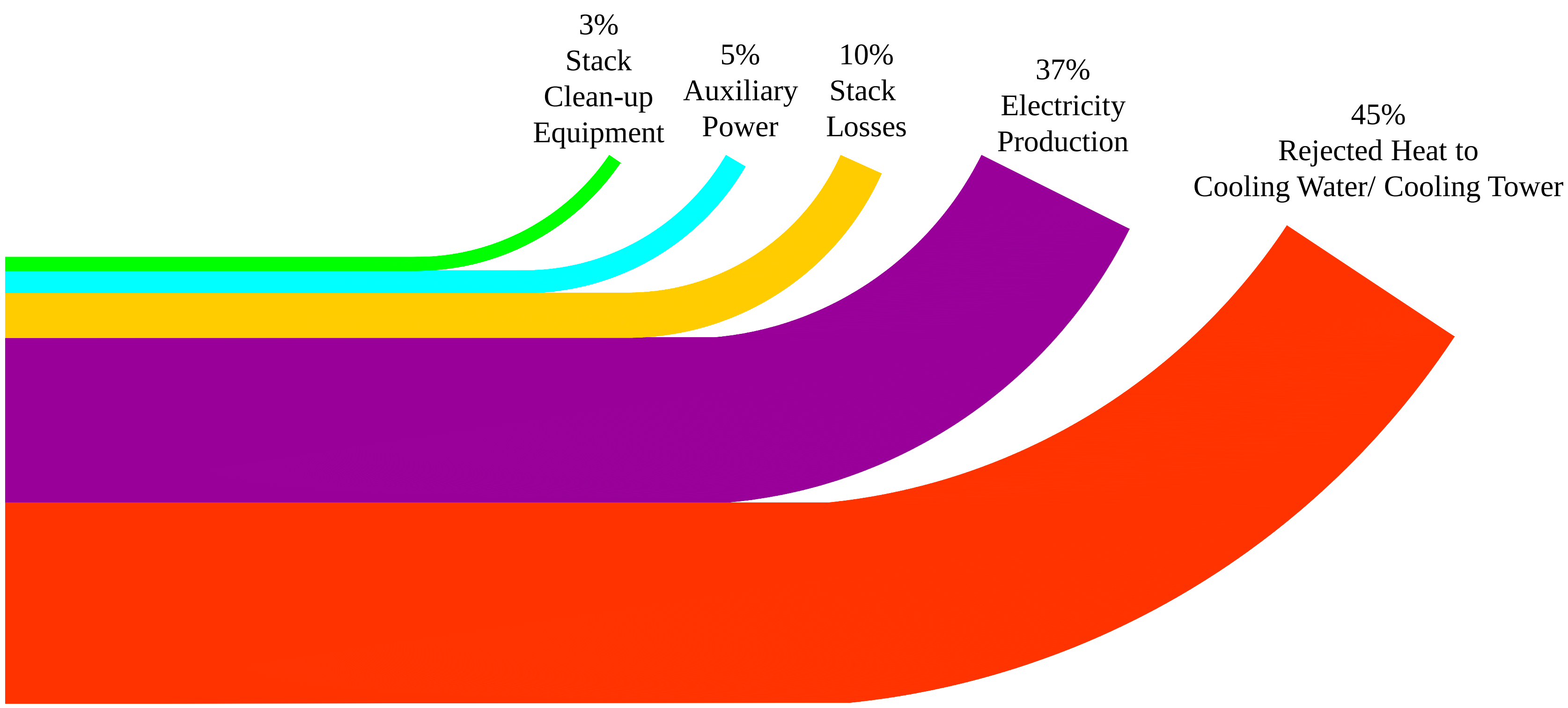
AUXILIARY POWER MEASUREMENT , OPTIMIZATION & ANALYSIS

Steag Energy Training Center

EEC WORKSHOP-25.09.2013 to 27.09.2013

Heat Input into a Large Coal Fueled Power Plant- Large Sub Critical design.



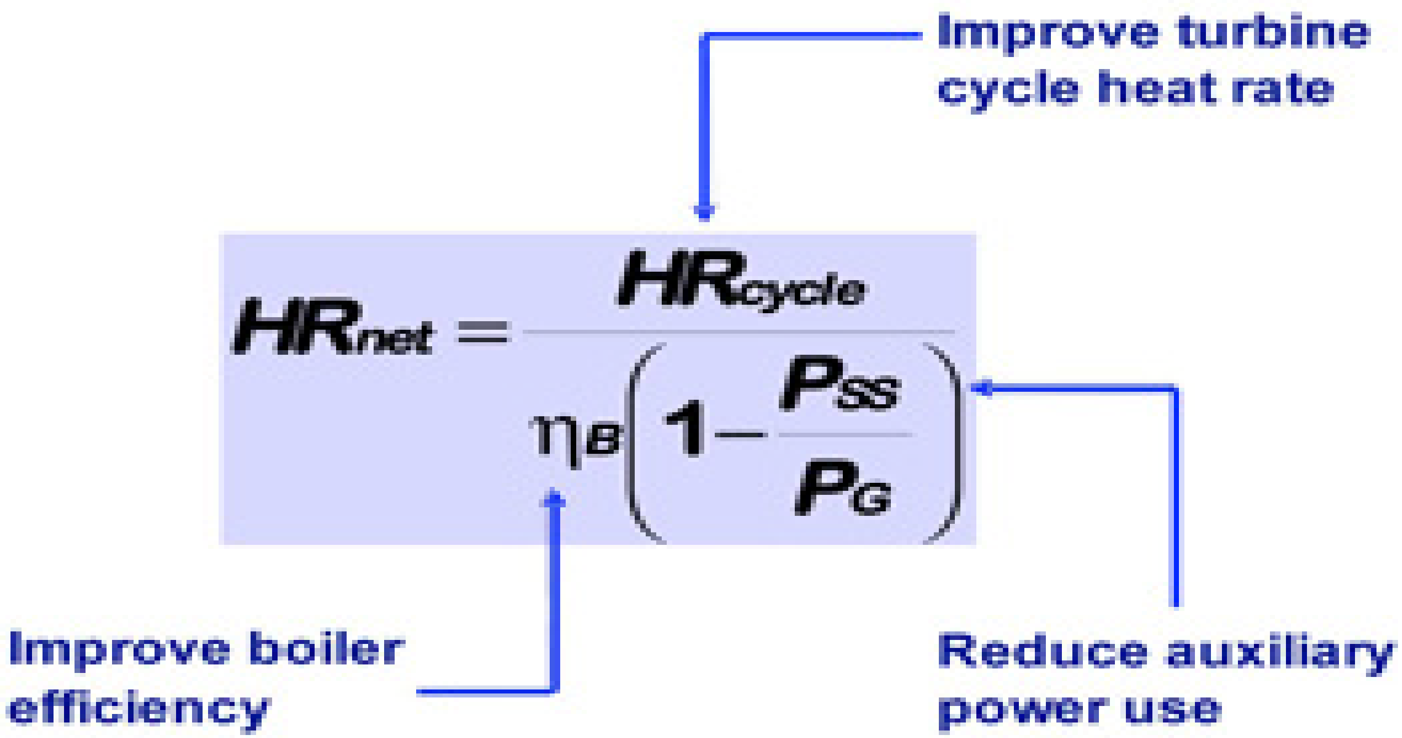
Power Plant –Fossil fuels

- Fossil fueled fired generating stations have very precise definition of Thermal efficiency.
- It is the ratio of heat equivalent of Fuel fired to the heat equivalent of electricity sent to transmission net work.
- Auxiliary power consumption has two components.
- Unit auxiliary power consumption & station auxiliary powerconsumption.

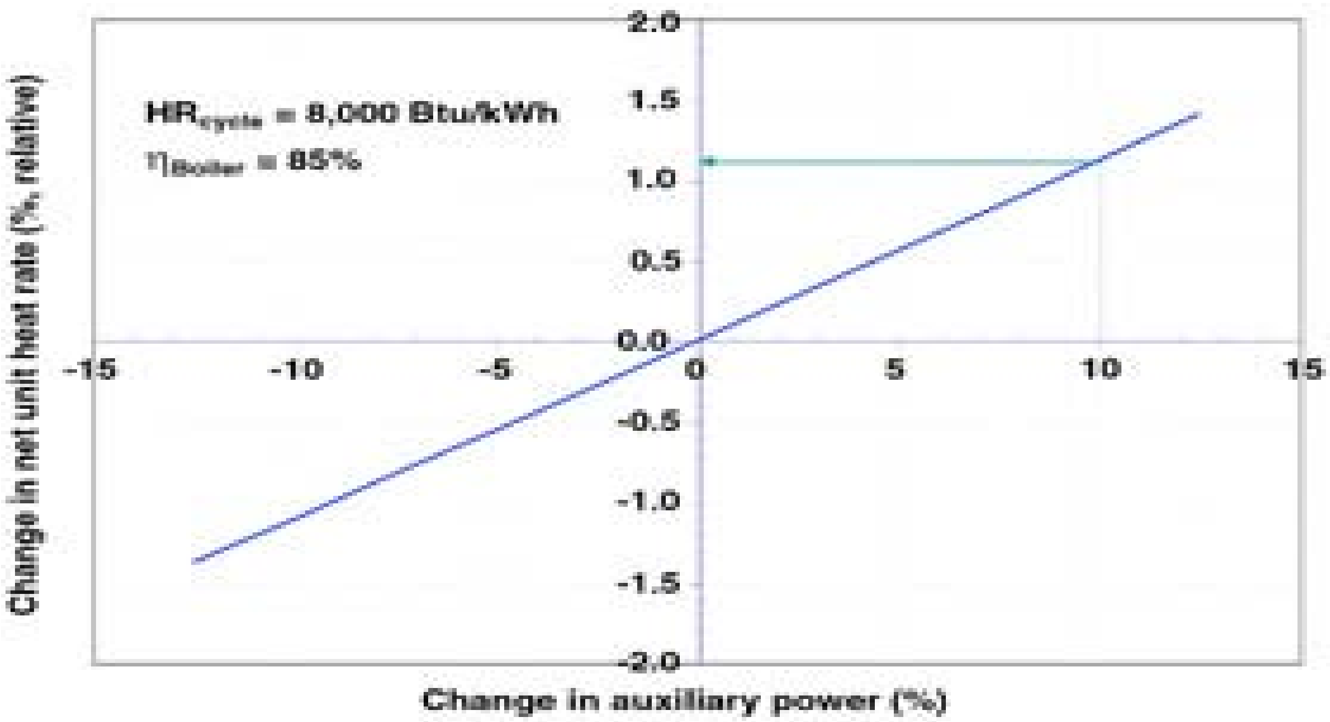
Power plant cycle efficiency

- Role of Steam Generator is to generate steam which is used to convert heat energy into kinetic energy.
- Conversion cost includes usage of steam produced for internal consumption such as SCAPH , TDBFP, Air Condtioning based on VAS
- Aux. power consumption would depend on coal quality and on type of cycle.
- Why not use better coal, which would lower auxiliary power consumption and an optimum performance can be sustained with less expenditure on O&M Cost.

The definition of net unit heat rate, expressed in terms of its component parts (Figure 1), provides a set of potential heat rate improvement options. Reducing auxiliary power use is an important option for improving net unit heat rate.



To illustrate the magnitude of this effect, a sensitivity analysis was performed for an 800-MW (gross) power plant with a turbine cycle heat rate of 8,000 Btu/kWh and boiler efficiency of 85%. The baseline auxiliary power use was 80 MW, and baseline net unit heat rate was 10,458 Btu/kWh. The results, presented in Figure 2, show that a 10% reduction in auxiliary power use will improve net unit heat rate by approximately 1.1%.



The breakdown of auxiliary power loads for a large coal-fired power plant is presented in the Table . The feed water system loads are determined by operating parameters of the Rankine cycle (where boiler feedwater pump power depends on the main steam pressure), and there is little opportunity for reducing these auxiliary power loads except in the selection of drives. The feed water system loads include the main feedwater pumps and condensate booster pumps. **Auxiliary power use in coal-fired power plants by technology.**

Component	Technology			
	Subcritical	Supercritical	Ultra-supercritical	Future ultra-supercritical
Feedwater system	32.2	40.9	42.2	48.3
Cooling water system	17.1	14.9	14.6	13.0
Pollution control system	13.3	11.6	11.4	10.2
Combustion air and flue gas	18.8	16.4	16.0	14.3
Fuel handling	5.0	4.3	4.2	3.8
Other loads	13.6	11.9	11.6	10.4
Total	100.0	100.0	100.0	100.0

Power plant cycle efficiency

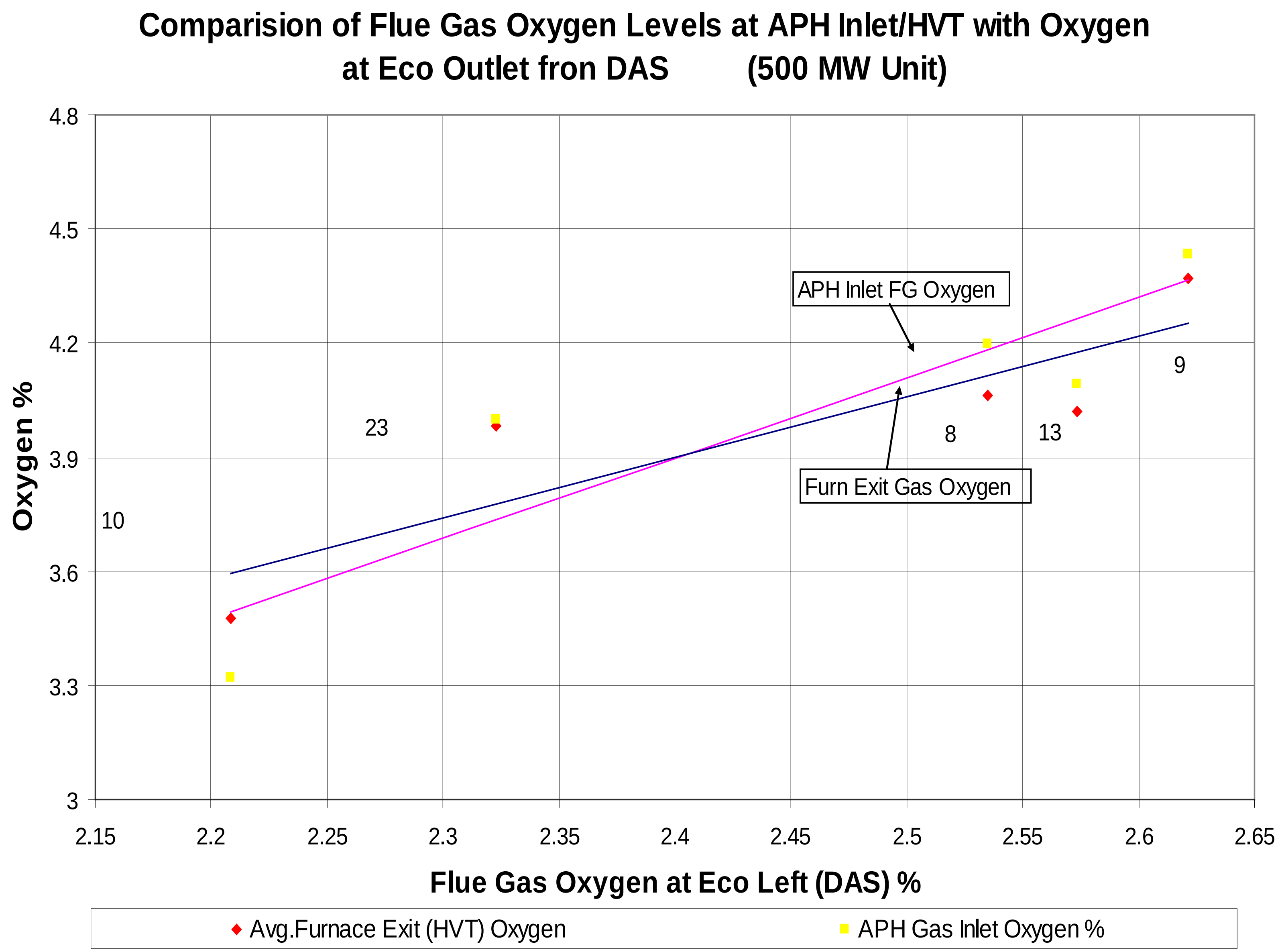
- Gross boiler efficiency at any point of operation can be improved by consuming more electricity through Mills & fans.
- When we are using low cost – inferior coals- we consume more auxiliary power consumption to improve operating efficiency.
- Usage of an additional pulverizer to handle poor coal results in increased power consumption , however, corresponding improvement in Gross boiler efficiency may not be achieved.

IMPORTANCE OF AUXILIARY POWER CONSUMPTION

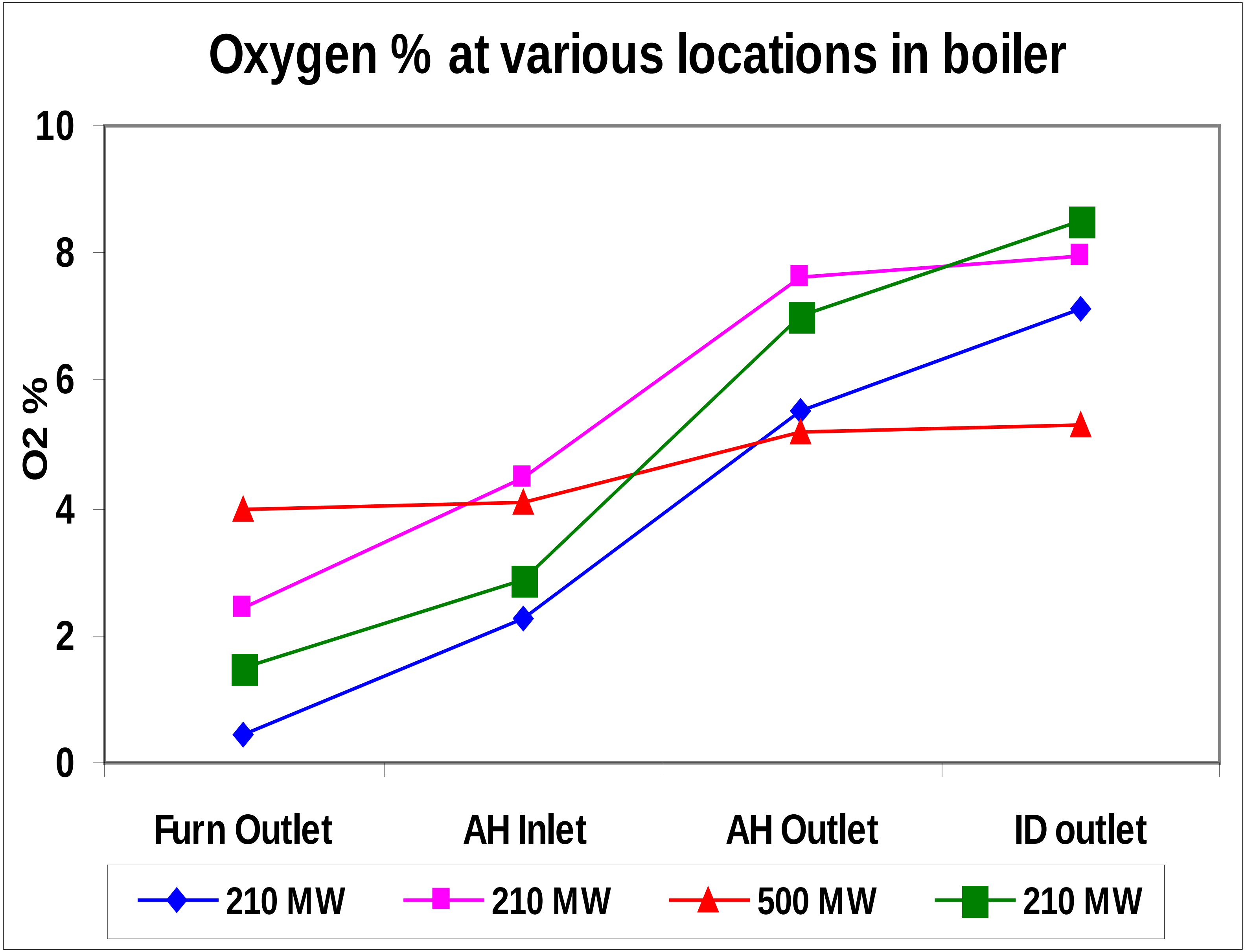
- **DEGRADATION OF EQUIPMENT PERFORMANCE CAN BE READILY GUAGED FROM POWER CONSUMPTION .**
- **UNIT OR BOILER POWER CONSUMPTION IS MONITORED AS % OF GENERATION WHICH IS JUST A GROSS INDEX.**
- **POWER CONSUMPTION GUARANTEE ON BOILER COVERS ALL MAJOR DRIVES.**
- **POWER CONSUMPTION SHOULD BE MEASURED TOGETHER IN A TYPICAL BOILER EFFICIENCY TEST.**

Change in plant Conditions with time increases Auxiliary power

- Air in leakage to boiler gas enclosure
- Fouling of Boiler heating Surface –higher dry gas loss would increase power consumption
- Higher draft loss due to air ingress and ash deposition.
- Air heater leakage / Air ingress after APH’s
- Deterioration of Turbine Steam Path Condition.
- Condenser pressure/ condenser cleanliness- air ingress and extent of tube pluggage
- Steam and water leaks from drains and vents.



Comparision of Flue Gas Oxygen Levels at APH Inlet/HVT with Oxygen at Eco Outlet fron DAS (500 MW Unit)
Oxygen %
4.8
4.5
4.2
3.9
3.6
3.3
3
2.15
2.2
2.25
2.3
2.35
2.4
2.45
2.5
2.55
2.6
2.65
Flue Gas Oxygen at Eco Left (DAS) %
APH Inlet FG Oxygen
Furn Exit Gas Oxygen
10
23
8
13
9
Avg.Furnace Exit (HVT) Oxygen
APH Gas Inlet Oxygen %


Oxygen % at various locations in boiler
O2 %
10
8
6
4
2
0
Furn Outlet
AH Inlet
AH Outlet
ID outlet
210 MW
210 MW
500 MW
210 MW

NET HEAT RATE

- **NET HEAT RATE MONITORING WOULD COVER IMPACT OF AUX. POWER CONSUMPTION OF DIFFERENT DRIVES**
- **NET HEAT RATE MONITORING CAN BE ADOPTED FOR INERNAL PROCESSESS.**
- **THIS WOULD CALL FOR INDIVIDUAL MONITORING OF DRIVES USING ACCURATE ENERGY METERS .**
- **SUCH A SYSTEM IS BEING INTRODUCED AS A RETROFIT IN ALL OLD PLANTS IN NTPC & CONSUMPTION LEVELS ARE BEING TRACKED FROM OVERHAUL TO OVERHAUL.**

MAJOR DRIVES

- **DRIVES ARE LISTED FOR A TYPICAL 500 MW UNIT.**
- **AUXILIARY POWER CONSUMPTION MEASUREMENT CAN BE DONE AS PER A STANDARD TEST CODE.**
- **HOWEVER NO TEST CODE COVERS CORRECTION METHODOLOGY WHICH WOULD BE WORKED OUT BASED ON PROCESS DESIGN.**

MEASUREMENT-METHODOLOGY

- **ACCURATE ENERGY METERS OF 0.25% ACCURACY DULY CALIBRATED ARE USED FOR POWER MEASUREMENT.**
- **ALL DRIVES INCLUDING UNIT AUX. TRANSFORMER SHOULD BE COVERED**
- **ENERGY METERS SHOULD BE CAPABLE OF CONNECTION IN A RUNNING UNIT**
- **MEASUREMENT TO BE DONE ALONG WITH BOILER EFFICIENCY TEST**

PERFORMANCE ANALYSIS

- **MEASURED TOTAL POWER COULD BE DIFFERENT FROM BASE LINE VALUES FOR CHANGES IN OPERATING REGIME**
- **IT SHALL BE HIGHER WHEREVER BOILER PERFORMANCE HAS DEGRADED**
- **GROSS POWER COULD BE SAME BECAUSE SOME AUXILIARIES MAY BE DOING BETTER AND SOME OPERATING AT WORSE POINT DUE TO PERFORMANCE DEGRADATION**

CORRECTION METHODOLOGY

- CORRECTION METHODOLOGY IS JOINTLY DEVELOPED WITH VENDOR AS IT IS NOT GENERALLY COVERED IN TEST CODES
- APPLICATION OF CORRECTION REQUIRES ACCURATE MONITORING OF PROCESS PARAMETES USING ACCURATE OFF LINE INSTRUMENTS
- COAL VARIATION WOULD HAVE MAJOR EFFECT ON UNIT PERFORMANCE AND THUS POWER CONSUMPTION.

BOILER FEED PUMP

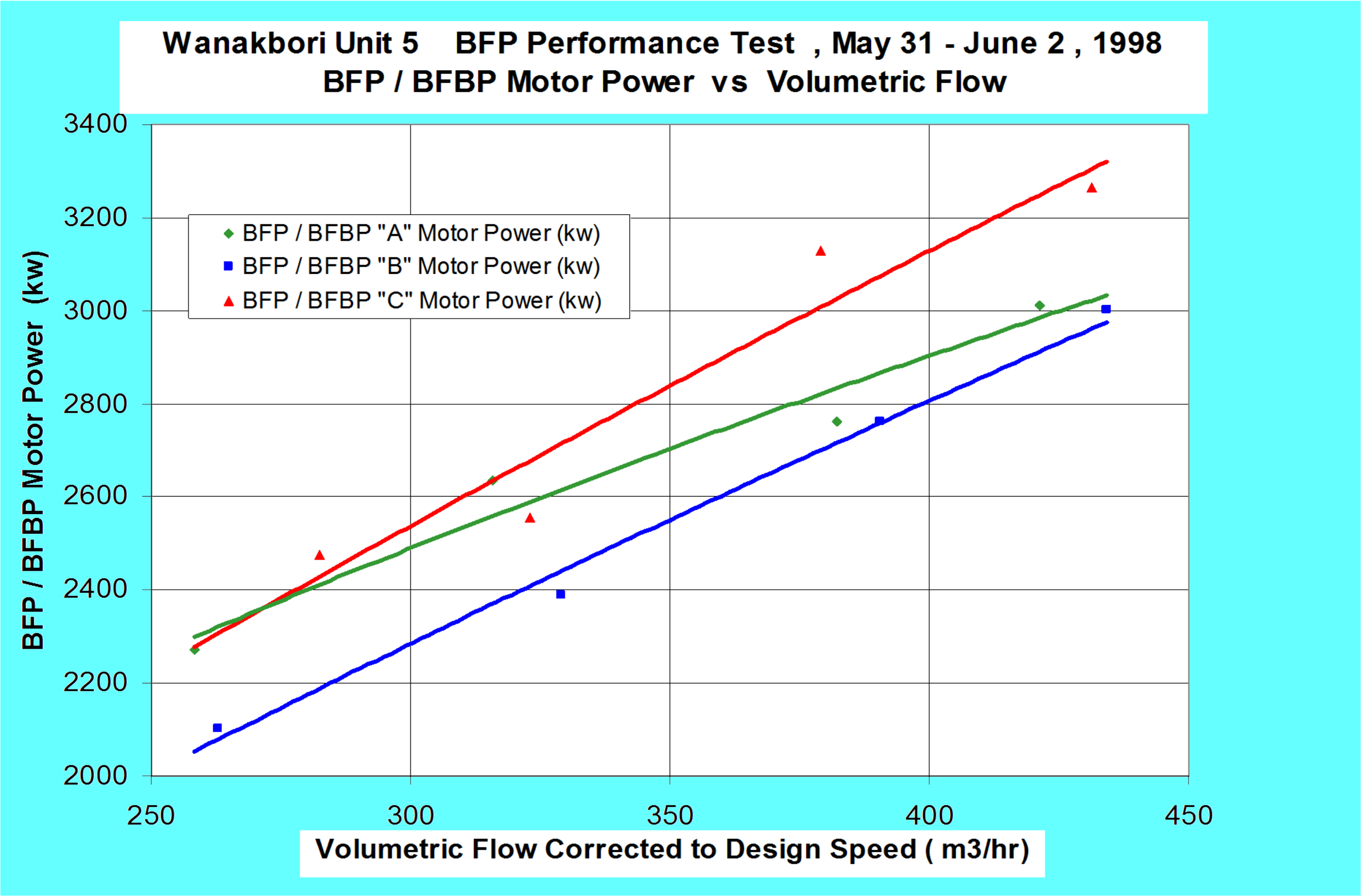
- BOILER FEED PUMP IS NOT A BOILER AUXILIARY AND ITS POWER CONSUMPTION VARIES IN RESPONSE TO TURBINE MODE OF WORKING AND ITS DEGRADATION
- BFP POWER CONSUMPTION CAN BE OPTIMIZED USING VARIABLE PRESSURE OPERATION; REDUCTION OF SPRAY RATES WOULD ALSO HELP.

BOILER FEED PUMP

- **BFP POWER CONSUMPTION CONSTITUTE A MAJOR CHUNK OF POWER CONSUMED BY UNIT AUXILIARIES.**
- **USAGE OF STEAM DRIVEN FEED PUMP RESULTS IN REDUCTION OF APC %.**
- **USAGE OF TURBO DRIVEN FEEDPUMP IMPROVES CYCLE EFFICIENCY .**
- **ANY FEEDBACK ON TDBFP PERFORMANCE DUE TO CONDENSER DEGRADATION !**

Boiler Feed Pump Performance Testing

BFP	F low t/hr	Train Efficiency %	Power Consumption kw	BDLO flow t/hr
A	327	61	2761	29.4
B	337	62	2760.8	28
C	319	51.4	3128	42.2



Wanakbori Unit 5 BFP Performance Test , May 31 - June 2 , 1998
BFP / BFBP Motor Power vs Volumetric Flow
BFP / BFBP "A" Motor Power (kw)
BFP / BFBP "B" Motor Power (kw)
BFP / BFBP "C" Motor Power (kw)
BFP / BFBP Motor Power (kw)
3400
3200
3000
2800
2600
2400
2200
2000
250
300
350
400
450
Volumetric Flow Corrected to Design Speed (m3/hr)

ID FANS POWER CONSUMPTION

MEASURED ID FANS POWER CONSUMPTION IS GENERALLY HIGH FOR FOLLOWING DEVIATIONS

- **HIGHER FLUE GAS VOLUME**
- **HIGH AIR HEATER LEAKAGE.**
- **HIGH ESP LEAKAGE.**
- **HIGHER FLUE GAS TEMPERATURE.**
- **HIGHER PRESSURE DROP CHIMENEY.**
- **IMPELLER EROSION REFLECTS DEGRADATION**

TYPICAL CORRECTION DATA

- **MEASURED POWER FOR ID FAN 2A 2427.5 kW**
- **CORRECTION FOR FREQUENCY -5.0 kW**
- **CORRECTION FOR HIGH GAS FLOW -290.0 kW**
- **CORRECTED POWER CONSUMPTION 2132.5 kW**

POWER CONSUMPTION CAN BE HIGH ON ACCOUNT OF HIGHER PRESSURE DROP ACROSS CHIMNEY.

THIS COULD BE ONE OF THE MAJOR CAUSE FOR ID FAN FULL LOADING IN MANY OF THE UNITS. NO CORRECTION APPROACH .

PRIMARY AIR FANS

- **PA FANS DESIGNED FOR HIGH MARGINS TO HANDLE HIGH MOISTURE COAL AND INCREASED PRESSURE DROP ACROSS A. H.**
- **INTRODUCTION OF ADDITIONAL MILL WOULD INCREASE PA FAN LOAD AND RESULT IN HIGH AH LEAKAGE EXHAUSTING ID FANS MARGIN**
- **PA CROSS SECTION ACROSS AIR HEATERS HAS BEEN INCREASED TO HANDLE HIGH MOISTURE COALS & ADDITIONAL PA FLOW REQUIEMENT**
- **THIS HAS EASED OFF LOADINGS ON PA FANS AND IMPROVED ID FAN MARGINS.**
- **INCREASED PA FLOWS TO MILL COULD IMPROVE BOILER LOADING BUT IT IS AT COST OF INCREASED UNBURNT LOSS & HIGHER POWER CONSUMPTION.**

CORRECTIONS TO PA CONSUMPTION

- **HIGHER COAL MOISTURE**
- **HIGHER AIR HEATER LEAKAGE**
- **HIGHER AMBIENT TEMPERATURE**
- **MEASURED POWER FOR PA FAN 2A 1825.0 kW**
- **CORRECTION FOR FREQUENCY -7.6 kW**
- **CORRECTION FOR HIGH PA FLOW TO MILLS -255.0 kW**
- **CORRECTED POWER CONSUMPTION 1632.4 kW**

FD FANS

- FD FANS POWER CONSUMPTION DEPENDS ON EXCESS AIR LEVEL AND WIND BOX PRESSURE SETTING
- ADDITIONAL MILL AND HIGH PA LOADING RESULTS IN REDUCTION OF FD FANS POWER
- POTENTIAL FOR FANS' POWER CONSUMPTION OPTIMIZATION IS MAXIMUM AND A TOTAL REDUCTION OF 500 kW LOOKED ACHIEVABLE IN A 200 MW UNIT
- TWO SPEED FANS ARE USED IN SOME OF THE PLANTS TO IMPROVE PART LOAD OPERATION

CORRECTION METHODOLOGY

CORRECTIONS APPLICABLE TO FD FANS COVER

- **COAL BEING DIFFERENT FROM DESIGN**
- **AMBIENT TEMPERATURE**
- **HIGHER AIR HEATER LEAKAGE**
- **BOILER OPERATION AT DIFFERENT EXCESS AIR**
- **MEASURED POWER FOR FD FAN 2B 592.8 kW**
- **CORRECTION FOR HIGHER AIR FLOW -40.0 kW**
- **CORRECTION FOR FREQUENCY 0.0 kW**
- **CORRECTED POWER 552.8 kW**

PULVERIZERS

- **PULVERIZER POWER CONSUMPTION HAS MANY TRADE OFFS,SUCH AS MILL FINENESS, MILL OUTPUT & PA FLOW.**
- **REGULAR PERFORMANCE TESTING OF MILLS SHOULD ENABLE THE ESTABLISHMENT OF BASE LINE DATA FOR MILLS.**
- **COAL AND HGI DATA ARE TAKEN TO CORRECT FOR ANY DEVIATION.**

TYPICAL CORRECTION METHODOLOGY

- CORRECTIONS FOR MILLS COVER,
- MEASURED POWER FOR MILL 2B 263.4 KW
- CORRECTION FOR FEEDER SPEED 24.0 KW
- CORRECTIONS FOR HGI FACTOR -40.0 KW
- CORRECTIONS FOR MOISTURE -10.0 KW
- CORRECTION FOR FINENESS 00.0 KW

- CORR. POWER CONSUMPTION 386.6 KW

Power plant cycle efficiency

- Impact of coal quality on expected Boiler Efficiency is rather difficult to predict.
- Modeling tools are generally not available with a station to understand the role of change in operating regime on expected performance.
- Based on actual Performance, we can revise our targets and instead of comparing performance with design values , we can compare with expected values.

Summary -Boiler Performance Tests							
			Pre Outage	Post Outage			
Test Number		Predicted Data	Test 2	Test 2	Test 4	Test 5	Test 6
Unit Load	MW	210	190	208	208	207	210
MS Flow	t/hr	662	625	690	680	680	700
MS Pressure	Ksc	136	115	121	121	122	125
MS Temperature	C	540	530	530	528	531	530
SH Attemporation	T/hr	---	16	5	10	35	18
RH Steam Temperature	C	540	532	530	528	531	530
RH Attemporation	T/hr	----	16	20	25	35	32
FW Temp at Econ. Inlet	C	246	235	240	240	240	240
PA Fan A Current	Amp	---	119	95	95	103	97
PA Fan B Current	Amp	---	114	100	95	105	93
FD Fan A Current	Amp	---	26	30	30	28	28
FD Fan B Current	Amp	---	26	34	30	30	34
ID Fan A Current	Amp	---	121	105	100	103	102
ID Fan B Current	Amp	---	123	100	105	108	102

ELECTOSTATIC PRECPITATOR

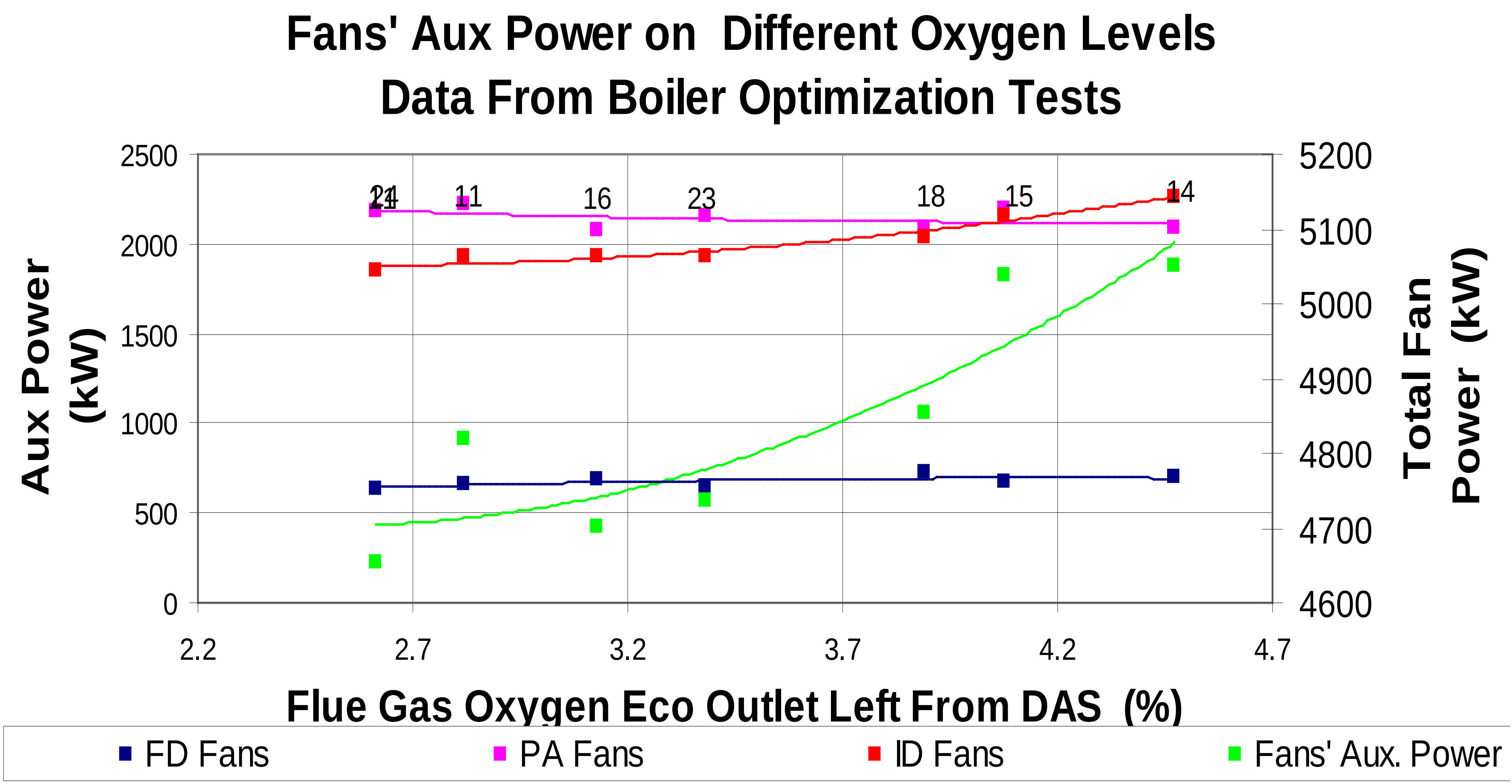
- IT IS AN AUXILIARY WHOSE POWER CONSUMPTION IS DEPENDENT ON ASH CHRACTERSTICS AND OF COURSE ON BOILER OPERATING REGIME.
- PULSE ENERGISATION SYSTEM HAS RESULTED IN MAJOR SAVINGS OF INPUT.
- EFFECTIVE RAPPING SHOULD HELP.
- UPGRADATION HAS BEEN UNDERTAKEN IN ALL UNITS TO REDUCE POWER INPUT.

ELECTOSTATIC PRECPITATOR

- CORRECTION METHDOLOGY FOR ESP IS VERY DIFFICULT TO WORK.
- IT IS REGULATED BY ASH RESISITIVITY WHICH IS COTROLLED BY GAS EXIT TEMPERATURE AND COAL MOISTURE.
- EFFECTIVENESS OF RAPPING SYSTEM SHOULD HELP TO REDUCE THE OPERATING POWER CONSUMPTION.
- SWITCHING OFF FIRST FIELD IS PRACTICSED AT SOME STATIONS WHICH IS DEBATABLE.

CONCLUSION

- AUXILIARY POWER CONSUMPTION AUDITS HAVE A TREMENDOUS PAY BACK AND INCREASE AWARENESS REGARDING EQUIPMENT PERFORMANCE.
- IT COULD BE VERY EFFECTIVELY ADOPTED AS A PART OF ON LINE DAS SYSTEM AT A VERY NOMINAL COST.
- ASSESSMENT OF DEVIATION WOULD CALL FOR ACCURATE PROCESS DATA.


Fans' Aux Power on Different Oxygen Levels
Data From Boiler Optimization Tests
Aux Power (kW)
Total Fan Power (kW)
Flue Gas Oxygen Eco Outlet Left From DAS (%)
2500
2000
1500
1000
500
0
5200
5100
5000
4900
4800
4700
4600
2.2
2.7
3.2
3.7
4.2
4.7
21
24
11
16
23
18
15
14
FD Fans
PA Fans
ID Fans
Fans' Aux. Power