Investigations on Increasing of boiler Performance with steam coil air preheater

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Abstract: - Air pre-heaters (APH) are heat exchangers, which are used to pre-heat the air before entering into the boiler furnace of power plants. APH have wide applications in power plants and Automobiles which increases the incoming air and thereby enhancing the combustion efficiency and further the boiler performance. Generally, the air preheaters are in direct contact with atmospheric air, which may cause for corrosion. This equipment can also have an additional purpose of preheating the combustion air during unit startup by increasing the ambient air temperature up to a suitable temperature to reduce fuel oil consumption.

Hence in the present experimentation, steam coil air preheaters are used for heating the atmospheric air and later the heated air will be further heated in flue gas heater. In this flue gas flows inside the tube while air passes over tube, through baffle plates. It is generally used for heating the combustion air for all type high pressure boilers, and dryers etc. For the heaters required amount of atmospheric air will be supplied by forced draught fan. This heating of air enhances the combustion in furnace and further the performance of boiler. In the present investigation, the effective parameters measured are heat transfer rate and boiler performance, which are enhanced by the air preheaters.

Introduction

Air pre-heater is a heat transfer surface in which air temperature is raised by moving heat from other medium. These preheaters are widely used in power plants to increase the overall performance of the boiler. In Air preheater the combustion air is preheated before admitting the air to combustion zone. The air preheating is depends on the type of combustion and type of fuel used. Generally the heat transfer medium will be flue gases. This preheating reduces the fuel consumption by 5-10% and increases the atmospheric temperature to 100-150°C.

With the increasing rate of fuel and technology improvements, the size of a boiler that can be economically equipped with a pre-heater should become smaller. Air heaters can also use extraction steam or other sources of energy depending upon the particular application. These units are usually employed to control air and gas temperatures by preheating air entering the main gas-air heaters. The heated air produced by air heaters enhances combustion of all fuels and is needed for drying.

Waste heat gases discharged to the atmosphere, heated products exiting industrial process, and heat transfer from hot equipment surfaces. The exact quantity of industrial waste heat is poorly quantified, but various studies have expected that as much as 20 to 30% of industrial energy consumption is ultimately discharged as waste heat. While some waste heat losses from

industrial processes are inevitable, facilities can reduce these losses , such as waste heat recovery systems and Pre heaters etc.

Literature review :

As per Shansibasher[1]et. al.[1]with the regenerative air pre heaters the boiler performance will enhance. Regenerative air per-heaters are compact based on requirement.. In a high pressure boilers the combination of tubular and regenerative type air Pre heaters are mostly preferred. The tubular is primary air heating and the regenerative is the secondary air heating applications.. Normally the ambient air is heated to about 100 to 150 ^{o}C. This results in a flue gas temperature drop of around 100 to 150oC. Based on this each degree pick up in air temperature, roughly 0.8 degree drop in flue gas temperature is achieved.

As per the H.A.Wadekar1 et. al. [2]the technology of heating and cooling of systems is one of the most basic areas of mechanical engineering. These heating and cooling systems have lot amount of applications like heat and cool homes, offices, markets, shopping malls, cars, trucks, trailers, aero planes, and other transportation systems. The air Pre heater is particularly used to heat the atmospheric air to required process temperature by mean of steam. Steam flows inside the tube and air flows over tube. It is generally used for heating the combustion air for boilers, recovery boiler and dryers etc. where in winter season temperature rages below 10^{0}C consistently. In this module, they analyzed the heat exchangers to include the convection rate equation, and demonstrate the methodology for predicting heat exchanger performance that include both design and performance rating problems. They concluded from their experimentation that the performance will enhance with preheating.

Bhanu Pratap et. al.[3] discussed on theories and complications related to air-preheater & the heat transfer surfaces used in it. Air-preheaters are used to pre-heat the air before any other process takes place. APH in wide applications such as power plants, automobiles and all such areas where there is a need to pre-heat the air and save fuel. A thorough survey of air-preheaters for the transfer of heat between cold and hot fluid. According to them air preheaters plays a crucial role in enhancing the performance of the boiler.

P.N.SAPKAL[1], et. al. [4]designed an approach for the optimization of air preheater design with inline & staggered tube arrangement. The performance of an air preheater in the power plants is one of the main reasons for high heat rate & is responsible for deterioration in boiler efficiency. The troubles of air preheater is the leakage of air to the flue gas and these resulting in poor thermal performance. The percentage of Ash also is one of the effecting parameter in efficiency of Air Pre heater. Air preheaters are designed based on performance requirements with consideration of parameters ex:-. heat transfer, leakage and pressure drop. The model can also be used while selecting a new type of surface geometry for optimizing the design of air preheater.

According to S.Sudhakar[1] et. al.[5] the primary objective of air preheaters are increasing the thermal efficiency of the process. In this process, combustion air pre-heaters used in large boilers found in thermal power stations producing electric power from e.g. fossil fuels, biomasses or waste. The function of air preheater is to recover the heat from the flue gas and increases the inlet air temperature of the boiler by reducing the heat loss of the flue gas in air pre-heater. This

analysis how operation parameters of an regenerative air preheater can be optimized in order to increase its efficiency and consequently the overall efficiency of a boiler

According to M.Nageswara rao[1]et.al.[6]An air preheater is a heat exchanger, designed to heat air before another process.Over all heat transfer coefficient of the shell and tube heat exchanger is based on the results of effectiveness-NTU approach and LMTD approach. In the present work, they presented the complete presentation of thermal and mechanical design, fabrication model, Overall heat transfer coefficient.

Air Pre-Heater

Air pre-heater is a heat transfer device; it transfers the heat from the flue gas to the combustion air. The flue gas heat loss reduces with the primary objective and increasing the thermal efficiency of the process. The fuel consumption is reduced to 5 %, depending on the duty. In Air preheater the combustion air is preheated before admitting the air to combustion zone. The atmospheric air enters in to the air Pre heater at 27-30 degrees. The furnace inlet temperature rise.up to 200^0C from ambient temperature based on the type of combustion. The flue gases are also conveyed to the flue gas stack at a lower temperature.

Types of air pre- heaters

Air pre- heaters are generally classified into two types they are

1. Recuperative type
2. Regenerative type
    a. Stationary plate air Pre-Heater
    b. Rotating blade air Pre heater

1. Recuperative type :

Recuperative air Pre- heaters are also known as tube and shell air Pre-heater. In tubular type air Pre-Heater, the ambient air enters in side of tubes and the hot flue gas passes out side of the tubular section and the shell. In this the heat transfer will be from the exhaust gas to the air inside the preheater. Ambient air is circulated by a forced draught fan through ducting at one end of the preheater tubes and at other end the heated air set of ducting, which carries it to the boiler furnace for combustion.

Fig :- Recuperative air pre heater (shell and tube)

The air enters inside the tube bundle from the right ide, exits on the left side and then enters the middle tube bundle on the left-hand side and exits on the right-hand side. Finally, the air enters the outer tube bundle on the right side and exits on the left side. In such a design is similar to the 3-pass design of above except that the air is in the tubes rather than outside the tubes. Tubular air heaters consist of straight tube bundles which pass through the outlet ducting of the boiler and open at each end outside of the ducting. Inside the duct, the hot flue gases pass around the preheater tubes, transferring heat from the exhaust gas to the air inside the preheater. Atmospheric air is forced by a fan through duct at one end of the preheater tubes and other side heated air from inside of the tubes merging into another set of duct. These heated air carries to the furnace for combustion.

In the present work, boiler losses are calculated in indirect method, which is also called as heat loss method. The efficiency can be calculated by subtracting the heat loss from 100. Do not include blow down loss in the efficiency determination. A procedure for calculating boiler efficiency by indirect method is given below.

The principle losses that occur in a boiler are:

a. Loss of heat due to dry flue gas
b. Loss of heat due to combustion of hydrogen
c. Loss of heat due to moisture in fuel
d. Loss of moisture in combustion air
e. Loss of heat due to incomplete combustion
f. Unburnt loss in fly ash
g. Unburnt loss in bottom ash
h. Loss of heat due to radiation

The calculations are as follows.

- Theoretical air requirement : 8.93 Kg of air
- Air fuel ratio : 8.93:1
- Percentage of Excess Air supplied (EA) : 47.88
- Actual mass of air supplied/ kg of fuel (AAS) : 13.12 kg of air/kg of coal
- Percentage of heat loss due to dry flue gas (L1) : 14.1%
- Percentage heat loss due to evaporation of water formed due to H2 in fuel (L2) : 8.6%
- Percentage heat loss due to evaporation of moisture present in fuel. (L3) : 5.5%
- Heat loss due to moisture present in air (L4) : 2.2%
- Heat loss due to incomplete combustion (L5) : 3.64%
- Percentage heat loss due to unburnt in fly ash (L6) : 0.53%
- Percentage heat loss due to unburnt in bottom ash -(L7) : 1.42%
- Percentage heat loss due to radiation and other unaccounted loss –(L8) : 1-2%

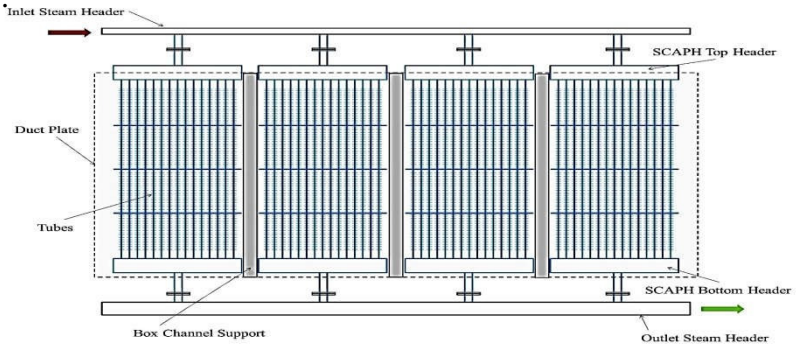
The radiation and convection losses are difficult to calculate because of particular emissivity of various surfaces, its inclination, air flow pattern etc. In a relatively small boiler, The

losses amount between 1% and 2% of the gross calorific value of the fuel. The loss may be assumed appropriately depending on the surface condition.

Efficiency of boiler (η) = 100 – (L1+ L2+ L3+ L4+ L5+ L6+ L7+ L8) = 63.01%

2. Steam coil air pre-heater :

This air Pre heater is used to heat atmospheric air to the required process temperature by means of saturated steam. Steam Coil Air Pre Heater (SCAPH) is a shell and tube type heat exchanger. Steam flows inside the tubes and air passes over the finned tubes. SCAPH use with all types of High pressure boilers, Recovery Boilers, and Dryers etc. Steam coil air pre-heaters are used to heat air entering the air heater recuperative or regenerative type, have corrosion sections that are more readily maintained this type of air heater uses extended surface, normally referred to as fins, to reduce the overall size of this air pre-heater. This type of air Pre heaters normally placed into design of a boiler unit for low load operation and startup operation particularly in those areas with low ambient air temperatures. It is generally located in the duct between the Forced Draft(FD) and the main air preheater. In those areas that have extremely low ambient air temperatures, it is common to have this ahead of the FD fan that could pre heat cold winter air upto20^{0}C. The shell and tube heat exchangers is used to recover heat from flue gas of the boiler and transfer this heat energy to increase the temperature of combustion air (air pre-heater) or boiler feed water (economizer). This temperature is calculated by overall temperature of flue gas and ambient air. The ambient temperature is low, it affects SO3 and H2O present in the flue gas start to reacts with each other. To increase the boiler efficiency, we are introducing SCAPH system before air pre-heater. The exhaust steam or one of the bleed steams from the turbine is utilizing in this heat exchanger.



SCAPH design parameters and operational usage details — SCAPH (Steam Coil Air Pre-Heater) is equipment fitted between forced draft fans and air pre-heater to avoid the acid dew point condensation which occurs at the flue gas side in the air pre-heater due to the low temperature of the atmospheric air. The design parameters of SCAPH at SPL are as follows:

- Number of SCAPH Assembly : 2 – each one – 2 M2
- Number of coils in one assembly : 4 coils
- Number of Tubes : 40 in one coil
- Inlet Header size : 50 mm

- Outlet Header Size : 75 mm
- SCAPH weight : 1 MT
- Steam flow : 2000 kg/hr
- Pressure : 9.6 kg/hr

Heat transfer rate of the steam coil air Pre heater with steam to air in a convective heat transfer is calculated as follows:

Over all heat transfer $Q = HA\Delta T$ = 29372.4 (W/m C)
Where ,

Q = Heat transfer rate
H = Convection heat transfer co efficient
A = Surface area
ΔT = Temperature difference

Boiler furnace inlet air temperature with steam coil air preheater is = 102^{o}C

(where as Boiler furnace air temperature with flue gas air preheater = 93^{o}C)

Boiler Efficiency is calculated as follows

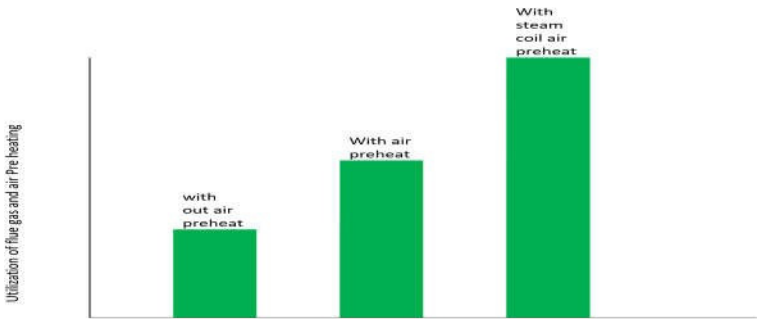
1. Loss due to dry flue gas : 11.4%
2. Heat loss due to evaporation of water formed due to H2 in fuel : 2.9%
3. Heat loss due to moisture present in fuel : 3.2%
4. Heat loss due to moisture present in air : Neglected

(As the air is heated two times i.e steam coil and flue gas air preheater, moisture losses are neglected)

5. Heat loss due to incomplete combustion : 2.8 %
6. Percentage heat loss due to unburnt in fly ash : 0.23%
7. Percentage heat loss due to unburnt in bottom ash : 0.62%
8. Losses due to radiation : Neglected

Efficiency of Boiler = (100)– (11.4+2.9+3.2+2.8+0.23+0.62) = 78.85%

Results and Discussion



50% 63% 78.85%

Boiler performance

The flue gas preheater normally works with waste flue gases which are at higher temperatures in the plants. In the present work, with the flue gas air pre-heater the efficiency of the boiler is 63.01%.

For further heating, the waste steam is used in steam coil air preheater. With help of steam coil air pre-heater + flue gas air pre-heater the efficiency of the boiler is = 78.85%

This shows that with the combination of both the air preheaters the performance of boiler increased enormously. The performance of the boiler is shown in the graph with using of flue gas air pre-heater and steam coil air pre-heater and without air pre-heater

Conclusion

- The boiler efficiency is increased based on the steam coil air pre heater and emissions are also reduced.
- Production of ash quantity reduced
- Un-burnt, in-complete combustion are fully eliminated.
- With the flue gas air pre heater, furnace inlet air temperature is increased which results reduction in moisture content
- With the help of both flue gas air preheater and steam coil air preheaters the acid dew point corrosion is reduced.
- Steam coil air pre heater along with flue gas air preheater is most efficient in future days which increases the energy savings.

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