IMPROVING THE BOILER EFFICIENCY BY OPTIMIZING THE COMBUSTION AIR

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ABSTRACT:

Boilers are the widely used and the most common equipment in production of steam, often consuming the majority of the facility's fuel. The most commonly used fuel is coal. Coal is burnt in the boiler and the water in the boiler tube is heated to the required temperature to produce steam. As the result of burning the coal flue gas is generated, which travels all over through the boiler to the chimney. The load on a boiler plant constantly fluctuates depending on weather conditions, occupancy rate, and internal heat gains.Proper control of part-load operation can significantly affect energy use. One primary factor affecting a boiler's efficiency is excess air used in the fuel combustion. This excess air must be given to the boiler in an exact calculated amount. The excess air is given to the boiler to ensure complete combustion. Boilers are most efficient when combustion air intake is only slightly higher than the minimum air required for combustion. Maintaining low excess air levels at all firing rates provide significant fuel and cost savings.This project suggests the various methods to improve the boiler efficiency by optimizing the combustion air given to the boiler after studying the various losses in a boiler caused by various sources.This improvement in the boiler efficiency is also theoretically proved by mathematically calculating the excess air trends in the boiler and comparing it with the boiler efficiency.

Keywords*:* Boilers – excess air , boiler efficiency

CHAPTER 1
INTRODUCTION

1.1 ORGANIZATION PROFILE

Tuticorin thermal power station (TTPS) is located in Tuticorin harbour estate about 7km away from the main town on the sea shore of Bay of Bengal. It has the power production capacity of 1050MW (5 X 210 MW). This plant plays a vital role in meeting the electricity needs of Tamil nadu.

All 5 units were commisioned in between 1979 and 1992. The cost of first three units under stage I and II comes to about 270 crores and the cost of additional two units under stage III was about 605 crores.

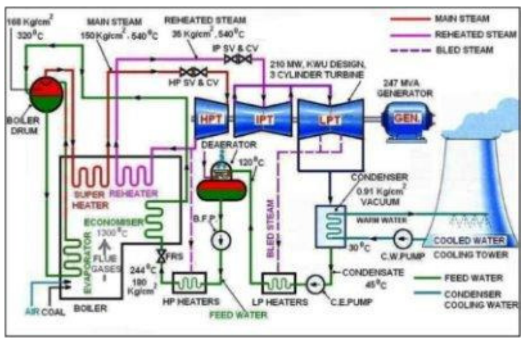
The annual generation of TTPS is 9000 million units and the cost of generation is 160 paise per unit. The generation unit and the rotor synchronous speed are 15.75KV and 3000 rpm respectively. The maximum ash discharge from each unit is 30 tonnes per hour.

The boilers used in this plant are designed such that both coal and oil can be used as fuel. For economic reason 100% coal firing is preferred and the oil is used mainly for lighting up purpose. The annual requirement of coal for the power station is brought from eastern coal fields like Bengal and Bihar, Mahanadhi coal field in Orrisa and Singareni coal field in Andhra pradesh by ships to Tuticorin port.The coal is directly taken to the plant's coal yard by the 4km long separate conveyor laid in between Tuticorin port's coal jetty and plant. The furnace oil required for the power station is supplied by M/S Indian oil corporation. The per day water requirement for the plant is in the order of 6.5MG.

TWAD board is supplying the water from the river Tamarabharani, pumped from their Manjalneerkayal water works, which is situated about 20km away from the power plant. The boilers, turbines, generators and the most of the auxillaries in the station are manufactured and supplied by M/S BHEL,India. The station meets almost one third of the electricity demand of Tamilnadu. It has received the meritorious productivity award instituted by the Government of India several times and is known as one of the best environmentally maintained power station in the country. Nearly 2500 staffs are being engaged in this station. This station has gone for full production of 1050MW since 7th January 1994 and had achieved the super thermal station status.

CHAPTER 2

TTPS LAYOUT



SCHEMATIC DIAGRAM OF TTPS LAYOUT

2.1Fuel and ash circuit

Coal is the main fuel. It is transported from the coal mines of Orrisa and West Bengal. TTPS collects the coal in its own port. The coal is directly taken to the coal yard by separate conveyor laid for about 4 kms from coal jetty inside the port premises. Coal from the coal yard is initially crushed to a size of less than 40mm in the primary crushers and crushed to a size of less than 25mm in the secondary crushers. It is conveyed to the coal mills through conveyor rubber belts. This raw coal is measured in a volumetric feeder and pulverized in the mills. There are six numbers of mills per boiler out of which 5 numbers are operated for getting full load. The pulverized coal is carried to boiler furnace corners through coal pipes with the assistance of hot primary air.

Light diesel oil is also used for lighting up of the boiler. Fuel is burnt in the combustion chamber of the boiler and the ash produced is collected in the bottom of the ash hopper, economizer hopper and mainly in the electro static precipitator (ESP). Expect in the ESP ash is collected and is mixed with water. This slurry is finally pumped to the ash pit.Dry ash is collected in the ESP through vaccum compressors , collected in silos and sold to customers .Dry ash has become a by product of boiler .

2.2 Air and flue gas circuit:

Two primary air fans and two forced draught fans supply air required for combustion of fuel in the furnace of the boiler. The flue gases from the furnace pass over boiler tubes and super heater tubes. Then the flue gas passes through economizer to heat the feed water. After that it passes through the air pre-heater to pre heat the incoming air. Flue gas in the air pre-heater preheats the incoming cold primary air supplied from primary fan and the hot primary air enters the bowl mill where it pushes the pulverized coal and air mixture to the coal furnace. Again flue gas in the air pre-heater preheats the incoming cold secondary air supplied from the FD fan and the hot secondary air enters the wind box of boilers . The flue gas then passes through the dust collection and finally exhausted to the atmosphere through the chimney. With the help of two ID fans connected between ESP and chimney .

2.3 Water and steam circuit:

Water at a pressure of 160kg/sq.cm is pumped from boiler feed pump to the economizer, after getting heated up in the economizer it goes to the boiler drum. It is circulated from the drum through the down comer pipes, bottom inlet header, water wall tubes, outlet headers and riser tubes to the drum turbo separator and screen driers from the drum it goes to superheater tubes . The final superheated steam taken from the fourteenth header of the boiler is at 540^0C. This steam does useful work in the high pressure turbine. After high pressure turbine the steam is again reheated in the boiler. The reheated steam goes to the intermediate pressure turbine and then to the low pressure turbine. The condenser is placed at the bottom of low pressure turbine and the steam gets condensed there. The condensed water is pre heated, deaerated and pumped back to the economizer through the HP heater. This cycle repeats and mechanical energy is produced continuously in the turbines. Anywater to be makeup is sent to the hot well of the condenser.

CHAPTER 3

BOILER OVERVIEW

3.1 Boiler description:

Boiler is a steam generating equipment, which is intended to produce steam at a rate of 700 tonnes/hr at 540^0 C and at 137 kg/cm^2. Also the boiler should supply steam uninterruptedly to suit the load condition of the turbo generator.

Though boiler is a mechanical equipment, its control and protection system and huge supporting structures call its design for various disciplines of engineering like mechanical, electrical, computer, civil, instrumentation and chemical engineering.

Now a day's all coal fired boilers are working automatically and needs less man power for operation. The specification of the important boiler pressure parts are given below.

3.1.1 Furnace:

Furnace width - 13.88m

Furnace depth - 10.592m

Furnace volume - 5494m^3

Furnace plan area - 147m^2

3.1.2Drum:

Drum diameter -1676m

Thickness -133mm

No. Of down comers - 8

No. Of up risers - 134

No. Of feed water inlet lines - 4

No. Of turbo separators - 100

No. Of safety valves - 3

3.1.3Super heater:

Stage I LSTH - 5974m^2

Stage II platen SH - 1268m^2

Stage III pendant SH - 1037m^2

3.1.4 Safety valve:

Spring loaded safety valve - 2

a. Size - 6.23cm
b. Pressure - 144.5 kg/cm^2
c. Retrieving capacity- 500.63 T/hr

Impulse safety valve - 1

a. size - 6.125cm
b. pressure - 141.3 kg/cm^2
c. retrieving capacity - 87.213 T/hr

3.1.5 Reheater:

Total heating surface - 2650cm^2

i. Cold reheat - 4

a. size - 15cm

b. pressure - 33.4 kg/cm^2

c. retrieving capacity- 500.63 T/hr

ii. Hot reheat -

a. size - 15cm

b. pressure - 28.48 kg/cm^2

c. retrieving capacity- 500.63 T/hr

3.1.6 Economizer:

Total heating surface - 3978 m^2

No of coils - 270.

3.2 Air pre-heater:

Air is a primary auxiliary of boiler, There are two airpreheater per boiler . In each of these equipments, the ambient air needs to be heated up to very high temperatures. Preheating the incoming air largely improves the thermal efficiency of the system, thereby increasing the energy savings of the industry and results in lower operating costs. In fact, every 22 ^{0}C rise in combustion air temperature increases the boiler efficiency by nearly 1%. Heat exchangers can be used to recover the heat from various processes to preheat the air. However, the heat transfer coefficient of air is low, and hence, fins or extended surfaces are used to enhance the heat transfer. It is a common industrial practice to utilize the heat of exhaust gases or flue gases and process steam to preheat ambient air.

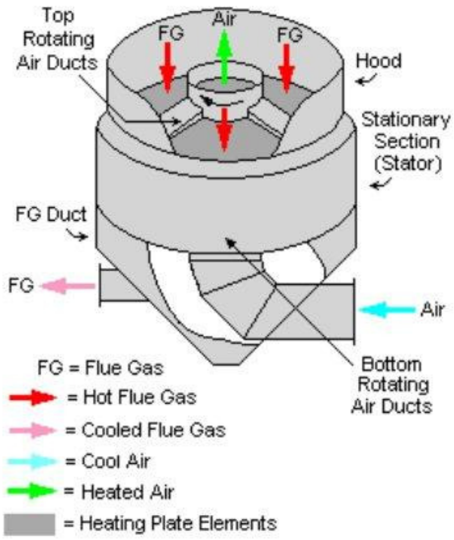
Air pre-heater is the most common equipment responsible for deterioration in boiler efficiency and increase in auxiliary power consumption in ID, FD, and PA fans.

3.2.1 Specification of air preheater:

Type : 27-VI-72 (T) 74"

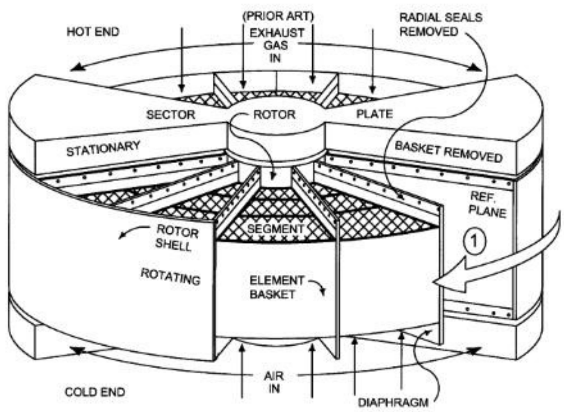
Where, 27 is the nominal diameter of rotor in feet
V stands for vertically erected down flow air pre-heater
I stands for interchangeable heating element .
72 is the height of rotor in inches
74" is the height of casing in inches

This air preheater is divided into 3 sectors of 72, 108 and 180 degrees. Flue gas is allowed to pass from top to bottom vertically through the 180 degree sector. Primary air is allowed to pass from bottom to top upward through the 72 degree sector and similarly secondary air passes upwardly through 108 degree sector. The rotor is divided into 12 sectors by vertical diaphragm plates. Heating elements are arranged in these sectors in 3 layers, the top layer hot end, intermediate and the bottom layer-cold end. Heating elements at hot end and intermediate end are identical. The top and bottom sides of the diaphragm plates are mounted with 12 sets of radial seals each and the vertical sides of the rotor are mounted with 12 sets of axial seals.



Typical Stationary Plate Air Preheater

Exploded view of air pre heater



3.3 Boiler efficiency:

The efficiency of the boiler may be defined as the ratio of heat actually used in producing the steam to the heat liberated in the furnace.

Boiler efficiency = ???????????? ???? ?? ????????? ????? x 100
??????????? ?? ?????????

= ? ?? ??? ?x 100

? ? ? ??

Where, m_s = mass of steam kg

h_s = enthalpy of steam kJ/kg

h_w = enthalpy of water kJ/kg

cv = calorific value of fuel kJ/kg

m_f = mass of fuel kg

from the known data,

m_s = 680 T/hr; m_f = 124 T/hr;cv = 3940 kJ/kg

h_w = 1037.6 kJ/kg ;h_s = 3500 kJ/kg

(h_s value is taken from steam table for the pressure of 133kg/cm^2 and temperature of 540^{0}C)

by substituting,

Boiler efficiency = ???????????????????????????x 100

Boiler efficiency = 82 %

Therefore, the total loss in the boiler efficiency = 100% - 82% = 18%

CHAPTER 4

HEAT LOSSES IN BOILER

4.1 Various losses in boiler :

The various heat losses that the boiler encounters are given below

1. Heat carried away by dry flue gas
2. Heat loss due to moisture in fuel
3. Heat loss due to the presence of hydrogen in fuel
4. Heat loss due to unburnt carbon in ash pit
5. Heat loss due to incomplete combustion.
6. Heat carried away by bottom ash .
7. Heat carried away by fly ash .

4.1.1. Heat loss due to dry flue gas(Q_{dry}) :

A part of heat is lost in the flue gas exhausting out, which carry only sensible heat since no change of state was involved. These products are carbon dioxide (CO_2), carbon monoxide (CO), oxygen(O_2), nitrogen (N_2) and sulphur dioxide (SO_2).Concentrations of SO_2 and CO are normally in the parts-per-million (ppm) range so, from the viewpoint of heat loss, they can be ignored.This loss occurs due to the presence of excess air given to the combustion chamber. Due to high excess air, a lot of heat is transferred to the departing flue gas.

4.1.2. Heat loss due to moisture in fuel(Q_{moist}):

The coal which is used for combustion should not possess any moisture of higher value. If the moisture is high in the coal then the heat needed to burn the coal will be high which leads to unwanted heat loss.

4.1.3. Heat loss due to the presence of hydrogen in fuel($Q_{hydrogen}$):

The hydrogen component of fuel leaves the boiler as water vapour, taking with it the enthalpy – or heat content – corresponding to its conditions of temperature and pressure. The vapour is a steam at very low pressure, but with a high stack temperature. Most of its enthalpy is in the heat of vaporization.

4.1.4. Heat loss due to unburnt carbon in ash pit(Q_{carbon}):

During combustion some coal particles becomes unburnt due to incomplete combustion. This unburnt fuel has unburnt carbon content in it. This carbon content in the coal gains a considerable amount of heat and falls to the ash pit without combustion.

4.1.5. Heat loss due to incomplete combustion (Q_{inc}) :

The heat loss due to incomplete combustion is a result of less input air to the furnace. As a result of incomplete combustion carbon monoxide is released to the atmosphere. The loss of heat due to incomplete combustion can be calculated using the carbon monoxide level in the flue gas

4.2 Heat balance sheet:

A heat balance sheet shows the complete account of heat supplied by 1kg of dry fuel and heat consumed. The heat supplied is mainly utilised for raising the steam and the remaining heat is lost. In the heat balance sheet the above mentioned various losses has been calculated with the relevant formula.

Input data :

THERMAL PLANT PARAMETERS :

PARAMETERS		UNITS	SAFE LIMIT	FULL LOAD READINGS (210 mw)
Id fan load current	A	A	170	128
	B	A	170	130
Furnance draft		mmW	-10	-5

			cl		
Flue gas pressure	Id fan outlet	R	mmWcl	40	-
		L	mmWcl	40	22
	Esp outlet	R	mmWcl	-350	320
		L	mmWcl	-350	310
	APH outlet	R	mmWcl	-180	210
		L	mmWcl	-180	-
	Economiser outlet		mmWcl	-60	-31
	Conv SH outlet		mmWcl	-40	-15
	SH outlet		mmWcl	-30	-
Fd fan load Current	A		mmWcl	60	46
	B		mmWcl	60	45
Secondary air pressure	APH outlet	R	mmWcl	80	-
		L	mmWcl	80	-
	APH inlet	R	mmWcl	200	165
		L	mmWcl	200	194

Tabulation 2 :

PARAMETERS			**UNITS**	**SAFE LIMIT**	**FULL LOAD READINGS(210 mw)**
Secondary air pressure	Fan discharge	A	mm Wcl	250	180
		B	mm Wcl	250	210
Wind box to furnance Dp			mm Wcl	75	92
wind box pressure		R	mm Wcl	65	85
		L	mm Wcl	65	90
secondary air flow		R	T/Hr	300	205
		L	T/Hr	300	220

Scanner air fan discharge HDR pressure		Mm Wcl	240	406
Atom air pressure		Kg/cm^2	7.5	5.9
Instrument air pressure		Kg/cm^2	7.5	5.5
Light oil	Light oil pump discharge	Kg/cm^2	23	429
	Light oil header pressure	Kg/cm^2	7	835
	Flow meter reading	Kl	-	414571
Heavy oil pressure	Pump discharge	Kg/cm^2	23	16
	After oil heating station	Kg/cm^2	20	-
	Heavy oil header	Kg/cm^2	10	10
	Flow meter reading	Kl	-	-

TABULATION 3 :

PARAMETERS			**UNITS**	**SAFE LIMIT**	**FULL LOADING READINDS IN 210 MW**
Atom steam pressure			Kg/cm^2	8.5	13
Temp at ‘0’ mtr (steam)			°C	115	680
Temp at ‘18’ mtr			°C	110	141
Total air flow			T/Hr		750
SH steam temperatu	outlet	L	°C	540	13

re		R	°C	540	680
	Attemp inlet	L	°C	470	141
		R	°C	470	750
	Attemp outlet	L	°C	400	540
		R	°C	400	540
CRH station temperature	Attemp inlet	L	°C	330	461
		R	°C	330	273
	Attempt outlet	L	°C	540	284
		R	°C	540	403
HRH station	L		°C	540	540
	R		°C	540	535
CST			mtr	6-7.5	6.3
Co			Ppm	150	75
O^2 in flue gases (dust)			%	5	3.9

Tabulation 4 :

PARAMETERS			UNIT	SAFE LIMIT	FULL LOAD READINGS IN 210 Mw
Fw temp at Economiser	Inlet		°C	247	242
	Outlet		°C	278	285
Flue gas temperature	Inlet	L	°C	350	388
		R	°C	350	391
	Outlet	L	°C	145	154
		R	°C	145	154
Flue gas temperature at outlet	Pi SH		°C	400	912
	RH		°C	800	640
	Conv SH		°C	450	440
Attemperation flow	SH	L/R	T/Hr	Coal flow	124
	RH	L/R	T/Hr		10.2
PA Fanload current	A		Amps	85	71
	B		Amps	85	71
PA HDR Pr			mm Wcl	800	832
PA pressure	Discharge	A	mm Wcl	850	975
		B	mm Wcl	850	1025
	At APH outlet	L	mm Wcl	820	820
		R	mm Wcl	820	820
Seal air pressure			mm Wcl	1000	1000

TABULATION 5 :

PARAMETERS		UNITS	SAFE LIMIT	FULL LOAD READINGS IN 210 Mw
Mill A	Load current amps	Amps	30	30
	R.C.F feeder coal flow	T/Hr	30	4.7
	P.A.flow	T/Hr	50	68
	Mill differential pressure	mmWcl	250	269
	Mill outlet temperature	°C	80	76
	W.S bearings DE	°C	85	60
	W.S .bearings NDE	°C	85	71
	Bottom bearings	°C	85	94
	Return oil	°C	85	67
Mill B	Load current amps	Amps	30	30

	R.C.F feeder coal flow	T/Hr	30	4.1
	P.A.flow	T/Hr	50	66
	Mill differential pressure	mmWcl	250	274
	Mill outlet temperature	◦C	80	54
	W.S bearings DE	◦C	85	74
	W.S .bearings NDE	◦C	85	78
	Bottom bearings	◦C	85	88
	Return oil	◦C	85	71

Mill c	Load current amps	Amps	30	30
	R.C.F feeder coal flow	T/Hr	30	3.6
	P.A.flow	T/Hr	50	72
	Mill differential pressure	mmWcl	250	230
	Mill outlet temperature	◦C	80	90
	W.S bearings DE	◦C	85	93
	W.S .bearings NDE	◦C	85	77
	Bottom bearings	◦C	85	-
	Return oil	◦C	85	79
Mill D	Load current amps	Amps	30	30
	R.C.F feeder coal flow	T/Hr	30	5.9
	P.A.flow	T/Hr	50	29
	Mill differential pressure	mmWcl	250	269
	Mill outlet temperature	◦C	80	90

	W.S bearings DE	◦C	85	68
	W.S .bearings NDE	◦C	85	75
	Bottom bearings	◦C	85	-
	Return oil	◦C	85	71

Mill E	Load current amps	Amps	30	30
	R.C.F feeder coal flow	T/Hr	30	4.1
	P.A.flow	T/Hr	50	59
	Mill differential pressure	mmWcl	250	255
	Mill outlet temperature	◦C	80	90
	W.S bearings DE	◦C	85	76
	W.S .bearings NDE	◦C	85	60
	Bottom bearings	◦C	85	-
	Return oil	◦C	85	60

Heat loss in exhaust flue gas(dry loss)

Heat loss due to dry flue gas = ? ?? ??? ??????? ? / ??

Where, m_g = mass of flue gas.

C_{pg} = specific heat of flue gas.

t_g = temperature of flue gas after APH

t_b = temperature of boiler room

mass of flue gas = mass of fuel burnt/hr + total mass of air supplied/hr

Total mass of air supplied = primary air + secondary air

= 322 + 425 = 747 T/hr

Mass of flue gas (m_g) = 124 + 747

= 871 T/hr

Heat loss due to dry flue gas = ????? ???
= 847.1 kJ/kg of fuel

% of heat loss due to dry flue gas= ?????????????X 100
= 5.14%

Heat loss due to moisture in fuel ($Q_{moisture}$):

Heat loss due to moisture in fuel = m_m(h_{sup} – h_b)

Where, m_m = mass of moisture per kg of fuel

h_{sup} = enthalpy of superheated steam

h_b = enthalpy of water at boiler room temperature

Total moisture in fuel = 29.76%
= ???????
= 0.2976

Heat loss due to moisture in fuel = 0.2976 (2780 – 419.1)

= 702.60 kJ/kg

% of heat loss due to moisture in fuel = ?????????????X 100
= 4.2%

Heat loss due to presence of hydrogen in fuel($Q_{hydrogen}$):

Heat loss due to presence of hydrogen in fuel = $9H_2$ (h_{sup}- h_b)

????Total amount of hydrogen in flue gas = 2.741%= ??? = 0.02741
= 9 (0.02741) (2780 - 419.1)

= 582.41 kJ/kg

?????%of heat loss due to presence of hydrogen in fuel = ????? ??? X 100

= 3.5%.

Heat loss due to unburnt carbon in ash pit (Q_{carbon}):

Carbon content in fly ash = 0.35%

Carbon content in bottom ash = 2.8%

Heat loss due to unburnt carbon in ash pit = m_c X CV_c

Where, m_c = mass of carbon in ash pit

= (mass of carbon in bottom ash + mass of carbon in fly ash)

CV_c= calorific value of carbon

m_c= 0.0035+0.028 = 0.0315

heat loss = 0.0315 X 3940 X 4.18

= 518.77 kJ/kg

???? % of heat loss due to unburnt carbon in ash pit
= ??? = 5.18%

Heat loss due to incomplete combustion(Q_{inc}):

Heat loss due to incomplete combustion = mass of CO X CV_{co}

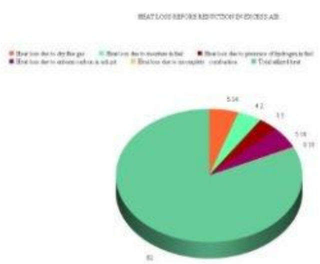
= 19 x10^{-6} x 10100

%of heat loss due to incomplete combustion = 0.19%

Therefore, the total heat loss in the boiler = Heat loss due to dry flue gas+
Heat loss due to moisture in fuel+ Heat loss due to presence of hydrogen in fuel+
Heat loss due to unburnt carbon in ash pit+
Heat loss due to incomplete combustion.

= 5.14+ 4.2+ 3.5+ 5.18+ 0.19

Total heat loss in the boiler = 18% (approx.)



Chapter 5

EXCESS AIR TRENDS

5.1 Theory of combustion:

The combustion of fuels may be defined as a chemical combination of oxygen, in the atmospheric air and hydro carbons. It is usually expressed both qualitatively and quantatively by equations known as chemical equations .The term “fixed” carbon is use to distinguish that part of the carbon that remains unmixed, chemically , with any other substances from the carbon that is contained in the volatile matter in chemical combination with hydrogen. These mixtures of hydrogen and carbon contained in the volatile matter are known as hydro carbons ; which , when the coal is heated , is driven off in the form of a gas or of a semiliquidtary substances.

The moisture or water in coal is made up of hydrogen and oxygen .The ash usually contains some of the clinker and honeycomb forming elements ,sulpur and iron , which is so often a source of trouble to the fireman .in addition there may be chemical compounds known as the oxides of silica , aluminum , calcium and magnesium .Carbon and hydrogen are the “fuel” elements contained in coal , or any other form of fuel .The chemical combination of the fuel elements – carbon and hydrogen, with oxygen from the air is called combustion , and combustion results in changing chemical energy into a form of energy which we known heat.

A body will burn and given out heat when it unites with oxygen .This is what the carbon in coal does when burnt in a fire box.The oxygen is supplied by the air which is the mixture of 23 parts oxygen and 77 parts nitrogen in every parts by weight .

The nitrogen takes no combustion .Combustion is known as a chemical combination, but the cause of chemical combination has always been,and still is, more or less a mystery .Any explanation of the mechanism of combustion is therefore not only rather difficult to make but is also open to question .

When carbon burns combustion can take place in two ways .Combustion takes place by the uniting together of very minute particles or atoms of substances .These minute particles have different weights –each carbon atom weighs 12 and each oxygen atom 16 , as compared with the atom of hydrogen - the weight index figure of the latter being taken as 1 .

In the incomplete combustion of carbon , each atom unites with the one atomof oxygen combine with one atom of carbon and this is called carbon dioxide .If sufficient air is supplied the carbon will be burnt to carbondioxide gas at the bottom of the box ; if sufficient air is suppliedit will be immediately burnt to carbon monoxide gas , the complete combustion of the fueltaking place in the latter case , above the fire.

If there is a plentiful supply of air 12 parts by wweight of carbon will unite with 32 parts by weight of oxygen and a 44 part of inflammable gas called carbon monoxide is produced(Complete Combustion).

5.1.1 Incomplete combustion :

Carbon = 12 parts by weight unites with oxygen =16 parts by weight forming carbonmonoxide =28 parts by weight.

$$2C + O_2 = 2CO$$

2mol +1mol = 2mol
2X12 kg +2X 16 = 2 X28 kg 1
kg + ?? kg = ?? kg .

This gives off only 3-10th of the heat in the fuel .Now we know 2 atoms of oxygen are required to complete combustion with one atom of carbon bring in more air , and you get ---

- Carbon monoxide =28 parts by weight .
- Unites with oxygen =16 parts by weight
- 44 parts by weight

This gives off the remaining 7-10thy of the heat in the fuel .

$$2CO + O_2 = 2CO_2.$$

2mol + 1 mol = 2mol
2 X28 kg + 2X 16 kg = 2X44 kg .
1kg +?? kg =???kg .

5.1.2 complete combustion :

Carbon = 12 parts by weight , uniting with , two atoms of oxygen =32 parts by weight , forming carbon dioxide =44 parts by weight , which releases all the heat contained in the fuel .In burning to carbon monoxide , carbon gives out only 3-10ths as much heat as it does in completely burning to carbon monoxide and therefore if , through not admitting enough air through the firehole door , carbon dioxide only is formed , about 7-10ths of the heat is lost or about 7lbs of coal out of every 10 consumed oin this way are wasted .

$$C + O_2 = CO_2 .$$

1 mol+1 mol = 1 mol. 12 kg +? 32 kg??= 44 kg.
1 kg + ? kg = ? kg .

Heat can also be wasted by admitting tomo much air ; this will be explained later on (see marks on nitrogen) .To completely burn 1lb of carbon the two 2 -3rd lbs of oxygen contained in 121 lbs of air are required and this air , at the ordinary temperature , would kmeasure about 156 cubic feet about 12 ½ foot square .

We have already pointed out that coal does not wholly consist of carbon .the best coal has about 80 per cent , carbon,the remainder consisting of hydrogen , nitrogen , sulpur , ash and water .

The hydrogen is partly united to the oxygen and these together are given off as water vapour when the coal is burnt .Another portion of the hydrogen is given off in the form of hydrocarbon vapours and this produces the luminuous flames .When the boiler is being fired without the blower on ,or without the exhaust steam discharge , the hydrocarbons can be seen coming from the chimney as ayellowish smoke .

At the high temperature of the firebox , when running , these hydrocarbons are nclined to split up into carbon and hydrogen and if sufficient oxygen is not present to completely burn the carbon , some of it escapes unburnt , causing a black smoke . This is waste of coal and money

.A good fireman does not allow his smoke stack to blech forth black smoke , a poor or lazy fireman does .

The heat given off by hydrogen in burning is much greater than theat given off by an equal weight of carbon , but the amount of hydrogen in coal is small and some is already united with the oxygen in the coal and therefore gives out little or no heat when the coal is burnt .

5.1.3 sulpur ash and clinker :

The sulpur in coal is usually united with iron in the iron pyrites .The sulpur burns out but the iron is left behind and tends to run together forming clinker .Clinker , of couse ,as all fireman know ,spreads across the fire bars and if not removed prevents the air from passing up through the fire grate and the steam is not produced

.Some coals do not clinker ,but fall into the ashpan in state of powder .This ash is of an earthy nature and consists principally of silica and calcium and magnesium

.The chemical reacytion of sulpur reaction with oxygen is given below.

$S+O_2 = SO_2$

1mol+ 1mol =1 mol .

32 kg + 2X 16 kg = 64 kg

1 kg + 1 kg= 2kg.

5.1.4 nitrogen :

The nitrogen in coal is very small and plays no part in combustion ; it passes up the smoke atck when the coal is burnt carrying with it some heat.

Of great importance is the large volume of nitrogen which has to pass through the fire box in the air required to burn the coal .This will be understood when you remember that to burn 1lb of coal requires 12 lbs of air of which 9 lbs is nitrogen .

This nitrogen does not itself burn , but it reducesthe rate of combustion and having to be heated up with the other gases leave the smoke stack is often over 800 deg .F. and to heat 91lbs of nitrogen to this temperature will take about 1-9 th of a lb of coal .

You will see then how necessary it is only the amount of air required for burning of fuel is allowed to pass through the firehole and damper doors owing to the loss arising from the heat carried away by any superfluous air which may be drawn in .

5.1.5. Moisture in coal :

All coals contain water which has to be evaporated in the firebox and converted into steam .This carries away useful heta .It has been proved that 25^{th} part of the total heat given out by coal in burning may be carried away in the steam formed by the evaporation of the water contained in the coal and that formed by the combustion of hydrogen .

The presence of water ,volatile hydrocarbon and earthy matter mechanically mixed in with the fixed carbon, accounts for then ease with wchich a lump of coal disintegrates and break up into smaller pieces when heated .

5.2 3T's of Combustion :

The 3T's of combustion is the basus for understanding the process of combustion .The 3T's represents time , turbulence and temperature . All the 3 parameters must be in the correct proporation tp ensure complete combustion

.If anyone parameter changes , he other two parameters must be adjusted according to the variations .If the 3 parameters are not in proportion then it leads to incomplete combustion in the furnance .

5.3 Analysis of coal :

There are two methds : ultimate analysis and proximate analysis. The ultimate analysis determines all coal component elements , sold or gaseous and proximate analysis determines only the fixed carbon , volatile matter , moisture and ash percentage . The ultimate analysis is detrmined properly equipped laboratory by askilled chemist ,while proximate analysis can be determined with a simple apparatus .It may be noted that proximate has no connection with the word approximate .

5.3.1.Measurement of moisture :

Determination of moisture is carried out by placing a sample of powdered raw coal of size 200 micron size in an uncovered crucible and it is placed in the oven kept at $108+2^{\circ}$ C along with the lid .Then the sample is cooled to room temperature and weighed again

.the loss in weight represents moisture .

5.3.2 Measurement of Volatile Matter :

Fresh dample of crushed coal is weighed ,placed in a covered crucible , and heated in a furnance at $900 +15 ^{\circ}C$ .For the methodologies including that for carbon and as^{h} , the sample is colled and weighed .Loss of weight represents moisture and volatile matter .The remainder is coke (fixed carbon and ash).

5.3.3 Measurement of carbon and ash :

The cover from the crucible used in the last testcis removed and the crucible is heated over the Bunsen burner until all the carbon is burned .The residue is weighed , which is the incombustible ash .The difference in weight from the previous weighing is the fixed carbon . In actual practice fixed carbon or FC derived by subtracting from the 100 the value of moisture , Volatile matter and ash .

5.3.4 Proximate analysis :

Proximate analysis indicates the percentage by weight of the Fixed carbon ,Volatiles, Ash ,and moistures content in coal.The amount of fixed carbon and volatile matter directly contribute to the heating value of coal .Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel .The ash content in control equipment and ash handling sytems of a furnanc .A typical analysis of various coals is given below .

Table 06 TYPICAL PROXIMATE ANALYSIS OF VAIOUS COALS

PARAMETERS	INDIAN COAL	INDONESIAN COAL	SOUTH AFRICAN COAL
MOISTURE	5.98	9.43	8.5
ASH	38.63	13.99	17
VOLATILE MATTER	20.70	29.79	23.28
FIXED CARBON	34.69	46.79	51.22

SIGNIFICANCE OF VARIOUS PARAMETERS IN PROXIMATE ANALYSIS :

A) FIXED CARBON :

Fixed carbon is the solid fuel left in the furnance after volatile matter is distilled off .It consists mostly of carbon but also contains some hydrogen , oxyen , sulpur and nitrogen not driven off with the gases .Fixed carbon gives a rough estimate of heating value of coal.

B) VOLATILE MATTER :

Volatile matter are thye methane , hydrocarbons ,hydrogen and carbon monoxide and incombustible gases like carbon dioxide and nitrogen found in coal.Thus the volatile matter is an index of the gaseous fuels are present .Typical range of volagtile matter is 20 to 35% .

C) ASH CONTENT :

Ash is an impurity that will not burn .Typical range is 5 to 40%.

∑ Reduces handling and burning capacity

∑ Increases handling costs .

∑ Affect6s combustion efficiency and boiler efficiency .

D) MOISTURE CONTENT :

Moisture in coal must be transported , handled and stored .Since it replaces combustible matter ,it decreases the heat6 content per kg of coal .Typical range is 0.5 to 10%. Moisture

∑ Increases heat loss , due to evaporation and superheating of vapour

∑ Helps to a limit ,in binding fines .

∑ Aids radiation heat transfer .

E) SULPUR CONTENT :

∑ Affects clinkering and slagging tendencies

∑ Corrodes chimney and other equipment such as air heaters and economizers

∑ Limits exit flue gas temperature .

5.3.5.Ultimate analysis :

The ultimate analysis indicates the various elemental chemical constituents such as Carbon ,Hydrogen ,Oxygen etc.,,It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases .Typical ultimate analyses of various coals are given in the table below .

RESULTS OF ULTIMATE ANLYSISOF COAL

PARAMETERS	INDIAN COAL	INDONESIAN COAL
Moisture	5.98	9.43
Mineral matter	38.63	13.99
Hydrogen	2,.76	4.16
Sulphur	0.41	0.56
Carbon	41.11	58.96
Nitrogen	1.22	1.02
Oxygen	9.89	11.88

5.4 Theoretical air :

Power plant boilers normally run about 10 to 20 percent excess air. Natural gas-fired boilers may run as low as 5 percent excess air. Pulverized coal-fired boilers may run with 20 percent excess air. The percentage of excess air is the amount of air above the stoichiometric requirement for complete

combustion.when the amount of air in a combustion process greater than the amount theoretically required for complete oxidation.

The combustion process can be explained can be expressed as :

$[C+H(fuel)]$ $+[O_2$ $+N_2(Air)]$-> (Combustion Process)->$[CO_2+H_2O+N_2(heat)]$

C=Carbon.

H=Hydrogen.

O=oxygen.

N=nitrogen .

Process heating equipment are rarely run that way .”On-ratio” combustion used in boilers and high temperatures process furnances usually incorporates a modest amount of excess air –about10 to 20 % more than what is neede to burn the fuel completely .

If an insufficient amount of air is su[pplied to the burner , unburned fuel,soot ,smoke ,and carbon monoxide exhausts from the boiler –resulting in heat transfer surface fouling , pollution ,lower combustion efficiency , flame instability and a potential for explosions .

- If air content is higher than the stoichiometric ratio-the mixture is said to be fuel –lean.
- If air content is less thah the stoichiometric ratio-the mixture is fuel rich .

The basic formula to calculate the theoretical air is

? ???? ?? ?? ??? −?? ?

? ??? ??? ? ?????????? ?????????? ??????

Theoretical air required /kg of fuel = 4.87 kg/kg of fuel .

Total quantity of fuel = 124 X ? kg /hr .

Theoretical quantity of air for ??124 T/hr = 124 X ??? X theoretical air

124 X ???

X 4.87 =

Theoretical quantity of air required for 124 T/hr = 604 T/hr.

5.5 Excess air :

In theory , to have the most efficient combustion in any combustion process ,the quantity of fuel and air would be in a perfect ratio to provide perfect combustion with no unused fuel or air .This type of theoretical perfect combustion is called stochiometric combustion . In practice , however , for safety and maintenance needs , additional air beyond the theoretical “perfect ratio” needs to be added to the combustion process –this is reffered to as excess air . from a safety standpoint , properly controlling excess air reduces flame instability and other boiler hazards .Even thoughexces air is neede from a practical standpoint , too much exces air can lower boiler efficiency . so a balance must be found between providing the optimal amount of excess air to achieve ideal combustion and prevent combustion problems associated with too little excess air , while not providing too much excess air to reduces boiler efficiency .research has shown that 15% excess air is the optimal amount of excess air to introduce that the combustion process .To complicate matters , most boilers operate on the lower end of the firing range –so selecting a boiler that has low excess air throughout the firing range is important . This will ensure that you are always operating at high boiler efficiency .

VALUES FOR CO_2 AND O_2 IN THE FLUE GAS RESULT OF EXCESS AIR

Excess air %	Carbondioxide –CO_2 in flue gas (% volume)					Oxygen in flue gas for all fuels
	Natural gas	Propane gas	Fuel oil	Bituminuous coal	Antharacite coal	
0	12	14	15.5	18	20	0
20	10.5	12	13.5	15.5	16.5	3
40	9	10	12	13.5	14	5
60	8	9	10	12	12.5	7.5
80	7	8	9	11	11.5	9
100	6	6	8	9.5	10	10

CHAPTER 6

AIRPREHETER CALCULATIONS

6.1 AIRPREHEATER LEAKEAGE CALCULATION :

The air preheater plays avital role in the boiler efficiency .The amount of air passage through it and the amount of air passing through it and the amount of air leakage through it should be calculated .

Actual amount of air used in the boiler = primary air + secondary air .

= 322 + 425 .

= 747 T/hr.

To find the amount of excess air ,

Excess air = Actual air – Theoretical air .

= 747- 604 .

= 143 T/hr .

As we know ,

Theoretical air supplied /kg of fuel =4.87 kg/kg .

Actual air supplied /kg of fuel =??? ??? = 6.02 kg/kg .

Excess air supplied /kg of fuel = 6.02 -4.87

= 1.15 kg /kg of air .

6.1.1 percentage of excess air before air preheater :

% of excess air =?????????????? ????????? X 100 = ??? ???

X100 .

` = 23.6 % .

6.1.2 percentage of excess air after air preheater :

To find the amount of excess after APH , the oxygen level in the flue gas is determined .

Amount of oxygen in flue gas after APH = 6.3 %.

Excess air = ??? ?? X 6.3

= 27.39 %.

Thus the amount of excess air before the air preheater and after the air preheater has been calculated .Now the difference between these two amounts is determined to be the air leaked through the air preheater .

% of air leaked through the air preheter = 27.39-23.6

= 3.79 %.

Amount of air leaked through the air preheater = ?????? X 747 .
= 28.31 T /hr .

This quantity is very high and so efforts should be carried out to minimize the leakage quantity.

CHAPTER 7

EXCESS OXYGEN REDUCTION

7.1 Excess oxygen :

The excess oxygen in the out coming flue gas is used to determine the amount of excess air given to the boiler. For every 1% oxygen level in the flue gas . 4% excess air is given to the boiler .The efiiciency of the boiler can be increased if the excess air given to the boiler is decreased .the amount of reduction of excess air must be accurately calculated for various values to increase the boiler efficiency and to ensure complete combustion .

If the excess oxygen is reduced is reduced by 1% then the flue gas temperature will be reduced to a considerable amount .

7.1.1 Calculation :

Reduction of 1% in excess air = 1% reduced PA +1% reduced SA
= (322 - ??????) + (425 - ??????) .
= 318.78 + 420.75

= 739.53 T /hr.

7.1.1.1 Heat loss due to dry gas after reduction in air quantity :

Heat loss in dry flue gas = 863.53 X 1.005 X(154-34)
= 839.85 kJ/kg.
=?????????????? X 100 = 5.14
% of heat loss in dry flue gas = 5% .

Difference in dry gas losses = 5.14 -5 =0.14 %

7.1.1.2 heat loss due to excess air :

Heat input to boiler = m_f X CV .

When additional air is given a part of heat is carried away by this excess air and total useful heat energy is reduced directly .

Current heat loss due to excess air = m_a c_{pa} ($T_{fur(theo)}$ – $T_{fur(act)}$)
=
???? ????? ???
= 0.73 %

Heat loss due to1 % excess air = m_a c_{pa} ($T_{fur(theo)}$ – $T_{fur(act)}$)
???? ????? ???

% of heat loss due to 1 % reduced excess air = 0.53 % .

Total air flow =747 T/hr.

Efficiency of the boiler = 82% .

If the excess air is reduced by 1 % , then the amount of air will be 1% reduced in 747 T/hr (i.e) 739.53 T/hr .

Theoretical furnance temperature =1170 $^\circ$ C

Actual furnance temperature for 747 tonnes of air = 1150° C .

Actual furnance temperature for 739.53 tonnes of air =1155° C .

Current heat loss for 747 T /hr = m_a c_{pa} ($T_{fur(theo)}$ – $T_{fur(act)}$)

=747 X 1.005 X(1170-1150)

= 14940 kJ.

Heat loss for the 739.53 T/hr of air = m_a c_{pa} ($T_{fur(theo)}$ – $T_{fur(act)}$)

=747 X 1.005 X(1170-1150)

= 11092.25 kJ.

We have the O_2 level in flue gas as 4.3 % .But the allowed level of O_2 in flue gas is 1% .

Amount of excess oxygen = 4.3 -1 =3.3 %

3.3% oxygen =14.19% of excess air .

We have to reduce the 14.19% of excess air to improve the boiler efficiency

14.19 % of excess air in tonnes =

= 105.99 T/hr .

??????? X 747 .

In 105 .99T/hr we reduce 1 % oxygen (i.e) ???? in

= ?????/???? X ???/??

= 32.11 T/hr .

For reduction of 1 % oxyugen amount to be reduced = 32.11 T/hr .

For 1.3% oxygen level the amount of air = 143 –(3 X 32.11) 46.67 T/hr .

Now there is only 0.3 % of excess oxygen .

The amount of excess air for 0.3% oxygen = 10.77T/hr .

To maintain 1% oxygen level the amount of air should be given = 46 .67 – 10. 77

= 35 .9T/hr .

To maintain 1% oxygen level the amount of air should be given = 35. 9T/hr .

Therefore , actual air that must be given to the furnance =604+35.9 =639.9 T/hr .

7.1.1.3 Heat loss due to dry flue gas at 1% oxygen level :

Total air flow =639. 9T/hr .

Mass of flue gas =124 +639 .9 =763.9 T/hr .

= ???? ????? ??? X 100 = 3.75%

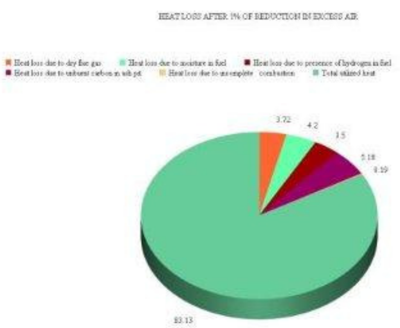
Therefore the total heat loss $= Q_1 + Q_2 + Q_3 + Q_4 + Q_5$.

= 3.75 +4.2+ 3.5 +5.18+ 0.19 .

= 16.82 % .

Difference in total heat loss = 18 – 16.82 .

= 1.18 % .



CHAPTER 8

COST ANALYSIS

The optimization in combustion air also leads to cost reduction .Cost reduction means profit to the organization .

The difference in heat loss optimizing the combustion air =1.18%

Therefore the efficiency of the boiler is increased by 1.18%

The amount of input for 82% efficiency is I_1 = ?????????

= 0782??????

The amount of input for 83.18% efficiency is I_2 = output = ?

Dividing the above two equations we get ??/?? = 1.012 .

From the above result it is evident that when efficiency is increased by 1.03%

Input is reduced by 1.012% .

I_1 = 124 T/hr .

I_2 = 122.76 T/hr .

Saving in fuel = 1.24 T/hr

Cost of fuel = Rs. 4000 /Ton .

Saving in 1hr per boiler = Rs.4960 .

For boilers per year = 365 X 24X 0.9 X 4940 X 5 .

=Rs.20 crores .

CHAPTER 9

SUGGESTION FOR IMPROVING THE BOILER EFFICIENCY

9.1 Operating the boiler with optimum air

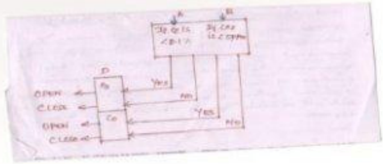
When excess air quantity is below the optimum level, there will be a drastic rise in the CO level due to incomplete combustion .When the excess air quantity is above the optimum level, it leads to both dry and wet gas loss besides overloading of the ID fans. So the right quantity of excess air must be given to the boiler for complete combustion. It must be accurately calculated and given.

9.2 Operating with optimum primary air header pressure

Boiler efficiency can be increased by maintaining the PA header pressure at the minimum possible value. Leakage in the airpreheater is a function of the differential pressure between primary air and flue gas. If the PA header pressure increases, losses due air ingression in airpreheater increases leading to heat loss.

9.3 Software to control excess air:

Install logic control system for monitoring the O_2 and CO value in flue gas .



A - O_2 SENSOR

B- CO SENSOR

C - LOGIC UNIT (Compare the O_2 and CO value with the standard value)

If oxygen is more than 0.1% in the flue gas leaving airpreheater , the control system will reduces the total air flow to the boiler for comb ustion by operating the outlet guide vanes and secondary air dampers

CASE 1 :

If the value of O_2 is < 0.1% , then the regulator will OPEN .

CASE 2 :

If the value of O_2 is not less than .1% , then the regulator will be CLOSED .

Case 3 :

If the value of CO is < 5 ppm , then the regulator will OPEN .

CASE 4 :

If the value of CO is NOT < 5 ppm , then the regulator will be CLOSED .

9.4 IMPROVEMENT WORKS IN AIRPREHEATER:

The boiler efficiency can be improved by reducing the heat carried away by exhaust flue gas .This loss is directly proportional to the flue gas outlet temperature .Air preheater are the last heat exchanger provided in the flue gas path. Hence they have to work properly.

By doing some improvements, more heat from flue gas can be extracted for heating the air. The following improvement works are suggested.

A) Addition of more Heating element :

The corrugated carbon steel sheets of 0.1mm thick are the heat transferring elements in the rotating type of airpreheater. They are packed in 27 inch dia and 2000mm high rotor. If more heating elements are packed by increasing the diameter and height, the convective heat transfer (proportional to the heating surface area) can be increased .By this method the existing flue gas temperature of 172 ° c can be reduced to 150° C. which is equivalent to 1% increase in boiler efficiency.

B) Double sealing systems :

When the rotor is rotating with in a housing, there are gaps in the radial, axial and circumferencial path. As air pressure is a round + 900 mmwc and flue gas pressure is around – 125 mmwc , there is a tendency for the positive pressure air to ingress into the negative pressure flue gas side. Seals are provided in the rotor and housing to arrest these leakages .The rotor is divided into 12 segments and radical ,axial and circumferential seals are mounted. If the rotor seals are mounted in the 24? segments , the leakage quantity can be reduced by √? times as below , Leakage quantity $Q = a_g V_a$.

Where ,

h = pressure head .

Since by double sealing the pressure reduces to half time

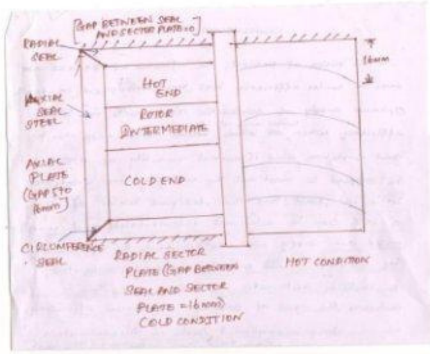
New leakage quantity $Q_m = a_g$?X ???*h*?? . = √? times Q .

C) Automatic Leakage Control systems (ALCS) :

We known leakage quantity $Q = a_g V_a$.

Hence by reducing the gap area a_g , leakage can be minimized.

In the air heater all the radial , axial ,and circumferential seals are mounted at cold condition (room temperature) only . hence at hot condition , the 250 T heavy weight rotor expands downwards by about16mm as shown below.



Since there is a gap of 16 mm at the hot end when the rotor is at hot condition, approximately5.5 to 7 % of primary and secondary air leeks towards flue gas .Hence hot air does not go to boiler for combustion , but goes to the chimney and so all the fans are overloaded and there is a huge loss in auxiliary power consumption .

To avoid the above problem , the radial sector plates can be made of a deflective material and by auto adjusting mechanism , the plates can be moved downwards and close the gap to near zero value.

9.5) IMPROVEMENTS IN COAL PULVERISERS

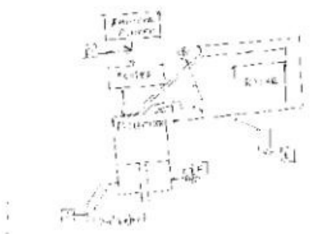
Inclusion of software to reduce coal rejects and unburnt carbon in boiler :

We known when the mills are overloaded with excess coal , the pulverisers can not grind them , instead they come out as rejects .This is a huge loss of fuel which is left out as waste and so it has to be reduced .Similarly when we supply more quantity of hot air to mill , they take away the uncrushed coal with them to the boiler for burning .In the boiler they do not burn but fall down as unburnt carbon .Also when low quality of hot primary air is supplied to the mills , they cannot lift the pulverized coal particles and they fall down in the mills as rejects .All these heat losses in fuel have to be avoided .

At present no online monitors are available in TTPS .If a software is designed and installed , direct fuel loss and unburnt carbon losses can be avoided .

9.6) CONVERSION OF THE MANUAL SEPRATION INTO AUTOMATIC SEPRATION SYSTEM :

At present the separation of fine coal powder from coarse particles is done manually by adjusting the classifier control rods .This is a time consuming process and can not be done as and when required .To have a uniform finness value , the classifier vanes have to be operated automatically .Hence a pneumatic control system is suggested by us which is explained as below.



CHAPTER 10

CONCLUSIONS

In this piece of project , the influence of excess air over the boiler efficiency has been analyzed in depth optimum supply of combustion air results in higher efficiency .when boiler and all its auxiliaries are in good conditionand if correct quantity of excess airis supplied to met out the varying fuel conditions,it is no doubt that the designed boiler efficiency of 85% can be achieved .uncalculated and unoptimized air supply will detriotaethe efficiency by 1% to 3%. In this project it is suggested to include automatic control circuits to achieve the goal of maximum efficiency .

Some improvements works in airpreheaters nad coal pulverizers will reduce the heat carried away by flue gas and increase the boiler efficiency by another 2% .since sufficiency improvement will reduce the quantity of fuel requirement ,the expenditure incurred towards purchase of coal can be reduced , as discussed in this project work .we hope this work will certainly benefit TANGEDGO and boiler Engineers .

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