o}C with CAD in almost closed condition.
8. The fines of all the Mills are found to be less than 75%. Increased coal fines improve the combustion process. From the burner elevation arrangement, the retention time of coal particles in each elevation is different i.e. Top Burner EBCD Of Mill E have less retention time compared to the bottom burners VWZX of Mill A. So, the fines of bottom mills i.e Mill A, F & C are to be kept higher to 80 % & the fines of the top mills i.e. B, E & D should be kept around 75-80%. Presently all the fines are below 75% which do not promote equal distribution of fuel in the burners leading to improper combustion. The fines of +50 mesh should also be brought down to 0.1-0.2% for overall mill performance
9. From the analysis the Primary air flow is found to be higher than the design value. One of the reasons for high PA is high mill throat clearance. An oversized pulverizer throat require more than optimum primary air to minimize the coal rejects. For all mills the pulverizer throat clearance has to be reduced by right sizing the flow area and matching them for compatibility with the coal pipes.
10. Air register setting & wind box leakages to be attended during opportunity shutdown or unit overhaul.

6.0 Performance of Heat Exchangers

Under the conditions of incomplete combustion, unburnt carbon particles get deposited on the fireside of the tubes. This is called fouling and it greatly reduces heat transfer efficiency of the boiler. As the layer of soot builds up, the stack temperature increases and boiler efficiency reduces. So, it is very much essential to check the heat transfer characteristics in the high temperature zones of the boiler system such as superheater, reheaters and heat recovery system like economizer and air preheaters. The design & actual temperature profile across various heat exchangers is as follows

GAS SIDE	Actual	DESIGN
Furnace Exit	853	1016
Platen SH I/L	NW	1313
LTSH I/L	NW	1016
RH I/L	NW	815
RH O/L	NW	386
ECO I/L @ SH/RH Bank	NW	427/383
ECO O/L @ SH/RH Bank	331/312	370/311
APH I/L	331/312	337
ESP I/L	173/171	150
ESP O/L	158/153	137



From the above data

- ✓ The performance of APH can only be evaluated, whereas for the other heat exchangers the flue gas temperature across various heat exchangers system is not available. To evaluate the performance of the SH, RH, ECO & APH temperature points are to be provided across all heat exchangers.

By getting the temperature points the reason for high exit temperature of can be diagnosed by the temperature profiles across various heat exchangers. As the rated flue gas exit temperature at APH outlet is high, we need to check whether APH I/L temperature is increasing -If the answer is No, the problem is with the APH. If the answer is yes, we have to check whether the Eco I/L gas temperature is increasing. So, to carry out this study we need the temperature profiles across each heat exchanger. **The points are not available in stage -1 units, so the correct performance of the heat exchangers can never be analyzed until they are provided.**

7.0 Heat Pickup across Heat Exchangers

The heat in the flue gas is transferred to water and steam in two modes: Radiation and convention .Radiation mode of heat transfer is much superior and takes place when temperature is in excess of 750-800C & 90% of the heat is transferred through this mode, whereas the convention heat transfer heat transfer takes place when temperature comes below 750C.The radiation heat transfer is directly proportional to the 4^{th} power of the temperature ,even a little change in temperature affects the heat transfer more significantly. The heat exchanges like economizer, APH, LTSH are through convention heat transfer mode. The factors affecting the convention heat transfer are the available area, temperature of the gas and the mass flow of the
gas. If for any reason heat transfer in the radiation zone is inadequate in the system, it would lead to increase in the exit gas temperature. Though heat exchangers in the convection zone would pick more heat some heat would be lost as convention heat transfer is much inferior to the radiation heat transfer mode. The heat pickup across the heat exchangers is as follows:

STEAM SIDE	ACTUAL	DESIGN
PRIMARY SH BEFORE D/S (Btw Platen-1&2)	455/450	**450/450**
PRIMARY SH AFTER D/S	437/425	450/450
1ST STAGE SPRAY	35	0
Secondary SH BEFORE D/S (Btw Platen-2 & tertiary)	469/475	480/480
Secondary SH AFTER D/S (Btw Platen-2 &	468/468	480/480

tertiary)		
2ND STAGE SPRAY	16	0
MS STEAM TEMP	530/530	540/540
CRH BEFORE D/S	340/341	350
CRH AFTER D/S	318/319	350
RH SPRAY D/S	25	**0**
HRH	528/500	540/540

From the above table it ca be emphasized that the heat pick in Platen heater 1 is 32 C i.e 469-437 which is equal to the design value of 30 C (480-450) & the heat pickup in the tertiary SH is 62C (530-468) which is again to the design value of 60C (540-480) .To maintain the rated outlet temperature additional spray is been given in the superheaters. The Platen & tertiary super heater are given their rated heat pick. So additional heat is getting pickup in the 2nd pass of SH1 due to higher velocity of flue gas due to excess air. Providing the steam, I/L & O/L temperatures of SH 1 & flue gas temperature across LTSH would get more data and analysis regarding the heat exchangers in the 2nd pass. In order to reduce the heat pickup in the secondary pass the total air can be reduced and we could get more margin the ID fan which enable us to control the SH/RH dampers thus improve the RH temperature if not attained.

Note: Steam temperatures are maintained low against the design values due to limitation in Turbine Expansions, which leads to turbine vibrations.

8.0 APH Performance

APH PERFORMANCE	Air I/L	Air O/L	Gas I/L	Gas O/L	Damper
APH A	42	252	322	171	100
APH B	42	249	315	170	100
Design	33	282	337	150	
	APH Gas Side Efficiency		**APH X-Ratio**		
APH A	49.36652351		0.658220313		
APH B	48.41099606		0.638463861		
Design	**62.56**		0.83		

From the above data it can be analyzed that the gas side efficiency is less which indicates there are APH chokes. During next opportunity APH baskets to be cleaned for a better APH Performance.

9.0 Conclusion

In the process of thermal power generation, the performance of boiler combustion control system affects the thermal efficiency of whole power plant, so reasonable and effective performance improvement assessment has been done which can improve the economic performance of whole power plant. The following trails have to be conducted & checked for process improvement.

1. The fineness of the Bottom Mills to be kept at more than 80% @-200 mesh & for top Mills at 75-80% @-200 mesh. & for all mills@+50 mesh to be brought down to 0.1-.2%
2. The throat clearance of all the mills to be reduced.
3. To analyze whether coal delivered to each burner is distributed equally dirty air velocity test to be carried out.
4. Coal sample points to be provided for all coal pipes.
5. Primary air flow is very high compared to the measured value which needs to be corrected.
6. Flue gas exit temperature points to be provided near all heat exchangers.
7. Steam Inlet temperatures at all SH & RH banks to be provided
8. APH Baskets cleaning to be done during opportunity.

Study and Analysis of Boiler System Performance Through Diagnosis of Process Parameters at NTPC Jhajjar

NTPC - Jhajjar

Submitted by
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Devendra Kumar Rathore- Manager (Operations)

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Objective - Identification of performance irregularities in Boiler system through Diagnosis of process parameter.

Study and analysis of process parameters of unit#3 boiler system was carried out on 12.10.2020 after the completion of the training workshop for this purpose.

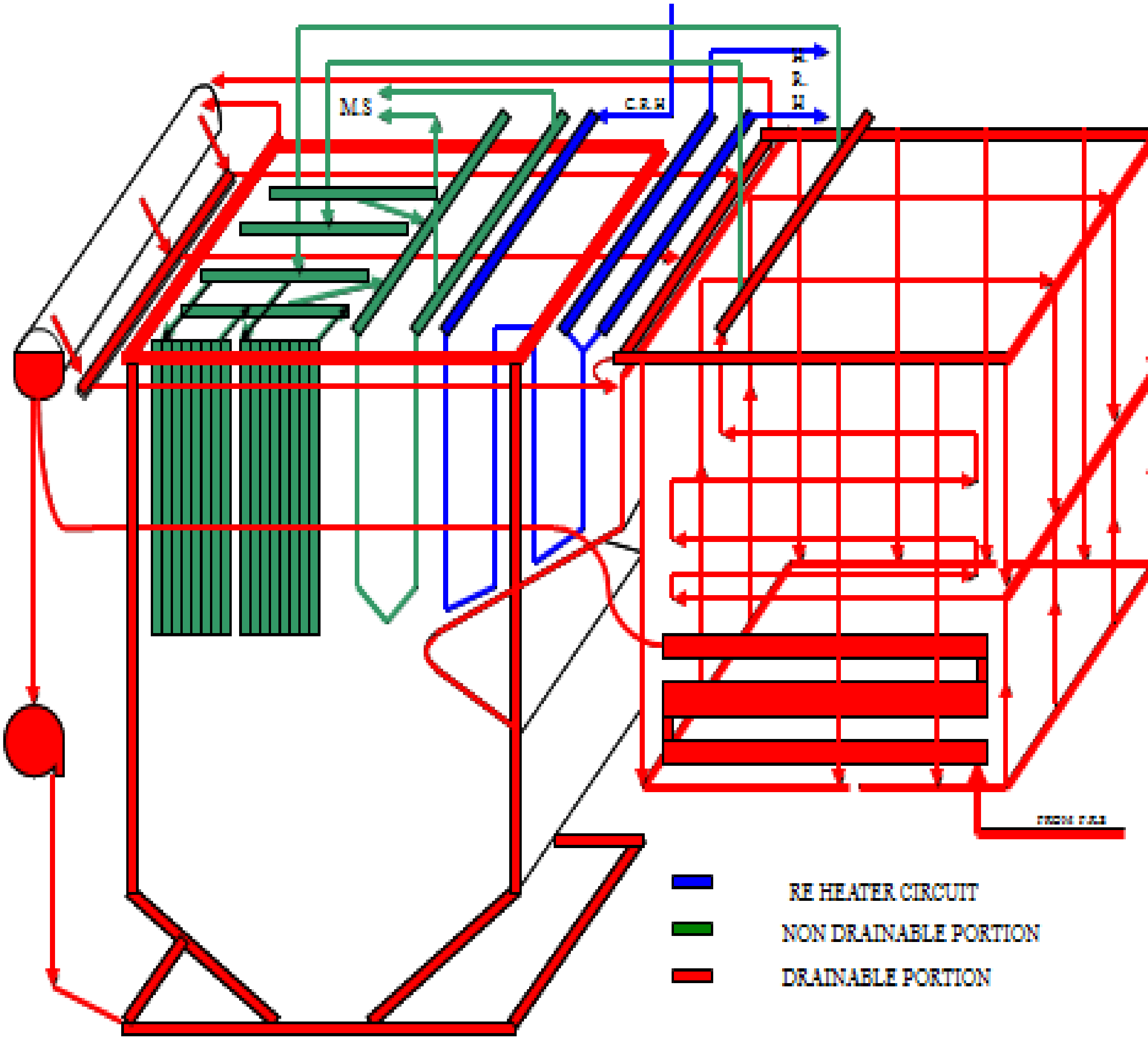
Overview of the system-

A steam power plant consists of a boiler, steam turbine and generator, and other auxiliaries. The boiler generates steam at high pressure and high temperature. The steam turbine converts the heat energy of steam into mechanical energy. The generator then converts the mechanical energy into electric power.

NTPC Jhajjar has three units of 500 MW each with drum type sub critical boiler. The steam generator is a controlled circulation plus radiant reheat type boiler. This is balanced draft furnace with water cooled with down comers, water wall headers, steam generating tubes, furnace bottom hoppers, drains, vents, sampling line connections etc.

Boiler Drum pressure – 209 ksc
SH outlet pressure- 178 ksc
SH outlet temperature- 537 deg C
CRH pressure- 45 ksc
HRH pressure- 42.4 ksc
HRH temperature- 568 deg C
Steam Flow – 1590 TPH
Mills- XRP 1003 (BHEL provided)

Overview


M.S
C.R.H
H.
R.
H
RE HEATER CIRCUIT
NON DRAINABLE PORTION
DRAINABLE PORTION

Methodology:

A. Recording process parameters and computing performance matrices
B. Identification of irregularities
C. Diagnosis of possible root causes
D. Conducting trial after minor changes of process conditions to validate
E. Conclusion and suggestions

A. Parameters recorded for Exit gas temperature :

Load		Tg	O_2 in	O_2 Out	T air in	Air Heater lkg	Tg(Corct)	Tg(Design)
505	PAPH A	154	4.2	7.1	37	19.42	175.77	125
	PAPH B	154	4.1	7.2	37	19.43	175.77	125
	SAPH A	142	3.7	6.0	32	13.8	156.12	125
	SAPH B	143	3.7	6.2	32	14.9	157.7	125
	Average	148	3.95	66.6	35	16.10	166.9	125

Coal Proximate Analysis:

M	A	VM	FC	GCV
13.83	34.48	21.8	29.7	3468

B. Observations:

i) Exit gas temperature is very high which is leading to high dry flue gas loss
ii) High APH horizontal seal leakage

A. Parameters recorded for controllable losses:

Load	Coal flow	Air flow	Air/ coal	$Tg_{(Correct)}$	T Air	UB% (FA)	UB% (BA)	CO %	CO_2 %
505	320	1680	5.25	166.02	37	0.56	1.51	2.2	11.72

B. Observations:

i) Both fly ash and bottom ash un-burnt are more than best practice parameters (though within OEM limit). Mill fineness and PA flow requires attention.

Various heat losses influencing Performance of Boiler:-

Flue gas

- Dry flue Gas Loss
- Loss due to moisture in fuel
- Loss due to Hydrogen in Fuel
- Loss due to moisture in air
- Loss due to Carbon monoxide (incomplete combustion)

Ash

- Loss due to un-burnt Carbon in fly ash bottom ash
- Loss due to sensible heat in Fly ash
- Loss due to sensible heat in Bottom Ash

The various losses are calculated as under.

- Heat lost with dry flue gas through chimney
  = mg x Cg x (Tg - Ta) kcal/ kg of fuel
- Heat loss due to moisture formed by combustion of Hydrogen in fuel
  = 9H x {584 + 0.45 x (Tg - Ta)} kcal/ kg of fuel

- Heat loss due to moisture present in fuel

  = Mw x {584 + 0.45 x (Tg - Ta)} kcal/ kg of fuel

- Heat loss due to moisture present in combustion air

  = Ma x FH x 0.45 x (Tg - Ta)} kcal/ kg of fuel

- Heat Lost due to incomplete combustion

  = C x {CO% / (CO% + CO2%)} x 5654 kcal/ kg of fuel

- Heat lost due to un-burnt

  = Mash x {0.8 x (UBFA%/ 100) + 0.2 x (UBBA%/ 100)} x 8084 kcal/ kg of fuel

- Sensible Heat lost due to fly ash

  = 0.8 x Mash x 0.2 x (Tg - Ta) kcal/ kg of fuel

- Sensible Heat lost due to bottom ash

  = 0.2 x Mash x 0.2 x (Tash - Ta) kcal/ kg of fuel

- Heat Lost due to radiation and convection: Based on ABMA curve, radiation losses is assumed as 0.4% for power station boiler.

Few formulas that we have used for performance assessment:

Conversion formula for proximate analysis to ultimate analysis:-

%C = 0.97C + 0.7 (VM + 0.1A) - M (0.6- 0.01M)
%H2 = 0.036C + 0.086 (VM- 0.1xA) - 0.0035M2 (1- 0.02M)
%N2 = 2.10 - 0.020 VM
Where C = % of fixed carbon
A = % of ash

VM = % of volatile matter
M = % of moisture

Mass of dry flue gas Mg = (Aa + 1) – (A + 9H + Mw)
Aa = (FD flow + PA flow)/ Fuel flow

A, Mw and VM are ash, moisture and volatile matter from the proximate analysis Respectively in kg per kg of fuel.

One way of assessing and improving the performance is to ensure that minimum heat is lost in the system.
We can therefore target those losses which are controllable by adjusting the operating parameters to improve performance. The controllable losses are:

1. Heat lost with dry flue gas through chimney
2. Heat Lost due to incomplete combustion, and
3. Heat lost due to un-burnt

Performance Matrices calculations:

Descriptions	Kcal/ kg of coal
Heat lost with dry flue gas through chimney	176.55
Heat Lost due to incomplete combustion	0.425
Heat lost due to un-burnt	10.9
Total Controllable losses	197.9

Excess air as calculated from O_2 at Eco out: 20.68%

Excess air as measured from actual air to fuel ratio: 3.02 %

B. Observations:

i) Excess air as calculated from total air flow is significantly less than the excess air that was calculated from measured O_2%. There is a strong possibility that the air flow measurement in not correct. This needs to be verified through other parameters.

ii) High dry flue gas loss on account of high gas exit temperature. This loss is likely to be even more, if the air flow measurement is actually more than what it shows. There could be significant scope of loss reduction here.

iii) Un-burnt losses appear to be within limit as specified by OEM. We can try to reduce the fly ash un-burnt percentage by a some margin though (< 0.1 %) to match the best practices.

A. Mill performance parameters

Mill	Load	Coal flow	Air flow	PA/ coal	Design Air/Fuel ratio	Air I/L temp.	Mill O/L temp	Mill DP	APH O/L Air temp	CAD
B	505	52	100	1.92	1.52	298	78	155	320	0%
C		52	100	1.92		286	74	200		0%
E		52	100	1.92		294	68	140		0%
F		54	100	1.85		302	67	160		0%
G		54	100	1.85		291	65	187		0%
H		54	100	1.85		285	66	150		0%

B. Observations:

i) The Mill air inlet temperature of C and H mill is decreasing by 30-40 degree despite the CAD is full close. The difference between mill inlet temperature and PAPH outlet temperature is more than design in almost every mill. This clearly indicates we have CAD passing. This could be one of the reasons behind our high exit gas temperature!

ii) Mill outlet temperature is lower than the design temperature as a result of the CAD passing since coal moisture is very near to the design moisture.

iii) High PA to coal ratio in all mills. This was on account to attain the Mill O/L temperature. Since no significant issues were observed when we are operating with low Mill O/L temperature, we should not try to increase this by increasing PA flow. It is detrimental to the combustion condition if we increase PA quantity to increase Mill O/L temperature.

A. Mill Fineness Report:

Mill	CP1		CP2		CP3		CP4	
	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh	- 200 Mesh	+50 Mesh
B	81.18	0.42	81.18	0.42	81.18	0.42	81.18	0.42
C	81.74	0.78	81.74	0.78	81.74	0.78	81.74	0.78
E	77.725	0.63	77.725	0.63	77.725	0.63	77.725	0.63
F	77.12	0.51	77.12	0.51	77.12	0.51	77.12	0.51
G	76.12	0.64	76.12	0.64	76.12	0.64	76.12	0.64
H	79.2	0.73	79.2	0.73	79.2	0.73	79.2	0.73

B. Observations:

i) While the (-) 200 mesh size fines are in the desired range, (+) 50 Mesh size is more. This could be due to higher PA flow being used in the mills. We should also check the grinder health.

ii) Samples from all four coal pipes are mixed to get average sieve analysis. We need to check the results for individual coal pipes for mill fineness parameters.

A. SADC position:

Elevation	Type	Opening	Wind box dP
A	Coal	20	Setpoint 68.43mmWC Actual- 65/69 mmWC
AB		96.4	
B	Coal	93.8	
BC		96.4	
C	Coal	93.8	
CD		96.4	
D	Coal	20	
DE		96.4	
E	Coal	93.8	
EF		96.4	
F	Coal	95.2	
FG		96.4	
G	Coal	95.2	
GH		96.4	
H	Coal	95.2	
HJ		96.4	
J	Coal	20	
JJ		20	
CCOFA-1		20	
CCOFA-2		20	
BOFA-A	Bypass Over fire dampers	20	
BOFA-B		20	
BOFA-C		20	
BOFA-D		20	

B. Observations:

i) After introduction of By-pass Over Fire Damper in boiler to control Nox formation, SADCs opening has increased more.

ii) For controlling NOx, arrangement has been made for diverting secondary air above furnace and for this purpose 2 out of 4 flaps have been locked in SADCs. So in order to maintain sufficient air for combustion SADCs opening is more.

iii) It has been observed during fast ramping up, flue gas CO is shooting up beyond limit

iv) Since total combustion optimization significantly depends upon proper distribution of air through SADC, it's correct position feedback and control need to be corrected and ensured.

A. Gas, water and steam side Temperatures

Flue gas side	Actual	Design
Furnace		
Divisional SH inlet	835/795	1382
Final SH inlet	810/788	1115
FEGT	857/778	
ECO inlet	498/510	535
ECO outlet	371/357	330
APH outlet	15154/142/143	125

Water side	Actual	Design
LP Heater inlet	45.6	48
LP Heater outlet	131.6	125
DA outlet	165	164.6
HP Heater inlet	166.6	166.5
HP Heater outlet	252.4	253.4
ECO outlet	318	321
Drum/ separator outlet	348	357

Steam side	Actual	Design
Primary SH d/s	395/406	395
Divisional SH inlet	378/389	391
Platen SH inlet	469/448	464
MS	540/538	537
Before CRH d/s	334	337
Reheater St-I o/L	475/474	493
HRH	565/564	565

Furnace temperature Profile measured with IR pyrometer:

Furnace Elevation	Corner1	Corner 2	Corner 3	Corner 4
3m above top burner	921	965	982	968
Mid furnace	852	810	800	831
Platen SH inlet	-	-	-	-

B. Observations:

i) Flue gas temperatures in the furnace (at divisional SH and final SH inlet) are significantly lower than the temperatures given by OEM. This could be due to furnace dilution due to use of higher quantity of air. The same is confirmed from the furnace temperature profile through IR pyrometer.

ii) The flue gas temperature drop across economizer is almost 60^{o}C less than the design temperature drop. Whereas the water side temperature pick up in the economizer is almost as per design. This is only possible if the Flue gas mass flow is more which again indicates that actual excess air is higher than what it is showing.

A. APH performance parameters:

	Inlet Gas	Outlet Gas	Outlet Gas (Design)	Inlet Air	Outlet Air	Outlet Air (Design)	Damper Position	Gas side efficiency	X-ratio
PAPH A	351	154	125	37	322	309	100	57.32484	0.6315
SAPH A	355	142	125	32	319	308	62/62	56.96594	0.6411
SAPH B	352	143	125	32	312	309	65/65	56.5625	0.6464
PAPH B	350	154	125	39	317	308	100	57.55627	0.6438

B. Observations:

i) The PAPH side air and gas outlet temperature is more. This could be due to CAD passing.

ii) SAPH side gas damper could be throttled a little more as SAPH outlet air temperature is more than rated temperature. This could improve the mill outlet temperature even after we reduce the PA flow

C. Diagnosis of parameters and preliminary conclusion:

i) The air flow measurement is incorrect and should be checked

ii) APH horizontal seal leakage needs to be attended

iii) Heavy passing of the Cold Air Damper.

iv) Very high exit gas temperature could be due to use of high excess air, passing of cold air damper.

v) High dry flue gas loss resulting due the above issues.

vi) Coal air and PA quantity to mills are high.

vii) The SADC feedbacks requires corrections and control resored

viii) Mill Fineness is poor. +50 mesh size should be brought down to less than 0.1 - 0.2%.

ix) Till we get the opportunity for attending the CAD passing, we should conduct a trial by reducing the PA flow near to the rated flow to each mill and throttle the SAPH side gas damper a little more and observe the parameters.

STUDY AND ANALYSIS
OF
Unit-1 BOILER SYSTEM PERFORMANCE
OF
NTPC Darlipali

Members of Team 20, NTPC Darlipali:

Ms. Biswa Varati Ghadei (Emp. ID -007742)
Sr. Manager (O&M, Chemistry)

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STUDY AND ANALYSIS OF BOILER SYSTEM PERFORMANCE FOR UNIT 1 BY DARLIPALI TPS

SUB INDEX

1.0 **Objective: -** Exploring performance irregularities in Boiler system through diagnosis of process parameters & understanding their possible impact in present & future performance of the unit.

- Study and analysis of process parameters of Unit-1 boiler system was carried out after the completion of the training workshop by M/s India Boiler Dot Com on "Diagnosis of Boiler Performance through Process Parameters".

2.0 Methodology:

A. Recording process parameters and computing performance matrices

B. Identification of irregularities

C. Diagnosis of possible root causes

D. Conclusion and suggestions

3.0 Overview of the Unit-1 NTPC Darlipali Boiler System:

Boiler: Alstom 800 MW
Design Steam Parameter: Main Steam- 257 KSC, 568°C
HRH – 56.14 KSC, 596°C

Fuel Firing Equipment:

Coal: Tilting Tangential, 36 No. Mill type: Bowl Mill HP 1203
Oil burner –LDO 20 No

SOFA- 5 Compartments, A,B, C, D & E

Design Coal: 533 TPH (CV 3200 kcal/kg), 426 TPH (CV 4000 kcal/kg),

DSTTPP Unit #1 COD was on 01.03.2020. This boiler is just a newly entrant 800MW boiler in NTPC Ltd, Slowly and steadily it is marching on the path of performance and creating milestones.

Design Proximate coal analysis Data

S.N	PROXIMATE ANALYSIS	UoM	DESIGN	WORST	BEST
1	**FC**	**%**	**24**	**21**	**30**
2	**VM**	**%**	**19**	**16**	**23**
3	**TM**	**%**	**15**	**17**	**12**
4	**ASH**	**%**	**42**	**46**	**35**
5	**HGI**	**No**	**55**	**50**	**60**
6	**GCV**	**Kcal/Kg**	**3200**	**2800**	**4000**

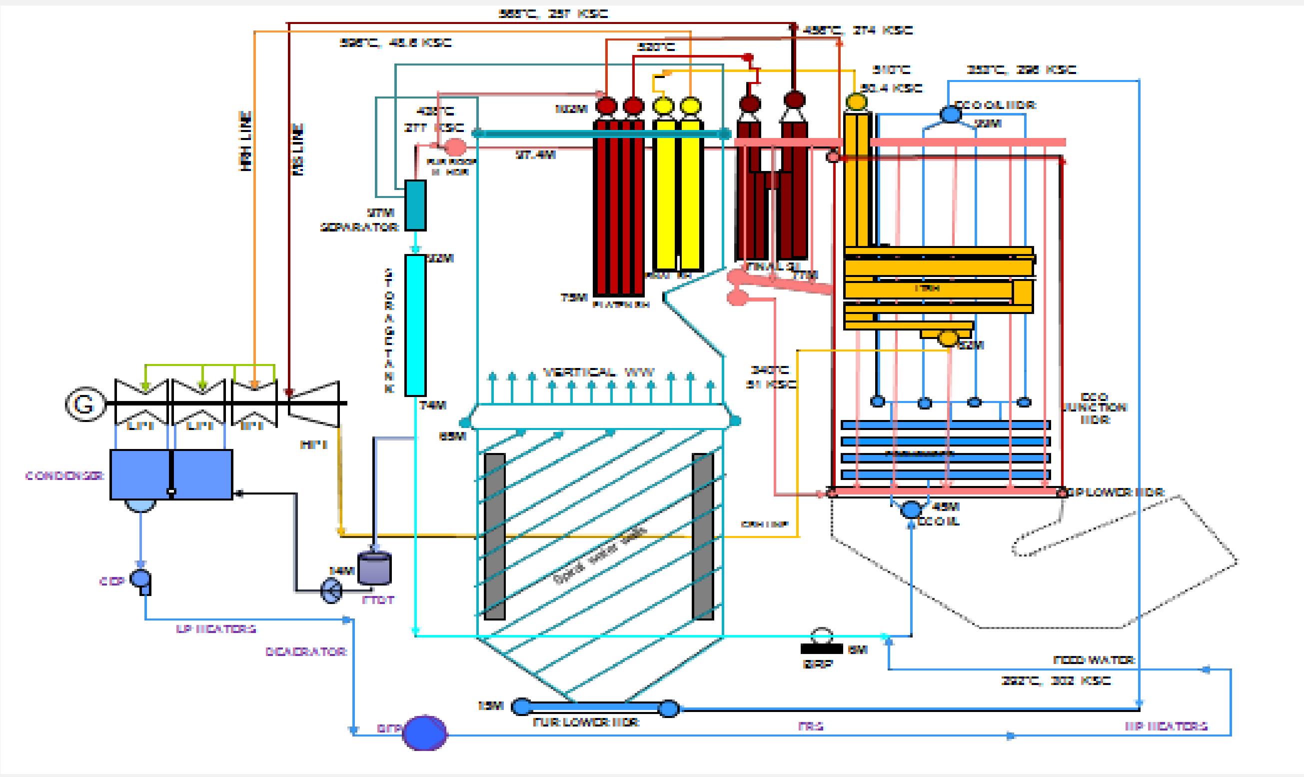


Fig: 1, Steam Water Cycle Circui of 800MW of DSTPP U#1 Boiler supplied by BHEL & Alstom

DSTPP U#1: at @800MW,

Unit	Day 1	Load	T_g	O_{2in}	O_{2out}	$T_{air\ in}$	AL	$T_{g\ correct}$	$T_{g\ design}$
1		800	158	3.83	4.55	38.06	0.0393	**162.53**	125
Fuel CV (kcal/kg)	**Fuel flow (T/hr)**	**Air flow (T/hr)**	**UB_{FA} %**	**$UB_{BA\%}$**	**CO%**	**CO_2%**	**Aa**	**Ta**	
3088	561	2893	**0.05**	**0.17**	0.01	16	**5.15**	**38**	

Fuel Analysis

FC	VM	A	Mw	C	H	N	S	O
23	**20.5**	**43.5**	**13**	0.33595	0.0177919	0.0169	0.003	**0.0613**

FC-fixed carbon, VM-Volatile matter, A- Ash Content, M_w- moisture content (Total Moisture).

C = $(0.97*FC+0.7*(VM+0.1*A)-M_w*(0.6-0.01*M_w))/100$

H = $(0.036*FC+0.086*(VM-0.1*A)–0.0035*M_w*M_w*(1-0.02*M))/100$

N = $(2.10-0.020*VM)/100$, **S = Taken as 0.3%,**

O = $1–((C+H+N+S+(A+M_w)/100)$

Aa = Air flow /Fuel flow

- Aa = Air flow /Fuel flow = 2893/569 = **5.08 kg/ kg of fuel**

Mass of Dry Flue gas per Kg of fuel

Mg = (Aa + 1) – (A+9H + Mw) = (5.08 + 1) – (0.435 + 9* 0.01779 + 0.13)
= 5.3579 kg/ kg of fuel

Excess Air (IDEAL) = $100 * O_2/(21-O_2)$

Min THEORETICAL AIR = (2.67 C + 8H – O + S) * 100/23

Excess Air (Actual)=100 * { (Air flow/fuel flow) – Theoretical Air } / Theoretical Air

Air leakage (AL) = (O2out - O2in) x 0.9/ (21 - O2Out)

T_g: APH gas outlet temperature

Tgcorrect =Tg +AL x Cpa x (Tg - Tair in)/ Cpg

where C_{pa}=0.23 & C_{pg}=0.24

Loss analysis

Heat lost with dry flue gas through chimney **(L1) = mg x Cg x (Tg - Ta)**

Heat Lost due to incomplete combustion (L5)

Heat Lost due to incomplete combustion **(L5) = {CO% / (CO% + CO2%)} x Cx 5654kcal/ kg of fuel**

Heat lost due to un-burnt (L6)

Heat lost due to un-burnt **(L6) = Mash x {0.9 x (UBFA%/ 100) + 0.1 x (UBBA%/ 100)} x 8084**

4.1 Performance Matrices calculations:

Theo Air (%)	Ideal EA (%)	Actual EA (%)	Mg	L1	L5	L6	TCL
4.265	22.306	19.20	5.36	160.169	1.5815	2.6022	164.35

Heat Losses in Kcal/kg	The day of study
Heat loss with dry flue gas through chimney	160.19 (kcal/kg)
Heat lost due to incomplete combustion	1.5815
Heat lost due to unburnt	2.6022
Total controllable losses	164.35
GCV of Coal	3088
% Loss	**5.32**

Observations:

i) APH outlet O_2 looks less. The correctness of this measurement was checked by local measurement later, there is some difference between online & offline measurement. Since this is incorrect, then the corrected gas temperature at APH outlet would be also incorrect.

ii) Air to fuel ratio looks high. This would be contributing largely towards the high dry gas loss (L1). Few air optimization trials required & since the unit is still under commissioning stage & BHEL the OEM is still there, regular follow up & trial is going on to improve the boiler performance

iii) Un-burnt losses are well within the limit.

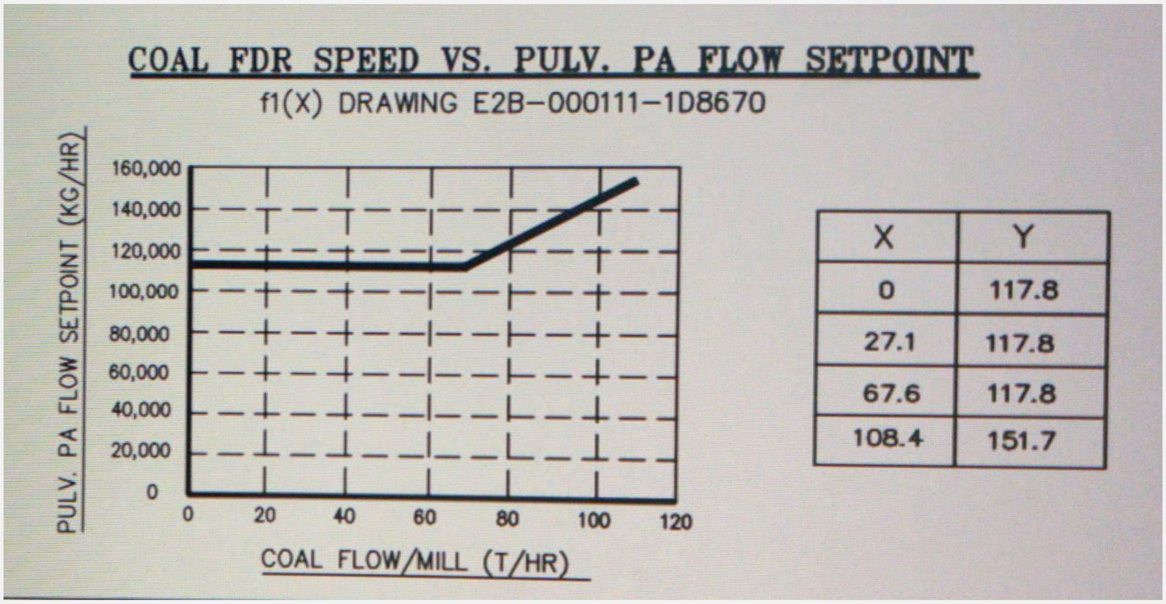
4.2 Mill Performance Parameters:

Load (MW)	Mill	Mill DP (mm WC)	Coal Flow (TPH)	PA Flow (TPH)	PA to Fuel Ratio	(-)200 Mesh (%)	Mill I/L air Temp (^{0}C)	Mill O/L Temp (^{0}C)
800	Mill B	359	60.64	155.6	2.565963061	73.7	303	76
	Mill C	372	67.21	160.67	2.39056688	78.5	304	74
	Mill D	396	72.04	146.92	2.039422543	76.2	304	80
	Mill E	412	70.62	145.83	2.064995752	74.5	301	78
	Mill F	412	71.67	145.83	2.03474257	76.3	303	75
	Mill G	412	72.68	171.05	2.353467254	77.2	302	81
	Mill H	412	72.85	167.49	2.299107756	74.1	301	78
	Mill J	412	70.25	177.9	2.532384342	83.4	298	81

Note* *Limitation of the study: Mill fineness for all mills done in 2 days as sampling from one corner not possible on the same day but next day samples collected under nearly similar condition of operation.

CP1, CP2,CP3 & CP4 individual not done but earlier report says not much variation

***Design Air/Fuel should be 1.74 to 1.85**



OEM curve for Coal flow vs PA flow (source: BHEL)

Mill Fineness		
	-200 mesh	**+50 mesh**
B	**73.7**	**0.1**
C	**78.5**	**0.01**
D	**76.2**	**0.01**
E	**74.5**	**0.05**
F	**76.3**	**0.03**
G	**77.2**	**0.03**
H	**74.1**	**0.07**
J	**83.4**	**0.08**

Observations: Primary air plays a vital role in combustion as primary air mixes with the fuel before entering the furnace to create the optimised combustible mixture. Excess Primary air is undesirable as it affects combustion.

i) High PA to coal ratio in almost all mills.
ii) As discussed with operation people no chocking of coal pipes except ingress of foreign material.

iii) Although quantity of PA is high, the fly ash un-burnt percentage is matching the best practice, which is contradictory. The PA flow measurement may be erroneous. The APH data should be reviewed to check this fact (later BHEL has done the dirty air traverse test one week back)

iv) The difference between APH outlet air temperature and Mill inlet temperature is negligible this indicates there may not be passing of CAD except for mill J. It can be observed the mill outlet temperature of J is also less despite the PA flow was significantly higher as compared to other mills which suggest the CAD might be passing might for Mill J.

*Note: Coal mill capacity test has not yet been done by OEM (BHEL), deficiencies, if any, shall be taken up with BHEL.

4.3 Gas, Water And Steam Side Temperatures:

Temperature to be recorded for Heat Transfer

	Actual	Design
FURNACE		
PLATEN SH INLET	Not available	1131
FINISH SH INLET	808/712 deg C	810 Deg C
FEGT	635/654	644.5
ECO INLET	Not available	503
ECO OUTLET	338/338 deg C	338 deg C
APH OUTLET	154.5	130
ESP INLET		
ESP OUTLET	122	122
@Full Load 800MW		
WATER SIDE	**ACTUAL**	Design
LP 1 I/L	**51.75 DegC**	49.3
LP 4 O/L Temp	**160.9 DegC**	158.1
DA O/L Temp	**178 DegC**	187.9
HPH 6 I/L Temp	**191 DegC**	192
HPH 8 O/L Temp	**294 Deg C**	286.1
DA OUTLET	**296.1 Deg C**	288
ECO OUTLET	**351.6 Deg C**	342
DRUM/SEPARATOR OUTLET		

Platen S/H d/S	**531/513 Deg C**
MS Spray	**294 Deg C**

MS	566
CRH d/S	330 Deg C
RH Spray	No spraying is done
HRH	565 Deg C

Observations:
We have quite a few irregularities in terms of steam temperatures. The gas, steam and water temperatures significantly help us to diagnose the irregularities in the heat transfer across various heat exchangers. In this system, we still do not have the correct feed backs. It is of vital importance that our C&I department should ensure with BHEL, so that we get correct feed backs from both the inlet and outlet of every heat exchangers in the system.
We also need the furnace gas temperature mapping (four corners) at least at three elevations above the topmost burner

6. Parameters to be recorded for APH performance						
	Inlet Gas	**Outlet Gas**	**Outlet Gas Design**	**Inlet Air**	**Outlet Air**	**Outlet air design**
PAPH A	345	150	125	43	320	290
SAPH A	340	144		43	290	
PAPH B	343	160		36	320.8	
SAPH B	341	163		36	280	
Average	**342.25**	**154.25**		**39.5**	**302.7**	

Damper position	
PAPH A	**100%**
PAPH B	**100%**
SAPH A	**100%**
SAPH B	**100%**

Observations:
PAPH outlet air temperatures are well above the design temperature. This again is a confirmation that our PA flow is less than what it shows
We should try to throttle the

11.0 Final Conclusion and Suggestions:

Though I could not make it possible to conduct any separate trial operation by reducing the PA flow but for more than a month (since 10th September) I have observed the unit performance under different set of conditions. Each day is a new day for the boiler performance in dynamic mode, with coal quality & variation of load the boiler performance parameter gets changed.

- **The PA flow is more than design value. Though PA is more combustion is under control this indicates a doubt on the PA flow value. The recent test carried out by BHEL confirms the actual PA flow is less by 10-20T/ hr for 2 mills, which might be true for all other mills which is yet to be reconfirmed. If this comes out to be true then the heat loss may be reduced to below 150deg C.**
- **Heat loss due to Unburnt C loss is minimum.**
- The coal quality meets the design quality except the HGI value. The PC fineness is good owing to the high HGI of the coal. The design HGI is 60 but actual is >88, so softness of the coal is helping in maintaining better fineness.
- % Loss due to **TCL is 5.32%.** By controlling the heat loss with dry flue gas through chimney the TCL can further be reduced.
- The temperature thermocouples for areas like PSH which are either unavailable/not working or not envisaged in the original design can be taken up with the OEM for installation even at additional cost for better performance monitoring while OEM BHEL is at project site.

"A Particular shot or way of moving the ball can be a player's personal signature, but # efficiency of performance is that wins the game of the team"……….Pat Riley

I find this quote very apt for boilers also, it is not the temperature of a particular component or air flow or pressure to maintain, we must strive for over all efficiency not doing the mistake of increasing the temperature of one component at the cost of others.

Disclaimer:. The study is for a limited period only and the performance parameter noted at a particular time and the conclusion and suggestions are based on that only which may be revalidated before taking any further action.

Message from the Faculty

I am grateful to PMI – Noida for giving me the opportunity to be a part of this great endeavour. It gives us great satisfaction as a trainer to find that our teachings are put into practice by those who have learnt from us.

Every engineer has an 'Analyst' inside. The whole perspective changes significantly, when we start taking the analytical approach in our work. Every boiler system speaks about itself. It is for us to learn its language and listen carefully to what it says.

The biggest challenge is the large numbers of unique limitations present in every system which lead to the deviation from the ideal conditions. This probably is one of the reasons why the analytical software's like PADO, etc. are not very successful. But when an O&M engineer, who has very clear understanding of these limitation, start using the same technique as used by these software's, the outcome can be astounding.

Publishing these reports was a great idea as the fruits of their labour would be now available to all other O&M personnel of NTPC Ltd and help them to adopt similar approach to continuously audit their system.

I would like to express my gratitude to Sri D Sarkar; ED-OS and Sri D S Rao; ED-PMI for encouraging and appreciating the works in their forewards

Ansuman Sensharma
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