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Energy Audit of Coal Fired Thermal Power Plant

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***Abstract*— An energy audit is feasibility study to establish and quantify the cost of various energy inputs to and flows within a factory or an organization in a given period. Energy Audit of Coal Fired Thermal Power Plant has been considered out. The aim is to calculate all the losses and give measures to rectify them and calculate the economic benefits after taking measures of rectification of losses. The Energy Audit of NTPC Dadri is done. The study is based on ASME BOILER TEST CODE method, BUREUEU OF ENERGY EFFICIANCY and GUDELINES FOR THERMAL POWER PLANT (INDO GERMAN ENERGY PROGRAM). From the calculation it can be easily concluded that the overall efficiency of the plant decreases with the decrease in the requirement of output load. Output Load of the thermal power plant depends on the demand of electricity. As the demand of electricity decreases, the output load of the thermal power plant decreases, and the overall efficiency of the plant is also lower because electricity cannot be stored so the plant is running on partial load. Now if the thermal power plant run at Full Output Load the overall efficiency of the plant is much higher**

I. INTRODUCTION

Systematic approach for decision making in energy management is done by the energy audit. The service to identify all the energy streams in a facility and balancing of total energy is done by energy audit. As per ENERGY CONSERVATION ACT 2001 energy audit is defined as ‘verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefits analysis and action plan to reduce energy consumption.

A. Need of energy audit

Energy, labor and materials are the three top operating expenses found in the industry If check the priority to save 3 of them, energy audit is the best option for same output and quality but reduced input. The scope of improvement can easily give and understood by energy audit.

The preventive maintenance and quality control programs which are vital for production and utilizing activities are done by positive orientation of energy audit. The energy cost, availability and reliability of supply of energy, appropriate energy mix, identification of energy conservation technologies is done by such audit programs.

The translation of conservation ideas into realities by leading technical feasibility with economic and other organizational consideration within a specified time is done by energy audit.

The energy consumption per unit of product output on to lower operating cost all is done by energy audit. Energy audit provides bench mark for managing energy in the organization and also provide basis for planning a more effective use of energy throughout the organization”.

B. Energy wastage in plants

- Poor civil structures which allows less natural light to entre.
- Poor natural ventilation of air which will lead to mechanical ventilation and consumes more power.
- Poor insulation which leads to losses of heat.
- Poor handling of coal thus leads to more moisture in coal and leads to decrease value of GCV from marshal yard to boiler bunker.
- Conveyor belts are partially loaded thus more power consumption of motor is there because conveyor belts are at a BLF (belt loading factor) of 60%. Thus, this can be increased easily.

C. Benefits of energy audit

- Reduces consumption charges drastically.
- Impact of operational improvements can be mentioned.
- Reduces specific energy consumption and operating cost.
- Identified energy losses for corrective actions.
- Improves overall performance of total system and profitability and productivity.
- Averts equipment failure.
- Estimates the financial impact on energy consumption projects.
- No extensive training or calculation involved.

D. Types of energy audit

- Comprehensive Audit
  It is time consuming and expensive process because it is very much detailed.
- Targeted audits
  To provide detailed analysis and provide data of specific targeted projects.

- Preliminary audits
  It seeks to establish cost and quantity of each form of energy used in this energy audit.
  Collecting data
  Analysing data
  Presenting data
  Establishing priorities and make recommendations

- Walk through audit
  This approach estimates the order of magnitude on energy consumption without involving rigorous estimations on calculation by using certain energy consumption equipment's.

- Total system audit
  This method requires rigorous data entry and analysis. This approach identifies area of improvement on energy quantity basis.

- Steam system audit
  Making of balance of total system and analysis of steam system from steam generators and consumption data is analysed here. If identifies energy loss due to steam leakage and heat loss.

- Electric system audit
  There are major energy consumers in process industries. The efficiency of total electrical system from electrical power consumption per day is checked in this type of audit.

- Cooling system audit
  In this type of audit we calculate the cooling efficiency of the cooling tower. The impact of fouling or corrosion is identified for total system.

- Insulation audit
  The process unit such as steam lines, tank insulation etc for improving the energy of complete system.

II. METHODOLOGY AND CALCULATION

The study is based on ASME BOILER TEST CODE method, BUREUEU OF ENERGY EFFICIANCY and GUDELINES FOR THERMAL POWER PLANT (INDO GERMAN ENERGY). The Energy Audit of NTPC Dadri is done. The plant is having capacity of 2649 MW from coal and 829 MW from gas-based station. More has been focused on heat losses in coal fired steam generator, economizer, air preheater and loss Marshal Yard to steam generator. The methods used for efficiency of boiler is direct and indirect method thus there is also comparison and we can easily find out where the losses take place and where is the maximum possibility of energy savings.

A. Boiler

Boiler is a pressure vessel in which firing energy is conveyed from furnace to the water in the water tank until the water changes its phase from liquid to vapour. The Water is a very convenient and inexpensive way for conveying heat. When water changes its phase from liquid to vapour by means of heat the volume is increased by 1600 times. This energy is conveyed in the complete cycle by radiation, convection and conduction.

The thermal efficiency is the amount of heat that is given and completely used to convert it to steam. There are two ways of checking the performance of boiler

The direct method

In this method the heat acquired of the functioning fluid is balanced with the heat content of the coal.

The direct method is also called the "INPUT- OUTPUT method" because in this method we consider the output i.e. water in vapour form and the energy input i.e. from coal for calculating the performance of the boiler

Parameter	Quantity of steam generated per hour (Q)	Enthalpy of saturated steam in kJ/kg of steam (H_g)	Enthalpy of feed water in kJ/kg of water (H_f)	Quantity of fuel used kg/hr (q)	Fuel fired GCV kJ/kg
Values	8 TPH	2782.8 kJ/kg	355 kJ/kg	1.34 TPH	953 kJ/kg
Boiler Efficiency	Heat Output X 100/Heat Input = QX(H_g H_f) x 100 /(q X GCV)				
Calculation	8X (2782.8355) X100/(1.34*17953)				
Result	Boiler Efficiency = 80%				

The Indirect Method

We can calculate the performance of boiler by calculating all the losses happening in the boilers using the indirect method of testing. All the demerits of direct method can be compensated by this indirect method because in this method calculate the losses which are there in the boiler. We can obtain the efficiency percentage by just subtracting the percentage of losses from 100.

The most important merit of this method is that the mistakes made by us in calculation of losses don't affect our result of efficiency to greater extent.

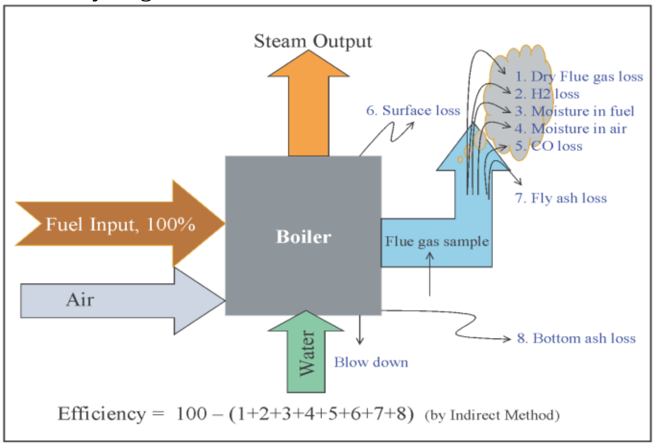

Figure 1 Explanation of Energy audit of boiler by indirect method from Bureau of Energy Efficiency

Boiler Efficiency Calculation (ALL READINGS ARE TAKEN FROM NTPC DADRI)

1. Fuel firing rate = 272155 kg/hr
2. Steam generation rate = 1315418 kg/hr
3. Steam pressure = 192 kg/cm^2 (g)
4. Steam temperature = 540 °C
5. Feed water temperature = 300 °C
6. %CO_2 in Flue gas = 3
7. %CO in flue gas = 0.22
8. Average flue gas temperature APH inlet=330 °C, APH outlet = 180 °C
9. Ambient temperature = 30 °C
10. Humidity in ambient air = 0.0204 kg / kg dry air
11. Surface temperature of boiler = 78°C
12. Wind velocity around the boiler = 1.66 m/s
13. Total surface area of boiler = 147 m^2
14. GCV of fly ash = 525.2 kCal/kg
15. Ratio of bottom ash to fly ash = 9010

Fuel Analysis (in %) (done in SAI LAB TIET)

Ash content in fuel = 41

Moisture in coal = 13

Carbon content = 34.05

Hydrogen content = 3.05

Nitrogen content = 1.40

Oxygen content = 6.05

GCV of Coal = 3401 kCal/kg

- Step 1. Find theoretical air requirement

Theoretical air required for complete combustion = [(11.6 X C) + {34.8 X (H_2 X O_2/8)} + (4.35 X S)] /100 kg/kg of coal

= 4.74 kg/kg of coal

Step 2. Find theoretical CO_2

$$\% \; CO_2 \text{ at theoretical conditions} = \frac{\text{Moles of C}}{\text{Moles of } N_2 + \text{Moles of C}}$$

$$N_2 \text{moles} = \frac{\text{Weight of } N_2 \text{ in theoritical air}}{\text{molar weight of } N_2} + \frac{\text{Weight of } N_2 \text{ in fuel}}{\text{Molar weight of } N_2}$$

Where moles of N_2 = 0.135525

Where moles of C = 0.02837

$$(CO_2) = \frac{0.02837}{0.135525+0.02837} = 17.30\ \%$$

- Step. 3 To find Excess air supplied

Actual CO_2 measured in flue gas = 14.0%

$$E.\ A = \frac{O_2\%}{21-O_2\%} \ X\ 100$$

= 16%

- Step. 4 To find actual mass of air supplied

Actual mass of air supplied = {1 + EA/100} x theoretical air

= 7.13 kg/kg of coal

- Step. 5 To find actual mass of dry flue gas

Mass of dry flue gas = Mass of CO_2 + Mass of N_2 content in the fuel +Mass of N_2 in the combustion air supplied + Mass of oxygen in flue gas

= 6.7765 kg/kg of coal

- Step. 6 To find all losses

1. Dry flue gas losses: -

Heat is vanished in the "dry" by-products of ignition, which is having only sensible heat because there was no change in state. The by-products of combustion of coal are carbon dioxide (CO_2), carbon monoxide (CO), oxygen(O_2), nitrogen (N_2) and sulphur dioxide (SO_2). Amount of SO_2 and CO are normally measured in terms of the parts-per-million (ppm) so heat loss can be ignored.

$$\text{Heat loss in dry flue gas } (L_1) = \frac{m X Cp\ X (T_f - T_a)}{\text{GCV of FUEL}} \ X \ 100$$

= 6.873 %

Where,

L_1= % Heat loss due to dry flue gas

m = Mass of dry flue gas in kg/kg of fuel

= Combustion products from fuel CO_2 + SO_2 + Nitrogen in fuel +

Nitrogen in the actual mass of air supplied + O_2 in flue gas.

(H2O/Water vapour in the flue gas should not be considered)

Cp = Specific heat of flue gas in kCal/kg°C

T_f = Flue gas temperature in °C

T_a = Ambient temperature in °C

2. Heat loss due to evaporation of water formed due to hydrogen in fuel (%)

The amount of hydrogen is present in the fuel. When this hydrogen makes compound with oxygen it makes water. The water formed is in gaseous state because of high temperature of the boiler which leads to change in phase of the water. The change in phase of water leads to formation of steam and this steam is having very high temperature by very less entropy. The most relevant loss is about 11 % for natural gas and 7 % for fuel oil.

$$L_2 = \frac{9 \text{ X } H_2 \text{ X } \{584 + Cp(T_f - T_a)}{\text{GCV of FUEL}}$$

Where

H_2 = kg of hydrogen present in fuel on 1 kg basis

Cp = specific heat of superheated steam in kCal/kg℃

T_f = Flue gas temperature in ℃

T_a = Ambient temperature in ℃

Latent heat corresponding to partial pressure of water = 584

L_2 **= 5.25%**

3. Heat loss due to moisture present in fuel

The water content which is present in the fuel when burned in the furnace is converted into the steam. The heat loss due to moisture is mainly comprised of three main components that is the heat needed to raise the temperature of the moisture to its boiling point, heat which is used to evaporate moisture and the superheating of the fuel so that the flue gasses can be reached to the temperature of the flue gas at the exit of the exhaust.

$$L_3 = \frac{M \text{ x } \{584 + Cp(T_f - T_a)\}}{\text{GCV of COAL}} \text{ X } 100$$

where

M = kg moisture in fuel on 1 kg basis

Cp = Specific heat of superheated steam in kCal/kg°C

T_f = Flue gas temperature in °C

T_a = Ambient temperature in °C

Latent heat corresponding to partial pressure of water vapour = 584

L_3= 3.41%

4. Heat loss due to moisture present in air

There is some amount of water content in the air thus to remove this water in the air we have to super heat the air . The water content in the air leads to raise the temperature of the stack thus this is considered as a boiler loss. The water content which is present in the air when burned in the furnace is converted into the steam. The heat loss due to moisture is mainly comprised of three main components that is the heat needed to raise the temperature of the moisture to its boiling point, heat which is used to evaporate moisture and the superheating of the air so that the air can be reached to the temperature of the gas at the exit of the exhaust.

$$L_4 = \frac{\text{AAS X Humidity factor X Cp X } (T_f - T_a)}{\text{GCV of Fuel}} \text{ X100}$$

Where,

AAS= Actual Mass of air supplied per kg of fuel

Humidity Factor= kg of water/kg of dry air

Cp= Specific heat of superheated stem in kCal/kg℃

T_f = Flue gas temperature in ℃

T_f = Ambient temperature in ℃

L_4 **= 0.28%**

5. Heat loss due to incomplete combustion

There is some incomplete combustion in the coal because there is less temperature required for the coal to burn completely. The components which are not burned completely and leads to in complete combustions are CO, hydrogen and various HC. We can only find out the amount of CO in boiler emission easily.

$$L_5 = \frac{\%CO \text{ X } C}{\%CO + \%CO_2} \text{ X } \frac{5744}{\text{GCV of Fuel}} \text{ X } 100$$

Where

L_5 = % Heat loss due to partial conversion of C to CO

CO= Volume of CO in flue gas leaving Economizer (%)

CO_2 = Actual Volume of CO_2 in flue gas (%)

C = Carbon content kg/kg of fuel

L_5 **= 1.42%**

6. Heat loss due to radiation and convection

Although the boiler body is highly insulated but we all know that there is no such system which is ideal and no heat is rejected to its surroundings so there is losses which are radiation losses and convection losses. As we are having some prerequisite knowledge of the boiler so we can easily say that the radiation and convection losses for industrial fire tube boiler = 1.5 to 2.5% For industrial water tube boiler = 2 to 3% For power station boiler = 0.4 to 1%

$$L_6 = 0.548 \text{ X } [(\frac{Ts}{55.55})^4 - (\frac{Ta}{55.55})^4] + 1.957 \text{ X } (T_s - T_a)^{1.25} \text{ X } \sqrt{[\frac{196.85 \text{ Vm} + 68.9}{68.9}]}$$

Where

L_6 = Radiation loss in W/m^2

Vm = wind velocity in m/s

T_s= Surface temperature (K)

T_a= Ambient temperature (K)

L_6 = 409.99 Kcal/m^2

Total radiation and convection/ hour = L_6 X surface area of boiler = 60268.6%

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$$\text{Radiation} = \frac{\text{total radiation X 100}}{\text{GCV of coal X fuel firing rate}}$$

$\%L_6$=0.397%

7. % Heat loss due to unburnt in fly ash

In fly ash there is some amount of carbon content thus we can easily find out that there is some losses in the boiler due to these unburnt losses. To calculate these heat losses we have to take the proximate analysis of the ash contents in the boiler. The amount of as made by the fuel should also be known

% Ash in coal = 11.93
Ratio of bottom ash to fly ash = 9010
GCV of fly ash = 542.25 kCal/kg
Amount of fly ash in 1 kg of coal = 0.1 x 0.1193
= 0.01193 kg
Heat loss in fly ash = 0.01193 x 542.25
= 6.498 kCal / kg of coal

$$\%\text{ heat loss fly ash} = \text{Heat Loss in fly Ash X } \frac{100}{GCV\ of\ COAL}$$

L7 = 0.19 %

8. % Heat loss due to unburnt in bottom ash

Amount of bottom ash in 1 kg of coal = 0.9 x 0.1193
= 0.10737 kg

GCV of bottom ash = 769 kCal/kg
Heat loss in bottom ash = 0.10737 x 769
= 82.56 kCal/kg of coal

$$\%\text{ Heat loss in bottom ash} = \text{Heat loss in bottom Ash X } \frac{100}{GCV\ of\ coal}$$

L_8 = 2.42 %

HEAT BALANCE FOR COAL FIRED BOILER	
Input/output Parameter	% loss
Heat Input	100
Losses in boiler	
Dry flue gas, L_1	6.873
Loss due to hydrogen in fuel, L_2	5.25
Loss due to moisture in fuel, L_3	3.41
Loss due to moisture in air, L_4	0.28
Partial combustion of C to CO, L_5	1.42
Surface heat losses, L_6	0.397
Loss due to Unburnt in fly ash, L_7	1.19
Loss due to Unburnt in bottom ash, L_8	2.42
η = 100 X$(L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8)$ = 77.72%	

Second Law Analysis of Boiler

➢ Equations

net rate exergy is carried *into* the control volume. Between point 1 & 2;

$$m_1[ef_1\ ef_2]=m_1\ [(h_1\ h_2)T_0(s_1\ s_2 R \text{ X } \ln\frac{P_2}{P_1})]$$

net rate exergy is carried *into* the control volume. Between point 3&4;

$$m_3[ef_3\ ef_4]=m_3\ [(h_3\ h_4)T_0(s_3\ s_4 R \text{ X } \ln\frac{P_4}{P_3})]$$

Energy destruction;

$$E_d = m_1[ef_1\ ef_2] + m_3[ef_3\ ef_4]$$

SECOND LAW EFFICIENCY OF BOILER

$$\varepsilon = \eta x \left[\frac{1-T_0\ /T_4}{1-T_0\ /T_1}\right] \text{ X } 100$$

Where

ε = Second law effectiveness of boiler
η = First law efficiency of boiler
T_0 = Ambient temperature
T_1 = Temperature of Flue gasses at inlet of boiler
T_4 =Stem temperature at outlet of boiler

Readings

	Parameters	Values
m_1	Mass flow rate of combustion gasses INLET	176.397 kg/sec
m_2	Mass flow rate of combustion gasses OUTLET	201.597 kg/sec
T_1	Temperature of Flue gasses at inlet of boiler	873K
T_2	Temperature of Flue gasses at outlet of boiler	673K
T_3	Feed water temperature at inlet of boiler	573K
T_4	Stem temperature at outlet of boiler	813K
P_1	Pressure of Flue gasses at inlet of boiler	0.0098bar
P_2	Pressure of flue gasses at outlet of boiler	0.0098bar
P_3	Feed Water pressure at inlet of boiler	137.2bar
P_4	Steam pressure at outlet of boiler	188bar

Results

Parameter	RESULT
Net rate exergy is carried into the control volume between point 1 & 2	395108.448 kW
Net rate exergy is carried into the control volume. between point 3&4	114581.45 kW
Energy destruction	280526.95 kWh

SECOND LAW EFFICIENCY OF BOILER= 29.97%

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B. Second law analysis of economiser

Equations (All equations are taken from Fundamentals of Engineering Thermodynamics, Michael J. Moran, Howard N. Shapiro) *net* rate exergy is carried *into* the control volume. Between point 1 & 2;

$$\mathbf{m_1 h_1 [ef_1 \, ef_2]=m_1} \, [(\mathbf{h_1 \, h_2})\mathbf{T_0}(\mathbf{s_1 \, s_2}\mathrm{R\ X\ ln}\frac{P_2}{P_1})]$$

net rate exergy is carried *into* the control volume. Between point 3&4;

$$\mathbf{m_3 h_3 [ef_3 \, ef_4]=m_3 \, [(h_3 \, h_4)T_0(s_3 \, s_4}\mathrm{R\ X}\ \mathbf{ln}\frac{P_4}{P_3})]$$

Energy destruction;

$$\mathbf{E_d= m_1 \, h_1 \, [ef_1 \, ef_2] + m_3 h_3 \, [ef_3 \, ef_4]}$$

$$\eta=\frac{\mathbf{m_3 h_3 [ef_3 - ef_4]}}{\mathbf{m_1 h_1 [ef_1 - ef_2]}}.$$

Readings

	Parameters	Values
m_1	Mass flow rate of combustion gasses inlet	206.6 kg/sec
m_2	Mass flow rate of combustion gasses outlet	158.77 kg/sec
T_1	Temperature of Flue gasses at inlet of economiser	673K
T_2	Temperature of Flue gasses at outlet of economiser	613K
T_3	Cold water temperature at inlet of economiser	525K
T_4	Feed water temperature at outlet of economiser	623K
P_1	Pressure of Flue gasses at inlet of economiser	0.0019 bar
P_2	Pressure of flue gasses at outlet of economiser	0.0029 bar
P_3	Cold water stream water pressure at inlet of economiser	166 bar
P_4	Feed water at outlet of economiser	156 bar

Results of Second law analysis of Economiser

Parameter	RESULT
Net rate exergy is carried into the control volume between point 1 & 2	12.904 MW
Net rate exergy is carried into the control volume. between point 3&4	6.247679 MW
Energy destruction	6.247679 MW

SECOND LAW EFFICIENCY OF ECONOMISER= 44.69%

C. Second Law analysis of Air pre-heater

Equations (All equations are taken from Fundamentals of Engineering Thermodynamics, Michael J. Moran, Howard N. Shapiro)
net rate exergy is carried *into* the control volume. Between point 1 & 2;

$$\mathbf{m_1 h_1 [ef_1 \, ef_2]=m_1} \, [(\mathbf{h_1 \, h_2})\mathbf{T_0}(\mathbf{s_1 \, s_2}\mathrm{R\ X\ ln}\frac{P_2}{P_1})]$$

net rate exergy is carried *into* the control volume. Between point 3&4;

$$\mathbf{m_3 h_3 [ef_3 \, ef_4]=m_3} \, [(\mathbf{h_3 \, h_4})\mathbf{T_0}(\mathbf{s_3 \, s_4}\mathrm{R\ X\ ln}\frac{P_4}{P_3})]$$

Energy destruction;

$$\mathbf{E_d= m_1 \, h_1 \, [ef_1 \, ef_2] + m_3 h_3 \, [ef_3 \, ef_4]}$$

$$\eta=\frac{\mathbf{m_3 h_3 [ef_3 - ef_4]}}{\mathbf{m_1 h_1 [ef_1 - ef_2]}}.$$

Readings

	Parameters	Values
m_1	Mass flow rate of combustion gasses inlet	206.6 kg/sec
m_2	Mass flow rate of combustion gasses outlet	80 kg/sec
T_1	Temperature of Flue gasses at inlet of air preheater	613 K
T_2	Temperature of Flue gasses at outlet of air preheater	413 K
T_3	Air temperature at inlet of air preheater	303 K
T_4	Air temperature at outlet of air preheater	533 K
P_1	Pressure of Flue gasses at inlet of air preheater	0.0058 bar
P_2	Pressure of flue gasses at outlet of air preheater	0.0107 bar
P_3	Air pressure at inlet of air preheater	214.7 bar
P_4	Air at outlet of air preheater to furnace	196.13 bar

Results

Parameter	RESULT
Net rate exergy is carried into the control volume. Between point 1 & 2	4.257 MW
Net rate exergy is carried into the control volume. Between point 3&4	1.627 MW
Energy destruction	2.63 MW

SECOND LAW EFFICIENCY OF Air preheater= 39.60 %

III. COST ANALYSIS

A. Coal handling plant

1) Cost estimation of losses due to air

To avoid air loss, we should cover the conveyer belt and don't let air to blow over it.
Maximum capacity of coal can be in inlet = 1400 ton/hour
Actual feed to bunker = 900 ton/hour
500 ton/h coal is lost due to air losses
Present cost of 1 ton of coal = Rs 3210
Cost of 500 ton of coal = 3210 x 500
= 1605000 /-

2) Cost estimation of losses due to transportation of coal

The clamps to hold the wagon should be of different material so that reduction in size of clamps can be done and same strength can be obtained and as size is less thus less coal will be stuck at that part according to this loss in coal will be less.

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Tippler losses = 10 Kg loss in clamps = 10 x 3.21

= 32.1 /-

In form of dust = 5 Kg = 5x 3.21

= 16.05 /-

Theft loss in wagon = Amount of coal feed in wagon = 100 ton Amount of coal lest at last when it reaches the power plant = 70 ton

30 ton of coal is theft which cost = 30 x 3210

= 96300 /-

3) Cost estimation of losses due to non-opening of gates in track hoppers system The pneumatic valves to open the gates of the wagon to let coal to fall in the hopper in track hopper system should be perfect so that the wagons can be cleared in less time to avoid demerge cost given to Indian Railway by plant.
Where the gate of wagon is not opened due to dust of coal complete wagon goes back to loss of coal in cost = 100 x 3210

= 321000 /-

4) Cost estimation of losses due to idling time of the motor

Motor at no load condition = 1 Kw

Motor at full load condition = 15 Kw

Thus, if no coal is being fetched then also 1 Kw power is being consumed by motor.

Motor consumes 1 unit of electricity in 1 hour

As if idling time is 1 hour daily then 1 unit of electricity is wasted daily

Per year 365 units is wasted

Which will cost = 365 x 8

= 2920 /-

5) Cost estimation of losses due to opaque walls and excessive use of electricity In CHP they are having closed rooms with less no. of windows and having concrete sealing at their top which are opaque. Thus, they can also use maxim no. of windows and can also give green sheet which is translucent in nature thus some amount of light can entre and reduces in electricity consumption. 11. Power factor of maximum motors in CHP was 0.6 to .07 thus can be improved up to 0.9 as BFP is working at .09 PF. In CHP where the officers sit there is very less number of windows and there are maximum opaque walls

1 tube light consumes 60/- in one month

30 tube lights are there in office = 30 x 60

= 1800/-

B. Boiler system

1) Cost of energy wastage by second law analysis of Boiler

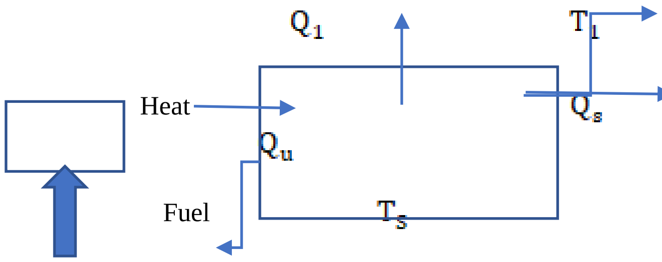

Figure 5.1 Energy distribution

Q_s = Rate of heat transfer receiving

T_s = Source temperature

Q_u = Delivery temperature

T_u = Delivery temperature

Q_1 = Rate of heat transfer to surroundings

T_1 = Temperature across the surface

Cost = CF X $[1-\frac{T_0}{T_1}]\,Q_1$

$[1-\frac{T_0}{T_1}]\,Q_1$ = Rate of energy destruction

CF = Cost decided by NTPC of 1 unit of electricity

Cost = 0.40 X 280526.95

= 112210.78 /-

2) Cost of energy wastage by second law analysis of Economiser

Cost = CF X $[1-\frac{T_0}{T_1}]\,Q_1$

$[1-\frac{T_0}{T_1}]\,Q_1$ = Rate of energy destruction

CF = Cost decided by NTPC of 1 unit of electricity

Cost = 0.40 X 6247.67

= 2499.068 /-

3) Cost of energy wastage by second law analysis of APH

Cost = CF X $[1-\frac{T_0}{T_1}]\,Q_1$

$[1-\frac{T_0}{T_1}]\,Q_1$ = Rate of energy destruction

CF = Cost decided by NTPC of 1 unit of electricity

Cost = 0.40 X 2680

= 1072 /-

4) Loss in CV from marshal yard to pulveriser

The CV of the coal from marshal yard to pulveriser is reduced by 200CV it can be avoided by keeping coal in less moist area.

Marshal Yard CV of coal= 3760 CV

Pulverised coal CV = 3560 CV

Heat input is constant Qi = M X CV

M1 X CV1 = M2 X CV2

M1 X 3760 = 75.59 X 3560

M1 = $\frac{75.59 \text{ X } 3560}{3760}$

= 71.56 Kg / sec

Loss = 4.02 Kg/ sec

= 347.328 Ton / day

Cost of loss of coal = 3260 X 347.328

= Rs 115898

5) Blow down
1 % of blow down implies 0.17% heat added in the boiler. So, blow down should be adhered to the chemist requirement.
Q = M X CV
= 75.59 X 3560
= 269100.4 X $\frac{0.17}{100}$
Loss of Q due to 1% of blow down implies 0.17 % of heat loss = 457.4
New Q after loss = 269557.8
269557.8 = M X 3560
M = 75.71
More M required = 0.128 Kg/ sec
M per day = $\frac{0.128 \times 24 \times 60 \times 60}{1000}$
= 11.059920Ton / day
Cost of Q due to 1% of blow down implies 0.17 % of heat loss = 11.0599 X 3260

= Rs 36052.992 /-

6) Soot blowing losses
Superheated steam with high enthalpy is used for soot blowing.
1% of steam required, contains 0.62% heat content. To make up the loss another 0.25% heat has to be added to feed water resulting in total heat loss of 0.87%.
Q = M X CV
= 75.59 X 3560
= 269100.4 X $\frac{0.87}{100}$
Loss of Q due to 1% of blow down implies 0.17 % of heat loss = 2341.173
New Q after loss = 266759.22
266759.22= M X 3560
M = 74.80 Kg/sec
More M required = 0.79 Kg/ sec
M per day = $\frac{0.79 \times 24 \times 60 \times 60}{1000}$
= 68.256Ton / day
Cost of Q due to 1% of steam required, contains 0.62% heat content. To make up the loss another 0.25% heat has to be added to feed water resulting in total heat loss of 0.87%.
= 3260 X 680256
= 222514.56 / -

7) Use of economiser in place of air pre-heater
Q of air pre heater = 25830 kW
Q of economiser = 4857 kW

Rate of heat transfer of air preheater is very much high than Economiser. Thus, to make an economiser of same rate of heat transfer we need to make 3100 tubes instead of 544 tubes. Thus cost of making economiser will be 6 times the construction of an economiser thus we do not use economiser in place of APH. This calculation is done in MATLAB and program is in Appendix 2. We use air pre-heater instead of this large economiser because it will occupy very large space and cost of construction is very high, but it is one-time investment. The motor responsible for rotation of air preheater is of 11 kW, 415 V, 3 phase which moves at 1460 rpm but the cost of maintenance and working of this motor is very much less as compared to construct an economiser of such a big size.

IV. CONCLUSION

From the investigation of this thesis, it is observed that the overall plant performance changes with the small variation in the output loads. From the calculation it can be easily concluded that the overall efficiency of the plant decreases with the decrease in the requirement of output load. Output Load of the thermal power plant depends on the demand of electricity. As the demand of electricity decreases, the output load of the thermal power plant decreases, and the overall efficiency of the plant is also lower, because electricity cannot be stored so the plant is running on partial load. Now if the thermal power plant run at Full Output Load the overall efficiency of the plant is much higher.
Rate of heat transfer of air preheater is very much high than Economiser. Thus, to make an economiser of same rate of heat transfer we need to make **3100 tubes** instead of **544 tubes.** Thus cost of making economiser will be **6 times** the construction of an economiser thus we do not use economiser in place of APH. We use air pre-heater instead of this large economiser because it will occupy very large space and cost of construction is very high, but it is one-time investment. The motor responsible for rotation of air preheater is of 11 kW, 415 V, 3 phase which moves at 1460 rpm but the cost of maintenance and working of this motor is very much less as compared to construct an economiser of such a big size.

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