Optimizing Boiler Efficiency by Using APH and Economizer

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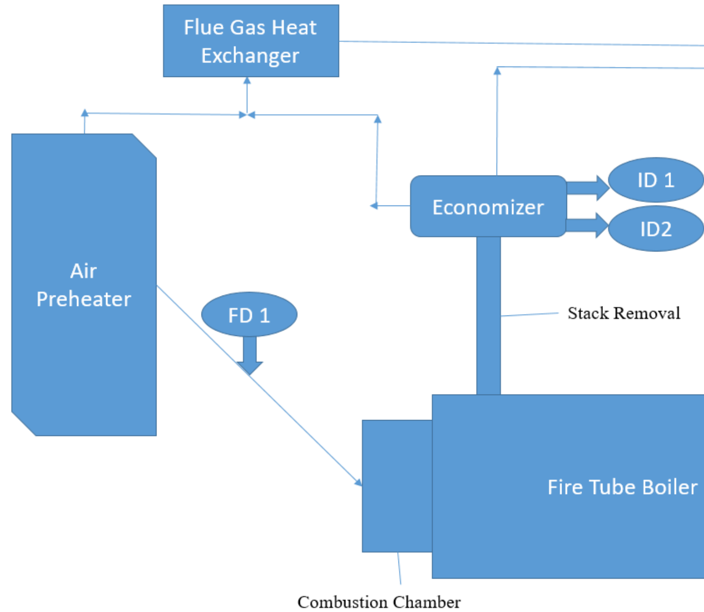

Abstract— Air pre-heater and economizer are heat transfer surfaces i transferring heat from other media such as flue gas. Hot air is necessary milling plants. So an essential boiler accessory which serves this purpose of steam generator, but they are used where a study of cost indicates that their use. The decision for its adoption can be made when the financial efficiency of the boiler increases with the increase in the temperature of t increased temperature of the flue gas in the air preheater and economiz maximum heat from the flue gas travelling through the air preheater and th

Index Terms— Air Preheater, Boiler, Calorific value, Economizer, Efficienc

1 Introduction

Improving boiler efficiency by using APH (Air Preheater) and Economizer combination helps to improve overall efficiency of Central Utility. Type of boiler used in company's central utility is horizontal tubular fire tube boiler, it has a horizontal cylindrical shell, containing several horizontal flue tubes.. Therefore, it is clear that increasing the efficiency of a steam boiler only marginally will reduce electricity consumption in large quantities. Boiler efficiency by recovering waste heat carries by flue gases. And at the same time also focus on how to control the emissions. In the combustion chamber of the boiler, fossil fuels are burned and the heat generated is transferred to the water by hot flue gas. Flue gas destroys a significant amount of energy because all the heat produced by the burning fuel cannot be transferred to the boiler in water or steam. Because the temperature of the flue gas release a boiler typically ranges from 150 to 250, about 10 -30% of the heat energy is lost through it. Other major heat losses from boilers include convection heat transfer, radiation, blow-down, fly ash and bottom ash losses. In order to operate the boiler plant at maximum efficiency, it is necessary to identify the main source of energy wastage and recover the wasted energy. The efficiency of the boiler is that the ratio of the net amount of heat that's absorbed by the generated steam to the net amount of heat that's supplied to the boiler. This will even be determined by subtracting net heat loss from the boiler from the net amount of heat supplied to the boiler. Therefore, so as to enhance the efficiency of the boiler, it's necessary to scale back the quantity of heat being wasted from the boiler by optimizing some parameters like extra air, fuel flow rate, steam demand, some other parameters. Since the majority of the heat is wasted by the high-temperature flue gas, the recovery of heat from high-temperature exhaust can lead to energy savings. Harnessing the waste heat from the heat temperature flue gas can have a great potential for energy saving for the boiler system.

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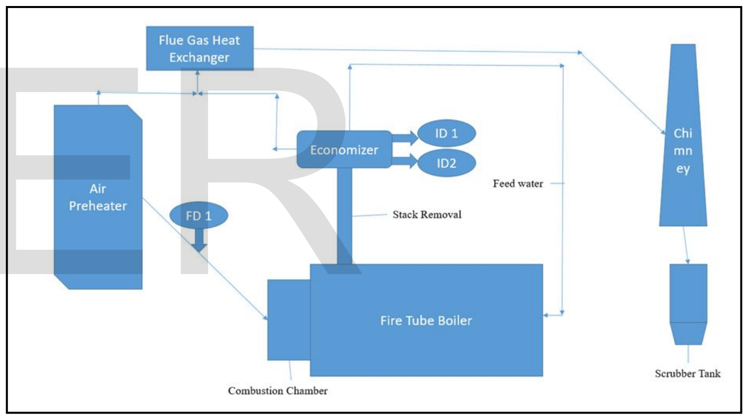

The main function of boiler to generate steam from water. Fire tube boiler consist of number of tubes in which hot gaseous are passed, this hot tube immersed into water, in closed vessel. These fire tube boiler heated up water and converted water into steam and steam remains in the same vessel. After steam generation which is the main function or objective of fire tube boiler the exhaust gaseous generally we called it as flue gaseous or stack. The stack temperature is almost around 210 degree Celsius direct eliminating stack from this temperature is the loss of energy that can be utilized for further operation. For that efficient operation and smooth flow of process we use boiler accessories economizer, air preheater and heat exchanger. The stack entered into the economizer by negative pressure created by ID fan 1 and ID fan 2 (Induced draft fan) and economizer preheat the feed water. After economizer stack entered into air preheater in air preheater preheat the atmospheric air which further used for combustion in boiler by FD fan (Forced draft fan). The entire process recovers the heat and energy which left unused into atmosphere.

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3 METHODOLOGY

To optimize efficiency, boiler systems today come with a proven combination economizer and air preheater. These two systems, when working together, can improve boiler efficiency by approximately in two digit. It's important that they work together, because an economizer by itself will only provide efficiency increases in the single digit range. In order to continue to compete with natural gas, solar, wind, and other forms of energy production, coal and biomass boilers have to max out on efficiency. A custom-designed air preheater and economizer combo can go a long way toward accomplishing this goal for modern-day power plants. A very good method to improve the overall efficiency of a thermal power plant is to preheat the air. If the incoming air for combustion is not preheated, then some energy must be supplied to heat the air to a temperature required to facilitate combustion. As a result, more fuel will be consumed which increases the overall cost and decreases the efficiency. There are many factors, which contribute to the deterioration of air preheater performance like high seal leakage, deterioration of heat absorption characteristics of basket elements due to fouling or plugging. Close monitoring of air pre heater performance and proper instrumentation would enable timely detection of performance degradation.

4 CALCULATIONS

To increase boiler efficiency by using Air Preheater and Economizer.

Economizer Design Calculations

Given:

Property	Value
Inlet gas temperature	210
Outlet gas temperature	198.81
Gas mass flow rate	10.07Kg/sec
Specific heat	1 KJ/Kg
Inlet water temperature	40 degree Celsius
Outlet water temperature	110 degree Celsius
Enthalpy inlet hf40°C	376.9 KJ/Kg
Enthalpy outlet hf210°C	461.3 KJ/Kg
Mass flow of water	0.390 Kg/sec

The outlet temperature of water is taken short of the saturation temperature at operating pressure of 17.5 bars, in order to prevent steaming.

Now applying energy balance;

Energy gain by water = Energy lost by the gases

Energy gain by feed water =m (h out –h in)

E gain = 0.390(461.3 – 167.5)

E gain = 114.58 kW

Therefore energy gain by water is equal energy loss by the gases

q Gain, H_2O =q lost, gas

114.58 KW=m C pΔ T

114.58 =10.07 × 1.02 × (Tin –Tout)

(Tin – Tout) gas =11.19°C

Tout =210-11.19

Tout, gas =198.81°C

Temperature for transport property

Average temperature of gas

T g, a v g: (210 + 198.81) / 2

: 204.405 °C

Average temperature of water

T w, a v g: (110 + 40) / 2

: 75 °C

Average film temperature of gas

Properties of fluid such as density viscosity prandtl number etc. are calculated at the film temperature (temperature of the fluid at solid fluid interface). Since temperature is changing continuously along the flow direction, therefore finding the mean of mean temperature of water and flue gases.

Tf = (T w, a v + v) / 2

= (75 + 204.405) / 2

= 139.70°C

Log-mean temperature-difference (LMTD)

Since the purpose of economizer is to preheat the fluid, therefore counter flow configuration is used. Otherwise disturbance would be created through steaming, especially when the flow is downward. Log mean temperature difference of parallel flow is less than that of counter flow. We select parallel flow configuration.

ΔT LMTD = ((ΔT a − ΔT b) / ln (Δ T a / Δ T b))

Δ Ta = TG, out –Tw, in

Δ Tb = TG, in – T w, out

T gas, in	210°C
T gas, out	198.81°C
T water, in	40°C
T water, out	110°C

ΔT LMTD =(((198.81-40)-(210-110))/(ln(198.81-40)/9210-110)))

= (58.81/ ln (1.5881))

= 127.146°C

Design Calculation of Air Preheater

ASSUMPTIONS:

The properties are remains constant under steady state conditions and neglect surrounding losses. Kinetic and potential energies are neglected.

DESIGN ANALYSIS:

Heat Transfer,

Q = m x c x Δ t

Where m = mass flow rate

C = specific heat of air in kJ/kg °C

C = 1.005

Δ t = temperature difference in °C

Here m = 10.07 kg/sec

Specific heat of water is 4.18 kJ/kg

Temperature difference,

Δ t = (110-40)
Δ t = 70
Q = 10.07 x 1.005 x 70
Q = 708.42 kW
Heat loosing of fluid,
Q = m x c x Δ t
= 5 x 1.005 x (270-200)
= 351.75 kW
LMTD = ((Th1–Tc2) - (Th2–Tc1)) / ln ((Th1–Tc2)-(Th2–Tc1))
= ((198.81-110) – (110-40))/ln ((198.81-110)/ (110-40))
= (88.81-70)/ ln (88.81/70)
= 79.03°C
Actually this Air pre-heater is a cross flow Air pre-heater so the LMTD equation
Becomes,
(LMTD) cross
= F X (LMTD) counter
Here F = correction factor
It is calculated by using graphical method by using dimension parameters P, Z from graph,
P= (Tc2-Tc1)/ (Th1-Tc2)
P= (110-40)/ (198.81-110)
P= 70/88.81
P= 0.788
Z = (Th1-Th2)/ (Tc2-Tc1)
Z = (198.81-110)/ (110-40)
Z = 88.81/70
Z = 1.26
From this values we get F = 0.84 (from graphically),
So we have multiplied the counter flow LMTD with correction factor F, then we get
LMTD of cross flow,
(LMTD) cross = F X (LMTD) counter
= 0.84 x 79.03
= 66.38°C
Q = UA ΔTm x F
Where,
U = overall heat transfer coefficient
A = Area of Air Pre heater
F = correction factor
U = 50 w / m sq. °C (As per standard tables)
From Average velocity in the tube and discharge we Calculate total flow are
Here correction factor F = 0.84
A = q / U ΔTm x F
= (708.42 X 1000) / (50 x 0.84 x 66.38)
= 254.09 sq. m

Efficiency enhancement calculation

- Boiler number 4 (Briquette Boiler)

Given:

Property	Value
Capacity of boiler	9 Tone/ hr
Water temperature (tw)	40°C
Mass of steam (ms)	7000 kg/ hr
Mass of fuel (mf)	34 tone/day = 1416.67 kg/ hr
Calorific value	3500kcal/kg = 14644kJ/kg
Temperature of steam (ts)	210°C
Enthalpy of water	167.5kJ/kg

Enthalpy of steam at 210 °C
Hs = hf + x hfg
= 897.7 + (0.8 x 1898.5)
= 2416.5 kJ/kg
Therefore, boiler efficiency = my (hs – Hw) / (mfv x c.v) x 100
= 7000(2416.5-167.5) / (1416.67 x 14644) x 100
= 75.88 %
Boiler Efficiency with economizer
Enthalpy of water at 95 °C (Hw) = 398kJ/kg
Enthalpy of steam at 210 °C (hs) = hf + x hfg
= 897.7 + (0.9 x 1898.5) (here quality of steam 90%)
= 2606.35 kJ/kg
Economizer with Boiler efficiency = ms (hs-hw)/mf x c.v x 100
= 7000 (2606.35 – 167.5) / (1416.67 x 14644) x 100
= 82.30 %
Boiler Efficiency with Air Preheater
Now we are introducing air preheater the fuel consumption reduced to 1416.67 kg to 1218 kg/hr
Boiler efficiency with air preheater = MS (HS–HW) / MF X CV X 100
= 7000 x (2606.35 – 398) / (1218 x 14644) x 100
= 86.668 %

- Boiler number 1 and 2 (Furnace Oil Boiler)

Given:

Property	Value
Capacity of boiler	13 Tone/hr
Water temperature (tw)	40°C
Mass of steam (ms)	11500 kg/hr
Mass of fuel (mf)	21000 lit/day = 875 kg/hr
Calorific value	9520kcal/kg = 39831.68kJ/kg
Temperature of steam (ts)	210°C
Enthalpy of water	167.5kJ/kg

Enthalpy of steam at 210 °C

Hs = hf + x hfg

= 897.7 + (0.8 x 1898.5)

= 2416.5 kJ/kg

Therefore, boiler efficiency = ms (hs – Hw) / (mfv x c.v) x 100

= 11500(2416.5-167.5) / (875 x 39831.68) x 100

= 74.20 %

Boiler Efficiency with economizer

Enthalpy of water at 95 °C (Hw) = 398kJ/kg

Enthalpy of steam at 210 °C (hs) = hf + x hfg

= 897.7 + (0.9 x 1898.5) (here quality of steam 90%)

= 2606.35 kJ/kg

Economizer with Boiler efficiency = ms (hs- Hw)/mf x c.v x 100

= 11500 (2606.35 – 167.5) / (875 x 39831.66) x 100

= 80.49 %

Boiler Efficiency with Air Preheater

Now we are introducing air preheater the fuel consumption reduced to 875 kg to 822.5 kg/hr

Boiler efficiency with air preheater = MS (HS–HW) / MF X CV X 100

= 11500 x (2606.35 – 398) / (822.5 x 39831.66) x 100

= **85.626 %**

5. Result

Company's central utility has one fire tube boiler based on briquette has initial efficiency of 75.88% after the air preheater and economizer combination efficiency increases significantly around 86.668% almost 11% of efficiency jump similarly central utility has two fire tube boiler furnace oil based has initial efficiency of 74.20% after air preheater and economizer combination efficiency increases 85.626 % same 11% increases in efficiency.One briquette based fire tube boiler was consumed 34 tone briquette per 24 hours after 11 percent efficiency jump boiler started consuming 3440 kg of briquette less, the cost of briquette is 5600 INR per ton which leads to 19264 INR daily. Two furnace oil based fire tube boiler consumed 21000 litters of furnace oil daily both boiler consumed 42000 liters per 24 hours. When efficiency increased with 11 percent boiler start saving 4620 liters of furnace oil daily. Furnace oil cost 70 liters per litters which leads save 323400 INR daily.

The annual cost saving of boiler number 4 = 365 x 19264

= 7031360 INR

The annual cost saving of boiler number 1 and 2 = 365 x 323400

= 118041000 INR

Combine saving of all three boiler = 7031360 + 118041000

= **125072360 INR**

Total cost saving annually is **125072360 INR**

Total cost saving in central utility

EIL heater consumed 32000 furnace oil daily which cost 817600000 INR annually

Total spending of briquette and Furnace oil is 942672360 INR annually which reduced to 942672360 – 125072360 = 817600000 INR

Total cost limited to **817600000 INR**

6. Conclusion

In conclusion, the exhaust gases which are leaving from the boiler has very high-temperature means these exhaust gases have very huge potential to recover heat and utilized in diverse processes. So there are a huge quantity of heat energy is lost from the boiler if any heat recovery equipment is not installed in after it. In this regard, a comprehensive review is presented for the waste heat recovery from exhaust gases. It was investigated that, one of the dominant method of waste heat recovery using an economizer. The economizer is used to reduce total energy consumption by creating additional heat sources. High-temperature flue gases leaving the boiler are entered into economizer due to this prevents high temperature flue gases are coming in contact with the environment. Also, an economizer device would reduce the impact on the environment by reducing emission which may very helpful to control global warming. Therefore this comprehensive review of waste heat recovery of flue gases using economizer is very helpful to improve boiler efficiency in an industrial area.

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