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Performance Analysis and Energy Conservation Opportunities in $210MW_e$ Boiler In Mettur Thermal Power Station

A Project Report

Submitted by

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in partial fulfillment for the award of the degree
of

Master of Engineering
in
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DEPARTMENT OF MECHANICAL ENGINEERING
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BONAFIDE CERTIFICATE

Certified that this project report entitled "**Performance Analysis and Energy Conservation Opportunities in 210 MW_e Boiler in Mettur Thermal Power Station**" is the bonafide work of

Mr. S. Ariharan - Register No. 71204407001

who carried out the project work under my supervision.

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Dr.T.P.Mani	**Mr.S.R.Raja Balayanan**
HEAD OF THE DEPARTMENT	SUPERVISOR

01/07/06.

Internal Examiner **External Examiner**

DEPARTMENT OF MECHANICAL ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY
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05/05/06

TAMILNADU ELECTRICITY BOARD

OFFICE OF THE EXECUTIVE ENGINEER
T&E / MTPS / METTUR DAM -6.

Thiru.S.Ariharan, Final year, M.E (Energy Engineering), Kumaraguru Institute of Technology, Coimbatore has done Project Work entitled **Performance Analysis and Energy Conservation Opportunities in 210 MW Thermal Boiler in MTPS** at Mettur Thermal Power Station during the period of 20.12.2005 to 30.04.2006

Specimen signature
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MECHSEM 2006

ANNAMALAI UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
MECHSEM 2006
NATIONAL LEVEL TECHNICAL SYMPOSIUM

CERTIFICATE OF APPRECIATION

This certificate is awarded to Mr/Ms. S. ARIHARAN
has presented a paper on PERFORMANCE AND ANALYSIS ENERGY CONSERVATION OPPORTUNITIES IN 210 MW , THERMAL BOILER IN MTPS
in the MECHSEM 2006 organised by the Mechanical Engineering Department held on April 12th, 2006

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ABSTRACT

Mettur Thermal Power Station has 4 units of 210MW_e thermal boilers. The boiler design efficiency 85.96%. However the operating efficiency is around 84.5-85%. To attain the design efficiency implementation of Energy Conservation Opportunities in boiler is suggested.

A detailed study of the boiler section, soot section, tubes, boiler pressure parts, fuel section etc. was carried out to identify possible energy-guzzling instruments and processes. After identifying such sections the scope for implementing Energy Conservation Mechanisms was analyzed.

Here stack temperature reduction by modifying the economizer coil and performance improvement on air pre-heater and auxiliary power consumption reduction in primary air fan, secondary air fan, and induced draft fan were analyzed.

Auxiliary power reduction methods by downsizing of forced draft air fan motor, replacing Inlet Damper Control with Guide Vane Control for primary air fan and Variable Speed Drive (or Variable Frequency Drive) for Induced Draft Control were studied.

The cost benefit analysis for all these proposed measures was carried out and simple payback period evaluated.

The project "**Performance Analysis and Energy Conservation Opportunities in 210 MW_e Thermal Boiler in Mettur Thermal Power Station**" presents the analysis, findings and recommendations for achieving energy and cost savings in the boilers of MTPS.

திட்டப் பணி சுருக்கம்

மேட்டூர் அனல் மின்நிலையம் நான்கு 210 MW உற்பத்தி திறன் உடையது. மின் நிலையத்தில் உள்ள கொதிகலனின் இயக்க திறன் 85.9% ஆனால் நடைமுறையில்கொதிகலனின் இயக்க திறன் 84 – 85 சதவீதமாக உள்ளது. எனவே ஆற்றல் சேமிப்பு வழிமுறைகளை பயன்படுத்தி கொதிகலனின் இயக்க திறன் அதிகரிப்பதற்கான வழிமுறைகளை கண்டறியும் ஆய்வு மேற்கொள்ளப்பட்டது. இயக்க திறனை அதிகரிப்பதற்காக சிக்கன அமைப்பு சூடேற்றி மாற்றம், காற்று முன் சூடேற்றியின் மாற்றம் மற்றும் உற்பத்தி மின்சாரச் செலவுகளை குறைப்பதன் மூலம் ஆண்டு ஒன்றுக்கு 15.148 மில்லியன் டன் நிலக்கரியை சேமிக்க முடியும். அதனால் 15 மில்லியன் டன் கரியமில வாயுவின் வெளியேற்றம் குறைக்கப்படும். இதற்கு ஆகும் மொத்த செலவு 6 கோடி. ஆற்றல் சேமிப்பின் மூலம் வருட சேமிப்பு 4.2 கோடி. தொகை திரும்ப கிடைக்கப்படும் காலம் 1.5 வருடம். எரிபொருள் சேமிப்பின் முக்கியத்துவத்தை உணர்த்தும் வகையில் ஆய்வு மேற்கொள்ளப்பட்டது.

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Last but never the least the author thanks all the Mettur Thermal Power Station persons for providing him with the information he required, taking pains to make the project great success.

CONTENTS

SYMBOLS, ABBREVIATIONS OF NOMENCLATURE

A	:	Area
APH	:	Air Pre Heater
C_p	:	Specific heat
D_i	:	Inner Diameter
D_o	:	Outer Diameter
GCV	:	Gross Calorific Value
FD	:	Forced Draft Fan
H	:	Heat transfer coefficient
ID	:	Inner Diameter
IDF	:	Induced Draft Fan
K	:	Thermal Conductivity
KSC	:	kg/cm^2
L	:	Length
mmWc	:	mille meter of Water Column
m_g	:	Flue Gas Flow Rate
MTPS	:	Mettur Thermal Power Station
Nu	:	Nusselt Number
PA	:	Primary Air Fan
P_r	:	Prandtl Number
Q	:	Heat Energy
Re	:	Reynolds Number
RH	:	Re Heater
SH	:	Super Heater
T_{fi}	:	Inlet Feed Water Temperature
T_{fo}	:	Outlet Feed Water Temperature
T_{gi}	:	Inlet Flue Gas Temperature
T_{ho}	:	Outlet Flue gas Temperature
T_m	:	Mean Temperature
U	:	Overall heat transfer coefficient
ρ	:	Density

CHAPTER 1

ENERGY CONSERVATION OPPERTUNITES IN BOILER

1.1. INTRODUCTION

Energy is one of the foremost requirements for development of any country. Every nation, developed or developing, requires energy to increase its productivity. Decreasing conventional energy resources and increasing cost are putting additional pressure on world economies. Hence, increasing the energy efficiency and conservation of energy is the need of the hour and is the concern for all in the power sector.

Energy conservation can be achieved by increasing the efficiency of power generation, improving the heat rate, reducing auxiliary power consumption etc., and all this has to be achieved at the least cost and without compromising on Environmental norms.

By implementing energy efficiency measures the benefit is just not to the company, but also to the nation and the globe. For the company it directly results in the fuel saving, thus reducing operating costs and reducing maintenance work. For the nation it means Energy Security, and the cash saved can be used for other development works.

For globe, the energy conservation measures result in lesser green house gas emissions, thereby controlling the global warming. So energy-conserving mechanisms have to be implemented wherever possible.

Coal fired stations are the backbone of the Indian power generating sector and account for over 76% of generated power. The overall efficiency of these plants is around 30 to 33%. Boiler takes up major portion of energy in any power plant. So research work on 210 MW boilers at Mettur Thermal Power Plant was carried out to determine energy conservation opportunities.

Mettur Thermal Power Station has 4 units of $210MW_e$ thermal boilers. The boiler design efficiency is 85.96%. However the operating efficiency is around 84.5-85%. To attain the design efficiency energy conservation opportunities in boiler can be implemented. Around 1 to 2% deficiency in efficiency is causing the plant a loss of 150 to 300 tons of coal per day. By adopting energy conservation measures in the boiler we can reduce the coal usage. In India 75% of power plants are thermal based. For conserving conventional energy sources we have to implement energy efficiency measures.

1.2. SCOPE OF WORK

For the 4 units of 210 MW_e thermal boilers at MTPS operating at 84.5% - 85% efficiency, excess coal of 150 tons to 300 tons, costing about Rs. 3.15 lakhs to 6.3 lakhs is being wasted per day.

To attain the design efficiency implementing energy conservation opportunities in boiler are suggested. Better efficiency through stack temperature reduction and reduction in auxiliary power consumption saves around **15.148 million tons** of coal per boiler per year; which means about **60 million tons** for MTPS. This also means elimination of nearly **60 million tons** of CO_2 per year. The total investment required is around 6 crores. The annual savings will be around 4.115 crores. Operation and maintenance work will also be reduced at better efficient operation conditions.

The simple pay back period: **1.45 Year**.

1.3. ENERGY CONSERVATION

By proper design of burner, furnace pressure parts and air heaters the exit gas temperature can be maintained as low as possible. This coupled with optimum excess air levels of combustion, results in higher efficiency. Every 10°C reduction in flue gas temperature results in a saving of nearly 7000 tons of coal per year for a 210 MW boiler (for calorific value of fuel of 3500 kcal/kg). Many of the coal fired units were originally designed for the exit gas temperature of 150°C in 1980s. New designs adopt only 125°C or lower temperatures for the exit gas with low sulphur fuels. The efficiency of the older units can also be improved by reducing the exit flue gas temperature to 125°C.

1.4. EFFORTS IN CONSERVATION

1) Introduction of higher pressure and temperature cycles
2) Efforts in reducing auxiliary power consumption
3) Smart wall blowing system
4) Acoustic steam in leak detection –a proactive measure
5) Visible light scanners
6) Improving availability through water chemistry audits
7) Coal beneficiation for multiple benefits
8) Residual Life Assessment studies for planned improvement

1.5. SUMMARY

Energy conservation is a continuous effort to be put forth by Equipment manufacturer, Utility and service provider. Introducing new /reliable technology for improving the heat rate, improving the boiler efficiency ,reducing the auxiliary power consumption and improved operational efficiency are contributing to energy conservation and availability improvement

CHAPTER 2

METTUR THERMAL POWER PLANT

2.1 INTRODUCTION

Mettur Thermal Power Station is the one and only inland thermal power station of Tamil Nadu Electricity Board (TNEB). The station is situated in the left flank of the Ellis Surplus course of the Stanley Reservoir, Mettur Dam. The main objective of the installation of Mettur Thermal Power Station with 4 Nos. 210 MW units is to cater to the need of industrial centers of the stat of Tamil Nadu. i.e. Salem, Erode and Coimbatore. The project work commenced in the year 1981 and the first unit was synchronized with the grid in 1987 and the fourth unit in 1900.

Mettur Thermal Power Station is getting its coal supply from Mahanadhi Coal Fields, Orissa. Coal form Paradeep Port, Orissia is transported through ship to Ennore port and from there by rail to Mettur. Four wagon tipplers have been erected to tip the coal wagons. The coal is fed into the coal bunkers through mechanical conveyor system. There is a coal yard with space to stack 4.0 lakh tons of coal, which is sufficient to meet one month's requirement. There are two stacker-cum-declaimers in the yard to stack the crushed coal and to retrieve the coal to bunkers.

A dyke has been constructed across the Perumpallam valley over an area of 1268 acres. The dyke consists of Upper Ash Dyke, Lower Ash Dyke and Two setting ponds in series. The ash slurry is pumped into the dyke. Ash settles down and the water flows into the primary pond and then to the secondary pond from where clear water is let into the river Cauveri. The effluent water is tested for very high degree of purity in accordance with the standards fixed by TNPCB.

2.2 POWER SUPPLY

The power generated at 15.75 kV is stepped up to 230 kV and fed into the Tamil Nadu Grid. The power generated in the station is being evacuated into the grid by the following 8 Nos. 230 kV feeders

1. MTPS – Mettur 230 kV Auto Sub station feeder.
2. MTPS – Ingur 230 kV Substation feeder
3. MTPS – Salem 230 kV Substation feeder
4. MTPS – Salem 400 kV Substation feeder-I
5. MTPS – Salem 400 kV Substation feeder-II
6. MTPS – Singarapet 230 kV Substation feeder
7. MTPS – Gobi 230 kV Substation Feeder.
8. MTPS – Mettur Thermal Power House feeder.

2.3 SAILENT FEATURES

1. Location :	Mettur (11°56' North Latitude and 77° 48' East Longitude)		
	Elevation 213 meter above MSL		
2. Area of the Plant :	1. Main Plant	: 362	acres
	2. Railway siding	: 30	acres
	3. Ash storing shed	: 73	acres
	4. Ash dyke I stage	: 781	acres
	5. Ash dyke II stage	: 487	acres
	Total	**: 1733**	**acres**
3. Cost of the Project	I stage	: Rs. 384.30 crores	
	II Stage	: Rs. 351.76 crores	
	Total	**: Rs.736.06 crores**	
4. Capacity of Unit	I Stage	: 2 x 210 MW	
	II stage	: 2 x 210 MW	
5. Probable generation p.a	I stage	: 2247 Million Unit	
.	II stage	: 2247 Million Unit	
6. Requirement of Fuel (Coal)		: 1400 tons /Day for 4 units	
7. Requirement of water		: 70 cu. secs.	
8. Chimney Height	I stage	: 130 meters	

	II Stage	: 220 meters
9. Main Parameters		
	i. Boiler Capacity	: 700 tons of steam/hour
	ii. Temperature of Steam	: 540°C
	iii. Pressure of Steam	: 137 kg/cm^2
	iv. Turbine	: 3 stage turbine
	v. Generation voltage	: 15.75 kV
	vi. Generation Capacity	: 210 MW
10. Coal Conveyor System		
	a. Capacity	: 2800 TPH (Two streams of 1400 TPH)
	b. Stacking Capacity	: 4 lakhs tons (Sufficient to feed 4 units for 30 days)
11. Cooling Water requirement		
	a. Raw Water	: 3800 m^3/hr for each stage
	b. Cooling Water	: 3200 m^3/hr for each unit
12. Station Transformers		: 2 x 31.5 MVA, 230/7 kV
13. 230 kV Feeders		: Total – 8 numbers
14. H.F.O Tank capacity		: 3 x 10,000 tons
15. H.S.D Oil Tank		
	Capacity	: 1 x 70 kL

2.4 GENERATION PROPILE

Coal is the major energy source for the power plant. Additionally, it is also possible to fire heavy oil and light oil. The coal transported from Talcher coal fields through rail-sea-rail route the average calorific value of the coal received is about 3300 kcal/kg and high ash content 45%, as against of design calorific value 4200 kcal/kg with Ash content of 32%.

Power generation, coal consumption, auxiliary consumption, specific coal consumption during December 2005 to February 2006 are listed in Table 2.1.

TABLE 2.1 GENERATION PROFILE FOR FOUR UNITS

Period	Generation Million Unit	Coal consumption MT	Specific coal consumption kg/kWh	Auxiliary power consumption
December 2005	605.546	359.601	0.6523	8.375
Jan 2006	470.425	339.09	0.7145	8.3075
Feb 2006	526.463	368.713	0.69975	8.1925

2.5 ENERGY COST

The following cost of coal and electricity has been consider for techno-economic calculation in the report

Electricity Cost	**: Rs 3 per kWh**
Coal cost	**: Rs 2100 per tons**

CHAPTER 3

PERFORMANCE ANALYSIS OF 210 MW_e BOILERS

3.1 INTRODUCTION

Steam generator is a machine that safely, reliably, and efficiently transfers heat released during the combustion of fuel to both feed water and steam. It is a water closed vessel used to produce stream from de-mineralised (DM) water by burning the fuel (coal or oil).

3.1.1 Type of Boiler (in MTPS)

1. Water tube boiler
2. Tangential fire boiler or corner fired
3. Coal fired boiler
4. Hanging type boiler
5. Single drum boiler
6. Re heater type boiler
7. Dry bottom boiler
8. Two pass boiler
9. Pendent type super heater
10. Direct fired
11. Natural circulation
12. Tangential tilting type

3.1.2 Mode of Heat Transfer

Reheater Zone		Mode of Heat Transfer
Water wall	-	Conduction
Re heater	-	Radiation
Super heater header & Economizer	-	Convection

3.2 CAPACITY OF BOILER

1. Producing steam	: 700 TPH
2. Steam temperature	: 540°C
3. Steam pressure	: 150 kg/cm²
4. Furnace temperature	: 1200°C
5. Working pressure	: 136kg/cm²
6. Super heater inlet	: 340°C
7. Bunker capacity	: 625 Tons
8. Coal consumption	: 30 TPH per mill
9. Flue gas out temperature	: 147°C
10. Total air flow to furnace Secondary & primary air	: 847 TPH
11. Secondary air temperature	: 328° C
12. Primary air temperature to Mill inlet	: APH out let 315°C : Mill inlet 180°C
13. Feed water supply	: 656 TPH

Wet bottom & Dry bottom

Wet bottom – furnace temperature more than Ash fusion temperature

Dry bottom– furnace temperature less than Ash fusion temperature

3.3 BOILER DETAILS

3.3.1. Drum

No of drum	: 1 no
Location	: 52 meters
Drum capacity	: 37.2 m³
Drum diameter	: 1676 mm
Drum length	: 4.2 meters
Drum material	: Plain Carbon Steel SA214 grade
Drum pressure	: 147 to 150 kg/cm²
Construction	: It contains 100 turbo separator screen dryers inside the drum and mounted three numbers of safety valves. All water wall tubes, economizer out let tubes and super heater inlet tubes are connected with drum and CBD, EBD are also taping from drum.
Purpose	: To separate, dry steam and water by using spiral separators (primary & secondary) and steam passes to SHH and water passes to ring header through down comers

3.3.2 Hydrostep Level Header

No of hydro step	: 2 no
Location	: 52 meter
Construction	: Fixed in front of the drum
Purpose	: To indicate the steam & water for local & UCB

3.3.3 Water Wall Tube

No of tubes	: 684 no
Metal	: Plain carbon steel (SA 213 grade)
Location	: from 7.2M to 52M (first pass)
Total length	: 27.36 kM
Purpose	: Water passing the drum through water wall tubes 5 mm thick

3.3.4 Downcomer Pipes

No of Down comers	: 6 Nos.
Location	: 52 mtrs
Construction	: Pipe connected between Ring Header & drum
Purpose	: To pass water from Drum to Ring Header
Material	: Plain carbons steal SA 2 B Grade
Diameter	: 406 mm

3.3.5 Soot Blowers

No. of water wall blowers	: 56 No. LRSH 2 Nos. Working
No. of Air Pre heater	: 2 No.

Location	: 32 Meter to 16 Meter except combustion chamber
Construction	: Soot blower device fixed in outer sides of the water tubes arranged in each floor of first pass
Purpose	: To clean out water wall tube over deposited the fly ash during burning the coal, to improve the thermal efficiency
Pressure	: 15 kg/cm² - 400°C
Traveling time	: 1.4 minutes WW/SB 3.4 Minutes in LRSB
Travel construction	: 305mm – WW/SB 7200 mm – LRSB.
Steam pressure	: WWSB – 25 kg/cm² LRSB –110 kg/cm²

3.3.6 Air Pre Heaters

No. of Air pre heaters	: 2 No. A & B Sides
Type	: VIT – 80 Vertical Tri sector invertible baskets 80" depth jungstran tri sector (Rotary) 11 kW motor
Location	: 16 Mtrs. II Pass side.
Construction	: fixed after economizer in the flue gas path
Cold elements	: Carbon steel
Purpose	: To pre heat the primary & secondary air for furnace & mill by using waste flue gas
Speed	: 16 RPM
Direction	: A side anti clock wise B side clock wise
Flue gas temperature	: 330°C (364 to 147°C)
Heading surface area	: 1900 m²

3.3.7 Steam Coil Air Pre Heater (SCAPH)

No of Steam coil Air Pre Heater	: 2 No A & B

Location	: 12 Mtrs Boiler front side
Purpose	: To preheat the secondary air before cold end corrosion occurring in APH rotors during cold start up boiler
Pressure and temperature	: 12 kg/cm^2 & 200^{0}C PRDS
Operation	: Operate only on light up.

3.3.8 Economizer

No. of Economizer	: 2 sets (lower bank, Upper bank)
Location	: 28 mtrs to 32 mtrs level.
Construction	: Coil fixed in the II passage of flue gas path before APH. Inlet connected from HP heater outlet line and out put connected to drum
Purpose	: To preheat the feed water by using waste flue gas to reducing flue consumption
Operating temperature & pressure	: 250^0 C to 290^{0}C (inlet & outlet)
Inlet & outlet of feed water	: 155 kg/cm^{2}S
Economizer valve	: E2 main inlet valve E1 NRV
Eco tube diameter	: 44.5 x 4.5 A1
Construction	: 2 No re circulation line connected with down commers & 1 drain line

3.3.9 Super Heaters

No. of super heaters	: 14 Nos.
Location	: Inter pass from 52 mtrs to 40 mtrs.
Construction	: Fixed between Drum and MSL (Platen SH, LTSH, final super Heater)
Pressure	: 140 kg/cm^2 & 540°C
Temperature	
SHH 9	: 346°C
SHH 10	: 434°C
SHH 11	: 427°C
SHH 12	: 515°C

SHH 14	: 540°C

3.3.10 Flame Scanners

No of flame scanners	: 36 numbers
Location	: 18 mtrs to 26 mtrs (AB to EF Elevation)
Construction	: Scanner device provided inside the furnace having 8 Nos. for each corner. 3 nos. for oil and 5 nos for coal. It was cooled by scanner air fan during service. 24 Nos. Fire ball scanners - fire in all 4 corners 12 Nos. decimator for each
Oil guns	: fire in any two opposite corner.
Purpose	: To indicate the flame condition inside the furnace whether the flame or not

3.3.11 Super and Re-Heater Header (SHH & RHH) Spray Station

No of spray lines	: 4 No. (2 No. for SHH – 2No. for RHH)
Location	: 18 mtrs RHS near APH's LOD's
Construction	: Spray lines are provided between spray control valves and SHH & RHH end. (SHH – 10 & SHH 11 in-between side) spray water inlet was taken from HPH –7 outlet before (full load control valve) FLCV
Purpose	: To supply spray water atooperation to reduce super heater steam temperature and maintain 540°C before enter the turbine
Carry out liquid	: Feed water.

3.3.12 Boiler Draught

Boiler draught means the differential pressure between forced draught and induced draught formed in the furnace.

Furnace pressure	: 5 to – 10MM / WC to maintain negative pressure inside the Furnace to wind box DP + 100 mm / WC

3.3.13 Ignitor

Name of igniter	: High energy ARC igniter.
No of igniter	: 12 Nos (4 x 3)
Location	: 18 mtrs to 26 mtrs (AB to EF elevation)
Construction	: Provided between coal nozzle and oil gun of the corner side.
Type	: Expendable (re traceable) 110V/1110V
Power reply condition	: To ignite the oil spray during light up

3.3.14 Pressure Reducing and De Super Heating System (PRDS)

No of header	: 1 No
Location	: 18.3 mtrs PRDS floor
Construction	: PRDS header provided SCAPH atomizing de aerators heating steam, ejector steam, fuel oil heating system, line area all connected in which the PRDS header.

Self changing control line of PRDS are 100% bypass, 100%main 30% and 30% by pass line are all connected together and its inlet was connected in the 2ms lines.

Operating control valve	: Pneumatic control valve
Operating pressure &Temperature	: 15 kg/cm^2 / 200°C
Carry out liquid	: Steam.

Reducing the pressure & Temperature of MSL from 136 kg/cm^2 540°C to 15 kg/cm^2 – 200°C

Purpose	: To supply steam with a pressure of 15 kg/cm^2 at 200°C to the ejector, atomizing steam to HFO, SCAPH, heading steam to de aerator and also heating steam to PH. If necessary steam supply to another unit for light up stem through inter connection line.

3.4 BOILER FILLING

Various type of boiler filling method are given in Figures 8.1, 8.2 and 8.3

Boiler filling by DM water through the following ways

1. Economizer inlet line at 28 mtr level.
2. Super heater header drains at 16 mtrs

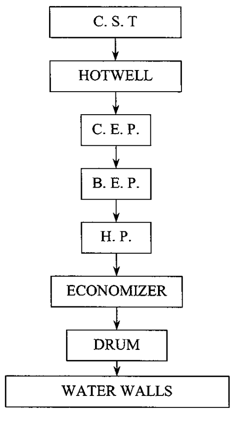

FIGURE 3.1 BOILER FILLING AT STARTUP

3. Low point drain at 0 m level.
4. Low point drain way (During light up)

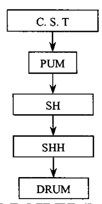

FIGURE 3.2 BOILER BACK FILLING

2. Super heater header way : (Hydraulic test only) (Back filling)

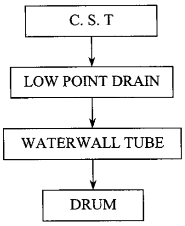

FIG 3.3 BOILER FILLING DURING LIGHT UP

Operating pressure : 5 kg/cm^2
Operating : DM water filling to drum during Hydraulic testing and light up time.
Purpose : To filling the boiler tube with water before firing to avoid starvation

3.5 SECONDARY AIR OR FD FAN

No. of fan : 2 nos. A & B
Location : 'O' mtrs LHS & RHS
Construction : Secondary air duct provided between fan and boiler wind box
Air flow : 339 TPH 80.5 m^3 sec.
Motor kW : 800 I stage
1250 II stage
Purpose : Hot air supply to furnace through wind box for efficient burning which is preheated by APH's and for maintaining 4.5% of 'O'
Operation : Continues running speed 790 rpm
Type of control : Inlet guidance control / axial fan
Cooling : grease cooling (roller bearing)

Fan discharge pressure : 281 mm WC

3.6 PRIMARY AIR FAN

No of fan : 2 any A & B
Location : 'O' mtr LHS & RHS
Construction : Primary air duct provided between fan and mill through APH – A & B
Air flow : 70 m^3 sec 300 TPH. (60 x 5 mills =300)
Header pressure temperature : 800 mm/WC 220°C
Motor : 1250 kW
Purpose : To bring the coal powder to boiler furnace from coal mill by using hot primary air
Operation : Continuous operation.
Type of control : Inlet dampers/Radial fan
Cooling / Lubrication : Oil cooling (journal bearing)
Type of coupling : Pin type flexible coupling
Speed : 1480 RPM

3.7 INDUCED DRAFT FAN (ID FAN)

No of fans : 2 nos A & B
Location : 0 mtrs ESP
Construction : Duct provided between boiler exhaust and chimney
Purpose : To producing draught in furnace and using ID fan air to remove the combustion product from boiler to chimney.
Operation : Continuous running
Motor : 1500 kW
Speed : 740 RPM
Type : Radial fan / variable speed scoop control & hydraulic coupling)
Cooling : Lube oil cooling (bearing)
Flue gas Pr. after ID : +17 mmWC
Draught : The draught produced by the forced draught fan & induced draught fan

difference pressure produced in the furnace is called 'Draught'
Furnace pressure : -5 to -10mmWC in furnace
Furnace to wind box DP : +100 mmWC

CHAPTER 4

ENERGY CONSERVATION OPPORTUNITIES

4.1 INTRODUCTION

The various energy efficiency opportunities in boiler system can be related to combustion, heat transfer, avoidable losses, high auxiliary power consumption, water quality and blowdown.
Examining the following factors can indicate if a boiler is being run to maximize its efficiency.

4.2 ENERGY CONSERVATION OPPORTUNITIES

4.2.1 Stack Temperature

The stack temperature should be as low as possible. However, it should not be so low that water vapor in the exhaust condenses on the stack walls. This is important in fuels containing significant sulphur as low temperature can lead to sulphur dew point corrosion. Stack temperatures greater than 200°C indicates potential for recovery of waste heat. It also indicates the scaling of heat transfer/recovery equipment and hence the urgency of taking an early shut down for water / flue side cleaning.

4.2.2 Feed Water Preheating Using Economizer

Typically, the flue gases leaving a modern 3-pass shell boiler are at temperatures of 200 to 300°C. Thus, there is a potential to recover heat from these gases. The flue gas exit temperature from a boiler is usually maintained at a minimum 200°C, so that the sulphur oxides in the flue gas do not condense and cause corrosion in heat transfer surfaces. When a clean fuel such as natural gas, LPG or gas oil is used, the economy of heat recovery must be worked out, as the flue gas temperature may be well below 200°C.

The potential for energy saving depends on the type of boiler installed and the fuel used. For a typically older model shell boiler, with a flue gas exit temperature of 260°C, an economizer could be used to reduce it to 200°C, increasing the feed water temperature by 15°C. Increase in overall thermal efficiency would be in the order of 3%. For a modern 3-pass shell boiler firing natural gas with a flue gas exit temperature of 140°C a condensing economizer would reduce the exit temperature to 65°C increasing thermal efficiency by 5%.

4.2.3 Combustion Air Preheat

Combustion air preheating is an alternative to feedwater heating. In order to improve thermal efficiency by 1%, the combustion air temperature must be raised by 20°C. Most gas and oil burners used in boiler plants are not designed for high air reheat temperatures.

Modern burners can withstand much higher combustion air preheat, so it is possible to consider such units as heat exchangers in the exit flue as an alternative to an economizer; when either space or a high feed water return temperature make it viable.

4.2.4 Incomplete Combustion

Incomplete combustion can arise from a shortage of air or surplus of fuel or poor distribution of fuel. It is usually obvious form the colour or smoke, and must be corrected immediately.

In the case of oil and gas fired systems, CO or smoke (for oil fired systems only) with normal or high excess air indicates burner system problems. A more frequent cause of incomplete combustion is the poor mixing of fuel and air at the burner. Poor oil fires can result from improper viscosity, worn tips, carbonization on tips and deterioration of diffusers or spinner plates.

With coal firing, unburned carbon can comprise a big loss. It occurs as grit carry-over or carbon-in-ash and may amount to more than 2% of the heat supplied to the boiler. Non-uniform fuel size could be one of the reasons for incomplete combustion. In chain grate stokers, large lumps will not burn out completely, while small pieces and fines may block the air passage, thus causing poor air distribution. In sprinkler stokers, stoker grate condition, fuel distributors, wind

box air regulation and over-fire systems can affect carbon loss. Increase in the fines in pulverized coal also increases carbon loss.

4.2.5 Excess Air control

Excess air is required in all practical cases to ensure satisfactory stack conditions for some fuels. The optimum excess air level for maximum boiler efficiency occurs when the sum of the losses due to incomplete combustion and loss due to incomplete combustion and loss due to heat in flue gases is minimum. This level varies with furnace design, type of burner, fuel and process variables. It can be determined by conducting tests with different air fuel rations.

Controlling excess air to an optimum level always results in reduction in flue gas losses; for every 1% reduction in excess air there is approximately 0.6% rise in efficiency.

Various methods are available to control the excess air

Portable oxygen analyzers and gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 20% is feasible.

The most common method is the continuous oxygen analyzer with a local readout mounted draft gauge, by which the operator can adjust air flow. A further reduction of 10-15% can be achieved over the previous system.

The same continuous oxygen analyzer can have a remote controlled pneumatic damper positioned, by which the readouts are available in a control room. This enables an operator to remotely control a number of firing systems simultaneously.

The most sophisticated system is the automatic stack damper control, whose cost is really justified only for large systems.

4.2.6 Radiation and Convection Heat loss

The external surfaces of a shell boiler are hotter than the surroundings. The surfaces thus lose heart to the surroundings depending on the surface area and the difference in temperature between the surface and the surroundings.

The heat loss from the boiler shell is normally a fixed energy loss, irrespective of the boiler output. With modern boiler designs, this may represent only 1.5% on the gross calorific value at full rating, but will increase to around 6%, if the boiler operates at only 25 percent output. Repairing or augmenting insulation can reduce heat loss through boiler walls and piping.

4.2.7 Automatic Blowdown Control

Uncontrolled continuous blowdown is very waste full. Automatic blowdown can be installed that sense and respond to boiler water conductivity and PH blowdown in a 15 kg/cm^2 boiler results in 3% efficiency loss.

4.2.8 Reduction of Scaling and Soot Losses

In oil and coal-fired boilers, soot buildup on tubes acts as an insulator against heat transfer. And such deposits should be removed on a regular basis. Elevated stack temperatures may indicate excessive soot buildup. Also same result will occur due to scaling on the water side.

High exit gas temperatures at normal excess air indicate poor heat transfer performance. This condition can result from a gradual built-up of gas-side or waterside deposits. Waterside deposits require a review of water treatment procedures and tube cleaning to remove deposits. An estimated 1% efficiency loss occurs with every 22°C increase in stack temperature.

Stack temperature should be checked and recorded regularly as an indicator of soot deposits. When the flue gas temperature rises about 20°C above the temperature for a newly cleaned boiler, it is time to remove the soot deposits. It is, therefore, recommended to install a dial type thermometer at the base of the stack to monitor the exhaust flue gas temperature.

It is estimated that 3mm of soot can cause an increase in fuel consumption by 2.5% due to increased flue gas temperatures. Periodic off-line cleaning of radiant furnace surfaces, boiler tube banks, economizers and air heaters may be necessary to remove stubborn deposits.

4.2.9 Reduction of Boiler Steam Pressure

This is an effective means of reducing fuel consumption, if permissible; by as much as 1 to 2% lower steam pressure gives a lower saturated steam temperature and without stack heat recovery, a similar reduction in the temperature of the flue gas temperature results.

Steam is generated at pressures normally dictated by the highest pressure / temperature requirements for a particular process. In some cases, the process does not operate all the time, and there are periods when the boiler pressure could be reduced. The energy manager should consider pressure reduction carefully, before recommending it. Adverse effects, such as an increase in water carryover from the boiler owing to pressure reduction, may negate any potential saving. Pressure should be reducing in stages and no more than a 20 percent reduction should be considered.

4.2.10 Variable Speed Control for Fans, Blowers and Pumps

Variable speed control is an important means of achieving energy savings. Generally, combustion air control is affected by throttling dampers fitted at forced and induced draft fans. Though dampers are simple means of control they lack accuracy, giving poor control characteristic at the top and bottom of the operating range. In general, if the load characteristic of the boiler is variable, the possibility of replacing the dampers by a VSD should be evaluated.

4.2.11 Effect Of Boiler Loading On Efficiency

The maximum efficiency of the boiler does not occur at full load, but at about two-thirds of the full load. If the load on the boiler decreases further, efficiency also tends to decrease. At zero output, the efficiency of the boiler is zero, and any fuel fired is used only to supply the losses. The factors affecting boiler efficiency are:

As the load falls, so does the value of the mass flow rate of the flue gases through the tubes. This reduction in flow rate for the same heat transfer area reduced the exit flue gas temperatures by a small extent, reducing the sensible heat loss.

Below half load, most combustion appliances need more excess air to burn the fuel completely. This increases the sensible heat loss. In general, efficiency of the boiler reduces significantly below 25% of the rated load and as far as possible; operation of boilers below this level should be avoided.

4.2.12 Proper Boiler Scheduling

Since, the optimum efficiency of boilers occurs at 65-85% of full load, it is usually more efficient, on the whole, to operate a fewer number of boilers at higher loads, than to operate a large number at low loads.

4.3 FACTORS AFFECTING THE BOILER PERFORMANCE:

1. Periodical cleaning of boilers
2. Periodical soot blowing
3. Proper water treatment programme and blowdown control
4. Draft control
5. Excess air control
6. Percentage loading of boiler
7. Steam generation pressure and temperature
8. Boiler insulation
9. Quality of fuel

All these factors individually/ combined, contribute to the performance of the boiler and reflected either in boiler efficiency or evaporation ratio. Based on the results obtained form the testing further improvements have to be carried out for maximizing the performance. The test can be repeated after modification or rectification of the problems and compared with standard norms.

CHAPTER 5

ENERGY MANAGEMENT AND ENERGY AUDIT

The objective of energy management is to achieve and maintain optimum energy procurement and utilization, throughout the organization

- To minimize energy costs/ waste without affecting production & quality
- To minimize environmental effects.

Energy Audit is the key to a systematic approach for decision – making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursing comprehensive energy management programmed.

As per the energy conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

5.1 NEED FOR ENERGY AUDIT

In any industry, he three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help in identifying the areas where waste can occur and where scope for improvement exists.

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are viral for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a "bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

5.1.1 Types of Energy Audit

The type of Energy Audit to be performed depends on:

Function and type of industry

Depth to which final audit is needed, and

Potential and magnitude of cost reduction desired

Thus Energy Audit can be classified into the following tow types.

i) Preliminary Audit
ii) Detailed Audit

5.2 PRELIMINARY ENERGY AUDIT METHODOLOGY

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and the easiest areas for attention
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set a reference point
- Identify areas for more detailed study/ measurement

- Preliminary energy audit uses existing, or easily obtained data

5.3 DETAILED ENERGY AUDIT METHODOLOGY

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost savings calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use in then compared to utility bill charges.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I	-	Pre Audit Phase
Phase II	-	Audit Phase
Phase III	-	Post Audit Phase

5.3.1 Phase I – Pre Audit Phase Activities

A structured methodology to carry out an energy audit is necessary for efficient working. As initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial site visit and preparation required for detailed auditing. An initial site visit may take one day and gives the Energy Auditor/ Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/ Engineer should carry out the following actions:

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyses the major energy consumption data with the relevant personnel.
- Obtain site drawings where available –building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering / Production.
- To finalize Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
- To decide whether any meters will have to be installed prior to the audit e.g. kWh, steam oil or gas meters.
- To plan with time frame
- To collect macro data on plant energy resources, major energy consuming centers
- To create awareness through meetings / Programme.

5.3.2 Phase II – Detailed Energy Audit Activities

Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product output by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the

improvements will be made to indicate the expected pay back on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

5.4 INFORMATION COLLECTED DURING THE DETAILED AUDIT

1. Energy consumption by type of energy, by department, by major items of process equipment, by end – use.
2. Materials balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc)
3. Energy cost and tariff data
4. Process and material flow diagrams
5. Generation and distribution of site services (e.g. Compressed air, steam).
6. Sources of energy supply(e.g electricity from the grid or self-generation)
7. Potential for fuel substitution, process modifications, and the use of co-generation systems (Combined heat and power generation).
8. Energy Management procedures and energy awareness training programs within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baselines data.

- Technology, processes used and equipment details
- Capacity utilization
- Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated.

CHAPTER 6

PERFORMANCE ASSESMENT

Before going for identifying the conservation opportunities in boiler the working condition performance have to be calculated. From that heat balance and energy balance are listed in Table 6.1.

TABLE 6.1 PERFORMANCE ASSESSMENT SHEET

Technical Specification of Boiler	
Boiler capacity rating	210 MW
Type of Boiler	Water Tube
Type of fuel used	Indian coal
Maximum fuel flow rate	160 TPH
Efficiency by GCV	85.96%, 4200 kcal/kg
Steam generation pressure & superheat temperature	136 KSC & 540°C
Heat transfer are in m^2	14625 m^2
Type of draft	Natural draft
Chimney height in meter	210 m

6.1 FUEL ANALYSIS

The fuel analysis is an important step involved. By analyzing the fuel being burnt the constituents of the flue gas can be predicted. We have two types of analysis methods.

1. Proximate analysis
2. Ultimate analysis

In Proximate Analysis very simple evaluation techniques are employed by which the fixed carbon, volatile matter, ash and moisture content values are obtained. At MTPS, the proximate analysis is carried out on a daily basis. The values presented in Table 6.2 are 3-day average values.

The ultimate analysis gives more detailed elemental figures of the fuel constituents. It is more elaborate evaluating the Carbon, Hydrogen, Sulphur, Nitrogen, Oxygen, Ash and Moisture content of the fuel. At MTPS, the ultimate analysis is done on a monthly basis. The figures given in Table 6.2 are 3-month averaged values.

TABLE 6.2 FUEL ANALYSIS DETAILS

Fuel Fired	135 TPH
GCV of fuel	3320 kcal/kg
Proximate Analysis	
Fixed carbon	27.43 %
Volatile matter	25.34 %
Ash	40.25 %
Moisture	7.62 %
Ultimate Analysis	
Carbon	30.02 %
Hydrogen	2.5 %
Sulphur	0.5 %
Nitrogen	1.5 %
Ash	40.45 %
Moisture	10 %
Oxygen	75 %
Flue gas Analysis	
CO_2	%
O_2	3.2 %
CO	40 PPM
Flue gas temperature	160 °C

6.2 HEAT BALANCE

Table 6.3 gives the heat balance for the boiler.

TABLE 6.3 HEAT BALANCE

		Working Condition	Design
Heat input in fuel		3386 kcal/kg	4200 kcal/kg
Percentage Losses in Boiler			
1	Dry flue gas loss	5.02	4.95
2	Loss due to H_2 & moisture in fuel	4.95	5.12
3	Loss due to moisture in air	1.45	0.22
4	Due to incomplete combustion of fuel	2.66	2.00
5	Surface heat loss	0.55	0.5
6	Due to fly ash and bottom ash	1	1
Total losses		**15.635**	**14.02**
EFFICIENCY		**84.365**	**85.98**

6.3 SCOPE FOR CONSERVATION

Flue gas temperature outlet is high against design value; by reduce the flue gas temperature the boiler efficiency can improve. For that temperature profile verified against design value. Economizer and Air Pre Heater temperature profile are widely varying.

CHAPTER 7
ECONOMIZERS

The function of an economizer in a steam generating unit is to absorb heat from the flue gases and add this as sensible heat to the feed water before the water enters the evaporative circuit of the boiler.

Earlier the economizers were introduced mainly to recover the heat available in flue gas that leaves the boiler and provision of this additional heating surface increased the efficiency of steam generation, saving in fuel consumption, thus the name "Economizer" christened. In the modern boilers used for power generation feed water heaters were used to increase the efficiency of the unit and feed water temperature and hence the relative size of economizer less than earlier units. This is a good proposition as the heat available in boiler exit flue gas can be economically recovered using air heater which is essential for pulverized fuel fired boilers.

Using of economizer or air heater or both decided by the total economy that will result flexibility in operation, maintenance and selection of firing system and other related equipment. Modern medium and high capacity boilers use both economizer and air heater. In low capacity boilers air heater alone may be selected.

7.1 LOCATION AND ARRANGEMENTS

It is usual to locate economizer ahead of air heater and following the primary super heater or re heater in the gas stream. Hence it will generally super heater or re heater. Counter flow arrangement is normally selected so that heating surface requirement is kept minimum for the same temperature drop in the flue gas. Economizer coils are designed for horizontal placement which facilitate draining of the coil and favors the arrangement in the second pass of boilers. Water flow is from bottom to top so that steam if any formed during the heat transfer can move along with water and prevent the lock up steam which will cause overheating and failure of economizer tube.

Economizer tubes are supported in such a manner that sagging, undue deflection and expansion prevention will not occur at any condition of operation. A recalculation line with a stop valve and non-return valve may be incorporated to keep circulation in economizer into steam drum when there is fire in furnace but no feed flow. (e.g. during- start up period). Tube elements composing the unit are connected to inlet and outlet headers. Manholes and adequate access and spacing between banks of tubes are provided for inspection and maintenance works. Normally the tube bank arrangement and steam soot blowers provision at appropriate location will facilitate efficient on load cleaning. An ash hopper below the economizer is provided if the flue gas duct is taking a turn from vertical.

7.2 TYPES OF CONSTRUCTION

7.2.1 Plain Tube

Plain tube economizer have several banks of tubes with either in-line or staggered type formation. Staggered arrangement induces more turbulence in the gas than the in-line arrangement. This gives a higher rate of heat transfer and requires lesser surface for a given duty but at the expense of higher draught loss. In-line arrangement may need about 10 to 15% more surface but effectively cleanable with the help of unload steam soot blowers. Hence selection of in-line or staggered arrangement depends on the nature of fuel (fouling) and transverse distance between tube and compact ness of the assembly required.

Economizer can be supported in water or steam cooled coils which can also be used to support primary repeater or super heater. The tubes are site welded to the stubs which are shop welded on to the inlet and manifold is dispensed with by continuing the economizer tube upwards to form the side walls of the super heater/re heater enclosure.

7.2.2 Welded Fin-tube

Large number of variation in this type is available. In earlier days cast iron shrouds were shrunk on mild steel tubes for use as economizer in stoker fired boilers. This type has a good resistance against gas side corrosion but heavy in

weight. But modern boiler uses only plain or fin welded design as gas side corrosion is not faced due to high feed water temperature and easy supporting of the banks with steam or water cooled tubes of suspended design due to low mass.

Fining of tube greatly increases the heating surfaces per unit length of tube (factor of between 2 and 8 according to design) and hence economy in tube, height of the banks and associated support, enclosure etc. are obtained. In-line arrangement is favored in this type for easy cleaning and inspection. Continuous fin type and spiral fin type are available in the market and various other types are generally available from an Economizer manufacturer.

As with plain tubes design, this is also completely welded and same constructions are employed on inled manifold. If the outlet tubes are continued to form side wall enclosure they may need some modification like bifurcation, etc.

7.3 ENERGY CONSERVATION PROPOSAL

The flue gas temperature reduction method was selected as there was scope for improving, efficiency here. The design dry flue gas losses were 4.8%. However, the operating losses were calculated were found to be 5.6%. To reduce the losses, the economizer coil area could be increased. Table 7.1 Shows the design and operating temperatures for the boiler.

TABLE 7.1. DESIGN AND OPERATING TEMPERATURE

Sl. No.	Parameter	Design	Operating
1	Inlet temperature at economizer	476°C	477°C
2	Outlet temperature at economizer	360°C	370 – 375°C

To attain the thermal load = **2578.225 kW** Providing additional heat transfer area **482m²** to require the heat .investment around **Rs. 26.51 lakhs**, from saving **Rs. 58.32 lakhs** per year and simple pay back period ≈ **6 months.** The calculations are listed in Appendix 1.

CHAPTER 8

AIR PRE HEATERS

Air heater is a heat exchanger in witch air temperature is raised by transferring heat from other fluids such as flue gas. Since air heater can successfully employed to reclaim heat from flue gas at lower temperature levels than is possible with Economizer, the heat reject to chimney can reduced great extent. Thus efficiency of the boiler. For every 20 ° C drop in the flue gas temperature, the boiler efficiency increases by about 1%.

8.1 ADVANTAGE OF AIR HEATERS

In addition to increase in boiler efficiency the other advantages that may result in are listed below:

- Stability of combustion is improved by use of hot air
- Intensified and improved combustion
- Burning poor quality fuel efficiently

Higher heat transfer rate in the furnace and hence lesser heat transfer area requirement

Less unburnt fuel particle in the flue gas thus complete combustion is achieved. Intensified combustion permits faster load variation. In the case of pulverized coal combustion, hot air can be used for transporting the pulverized coal to burners too.

8.2 TYPES OF AIR HEATERS

Air heater can classified as **recuperative** and **regenerative** types based on their operating principle.

8.2.1 Recuperative

In recuperative type heating medium is on one side and air is on the other side of tube or plate and heat transfer is by conduction through the material which

separates the media. These are of static construction and hence there is only nominal leakage through expansion joints, access doors, casing etc.

8.2.2 Regenerative

In Regenerative type the heating medium flows through a closely packed matrix to raise the temperature and then air is passed through the matrix to pick up the heat. Either the matrix or the hoods are rotated to achieve this and hence there is slight leakage through sealing arrangements at the moving surface.

8.3 LJUNGSTROM TYPE (REGENERATIVE)

The heat transfer elements are rotated at a constant speed and they pass alternately through the gas and air passes.the axis of rotation of rotation may be horizontal or vertical. The drive is normally electrical operated through reduction gear with compressed air motor as stand by. The air pre-heater's working mechanism is shown in figure 8.1.

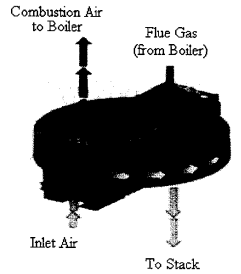

FIGURE 8.1 AIR PRE HEATER

The plates forming the elements (matrix) may be varied in spacing and thickness and cold ends are made of special corrosion resistance alloy such as corten or enamelled to achieve corrosion resistance. This type is very compact and lends

easily for ducting arrangement. Effective cleaning of heat transfer surface by soot blowing is possible. Figure 8.2 shows the Trisector air pre-heater.

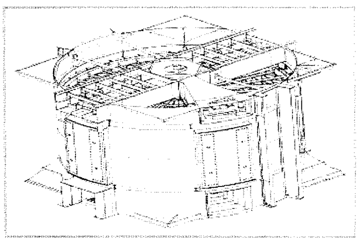

FIGURE 8.2 TRISECTOR AIR PRE-HEATER

8.4 FACTORS AFFECTING AIR PRE-HEATER PERFORMANCE

Deposits in air heater are initiated by condensation of acid or moisture from flue gas on metal surface operating temperature below dew point. Other things reaming same, degree of fouling depends on air pre heater heating element metal surface. Minimum metal temperature occurs at the cold end, where as a result, most fouling and corrosion occur.

As coal contains less sulphur, corrosion is not normally as much a problem as fouling and hence lower exit gas temperature to a level of 120°C is permissible. But in the case of oil firing, the corrosion and plugging due to corrosive products of combustion are very common. The gas outlet temperature and /or air inlet temperature has to be raised to restrict the corrosion to the permissible level. Operating the oil fired boiler at very low excess air reduces the acid formation and hence corrosion

During starting and at low load the flue gas temperature falls down to low value which leads to corrosion .One of the following methods is used to combat the problem:

- Use of low sulphur oil during starting condition
- By pass cold air so that gas temperature can kept at a higher level
- By pass of gas so that acid condensation on air pre heater does not occur at all
- Increase the air inlet temperature by having steam coil air pre heater
- Recalculate the hot air
- The recirculation of part of hot air can be utilized in normal operation also if the FD fan is designed for the same.

During the normal operation to minimize the corrosion one or some of the following method is used:

Air inlet temperature increased mostly by steam air heating to maintain the recommended cold end average temperature for the installation. Corrosive resistant alloys like Corten steel can be used for cold end. This is the easily and economically replaceable cold end portion of air pre heater with out much outage period. Effective on-load blowing of air heaters with superheated steam as moisture in accelerates fouling and corrosion. Soot deposit - Smart wall soot blowing system. Best practices of operation and maintenance must be followed.

8.5 ENERGY CONSERVATION PROPOSAL

In air pre heater temperature profile is varying in the work condition.

As per design value the inlet flue gas temperature must be at 364°C and outlet temperature at 147°C. In working condition inlet flue gas temperature is 370°C and the outlet temperature is 135°C. So reduction in flue temperature around 15°C can conserve the energy. That is thermal load 3.8 MW. Calculations are given in Appendix 2.

Fuel saving per hour	=	**1.0829 Tons**
Annual saving	=	8670 x 2100 x 1.829 x 0.9125
	=	**Rs 1.817 crores**

CHAPTER 9

AUXILLIARY POWER CONSUMPTION

At Mettur Thermal Power Plant the fixed target of auxiliary power consumption is less than 8%. However at working conditions the auxiliary power consumption stands at around 8.25% to 8.35%. To achieve the target major conservation measures for reducing auxiliary power consumption in the equipment must be adopted. Here the scope for conservation is in FD Fan, PA Fan & ID Fan.

9.1 REASONS FOR HIGH AUXILLIARY POWER CONSUMPTION

9.1.1 Plant Specific Factors

- Design deficiencies
- Technology
- Lack of instrumentation &control
- Forced outages
- Operational practices and constraints

9.1.2 External Factors

- Poor quality of coal
- High ash content

9.2 ENERGY CONSERVATION PROPOSAL: FD FAN

Forced Draft fan

The fans are of axial flow with inlet guide wane control. The rating of the fan is 105 m^3/sec at 520 mmWC. The operating head is 200 & 210 mmWC and flow as per the control room is 83 m^3/hr (320 J/hr), which is measured at APH discharge. As per the fan curve, for the head, the efficiency is about 50% and 60 m^3/hr flow. The higher flow measurement, at APH outlet, could be due to primary air infiltration into FD duct, since primary air has higher head than that of secondary air. Though the efficiency at rated capacity is 76% for the normal operating parameters of 306mmWC and 79.8 m^3/sec the fan efficiency is 60%, which is

quite low. The motor is also loaded to 38% of the rated capacity, hence it is imperative that the fan is not loaded to 83 m^3/hr. Hence, capacities of fans and motors are high for the normal operating parameters.

However, it is very uneconomical to have higher capacity of fans and motors and require down sizing with centrifugal fan of operating efficiency of 75%. The power saving for two fans could be estimated at 90 kW. The annual energy saving would be 7 lakh units per annum. Calculations are shown in Appendix 3.

9.2.1 Downsizing of Forced Draft Fan

Background: Though the forced draft fan are high efficient at rated load of 105 m^3/sec and 520 mmWC, the efficiency at running parameter is as low as 50 to 60% and motor is loaded only to 35% to 45% if a suitable rating high efficient (75%) Centrifugal fans and suitable motor capacity are adopted an energy saving to an extent of 90 kW to 100 kW (for 2 Fans) could be achieved. There will be saving in motor losses and improvement pf.

9.2.2 Energy Saving

Annual energy saving	: 0.3942 Million Units
Annual cost of saving	: Rs 11.826 lakh
Cost of Implementation	: Rs 8.5 lakh
Simple pay back period	: 9 months

9.3 PRIMARY AIR FANS

The fan is of radial type with inlet damper control. Against rated capacity of 70 m^3/sec and 1210 mmWC, the operating condition is 38 m^3/sec (measured after APH) and 800 mmWC. The inlet damper opening position was 55%. The measured head of Fan are 940 mmWC and 620 mmWC. The low head from Fan could be due to high infiltration of air from PA duct to FD duct and flue gas path in the air heater. Considering the flow indicated in the control room which is measured after APH, the average efficiency of the PA fan works. Considering the leakage of air into the APH and FD air duct, fan efficiency is the range of 60%. The lower efficiency is due to inlet damper control provided to the fan.

The inlet damper control for flow control is an inefficient way of controlling the flow rate, as it increases the system resistance. The operating fan efficiency of 40% could be improved by replacing the inlet damper control with either speed control or inlet guide vane control.

The speed control could be achieved by variable frequency drive or by fluid coupling. With the speed control, the saving in power will be cube times reduction in speed. The other way of energy conservation to a lesser extent (20% less that of the operating load) is by having inlet guide vane control instead of damper control.

The energy savings per fan by various controls are as shown in Table 9.1.

TABLE 9.1. ENERGY SAVINGS

Controlling Mechanism	Power	Energy saving/annum
Inlet damper control	1017 kW	-
Inlet guide vane control	815 kW	16.0 lakh units
Fluid coupling (scoop)	670 kW	27.5 lakh units
Variable speed control	550 kW	43.5 lakh units

The least installation cost would be by adopting inlet guide vane control.

9.3.1 Replacing Inlet Damper with Guide Vane for PA Fan

Background The PA fans are provided with inlet damper control for controlling flow of air. The system is least efficient way of control. The other controls are Inlet guide vane control, variable fluid and frequency drives. The Cost of variable frequency drive has high investment cost and next the fluid coupling and then vane control. For inlet vale control least modification is required and potential saving would to a minimum of 20% that of the existing power down

Recommendations

It is recommended to replace the inlet damper control with inlet guide vane control for both PA Fans. The potential saving would be to an extent of 2.6 Million Unit per annum.

Energy saving

Annual energy saving	: 2.6 Million Unit
Annual cost of saving	: Rs 78 lakh
Cost of Implementation	: RS 6 lakh
Simple pay back period	: less than 1 month

9.4 INDUCED DRAFT FAN

In Mettur Thermal Power Plant two 1500 kW, 740 RPM ID Fans are driven by squirrel cage induction motors with variable speed couplings are provided for speed control. That can replace with variable frequency control for reduce the auxiliary power consumption will reduce. Savings around 400 Units/hr. Calculation refer Appendix 4.

Benefit of VFD

- Smooth control of flue gas
- Absence of limitation of number of starts
- No voltage dips in the system from direct-on-line starting of large size motors
- Increased efficiency over wide operating speed range
- Increased life of motors due to soft starts
- Simple arrangements & no necessity of large cooling equipment for hydraulic coupling
- Reduction in size of unit/station of large rating & switchgear fault level

VFD for ID fans

Motor rating: 1500 kW

Number of fans: 2

Load on ID fan: 40 – 60%

Present condition of control: Hydraulic coupling

By installing VFD we can save around 40% of rated energy

= savings around 400 units/hr

Annual savings @ 3 Rs/unit:

= 400x 3 x 8760

= Rs.105.12 Lakhs

Investment for VFD:

= Rs.5 Crore (approximately)

Simple payback ≈ 3.2 Years

CHAPTER 10
CONCLUSIONS

In this project detailed study on energy conservation opportunities in 210 MW_e thermal boilers at Mettur Thermal Power Station was done. From that various Energy Conservation and Energy Management Opportunities were identified. By adopting energy conservation opportunities in boiler it was shown how to improve its thermal efficiency. The methods of economizer coil modification, performance improvement on air pre heater and reduction in auxiliary power consumption were studied and their advantages calculated.

By economizer coil modification providing additional heating surface area of around 480 m^2 the thermal load improvement on economizer was around 2.578 MW. Annual fuel savings were around 2777 tons of coal which convert to annual savings of Rs. 58.32 lakhs in terms of money. Performance improvement on air pre heater will improve the thermal load of 3.8 MW. Annual fuel savings of 9486 tons of coal can be achieved; an annual saving of around Rs. 1.817 crore.

Auxiliary power consumption can be saved by downsizing of Forced Draft Fan Motor rating, replacing the Damper Control with Guide Vane Control for Primary Air Fan Control and Variable Frequency Controlling Mechanism in Induced Draft Fan, thereby achieving annual savings of around 2.46 crore. The investment required is about Rs. 5.145 crores. Better efficient operation conditions, reduced auxiliary power consumption and stack temperature reduction give savings of around 15.148 Million tones of coal per Year. That eliminates approximately 15 Million tones of CO_2 per year. The total investment required is around Rs. 6 crores with an annual savings of around Rs. 4.115 crores.

The results are tabulated in table 10.1.

TABLE 10.1 RESULTS

Parameter	Investment	Savings	Payback
Economizer	Rs. 27 Lakhs	Rs. 58 Lakhs	6 months
Air pre-heater	Rs 3 Crores	Rs 1.817 crores	1.65 Years
PA FAN	Rs 6 Lakhs	Rs 78 Lakhs	< 1 month
FD FAN	Rs 8.5 Lakhs	Rs 10.8 Lakhs	< 9 Month
VFD in ID	Rs. 5 Crores	Rs. 157.768 Lakhs	3.2 years

APPENDIX

APPENDIX 1: ECONOMIZER MODIFICATION

The heat content of the flue gas to be recovered by reducing the outlet temperature from 370 °C to 360 °C (Q)

$= m\, c_p\, \Delta T$

= 275.746 (kg/sec) x 1.142 (kJ/kg K) x 10 (K)

= 2578.225 (kW)

Physical properties of flue gas at 370 °C:

ρ = 0.553 (kg/m^3) c_p = 1.142 (kJ/kg K)

k = 54.407 x 10^{-3} (W/mK) N_{Pr} = 0.643

ν = 56.01 x 10^{-6} (m^2/sec)

N_{Re} = D U_m / ν

= 12 x 0.0445 / 56.01 x 10^{-6}

= 9534.012

N_{Nu} = 0.023 $(N_{Re})^{0.8}$ $(N_{Pr})^{0.4}$

= 0.023 x $(9534.012)^{0.8}$ x $(0.643)^{0.4}$

= 29.406

h_o = N_{Nu} x k / D

= 29.406 x 54.407 x 10^{-3} / 0.0445

= 35.952 (W/m^{2}K)

Feed water-side physical properties at 244 °C:

ρ = 809.2 (kg/m^3) c_p = 4.6392 (kJ/kg K)

k = 630.12 x 10^{-3} (W/mK) N_{Pr} = 0.8716 ν = 0.1478 x 10^{-6} (m^2/sec)

$N_{Re} = D\,U_m / \nu$

$= 40 \times 0.0355 / 0.1478 \times 10^{-6}$

$= 9607577.88$

$N_{Nu} = 0.023\,(N_{Re})^{0.8}\,(N_{Pr})^{0.4}$

$= 0.023 \times (9607577.88)^{0.8} \times (0.8716)^{0.4}$

$= 8399.55$

$h_i = N_{Nu} \times k / D$

$= 8399.55 \times 630.13 \times 10^{-3} / 0.0355$

$= 48984.389$ (W/m²K)

Transfer coefficient U

$= (1/h_i + 1/h_o)^{-1}$

$= 35.9943$ (W/m²K)

Surface area required, A

$= Q / U\,\Delta T_{LMTD}$

$= 482.083\ m^2$

$\approx 482\ m^2$

Cost Benefit Analysis

Material cost/m²: Rs. 5000

Total cost = 482 (m²) x 5000 (Rs./m²)
= Rs. 24.1 lakhs

xed cost = 10% of Total cost
= Rs. 2.41 lakhs

Total investment required = Rs. 26.51 lakhs

After modification, improved efficiency = 85.1%

Estimated fuel savings = Fuel rate x $(\eta_{new} - \eta_{old}) / \eta_{new}$ = 0.317 (Tph)

Annual savings in fuel = 0.317 (Tph) x 8760 (hrs) = 2776.982 (T)

Fuel cost/ton = Rs. 2100

Annual savings = Rs. 58.31 lakhs

Simple pay back period = 26.51 / 58.31 x 12 = 5.4 month

Simple payback period ≈ 6 months

APPENDIX 2: AIR PRE HEATER

By reducing flue gas temperature by 22 °C the boiler efficiency will improve by 1%.

%age of fuel saving
= 0.7979 (Tph)

Annual saving = 8670 x 2100 x 0.7979 x 0.9125
= Rs. 1.33 crores (Availability factor 91.25%)

APPENDIX 3: FD FAN

Efficiency of axial fan at 79.8 m³/sec & 306 mmWC	: 60%
Efficiency of radial fan 95 m³/sec&350mmWC	: 75%
Improvement in efficiency	: 15%
Loading of motor (avg)	: 300 kW
Saving in power with higher efficiency in fan	: 0.15 x 300
	= 45 kW
Annual energy saving	: 45 x 8760
	= 0.3942 Million Unit
Annual cost saving	: Rs. 11.826 Lakhs
Cost of implementation	: Rs. 8.5 Lakhs

Simple payback period: < 9 months

Replacement of inlet damper with guide vane for PA Fan

By adopting guide vane damper instead of damper the energy saving is to an extent of 20%

Saving in power/fan	: 160 kW
Saving in power for two fan	: 320 kW
Annual energy saving	: 2.6 Million Unit
Annual cost of saving	: Rs. 78 lakh
Cost of Implementation	: Rs. 6 lakh

Simple payback period: < 1 month

APPENDIX 4: INDUCED DRAFT FAN

Load on ID fan: 40 – 60%

Present condition of control: Hydraulic coupling

By installing VFD we can save around 20% of rated energy
=> savings around 300 units/hr/fan

Total saving = 300 x 2
= 600 kW

Annual savings @ 3 Rs/unit:
= 600 x 3 x 8760
= Rs.157.768 Lakhs

Investment for VFD: Rs.5 Crore (approximately)

Simple payback ≈ 3.2 Years

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