

Energy Auditing of Thermal Power Plant

A Thesis submitted in partial fulfillment of

the Requirement for the award of degree of

Master of Engineering

In

Power System and Electric Drives



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DECLARATION

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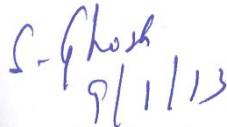
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ABSTRACT

The rate of exploitation of the energy resources has been expanding over time and may result in reduction of panic reserves. Efficiency of all resources is crucial both in an environmental and economic sense. Using energy inadequately creates waste in all the world's economies. It has environmental impacts with regional, local and global implications. Today, provided continues with the enlarged use of renewable resources and also restricted use of non-renewable resources.

The key object is to adopt energy management in every field in order to reduce the wastage of energy sources and cost effectiveness without affecting productivity and growth. Energy audits help to recognize the pattern of energy, form of energy consumption and amount of energy consumption so that identify the possible area of energy conservation. The load distribution or consumption patterns in the power plant and the operation of energy intensive equipments or systems were studied during the energy audit in order to identify potential areas where energy saving is practically possible.

INDEX

S. No.	Contents	Page No.
1.	Abstract	iii
2.	List of Tables	viii
3.	List of Figures	ix
Chapter -1		
	Energy Scenario	
1.1	Introduction	1
1.1.1	Power Capacity in India	1
1.1.2	Total Installed Capacity (October 2012)	2
1.2	Conventional Energy Sources	3
1.2.1	Renewable Power	3
1.2.2	Off-grid Renewable Power Programs	4
1.3	To increase the Efficiency of the Power System: Energy Audit a Tool	5
1.3.1	All audits should include the following	6
1.4	Literature review	8
1.5	Objective	12
1.6	Methodology used	12
1.7	Organized of The Thesis	12
Chapter – 2 Thermal Power Plant		
2.1	Thermal Power Plant	13
2.2	Working of a Thermal Power Plant	13
2.2.1	Working of a Coal Handling Plant	13
2.2.2	Working of Boiler	14
2.2.3	Working of Turbine	14
2.2.4	Working of Generator	15
2.3	Different Section of Super Heater	15
2.3.1	LTSH	15
2.3.2	RPSH	16
2.3.3	FSH	16
2.3.4	Re-Heater	16
2.3.5	Super heater and De-Super Heater	16
2.4	Economizer	16
2.5	Combustion of Pulverized Coal	17
2.6	Testing procedure	18
2.7	Salient Features of selected Unit	18
2.7.1	The plant profile	18
2.8	Actual test Conditions	21
Chapter – 3 Energy Audit of Thermal Power Plant		
3.1	Energy Audit	22
3.1.1	Walk Through Audit	22
3.2	Boiler and Its Auxiliary	22
3.2.1	Detail of Boiler	23

3.2.2	Boiler Efficiency	24
3.2.2.1	Coal	25
3.2.2.2	Signification of Proximate Analysis	25
3.2.2.3	Calculation	26
3.3	Furnace	28
3.3.1	Detail of furnace	29
3.3.2	Furnace Radiation Losses	29
3.4	Air Pr-heater	30
3.4.1	Flue Gas Path	31
3.4.2	Primary Air Path	31
3.4.2	Secondary Air Path	31
3.5	Turbine and Its Auxiliary	31
3.5.1	Steam Turbine	31
3.5.2	Design features	33
3.5.2.1	High Pressure (H.P.) Turbine	33
3.5.2.2	Intermediate Pressure (I.P.) Turbine	33
3.5.2.3	Low Pressure (L.P.) Turbine	34
3.5.3	Turbine Pressure Survey	35
3.6	Condenser	35
3.6.1	Condenser performance Tests	36
3.6.1.1	Readings are taken during the condenser performance test.	37
3.6.1.2	Loss due to High Inlet Pressure of Cooling Water	37
3.6.1.3	Loss due to Inadequate Quantity of Cooling Water	37
3.6.1.4	Loss due to Dirty Tubes or Air in Condenser	38
3.7	Regenerative system	38
3.7.1	H.P. Heater Survey (100% MCR)	38
3.8	Auxiliary Power Consumption	38
3.8.1	Readings of Different Equipments	39
3.9	Calculation and Cost of Losses	40
3.9.1	Deviation from Designed Performance	40
Chapter - 4	Calculations And Results	
4.1	Annexure I	42
4.2	Annexure II	44
4.3	Annexure III	46
4.4	Annexure IV	48
Chapter - 5	Conclusions And Future scope	
5.1	Conclusions	49
5.1.1	Boiler	49
5.1.2	Air Pre Heater	49
5.1.3	Furnace	50
5.1.4	Turbine	50
5.1.5	Condenser	50
5.2	Future Scope	51
Chapter - 6	References	52

LIST OF TABLES

Table No.	Description	Page No.
Table 1.1	Growth of Installed Power Capacity in India	2
Table 1.2	Installed Capacity in Respect of Various Resources	2
Table 1.3	Sector Wise Generation Total Capacity	2
Table 1.4	Region Wise Energy Generation in India	3
Table 1.5	Share of Different Renewable Sources in India	4
Table 1.6	Achievement in Off Grid Power System	5
Table A-I	Boiler Efficiency Calculation	43
Table 5.1	Result and Conclusion of Boiler	49
Table 5.2	Result and Conclusion of Air Pre Heater	49
Table 5.3	Result and Conclusion of Furnace	50
Table 5.4	Result and Conclusion of Turbine	50
Table 5.5	Result and Conclusion of Condenser	50

LIST OF FIGURES

Figure No.	Description	Page No.
Figure 2.1	Single Line Diagram of Thermal Power Plant	13
Figure 2.2	Complete Diagram of Thermal Power Plant	14
Figure 2.3	Complete Diagram of Combustion of Pulverized Coal	17
Figure 3.1	Boiler of G.H.T.P	23
Figure 3.2	Furnace of GHTP	29
Figure 3.3	Sectors of Air Pre Heater	31
Figure 3.4	Turbine of GHTP	32
Figure 3.5	Intermediate Turbine	34
Figure 3.6	Low Pressure Turbine	34
Figure 3.7	Blocked Condenser Tubes	36

CHAPTER-1

ENERGY SCENARIO

1.1 Introduction

About 70% of energy generation capacity is from fossil fuels in India. Coal consumption is 40% of India's total energy consumption which followed by crude oil and natural gas at 24% and 6% respectively. India is dependent on fossil fuel import to fulfill its energy demands. The energy imports are expected to exceed 53% of the India's total energy consumption. In 2009-10, 159.26 million tones of the crude oil is imported which amounts to 80% of its domestic crude oil consumption. The percentage of oil imports are 31% of the country's total imports. The demand of electricity has been hindered by domestic coal shortages. Cause of this, India's coal imports is increased by 18% for electricity generation in 2010.

India has one of the world's fastest growing energy markets due to rapid economic expansion. It is expected to be the second largest contributor to the increase in global energy demand by 2035. Energy demand of India is increasing and limited domestic fossil fuel reserves. The country has ambitious plans to expand its renewable energy resources and plans to install the nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20GW of solar power capacity. India increases the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9%. The country has five nuclear reactors under construction. Now, India became third highest in the world who is generating the electricity by nuclear and plans to construct 18 additional nuclear reactors by 2025, then India will become second highest in the world.

1.1.1 Power Capacity in India

The energy generates by different resources in the given table. This table also shows the growth of installed power capacity in India.

Table 1.1: Growth of Installed Power Capacity in India

Time period	Thermal (%) (MW)	Hydro (%) (>25MW)	Nuclear (%) (MW)	Renewable Power (%) (MW)
1.4.2002	70.85% 74429	25% 26269	2.59% 2720	1.55% 1628
1.4.2007	64.06% 87015	25.51% 34654	2.87% 3900	7.55% 10258
31.9.2010	63.95% 106518	22.41% 37328	2.7% 4560	10.90% 18,155

(Source: Ministry of New and Renewable Energy, Government of India)

1.1.2 Total Installed Capacity (October 2012)

The installed capacity in respect of various resources is as on 30.06.2012 from the Ministry of Renewable Energy. Note: The Hydro generating stations with installed capacity less than or equal to 25 MW are indicated under RES.

Table 1.2: Installed capacity in respect of various resources

Source	Total Capacity (MW)	Percentage
Coal	120,103.38	57.38
Hydroelectricity	39,291.40	18.77
Renewable energy source	24,998.46	11.94
Gas	18,903.05	9.03
Nuclear	4780	2.28
Oil	1,199.75	0.57
Total	2,09,276.04	

(Source: Ministry of Renewable Energy, Government of India)

Table 1.3: Sector wise Generation Total Capacity

Sector	Total Capacity (MW)	Percentage
State Sector	86,881.40	41.51
Central Sector	62,373.63	29.66
Private Sector	60,321.28	28.82
Total	2,09,276.04	

(Source: Ministry of Renewable Energy Government of India)

1.2 Conventional Energy Sources

India is not endowed with large primary energy reserves in keeping with large geographical growing population which increase final energy indeed.

Table 1.4: Region Wise Energy generation in India

Region	Target MU	Generation* MU	Deviation (+/-)	
			MU	(%)
Northern	51044.00	55839.79	(+)4795.79	(+)9.40
Western	14193.00	15041.53	(+)848.53	(+)5.98
Southern	31882.00	30518.04	(-)1363.96	(-)4.28
Eastern	9988.00	8991.10	(-)996.90	(-)9.98
N-Eastern	4245.00	3905.33	(-)339.67	(-)8.00
All India	111352.00	114295.79	(+)2443.79	(+)2.64

Source: Central Electricity Authority (CEA)

Energy audit through out the India indicates that coal is the main energy resource of the country. The coal is contributing 70% of the total energy production. The region wise energy generation is indicated in table. The generation is compared with initiative target in the given table.

1.2.1 Renewable Power

The Government has been promoting private investment for the setting up of projects for power generation from renewable energy sources and to the special tariffs being provided at the State level.

Table 1.5: Share of Different Renewable Sources in India

Resource	Potential (MW)	Upto 9th	Plan Upto 10th	Plan Upto 11th	Plan Target Upto 30.09.10	Cumulative Achievement	12th Plan Projection (2017)
Wind Power	48,500	1667	5,427	9,000	4,714	12,809	27300
Small Hydro Power	15,000	1,438	538	1,400	759	2,823	5000
Bio Power*	23,700	390	795	1,780	1,079	2,505	5100
Solar Power	20-30 MW/sq km	2	1	50	8	18	4000
Total		13,497	6,761	12,230	6,560	18,155	41,400

. (Source: Ministry of New and Renewable Energy, Government of India)

* Includes biomass, urban and industrial waste to energy

These include capital subsidies, accelerated depreciation and customs duties. The capital subsidy being provided depends on region and the renewable resources. The capital subsidies vary from 10% to 90% of project cost. The higher level of capital subsidies are given for projects in the North-Eastern Region or Special category States. Generation Based incentives have been introduced recently for Wind Power to attract private investment by Independent Power Producers. There are not availing Accelerated Depreciation benefit and feed in tariffs for solar power.

1.2.2 Off-Grid Renewable Power Programs

Most importantly, it provides energy access to large rural populations in which including those in unreachable areas. Those meet the un-obtained demand in many other areas.

Table 1.6: Achievement in Off Grid Power System

S.No.	Resource/System	Achievement up to 30.09.2010
1.	Biomass Power	263.1 MW
2.	Biomass Gasifier	128.2 MWeq
3.	Waste to Energy	60.8 MWeq
4.	Solar PV Power Plants	2.9MWp
5.	Hybrid Systems	1.1 MWp
6.	Family type Biogas Plants	4.27 million
7.	SPV Home Lighting system	6,19,428 nos.
8.	Solar lantern	8,13,380 nos.
9.	SPV Street Lighting System	1,21,227 nos.
10.	SPV Pumps	7,495 nos.
11.	Solar Water Heating - Collector Area	3.77 million sq m

(Source: Ministry of New and Renewable Energy, Government of India)

Perhaps the outmost areas can get electricity only through renewable sources. Secondly, very important, unrecognized consequence attributed to off-grid applications. In this way or the other, they replace fossil fuels. These can make a significant contribution to reduction in their consumption which is most important from the point of view of energy security. For instance, solar PV replaces diesel or furnace oil in various areas, rural lighting replaces kerosene, a biogas plant or solar cooking system replace cooking gas. Renewable energy can also meet the requirement of process heat in small enterprises and replace small diesel generator sets which consume diesel oil. It has a giant strength in its ability to supply power in a decentralized and

distributed mode which has the advantage of consumption at the production point and so reduces land and environmental concerns.

1.3 To increase the Efficiency of the Power System: Energy Audit a Tool

Energy audit is a powerful tool for exposure operational and equipment improvements that will reduce energy costs, lead to higher performance and save energy. Sometimes, the energy audit is also called an “energy assessment” or “energy study”. Energy audits can be done as a stand-alone effort but may be conducted as part of a larger analysis across an owner’s entire group. The purpose of an energy audit is to find out how, when, where and why energy is used. The energy audit is also used to identify opportunities to improve efficiency. Energy auditing services are offered by engineering firms, energy services companies and energy consultants. The energy auditors do the audit process.

The first thing energy auditor needs to be aware of end user expectations and then audit starts with an analysis of historical and current utility data. This sets the stage for an onsite inspection. The most important outcome of an energy audit is a list of recommended energy efficiency measures (EEMs). Energy audit serves the purpose of identifying energy usage within a facility, process or equipment, and then identifies opportunities for conservation, called energy conservation measures (ECMs). Audit provides the most accurate picture of energy savings opportunities. Energy audits can be targeted to specific systems i.e. boiler, turbine, generator and any motor etc.

1.3.1 All audits should include the following:

- a) Data acquisition
- b) Data analysis
- c) Recommendations

The complication and documentation required will usually read out the type of audit performed along with the available budget. Most audits will generally fall the following three categories:

- i. Data Collection
- ii. Analysis Steps
- iii. Report Preparation.

i. Data Collection:

- (a) Meeting with Key Facility Personnel: Set up a meeting with all key operating personnel and to go over audit objectives and roles and responsibilities of project team members, facility rules and regulations, scope of work and a description of scheduled project activities.
- (b) Site and Facility Walk-through: Conduct a walk-through of the facility to study the various operations and focusing on the main energy consuming systems.
- (c) Existing Available Document Review: Review existing facility documentation with facility engineering representatives. This documentation should include all existing architectural and engineering plans; facility operation and maintenance procedures and utility bills for the previous three years.
- (d) Facility Inspection: After a thorough analysis of the construction and operating documentation, the main energy consuming equipment and processes in the facility should be further investigated.

(ii) Analysis Steps

- a) Utility Analysis: The utility analysis is a detailed analysis of energy bills from the previous 12 to 36 months. This should include all purchased energy agreements and including liquefied petroleum gas, electricity, fuel oil, natural gas, and purchased steam.
- b) Calculate Feasible ECMs: Energy audits should expose both minor operation modifications and major facility modifications requiring detailed economic analysis offering simple or quick paybacks. Develop a list of most important ECMs for each of the major energy-consuming systems i.e. envelope, lighting, HVAC, process and power.
- c) Economic Analysis: Within the calculation, include the implementation cost, energy savings and simple payback for each of the ECMs. A lot of the detail and complexity is unnecessary or unjustified for many applications.

(iii) Report Preparation

- (a) Prepare Audit Report: Go over the results of findings and recommendations in a final report. The report should include a description of the facilities and their operation. It should also include a debate of all major energy-consuming systems and an explanation of all recommended ECMs with their specific energy impact implementation costs and benefits.
- (b) Present and Review Report with Facility Management: Clarify the process and all activities performed to confirm the report's conclusions. Provide economic results as a formal presentation of the final recommendations. Explain the data on the benefits and costs which make a decision

or set priorities on implementation of ECMs. After the audit: Read the report and understand the contents and give the prioritize improvements according to choice i.e. Energy reduction, Cost, Need (equipment failure) etc.

1.4 Literature Review.

Cropper Paul A. *et al.* (1991) [7] discussed the objective of the audit was to make a comprehensive study of the power plant operations and programs relating to the performance of the generating units and to identify areas of potential improvement. The results indicated that Heat rate improvements had been achieved and an already high level of reliability had been even further improved.

Bhansali V.K. *et al.* (1995) [1] presented the energy conservation was cost effective with a short payback period and modest investment. The results indicated that the energy conservation should be developed as a mass movement like family planning, literacy drive etc.

Khan Atif Zaman (1996) [19] discussed the application of the ECON techniques by which electrical energy could be saved and made cost efficient from the industrial perspective were presented for a sheet-glass industry in a developing country. The results indicated that recommendations if applied to any similar industry in other developing countries may also lead to very reasonable cost savings.

Babu N. Sundar *et al.* (1999) [2] described the Government has given higher priority for the power development projects, the Indian Power sector was struggling With formidable difficulties of meeting the heavy demands of electricity due to higher amount of power losses and energy thefts. The results indicated that their main functions for economic and emission controlled operation of the Power sector had been elaborately analyzed energy. This is achieved by raising the steam in the boilers, expanding it through turbine.

Hogg B. W. *et al.* (1999) [16] presented reviewing the performance monitoring practice of a typical 200 MW oil/gas fired thermal power plant at Ballylumford, N. Ireland, results indicated that The achievable best efficiency values of plant components, needed for comparative performance evaluation, had been shown to be more reliably and accurately obtainable through neural network performance models.

Bathae S.MT *et al.* (2000) [4] described the auxiliary service system of the NEKA steam power plant in the North of Iran is analyzed from the reliability point of view. The results

indicated that the applied indexes in the auxiliary service system of power plants reliability calculations and how these calculations were done. Though theoretically some of these systems could be modeled in a simple form by cut-set method and the reliability calculation could be done by this method.

Bose Bimal K. *et al.* (2000) [3] discussed on global energy generation scenario and the corresponding environmental pollution problem the results indicated that Electric/hybrid vehicle technology that played an important role in fuel saving and pollution control had been reviewed in this context.

Sabooh Dr. Y. (2000) [25] presented the model had been validated by experimenting the operation of an EAF transformer in Ahvaz Steel Making Plant. The results of analysis indicated that the simulation model could be applied in controlling the hot spot temperature of the transformer. This provided an appropriate means of increasing reliability of EAF transformer and preventing further damages to copper windings.

Lee Wei-Jen *et al.* (2002) [22] discussed energy management and energy conservation for motors, systems, and electrical equipment. The results indicated that electric motors constitute about 70% of energy consumption, special attention was given to their types, design, characteristics, applications, sizing, and their utilization.

Han Pu *et al.* (2003) [17] PFC algorithm for first- order plus dead time system was provided, another novel PFC algorithm based on Finite Impulse Response (FIR) model was also presented. The results indicated that the algorithm had not remnant difference due to the variety of set points and output disturbances.

Changliang Liu *et al.* (2004) [8] presented genetic algorithm introduced to identify the transfer functions and parameters non linear dynamic model of thermal process. The results indicated that genetic algorithm based identification method was of good practicability and satisfactory results could be got with it.

Kim Hoyol *et al.* (2006) [20] discussed the control strategy for the new thermal power plant having the steam condition of 3769psi and 1130F and the rated utility output of 1000MW were developed. This paper showed the system structure and information flow scheme. In addition, this paper showed the control strategy strictly following the hierarchical structure of the integrated control and management system.

Gupta J.B. (2006-07) [12] discussed the fact that the thermal energy is the major source of the power generation itself shows the importance of thermal power generation in India.

Rajput R.K. (2006-07) [24] presented a steam power plant converts the chemical energy of the fossil fuel into mechanical.

Guo Ying *et al.* (2007) [13] proposed a multi-objective optimizing control method, including two optimization procedures. The results had demonstrated the satisfactory performance of this novel multi-objective optimizing control strategy. One future research topic was to develop more efficient multiple fuzzy objective optimizing predictive controller for real-time implementation.

Guo Tieqiao *et al.* (2008) [14] described continuous Emissions Monitoring Systems (CEMS) permanently installed for selected processes require initial and periodic quality assurance audit tests to ensure that they were functioning properly and reporting emissions accurately. Results indicated that facility would perform continuing quality assurance (QA) on the CEMS.

Bera S. C. *et al.* (2008) [5] presented the performances of the typical ID fans in the steam generation unit of a naphtha and natural gas based captive power plant had been studied. It had been the considerable part of the losses in the ID fan was due to the over design than the present requirement and also the older design was another cause of low efficiency. So from this performance calculation of ID fan a better design of a fan had been proposed to improve the plant efficiency and save the energy for global interest.

Kamalapur G D *et al.* (2009) [21] presented the achievements and further challenges of electrical energy conservation in Indian context. The results indicated that Energy Conservation Act- 2001 by Government of India was the first step in this direction and had given encouraging results.

Jiang Tie-Liu *et al.* (2009) [17] discussed energy audit concept and purpose was analyzed. By analyzing current utilization situation of energy in China's coal-fired power plant, the significance of energy audit in coal-fired power plant to energy-saving and emission-reducing was introduced. Energy audit contents such as energy management audit, energy utilization audit and energy-saving potential analysis was given.

Qingsheng Bi *et al.* (2009) [23] presented two modes of heat pump heat regenerative of the system, and establish mathematical models for energy saving critical points. Through comparative study and analysis in actual case, the results demonstrated that only when the

coefficient of performance of heat pump (COP) was larger than the coefficient of performance of heat pump of energy-saving critical points, the thermal system was energy saving.

Cao Lihua *et al.* (2010) [9] discussed how to analyzed the reasons and sites which cause the standard coal consumption rate for generating increasing, and provided the basis to power plants for their overhauling and exploiting energy savings potential. The results indicated that the plant had a greater energy saving potential by reducing the condenser pressure and improving condenser vacuum.

Gao Han *et al.* (2010) [15] presented the main factors of fly ash carbon content was analyzed, so as to utilized BP neural networks for dynamic fitting fly ash carbon content value. In addition, the new method was checked up according to online data of some coal-fired boiler, which indicated the method could satisfy the request of practical application.

Chai Yuman *et al.* (2010) [10] described the calculation and analysis of energy destruction and energy efficiency was carried on for the specific working conditions on the basis of the calculation of thermodynamic parameters, and the comparison of the energy destruction of the components was also conducted. The results indicated that energy destruction of the boiler was the largest in the system, which accounted for more than 90% of the energy destruction of the system, so the boiler was the main source of the irreversible loss of the power plant.

Bentarzi H. *et al.* (2011) [6] presented a new approach to controlling the steam turbine of a thermal power plant using distributed controlled system with fuzzy logic technique. The resulted indicated that it was not generally suitable for non linear, time delay, high order and complex system.

Ding Jinliang *et al.* (2011) [11] discussed research results of modeling and simulation of thermal power units was reviewed. Several common models which was used for researches of thermal power control systems was analyzed, including simplified turbine and furnace models for unit coordinated control system (CCS) as well as local equipment models. The challenges of modeling and simulation of thermal power plant researches in the future were discussed.

Jankes Goran *et al.* (2012) [18] presented characteristics of energy consumption in industrial sector of Serbia, the methodology and results of energy audits (EA) performed in industrial sites and potentials for energy efficiency (EE) improvements. The results indicated that the present state of energy systems in Serbian industry could be characterized by significant technological out-of- date, low EE and low level of environmental protection.

Evonik Industries (2009) [26] Energy efficiency is a key for sustainable development. Energy conservation Act 2001 provides legal framework.

PSPCL manual (2007) [27] presented thermo dynamics was the basic subjected of thermal Engineering. It deals with the behavior of gases and water vapors when they are subjected to varying temperature and pressure. In the thermal plant, heat energy is converted into mechanical energy which is further converted into electrical energy.

T.E.R.I. (2011) [28] discussed the structure of the energy audit report is governed basically by the directives issued. The energy audit reports are details of energy consumption, their costs and specific energy consumption stitutional arrangement for promotion of energy efficiency.

1.5 Objective

The objective of the thesis is to increase the efficiency of thermal power plant by comparing the different types of losses on two different loads.

1.6 Methodology Used

Energy audit of thermal power plant is carried out on 80% and 100% MCR load. The measured values and calculated values are compared. To compare loads options, a simple approach is to increase the efficiency of plant by check and repair periodically of the equipments of plant and replacement of less efficient or damage equipments with more efficient or new equipments.

1.7 Organization of The Thesis

This thesis is divided into five chapters-

- 1) The first chapter introduces the energy scenario in India, Literature survey, objective of thesis, methodology used and organization of thesis literature survey.
- 2) Second chapter introduces and its working the profile of G.H.T.P. Lehra Mohabbat,
- 3) Third chapter contains methodology of energy audit in thermal plant and salient futures of selected unit.thermal plant and observation and analysis of different equipments of the plant.
- 4) Fourth chapter contains data and compares the results on 100% loads.
- 5) Fifth chapter contains results, conclusion and future scope.
- 6) Sixth chapter cantains references.

Chapter-2

Thermal Power Plant

2.1 Thermal Power Plant

A thermal power station is a power plant in which water is heated, turns into steam and spins a steam turbine. This turbine is coupled with generator. So, the generator is rotated. After steam passes through the turbine, the steam is condensed in a condenser. After condensing, it is recycled to where it was heated; this is known as a Rankine cycle as shown in figure.

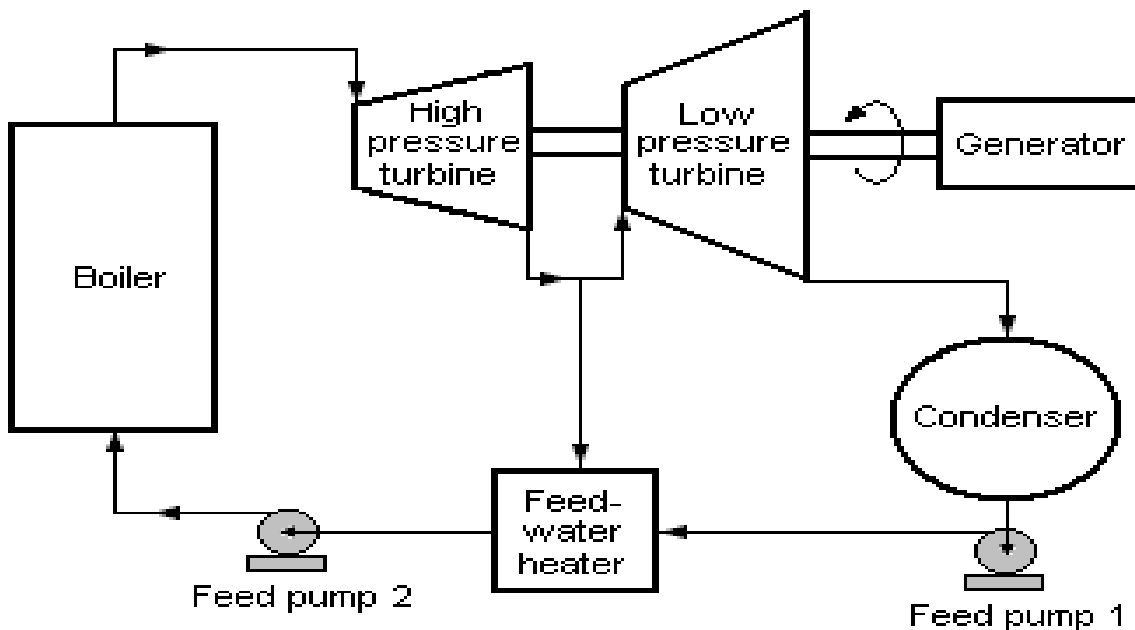


Figure 2.1 Single Line Diagram of Thermal Power Plant

2.2 Working of Thermal Power Plant:

1. Coal Handling Plant
2. Boiler
3. Turbine
4. Generator

2.2.1 Working of a Coal Handling Plant

The layout of a coal handling plant should be simple, easy and low maintenance. By the various combinations of conveyor belts, coal is conveyed to a crusher house. Before the coal enters in the crusher house, the ferrous materials are taken out with the help of suspended and rotating type magnetic separators which come along with the coal. Non-ferrous materials like shells, wood, stones etc. Coal is then fed to the coal crusher through mechanical feeder. Here coal is crushed to the size of 20-25 mm. By

using various belts, this sized coal send to coal bunkers and at last coal trippers. This coal is stored for further processing of coal for combustion in boiler furnace. This cycle is known as bunkering cycle

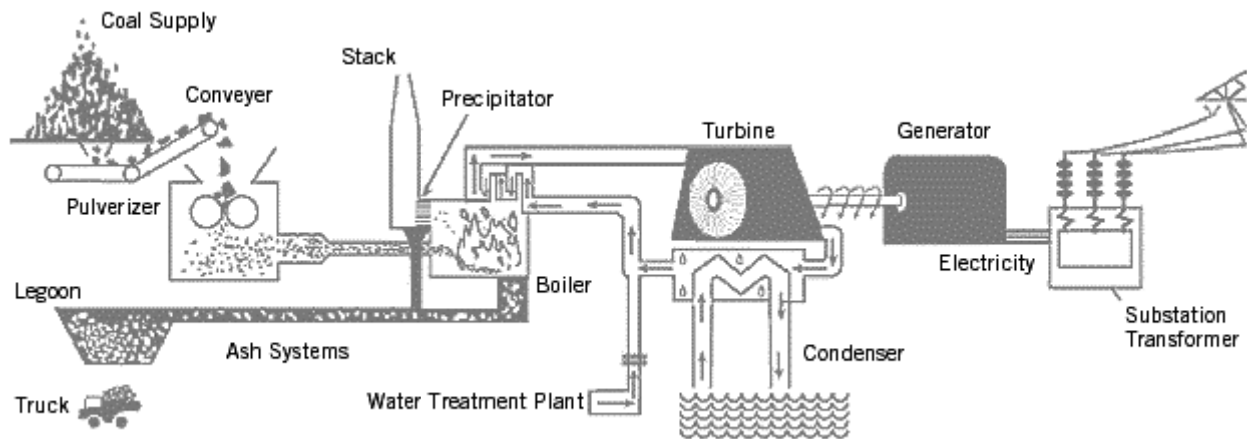


Figure 2.2 Complete Diagram of Thermal Power Plant

2.2.2 Working of a Boiler

In thermal power stations water tube type boiler is used. Water is fed to the boiler drum through the economizer. The heat energy developed due to combustion of coal in furnace. This heat is utilized for the evaporation of water in the boiler. This steam is a mixture of water and steam which enters in boiler drum without help of pump. The final steam that comes out of boiler is called saturated steam. Then, saturated steam is passed through number of super heaters. Temperature of this steam is 540°C (Pressure being 138 Kg/). In the boiler furnace, coal burn, hot flue gases passes through the first pass and then to the second pass to the exit of boiler. Economizer and super heaters are placed in second pass one above the other. In the combustion, the temperature of the flue gases zone is $1200^{\circ}\text{-}1400^{\circ}\text{C}$ and after furnace C . The temperature of flue gas slowly decreases to 400°C when these gasses leave second pass. Its temperature drops down to 140°C

2.2.3 Working of a Turbine

Turbine of thermal power plant is condensing, three cylinders, horizontal and diaphragm type with nozzle governing and regenerative feed water heating. Steam enters in two emergency stop valves (ESV) of high-pressure turbine (HPT). The steam feed to nozzle boxes located inside the HPT. The high-pressure turbine (HPT) has 12 stages. The direction of flow of steam reverse in HPT, rotation of the blades is designed anticlockwise in HPT, when viewed in the direction of steam flow. After passing through HP turbine, steam flows to boiler for reheating. Reheated steam enters to the intermediate pressure turbine (IPT) through two-interceptor valves (IV) and four control valves mounted on IPT. The IPT has 11 stages. IP and HP rotors are connected by rigid coupling and they have a common bearing.

Through two crossover pipes, steam enters the middle part of low-pressure turbine. LP turbine has four stages. After leaving the LP turbine the exhaust steam condenses in the surface condenser. The rotors of IP & LP turbine are connected by a semi flexible coupling. The rotation of rotor is clockwise. The three rotors are supported on five bearings.

2.2.4 Working of Generator

Boiler produces super heated steam of pressure 138 Kg/cm^2 and 540°C temperature. This steam comes to steam turbine. Due to the heat energy of steam; turbine rotates at 3000 rpm. The turbine is directly coupled to the generator rotor. Electricity is generated as per rule of the “Faradays Law” in generator. Magnetic field is produced by rotating field winding with help of turbine. In the alternator, field windings are wound over rotor and rotor is coupled to the turbine. Through slip rings, armature winding is connected to the excitation system. D.C. current is allowed to pass through the armature windings from excitation circuit and produces a magnetic field. So when the rotor rotates, D.C. current carrying windings also rotate and produce a magnetic field. This time varying magnetic field is cut by the stator windings of the alternator. The emf is induced in it. Electricity produced in the stator is passed through bus ducts to the transformer.

2.3 Different Sections of Super Heater

Steam is heated in a super heater at higher the steam pressure and this high pressure steam is used to do mechanical work.

2.3.1 LTSH

LTSH stands for Low Temperature Super-Heater. LTSH is located above the Economizer. This section is of continuous loops, horizontal in line spaced, drainable, plain, tubular type. LTSH has upward steam flow and downward gas flow arrangement. Convective spaced heating surface has 120 assemblies and 4 elements per assemblies. LTSH has vertical arrangement for outlet section.

2.3.2 RPSH

RPSH stands for Radiant Platen Super Heater. RPSH is located in the radiant zone. It is arranged at the furnace outlet section. RPSH section is of continuous loop, vertical in tangent tube type, non drainable, plain, tubular type. This section has parallel flow arrangement. The radiant platen heating surface has 29 assemblies and 7 elements per assemblies.

2.3.3 FSH

FSH stands for Final (Finish Pendant) Super Heater. FSH is located in horizontal pass. It is arranged after the re-heater. This section is of spaced type continuous loop, vertical in line

spaced type, non drainable, plain, tubular type. This section has also parallel flow arrangement. The convective final super-heater has 119 assemblies and 2 elements per assembly.

2.3.4 Re-Heater

This is arranged in between Radiant Platen Super Heater and Final Super Heater section. The re-heater front pendant and rear pendant section is located in horizontal pass. The re-heater section is a single stage, spaced type, continuous loop, vertical in line spaced, non drainable, plain, tubular type. This section has also parallel flow arrangement.

2.3.5 Super Heater and De-Super Heater

The de super heater is of welded type, spray nozzles. Two numbers of spray type De-Super-heater are located in the steam connecting links between Platen SH inlet header and the LTSH outlet header for controlling the final superheat steam temperature at the rated value. This inter stage of de-super heater has welded type. Two numbers spray type de-super heater is provided for emergency control of re-heater outlet temperature.

2.4 Economizer

The economizer, in two banks, is of the continuous loop plain, horizontal in line arrangement, drainable, plain tubular type. The flow of water is upward and flow of gas is downward. Economizer is mechanical devices which are used to reduce energy consumption. These are used to perform another useful function such as preheating a fluid. An economizer re-circulation system is provided, connecting the down comer (near water wall lower ring header) and economizer inlet pipe to ensure required flow through economizer tubes during starting condition of boiler.

2.5 Combustion of Pulverized Coal

Combustion system can be categorized into either of the following two categories:

1. Current commercial technologies

The most common are pulverized coal combustion, cyclone firing, and stoker firing. In this type of system, the coal is prepared by grinding to a very fine uniformity for combustion. Typically, 70% of the coal is ground to pass through a mesh screen. During coal combusts, ash is formed in the combustion chamber. The main advantage of pc combustion is the very fine nature of the fly ash produced. PC combustion results in roughly 65%–85% fly ash and the remainder is coarser bottom ash.

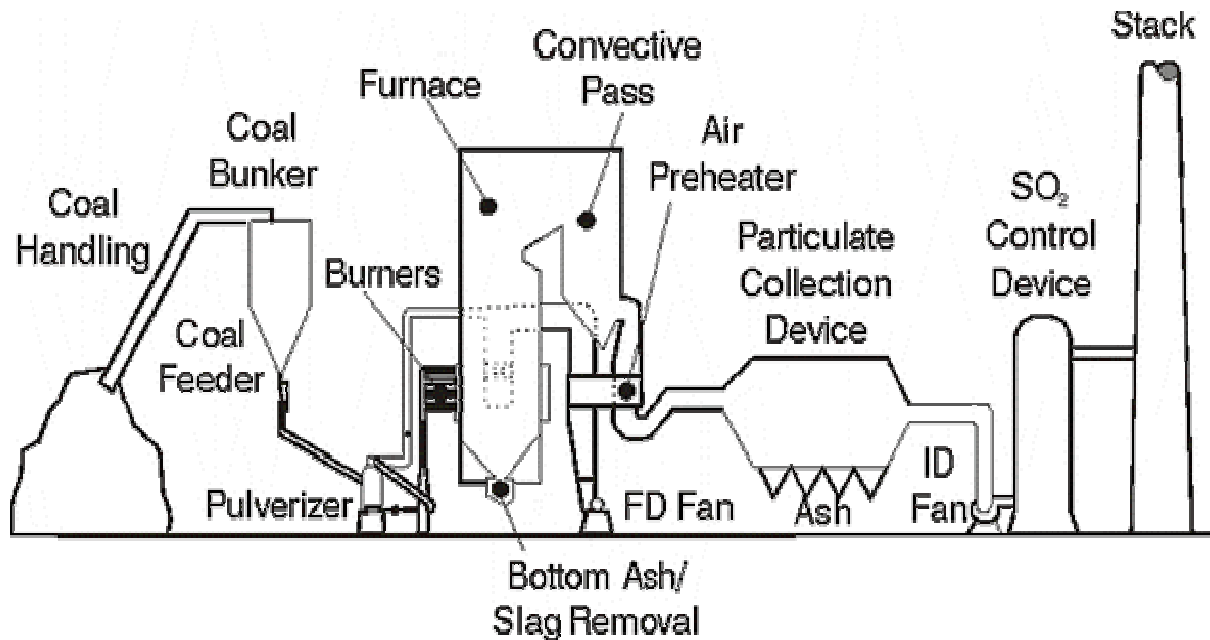


Figure 2.3 Complete Diagram of Combustion of Pulverized Coal

2. Emerging technology is being developed to efficiency environmental compliance and improves cost. Advanced clean coal technologies, including atmospheric fluidized-bed combustors (AFBCs), circulating fluidized-bed combustors (CFBCs) or pressurized fluidized-bed combustors (PFBCs), gasification systems and produce ash characteristics that differ significantly from conventional coal-firing technologies.

The literature supplied by the power station. Testing procedure for GHTP, Lehra Mohabbat as given below:

2.6 Testing Procedure

The tests can be carried out at the 100% MCR load.

2.7 Salient Features of Selected Unit

Tests were to be carried out on unit no.1 at 100% of the load. The brief detail about unit no.1 is given below:

Unit no.1 selected for Energy Audit test was commissioned in 29/12/1997. In the regenerative system, it consist of one reheat, one Dearator and five stages of regenerative feed water heating i.e. 3 L.P. heater and 2 H.P. heater. It has two types of cooler (Gland steam cooler and drain cooler). It consist of 210 MW single shaft reaction turbines, tandem coupled 300 rpm double flow exhaust, reheat type with initial parameters of 150 Kg/ cm² and 535⁰C. The boiler is

designed for pulverized coal having 41.24 % fixed carbon, 28 % volatile matter, 14.26 % moisture, 4036 Kcal/Kg Gross Calorific Value and 31.44% ash. The unit consists of 3 nos. boiler feed pumps (1 nos. booster and 2nos. condensate extraction pumps). Forced Draft (2 nos.), Induction Draft (3nos.) and Paul Allen (2 nos.) are types of fans.

To undertake the detailed energy audit of **GURU HARGOBIND THERMAL PLANT (GHTP)** Lehra Mohabbat. The basic objective of the detailed energy audit was to:

1. Study the load consumption/distribution pattern in the plant.
2. Study the operations of energy concentrated systems/equipments to identify potential area wherein energy savings are practically feasible.

2.7.1 The Plant Profile: GURU HARGOBIND THERMAL PLANT, Lehra Mohabbat.

1) COST OF PROJECT	a) Stage 1 – Rs. 1189 Crores
	b) Stage 2 – Rs. 2123 Crores
	29 December, 1997
2) DATE OF START	
3) LAND	
a) Power Plant Area	774 Acres
b) Ash Pond	160 Res
c) Township	91 Acres
4) RAILWAY TRACK	
a) Near Station Site	Lehra Mohabbat 1.5 kms
b) Near Airport Site	Amritsar- 190 kms.
c) Marshalling Yard	38.33 mm
5) HEIGHTS	
	220 m
a) Chimney	
b) Boiler	64 m
c) Station Building	50.25 m
6) COAL	
a) Coal Consumption / Year	18,60,000 Tons
b) Total Storage	4,80,000 Tons
c) Ash Generated Daily	1200 MT/ Unit
7) HEAVY FUEL DAILY REQUIREMENT	6000 kL for each tank
8) RAW WATER CAPACITY	2100 m ³ /Hr.
9) COAL HANDING PLANT	
a) Wagon Tiplers /Hr.	20 Nos.

b) Primary Crusher	4 Nos.
c) Secondary Crusher	4Nos.
d) Stacker	2 Nos.
10) BOLIER	
a) Type	Water Tube, Single Drum
b) Make	BHEL
c) Water Temperature	531 ⁰ C
d) Steam Pressure	140.1 kg/cm ²
e) Efficiency	87.25 %
11) ATOMSPHERIC EMISSION	
a) No. of Chimney Stacks	1 for 2 Units
b) Height of Stacks	220 m
c) Volume of Flue Gases Emitted	1042 Tons/hr./unit
d) Temperature of Fuel Gasses Emitted	135 ⁰ C
12) CONDENSER COOLING WATER SYSTEM	
a) Type	Direct/Indirect/Once
b) Pumps Capacity	15000 m ³ /Hr.
c) CW Pumps	3 Nos. per unit
13) TURBINES	
a) Make	BHEL
b) Capacity	210 MW
c) Type	Reaction Turbine
d) Rated Speed	3000 Rpm
e) No. of Stages	3(HP-25, IP-20,LP-8)
f) Efficiency	42.97 %
14) NUMBERS	
a) HP Heaters	2 per unit
b) LP Heater	3per unit
c) Dearator	1 per unit
15) GENERATOR	
a) Type	3-phase Double star 2 pole horizontal cylindrical rotor
b) Capacity	247 MW
c) Make	BHEL
d) KV	15.75
e) P.F	0.85 lag
16) MILLING PLANT	
Mills	
a) Type	Blow
b) Working/Stand by	4/ 2 Nos.
17) AIR PRE- HEATER	

- a) Type
- b) Nos.

Regeneration
4

18) UNIT SYNCHRONIZATION

UNIT

DATE OF SYCHRO.

1

26/09/1997

2

16/10/1998

3

16/10/2008

4

31/01/2009

2.8 Actual Test Conditions

1. There was no vibration in the operating unit.
2. High pressure (HP) was in service.
3. Oil burner was not in service.
4. Continuous Blow Down (CBD) was not in open position.
5. These instruments should be able at the time of tests. Instruments are:
 - a) Lux meter for measuring illumination.
 - b) Digital Barometer
 - c) Orsat Apparatus.
 - d) A dry and wet thermometer for temperature and relative humidity.
 - e) 20 Nos. polythene bags of 2 kg capacity for coal samples.
 - f) 15 Nos. polythene bags of 2 kg capacity for ash samples.
 - g) 5 Nos. scoops for taking Raw coal sample.

Chapter-3

Energy Audit of Thermal Power Plant

3.1 Energy Audit

Energy audit is the first step forward systematic efforts for conservation of energy like financial audit. It involves and collection of energy related data on regular basis. It tells how and where the energy is being consumed and it also tells how efficiently and effectively the energy is being used. It is not only study to identify various weak areas but also tells the tool to take corrective actions and monitor the performance. Energy audit provides with the tool to benchmark your consumption against your best figure.

3.1.1 Walk Through Audit:

Walk through audit commonly falls under the operations and maintenance financial plan. Encouraging employees to develop energy-efficient habits can be accomplished by setting new procedures. Repairing or replacing small items which are in poor working condition. Use the Walk-Through Checklist to identify the easy, low- to no-cost improvements you can make in your facilities. Once the audit has been completed, you will be able to identify energy-saving improvements.

Unit 1(209.3 MW) was chosen for conducting energy audit test. After discussions with the power station engineer, the following studies/tests were decided to carry out:

1. Boiler efficiency test
2. Air heater leakage test
3. Furnace radiation losses
4. Turbine heat rate
5. Condenser performance
6. Regenerative system performance
7. Auxiliary power consumption

3.2 Boiler and Its Auxiliaries

Pulverized coal is put in boiler furnace. Boiler is an enclosed vessel in which water is heated and circulated until the water is turned in to steam at the required pressure.

Figure 3.1 Boiler of G.H.T.P.

3.2.1 Details of Boiler:

1. Boiler

Type	Water Tube, Single Drum
Make	BHEL
Capacity	680 tons/ hr
Steam Temperature	540 ⁰ C
Steam Pressure	155 155 atm

2. Cooling and Circulating water

Technique	Once through cooling
Capacity	880 m ³
Actual Discharge	26400 m ³ / hr
Cooling Pump	2 3 Nos.

3. Boiler Parameters

Ambient Air Temperature	40 ⁰ C
Feed Water Temperature Entering Economizer	243 ⁰ C
Steam Temperature at RH. Inlet	342 ⁰ C
Steam Temperature at RH. Outlet	549 ⁰ C
Steam Pressure at RH. Inlet	37.6 Kg/ cm ²
Steam Pressure at RH. Outlet	36.1 Kg/cm ² (G)
Re-Heater Outlet Steam Flow	597.5 T/Hr
Super-Heater Outlet Steam Flow	690 T/Hr (MCR)
Steam Temperature at SH. Outlet	540 ⁰ C

4. Boiler Auxiliaries

Following are the major auxiliaries of boiler at

GHTP :-

Name	Numbers
ID Fan	3
FD Fan	2
PA Fan	2
ESP	28
Rotary Air Heater	2
Ash Handling Plant	
Fuel Oil System	
Scanner Air Fan	
Scout Blower	56

3.2.2 Boiler Efficiency Test

Due to poor combustion, poor operation, heat transfer fouling and maintenance, the performance of boiler is reduced with time. There are two other causes which also lead to poor performance of boiler i.e. Deterioration of fuel quality and water quality. Efficiency testing helps to observe, how far the boiler floats away from the best efficiency.

Indirect method:

The indirect method is also called the heat loss method. The efficiency can be calculated by subtracting the heat loss fractions from 100 as follows:

$$\text{Efficiency of boiler (n)} = 100 - (i + ii + iii + iv + v + vi + vii)$$

Whereby the principle losses that occur in a boiler are loss of heat due to:

1. Dry flue gas
2. Evaporation of water formed due to H_2 in fuel
3. Evaporation of moisture in fuel
4. Moisture present in combustion air
5. Un-burnt fuel in fly ash
6. Un-burnt fuel in bottom ash
7. Radiation and other unaccounted losses

3.2.2.1 Coal

Analysis of coal is very important part during boiler efficiency test. This analysis helps find out the quality of coal. Quality of coal is calculated by the percentages of different constituents which help in categorizing it as a high grade or lower grade coal. There are two types of tests involved in the analysis of coal:

i. Proximate analysis of coal

It includes the determination of carbon moisture, ash and volatile matter and fixed carbon. This gives quick and valuable information.

ii. Ultimate analysis of coal

It includes the estimation of ash, carbon, hydrogen, oxygen and nitrogen. It is essential for calculation heat balance in any process. Proximate analysis of coal is done in thermal power plant but ultimate analysis of coal is not performed, it is also done on annual basis.

3.2.2.2 Signification of Proximate Analysis

The main purpose of coal sample analysis is to determine the rank of the coal along with its intrinsic characteristics.

i. Moisture

Moisture is a main property of coal. All types of coal are mined wet. Groundwater and other extraneous moisture are known as adventitious moisture. Moisture may take place in four possible forms within coal:

a) Surface moisture

Water held on the surface of coal particles.

b) Hydroscopic moisture

Water held by capillary action within the micro fractures of the coal.

c) Decomposition moisture

Water held within the coal's decomposed organic compounds.

d) Mineral moisture

Water comprises part of the crystal structure of hydrous silicates such as clays.

ii) Ash

After coal is burnt, ash content of coal is the non-combustible remains left. During combustion, it represents the bulk mineral matter after carbon, oxygen, sulfur and water (including from clays) have been driven off.

iii) Fixed carbon

The fixed carbon content of the coal is the carbon found in the material. These are left after volatile materials are driven off. The total sum of percentages of moisture and ash subtracted from 100 gives the percentage of fixed carbon.

3.2.2.3 Calculation

Ash:

Weight of the empty crucible	W4g
Weight of crucible + sample	W5g
Weight of crucial + ash	W6g
% Ash	$= [(W6-W4) (W5-W4)] \times 100$

Moisture:

Weight of the empty crucible	W1g
Weight of crucible + sample	W2g
Weight of crucial + sample after heating	W3g

% Moisture

$$= [(W2-W3)(W2-W1)] \times 100$$

Fixed Carbon:

% Fixed Carbon

$$= [\% \text{ Moisture} + \% \text{ Ash}]$$

3.2.2.4 Formulas to calculate the different losses.

a) Wet Stack Losses

The wet products of combustion are deriving from the moisture (both inherent and surface) and hydrogen in fuel. The mainly controllable factor to control these losses is by reduction in exiting gas temperature.

$$\text{WSL} = \left[\frac{M+9H}{100} \right] [1.88(T-25)] + 2442 + 4.2(25-T)$$

$$\% \text{ WSL} = (\text{WSL}/\text{GCV}) \times 100$$

b) Dry Stack Losses

The components of fuel that burn to form dry product of combustion are sulphur and carbon. The carbon has greater significance therefore sulphur has low (0.42%) in India which is ignored. The major parameters of exiting gas temperature at air pre-heater outlet (APH) are proper index for quantifying the dry stack loss.

$$\text{DSL} = \left[\frac{100}{12(\text{CO}_2 + \text{CO})} \left(\frac{C}{100} + \frac{S}{100} - C \text{ in A} \right) \right] 30.6 (T-t)$$

c) Moisture in Combustion Air loss

The air is used for combustion. This air has small amount of moisture, which gives rise to heat loss. This is generally small and calculated as:

$$\text{MCA} = \left[\frac{3.034(N_2)}{(C_2 + \text{CO})} \left[\left(\frac{C}{100} \right) \left(\frac{S}{267} \right) - C \text{ in A} \right] \right] 1.88(T-t)h$$

$$\% \text{ MCA} = (\text{MCA}/\text{GCV}) \times 100$$

d) Sensible Heat Loss of Water Vapor

These losses refer to the losses sensible heat of water vapor. Latent heat of vapor is equal to the difference between gas calorific value and net calorific value. This loss is calculated as:

$$\text{SHLWV} = (\text{WSL}) - (\text{GCV} - \text{NCV})$$

$$\% \text{ SHLWV} = (\text{SHLWV}/\text{GCV}) \times 100$$

e) Radiation Loss

Radian losses are heat losses from boiler enclosure through insulation. Least conductive insulation can minimize the losses.

$$RL = \frac{Q_{rad}}{GCV}$$

$$\% RL = (RL/GCV) \times 100$$

3.3 Furnace

Furnace walls are made up of tubes. The water flows in these tubes. These tubes generate steam from water. So, these tubes are known as generating tubes. All these wall tubes are open to a 'boiler drum' from top headers. From the upper outlet headers of the water wall system, the steam water mixture are taken to the steam drum through 118 numbers pipes called up riser. For ignition quickly and completely, Heavy Fuel Oil (HFO) or Heavy Petroleum Stock (HPS) is sprayed on pulverize coal due to coal has lower ignition temperature.



Figure 3.2 Furnace of G.H.T.P.

3.3.1 Details of furnace:-

Furnace width	13, 868 m ²
Furnace depth	10, 592 m ²
Furnace volume	5, 200 m ³
Furnace area effective projected	2, 100m ²

3.3.2 Furnace Radiation Losses

Infra-Red Pyrometer is used to determine the radiation losses from the boiler due poor condition of the insulation. The equation to find out the radiation losses is

$$R = E.T^4$$

Where R = Radiation Losses

E = Emissivity factor of the surface

T = Temperature in degree Kelvin

The temperature measured at various locations of boiler with the help of infra-red pyrometer.

Location	Average temperature in ⁰ C
Furnace wall (Front) Drum to boiler floor	31.0
Furnace wall (Rear) Drum to boiler floor	42.0
Furnace wall (Right) Drum to boiler floor	49.0
Furnace wall (Left) Drum to boiler floor	50.5
Average Temperature	43.0

The surface temperature measured at other area with the help of infra-red pyrometer.

Location	Average temperature in ⁰ C
H.P. turbine surface temperature (Bottom)	56.0
I.P. turbine surface temperature	43.0
M.S. Line	32.0
H.R.H. Line	47.6

	Temp.in ⁰ C	Emissivity
Good insulation	36 (T)	0.98(E)
Boiler insulation	43(T _i)	0.95(E _i)
Ratio of Radiation Losses	$= \frac{(E_1 T_1^4)}{(ET^4)}$ $= \frac{[0.95 \times (273.2 + 43^4)]}{[0.98 \times (273.2 + 36^4)]}$ $= 1.06$	

Hence the increased radiation loss for the furnace area = 6%. It indicates insulation was first-class. Insulation was high-quality on other area like transfer pipes, economizer zone, cross over pipes, air heater zone etc.

3.4 Air Pre-heaters

An air pre-heater is a device which is designed to heat air before another process e.g. combustion in a boiler. The primary objective of air pre-heater is increase the thermal efficiency of the process. The air pre-heaters recover the heat from the boiler flue gas.

3.4.1 Flue Gas Path

Furnace (1156°C) → Platen SH (1026°C) → Re-heater (920°C) → Final SH (666°C) → LTSH (346°C) → Economizer (140°C) → APH → ESP → Induced Draft Fan → Stack.

3.4.2 Primary Air Path

Primary Air Fan is utilized to inject air from atmosphere into the air pre-heater. The outlet temperature of air pre-heater is utilized to raise the temperature of natural air.

P.A → Fan → Air Pre-Heater → Bowl Mill → Furnace

3.4.3 Secondary Air Path

With the help of Forced Draft (FD) fan; air from the atmosphere is forced into the air pre-heater. The temperature of air is raised above the initial temperature in the air pre-heater.

FD Fan → Air Pre-Heater → Furnace

In the boiler, considerable quantity of air leakages is called tramp air. As such air pre-heater performance test is carried out to find out the air ingress at the air heater at 100% MCR. The result of the test is given in annexure – II.

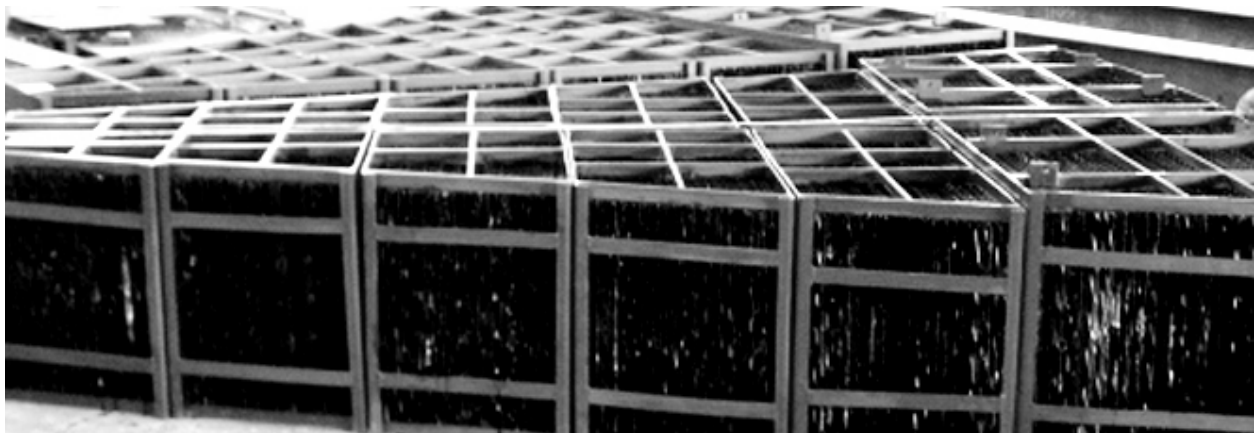


Figure 3.3 Sectors of Air Pre Heater

3.5 Turbines and Its Auxiliary

3.5.1 Steam turbine

Ideal steam turbines are considered to be an isentropic process or constant entropy process. In the constant entropy process, entropy of the steam entering the turbine is equal to the entropy of the steam leaving the turbine. There is truly no isentropic steam turbine. However, ranging from 20% to 90% of the typical isentropic efficiencies is based on the application of the turbine.



Figure 3.4 Turbine of G.H.T.P

Specifications:

Type	3 cylinder mixed flow tandem coupled
Make	BHEL
Capacity	210 MW
Speed	3000 rpm
Stages	3 (HP, IP, LP)
Efficiency	43%
Inlet Steam Pressure	147.1 Kg/cm ²
Inlet Steam temperature	535 ⁰ C
Overall Length	16.975 m
Overall Width	10.5 m

3.5.2 Design features

The type of turbine is Single shaft reaction turbine, tandem coupled with separate High Pressure (HP), Intermediate Pressure (IP) and Low Pressure (LP) cylinders. The turbine is single reheat condensing type. This turbine works on reaction principal with throttle governing.

3.5.2.1 High Pressure (HP) Turbine

The construction of outer casing is barrel type without any massive horizontal flange. This unique construction permits rapid start up at any high rates of load changes. HP turbine has 25 reaction stages and it is a single flow type turbine.

Specification:

Inlet Temperature	540 ⁰ C
Outlet Temperature	343 ⁰ C
Inlet Pressure	155 Kg/ cm ²
Outlet Temperature	37 g/ cm ²

3.5.2.2 Intermediate Pressure (IP) Turbine

Intermediate Pressure turbine has 20 stages. It is double flow with horizontal split type. Inner and outer casing are suspended from top halves on the way to eliminate the effect on TG centerline with the heating of the flanges. The horizontal casing construction permits rapid start up at any high rate of load changes of turbo set.

Specification:

Inlet Temperature	540 ⁰ C
Outlet Temperature	340 ⁰ C
Inlet Pressure	37 Kg/ cm ²
Outlet Pressure	7 Kg/ cm ²



Figure 3.5 Intermediate Turbine

3.5.2.3 Low Pressure (LP) Turbine

Low Pressure turbine has 8 reaction stages. It is also double flow type. Special design has been adopted to remove the moisture from the last stage. The thickness of the water film on the guide blades or buckets is reduced to remove the moisture. Inner casing is suspended from top halves on the way to eliminate the effect on TG centerline with the heating of the flanges.

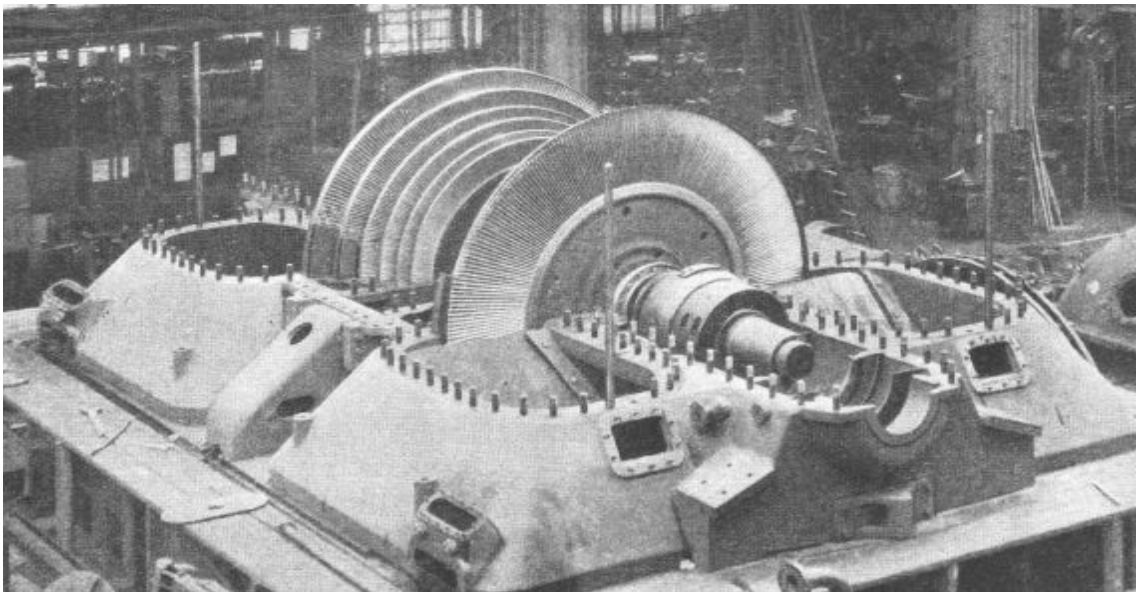


Figure 3.11 Low Pressure Turbine

Specification:

Inlet Temperature	360 ⁰ C
Outlet Temperature	45 ⁰ C
Inlet Pressure	7Kg/ cm ²
Outlet Temperature	0.85 Kg/ cm ²

3.5.3 Turbine Pressure Survey

Turbine pressure survey is carried out to determine the internal condition of H.P. and L.P. cylinder. The following table gives the optimum value of steam and designed pressure at various stages at 210 MW load.

	Designed value at 210 MW	Actual value
	(Kg/ cm²)	
H.P. cylinder		
Pressure at ESV	144	147.1
Pressure after Curtis wheel	146	139.7
Pressure at exit (HPH-6)	37	33.9
I.P. cylinder		
Pressure of HRH -6	34	31.9
Pressure to dearator external	7.6	7.2

3.6 Condenser

For efficient operation, maintenance of high vacuum is essential in the condenser. The condenser destroys the vacuum due to any leakage and causes (i) limits the useful heat drop in the prime mover (ii) a lowering of the partial pressure of the steam and of the saturation temperature along with it. This shows that the latent heat increase. Cause of it, more cooling water is required. This will result in lower efficiency.



Figure 3.11 Blocked Condenser Tubes

Area of condenser = 9655 m²

Cooling water flow rate = 24000 m³/ hr

3.6.1 Condenser Performance Tests

The reasons for departure of condensers conditions from optimum are:

- i. Dirty tubes.
- ii. CW inlet temperature different from design.
- iii. Air ingress into system under vacuum.
- iv. CW quantity flowing through the condenser incorrect.

3.6.1.1 Readings are taken during the condenser performance test.

	Optimum	Actual
CW inlet temperature (°C)	33.0	22.0
CW outlet temperature (°C)	42.1	32.0
CW temperature rise (2) to (1) (°C)	9.1	10.0
Saturated steam temperature corresponding to back pressure (°C)	49.0	44.0
Thermal temperature difference (TTD)(4)-(2)	6.9	12.0
Air suction temperature (°C)	46.0	27.0

Air suction depression (4)-(6)	3.0	17.0
Back pressure (Kg/ cm ²) abs	0.12	0.09

The offerings of various losses to departure of vacuum from optimum had been determined as following:

3.6.1.2 Loss due to High Inlet Pressure of Cooling Water

Actual CW inlet temperature (°C)		22
Optimum CW temperature rise (°C)		9.1
Optimum TTD (°C)		6.9
Condenser saturated temperature (°C)	22+9.1+6.9=	38.0
Corresponding condenser vacuum		0.068
Vacuum loss due to CW temperature		0.068-0.120
		= -0.052 bar (i.e. gain)

3.6.1.3 Loss due to Inadequate Quantity of Cooling Water

Actual CW inlet temperature (°C)		22
Actual CW outlet temperature (°C)		32
Actual CW temperature rise (°C)		10
Optimum TTD (°C)		6.9
Condenser saturated temperature (°C)	32+6.9=	38.9
Corresponding condenser vacuum		0.070
Loss due to incorrect quantity of CW		0.070-0.068= 0.002 bar

3.6.1.4 Loss due to Dirty Tubes or Air in Condenser

Actual CW inlet temperature (°C)		22
Actual CW outlet temperature (°C)		32
Actual TTD (°C)		12
Condenser saturated temperature (°C)	32+12=	44
Actual condenser vacuum		0.095
Loss due to dirty tubes or air		0.095-0.075
		= 0.025 bars

3.7 Regenerative System

An investigation was carried out for regenerative system at 100% MCR loads. The result of heater survey is shown in Annexure – IV.

3.7.1 H.P. Heater Survey (100% MCR)

A comparison of actual and design data for HPH – 6:

	Actual	Design
Bled steam temperature °C	347	343
Drip temperature °C	190	240
FW inlet temperature °C	192.8	198
FW outlet temperature °C	236	240
T.T.D °C (drain water)	-35	0
Exhaust steam flow (t/ hr)	49.8	57
F.W. flow (t/hr)	652	680
Bled steam pressure	33.9	40

3.8 Auxiliary Power Consumption

The bulk power consumption is utilized in pumps, mills, fans etc. The equipments like motor driven equipment, lighting, etc are accounted in auxiliary power consumption.

Auxiliary power consumption of unit- 1(During the audit)

Auxiliary power consumption (MW) = 18.7

Load in MW = 210

Auxiliary power consumption in % = $(18.7/210) \times 100$
= 8.95%

3.8.1 Readings of Different Equipments

During the audit at load of unit-1 (210MW), the current ratings of major auxiliaries were measured.

EQUIPMENT	AVERAGE CURRENT (Amps)
I.D. Fan – A	105
I.D. Fan – B	102
F.D. Fan – A	26.5
F.D. Fan – B	27.5
P.A. Fan – A	120
P.A. Fan – B	120
C.W. Pump – A	53
C.W. Pump – B	53
Mill – A	33.12

Mill – B	30.98
Mill – C	30.50
Mill – D	32.78

The current drawn by the various auxiliary are within limits and it is not dependable for higher power consumption equipment.

3.9 Calculation and Cost of Losses

As performance guarantee tests had been carried out on the unit – (1), present conditions of unit were compared. The cost of losses in various system and sub system condition had been calculated due to deterioration.

3.9.1 Deviation from Designed Performance

210 MW Unit – 1 (at 100% MCR)

Design turbine heat rate	1985 Kcal/ kwh
Designed boiler efficiency	87.6%
Designed unit heat rate	$1985 / 0.8716$ = 2277 Kcal/ kwh
Actual turbine heat rate	2596.93 Kcal/ kwh
Boiler efficiency	83.50%
Actual unit heat rate	$2596.93 / 0.8350$ = 3110 Kcal/ kwh
Deterioration in unit heat rate	$3110 - 2277$ = 833 Kcal/ kwh
Generation per day at 210 MW load	3528000 Kwh (Assuming a load factor of 70%)
GCV of coal (Approximately)	87.6%
Excess Coal consumed per day	392 tonnes
Rate of coal	Rs. 1000/ tone (Assumed)
Cost of excess coal being consumed per day	Rs. 3.9 lakhs/day

Chapter-4
Calculations And Results

4.1 (Annexure I)

GHTP, Unit- (I) 210MW at 100% MCR

Boiler Efficiency Calculations

1. Boiler Parameters:

Condition at Air Pre-Heater

CO ₂ at Air heater outlet (%)	14.42
O ₂ at Air heater outlet (%)	4.80
CO in flue gas (%)	0.00
A/H gas outlet temperature °C	137.00

2. Un-burnt Carbon in Ash

Bottom Ash	4.05
Fly ash %	1.38
Dry bulb temperature at F.D. inlet °C	33.08
Wet bulb temperature °C	31.03
Kg moisture/ Kg dry air	0.00
Steam flow	634.00
Boiler evaporation rate Kg/s	184.40

3. Analysis of Coal

Proximate Analysis of Coal

Ash (%)	31.44
Moisture (%)	14.26
Sulphur (%)	0.30
Gross Calorific Value (GCV)	15025.64(kJ/kg)

4. Ultimate Analysis of Coal

Carbon (%)	41.24
Hydrogen (%)	2.08
Nitrogen (%)	1.81
Oxygen (%)	10.78
Sulphur (%)	0.30
Net Calorific Value	14220.09 (kJ/kg)

Boiler Efficiency Calculations (Table A-I)

	Loss In KJ/Kg	%
Wet Stack Loss	868.64	6.10
Dry Stack Loss	729.55	5.13
Moisture in combustion Air Loss	61.44	0.40
Sensible Heat of Water Vapor	63.9	0.43
Un-burnt Gas Loss	0.00	0.00
Radiation And Unaccountable Loss	251.68	1.58
Total (%) Loss		13.64
Boiler Efficiency		83.50

% on NCV only

4.2 (Annexure II)

GHTP, Unit- (I) 210MW at 100% MCR

Air Heater Performance Test

1. Test Fuel Analysis %

Carbon	41.24
Hydrogen	2.08
Oxygen	10.78
Sulphur	0.30
Moisture	14.26
Ash	31.44
Nitrogen	1.81

2. Condition at Air Heater

Air Inlet Temperature °C	42.57
Air Outlet Temperature °C	330.00
Gas Inlet Temperature °C	353.00
Gas Inlet Temperature °C	140.00

3. At Inlet %

O ₂	3.55
CO ₂	15.68
N ₂	80.78

1. At Outlet %

O ₂	5.10
CO ₂	14.20
N ₂	80.78

2. Combustible in ash kg/kg fuel	0.015
3. Theoretical Air required Kg/kg fuel	5.70
4. Carbon burnt kg/kg fuel	0.39
5. Wet products of combustion kg/kg fuel	0.45
6. Dry products of combustion at A/H inlet kg/kg fuel	6.40
7. Products of combustion at A/H outlet kg/kg fuel	8.10
8. Leakage air at A/H	1.20
9. Heat given to leakage air KJ/kg fuel	115.04
10. Heat given up by dry products KJ/kg fuel	1140.10
11. Heat given up by wet products KJ/kg fuel	158.80
12. Total heat given up KJ/kg fuel	1307.98
13. Heat received by combustion air KJ/kg air	258.76
14. Air at A/H outlet kg/kg fuel	4.80
15. Excess air at A/H outlet kg/kg fuel	-1.23
16. Excess air % of theoretical air	-18.62
17. Total equivalent air at kg/kg fuel	6.55
18. Air at A/H air inlet kg/kg fuel	6.02

- 19.** Tramp air from A/H air outlet to A/H gas
- 20.** Tramp air as % of theoretical air

2.09
35.17

4.3 (Annexure III)

GHTP, Unit- (I) 210MW at 100% MCR

Simplified Turbine Heat Rate – Reheat Unit-1

Power Generated P	209.3
Turbine Stop Valve Steam Pressure P ₁	140.1
Temperature T ₁	531.0
Enthalpy H ₁	3405.86
Steam Flow W ₁	634.0
Economizer Feed Inlet Temperature T ₂	236.0
Enthalpy H ₂	1018.57
1. Heat Flow From Turbine Stop Valve	
HF ₁	=W ₁ (H ₁ -H ₂) =1513541.9
Reheat Steam Flow W ₂	=S. Flow-B. Flow to HP
W ₂	584.2
Turbine I.P. Inlet Steam Pressure P ₄	31.90
Temperature T ₄	526.50
Enthalpy H ₄	3512.58
Turbine H.P. Exhaust Steam pressure P ₅	33.90
Temperature T ₅	347.00
Enthalpy H ₅	3101.11
2. Heat Flow From Re-heater To Turbine	
H.P. Exhaust Steam	=W ₂ (H ₄ -H ₅)
HF ₂	240380.5
3. To Calculate Reheat Spray water Heat Rate	
Spray Water Flow Actual W ₃	0.00
Turbine I.P. Inlet Steam Enthalpy H ₆	3512.58
Reheat Spray water Enthalpy H ₇	1018.57
Heat Flow from Re-heater to spray water	= W ₃ (H ₆ -H ₇)
HF ₃	= 0.00
Total Heat Flow to Turbine	
HF = (HF ₁ + HF ₂ + HF ₃)	= 1753922.7
Total Heat Rate	= HF/(P×4.187) = 2001.42

4.4 (Annexure IV)

GHTP, Unit- (I) 210MW at 100% MCR

Heat Balance for No.6 H.P. Feed Heater to Determine Bled Steam Flow

H.P. Heater – 6 Bled Steam Pressure P_3	33.90
Temperature T_3	347.00
Enthalpy H_3	3101.11
Feed Water Inlet Temperature T_8	198.00
Enthalpy H_8	843.36
Feed Water Outlet Temperature T_9	236.00
Enthalpy H_9	1018.57
Feed heater drain temperature T^1	190.00
Enthalpy H^1	807.53
Feed Flow Through Heater W^1	652.00
Bled Steam Flow W_6	$=W^1(H_9-H_8)/(H_3-H^1)$ = 49.80

Chapter-5

Results Conclusions and Future Scope

5.1 Results and Conclusions

5.1.1 Boiler

Table 5.1 Results and Conclusions of Boiler

S. No.	Results	Conclusions
1.	Wet stack loss (6.10%) and dry stack loss (5.13%) are occurred due to moisture in coal.	The moisture of coal should be reduced before use. The moisture can be removed by primary air. The dry coal increases the boiler efficiency.
2.	6% of radiation losses are increased in the furnace.	The radiation loss occurs due to poor insulation. So, insulation should be good in quality e.g. Rock wool insulation.
3.	Un- burnt carbon in bottom ash and in fly ash was 4.05% and 1.38% respectively.	There should be proper crushing of coal. The classifiers in mills should be cleaned and checked periodically.

5.1.2 Air Pre Heater

Table 5.2 Results and Conclusions of Air Pre Heater

S. No.	Results	Conclusions
1.	Tramp air leakage was of order of 2.09 kg/kg at Air Pre-Heater which comes around 35% of theoretical air. It is indicated corrosion in heater elements.	Air leakage should be controlled or minimized. Because it makes the major effect on boiler efficiency.
2.	The flue temperature was 123 ⁰ C at outlet against designed value of 140 ⁰ C.	This loss of temperature can be reduced by replacement of metallic joints with fabric joints. The leakage was found large through metallic joints and this increased the loading on ID Fans.
3.	O ₂ contents were high being 5.10% in flue gasses. It indicates that air is not as per requirement and makes difficultly to complete combustion in furnace.	This loss of O ₂ can be reduced by replacement of metallic joints with non metallic (fabric) joints. Easy to handle, quickly installed, high flexible, no transfer of vibration are advantages of non metallic joints over metallic joints.

5.1.3 Furnace

Table 5.3 Results and Conclusions of Furnace

S. No.	Result	Conclusion
1.	In the furnace, the radiation loss was observed more than 6% during the test.	This loss can be reduced by improving the insulation of furnace. Rock wool insulation should be applied in place of glass wool insulation.

5.1.4 Turbine

Table 5.4 Results and Conclusions of Turbine

S. No.	Results	Conclusions
1.	The efficiency of turbine is reduced by leakage air and flue gasses.	Replacement of glass wool insulation by rock wool insulation to increase efficiency of turbine.
2.	Its efficiency also depends upon steam generated by boiler.	Reduced or minimized the steam leakage.
3.	No such changes can be done in case of blade and tip loss.	These can be minimized in the overhauling after every 5 years and replacement of damaged one.
4.	O ₂ contents come to the turbine due to makeup water used in regenerative cycle.	O ₂ should be minimized by use of dearator. O ₂ contents reduce the life of blade.

5.1.5 Condenser

Table 5.5 Results and Conclusions of Condenser

S. No.	Results	Conclusions
1.	Due to dirty tubes and air leakage, the drop in condenser vacuum was of order of 0.025 kg/ cm ² and substantial losses were occurred.	The condenser should be checked periodically.
2.	Drop in condenser vacuum due to incorrect quantity of cooling of water.	Condenser tubes and priming pumps should be checked and repaired periodically.
3.	Actual hot well was 33 ⁰ C but designed is 44 ⁰ C. It indicates under cooling of 11 ⁰ C.	Excessive water quantity of cooling water being supplied.
4.	Due to air leakage, the value of air suction depression was increased from optimum. The optimum value is 3 ⁰ C but the actual value was 17 ⁰ C.	Checking and repairing the tubes periodically.

5.2

Future Scope

In this thesis report, data of unit-1 of G.H. thermal plant is calculated and compared the data on two different loads. In the future, two or more than two units can also be taken at different loads and then can be compared and best one can be chosen on the basis of performance.

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