Performance Analysis of Air Preheater to Improve the Efficiency in 210 MW Thermal Power Station

R. Selvamuthukumarasamy and S. Manavalan

Abstract--- *The efficiency of boiler in 210mw thermal power station is greatly depending on the utilization of waste heat in the flue gas by air pre heater and economizer. The increasing in efficiency of 210mw boiler can be achieved by increasing the performance of air pre heater and economizer. To reduce the leakages in 210MW air pre heater and enhancing heat transfer rate by changing profile of air pre heater heating element surface will lead to increasing in performance of the air pre heater and economizer. In 210 MW north chennai thermal power station/stage-I notched flat profile and single seal with 12 sector air pre heaters is used as heat transfer. These are replaced by double undulated profile heating element and double seals with 24 sectors in air pre heaters. Hence heat loss in the air pre heater is minimized and the air pre heater absorbs additional heat from exhaust flue gas. The profile change in heating element and double seals arrangement air pre heater are to be analyzed. Based on the results the percentages of efficiency in air pre heater are to be calculated.*

Keywords--- *Air Preheater, Seals, Sectors, Heating Element, Efficiency.*

I. Introduction

Modern high capacity boilers are always provided with an air preheater. Air pre-heater is an important boiler auxiliary which primarily preheats the combustion air for rapid and efficient combustion in the furnace Serving as the last heat trap for the boiler system, a regenerative air preheater typically accounts for over 10% of a plants thermal efficiency on a typical steam generator. Considering this, when evaluating the performance of an air preheater one should take into account all of the process variables. 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. The combustion air preheater for the large fuel-burning furnaces used to generate steam in thermal power plants.

II. Air Preheater

An air preheater (APH) is a general term used to describe any device designed to heat air before another process (for example, combustion in a boiler) with the primary objective of increasing the thermal efficiency of the process. They may be used alone or to replace a recuperative heat system or to replace a steam coil.

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In particular, this article describes the combustion air preheater used in large boilers found in thermal power stations producing electric power from e.g. fossil fuels, biomass or waste. The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also conveyed to the flue gas stack (or chimney) at a lower temperature, allowing simplified design of the conveyance system and the flue gas stack. It also allows control over the temperature of gases leaving the stack (to meet emissions regulations, for example).

III. MODE OF HEAT TRANSFER IN APH

The process of heat transfer takes place in APH is Convection, it involves energy exchange between a bulk fluid and a surface or interface. Two kinds of Convective processes exist : (a) Forced Convection in which motion past a surface is caused by an external agency such as a pump or fan, and (b) Natural or Free convection in which density changes in the fluid resulting from the energy exchange cause a natural fluid motion to occur.

The Air Preheater is a regenerative type Rotary heat exchanger uses forced convection in which flue gases and air passes through a rotating cylinder filled with heat transfer surfaces (heating elements).The flue gas heat the rotating elements, which in turn preheat the air before it is re-circulated to the boiler. In the air heater, there is a heat recovery process .As the rotor revolves, the waste heat is absorbed from the flue gas streams and fresh air is heated by the accumulated heat.

IV. WORKING PRINCIPLE OF REGENERATIVE AIR PREHEATER

The Regenerative Air Preheater absorbs waste heat from flue gas and transfers this heat to the incoming cold air by means of continuously rotating Heat Transfer elements of specially formed metal plates. Thousands of these high efficiency elements are spaced and compactly arranged within 24 sector shaped compartments of a radially divided cylindrical shell called the rotor. The housing surrounding the rotor is provided with duct connections at both the ends, and is adequately sealed by Radial & Axial Sealing members forming an Air Passage through one half of the Preheater and Gas Passage through the other.

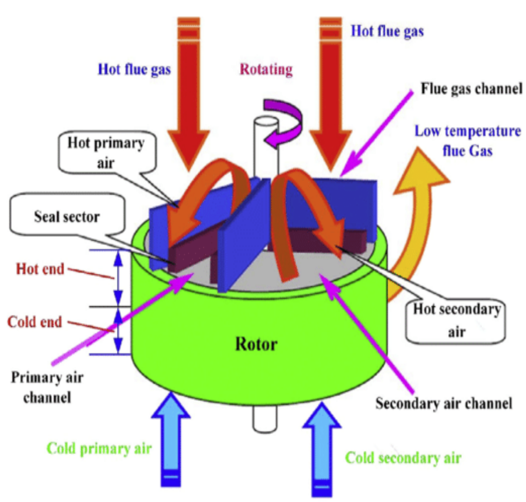

Figure 1: Trisector Regenerative Air Preheater view

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As the rotor rotates, it slowly rotates the mass of heating elements alternatively through the air and gas passages. The heat is absorbed by the element surfaces while passing through the hot gas stream, and then as the same surfaces are carried through the air stream, they release the stored up heat to the air, thus increasing the temperature of the incoming air.

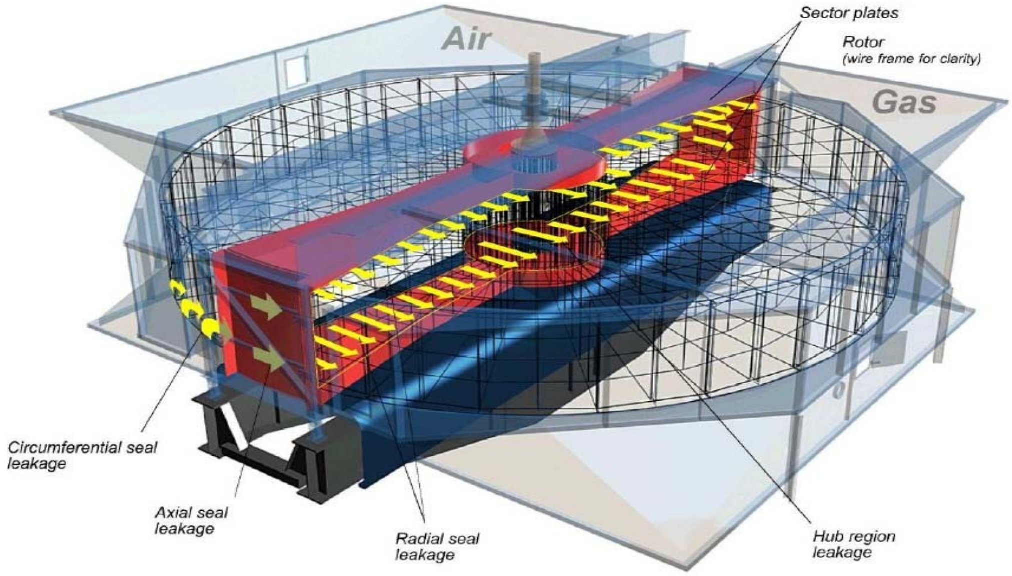

Figure 2: 3D View of Air Preheater

V. Improvement In Thermal Performance

Leakage Reduction

The seal setting done under better supervision should reduce the leakage. Seals are to be set, not only to be fitted.

Soft Touch Seal

A new concept has been developed to minimize the seal leak. As an introduction, this 'Soft Touch Seal' is provided for hot end radial seal only. This can be extended to axial seal also. Soft touch seal has flexile end that cannot escape air from one basket to another basket. That can be reduces the percentage of air leak to flue gas. Heat transfer is effectively utilized from flue gas to Primary Air and Secondary Air.

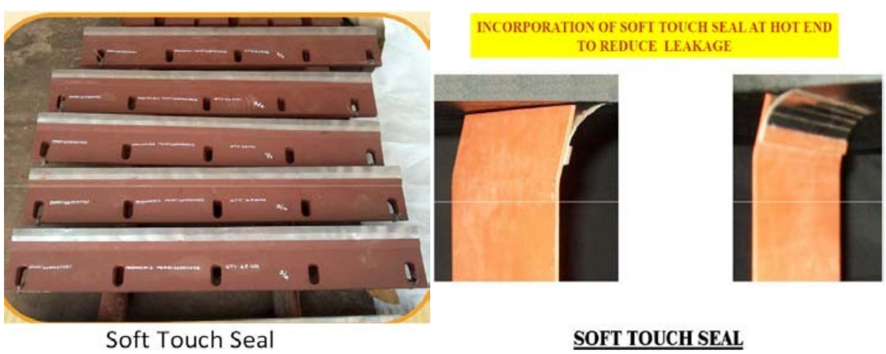

Figure 3: Soft Touch Seals

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Double Sealing

In double sealing an additional radial and axial seals are introduced along with the existing seals. This will reduce the overall leakage y 1.5% to 2% recently even triple seals have been introduced. Double Sealing is adapted in the recent design. For old air pre-heaters, this can be retrofitted. This modification will call for the change of all baskets dimensions.

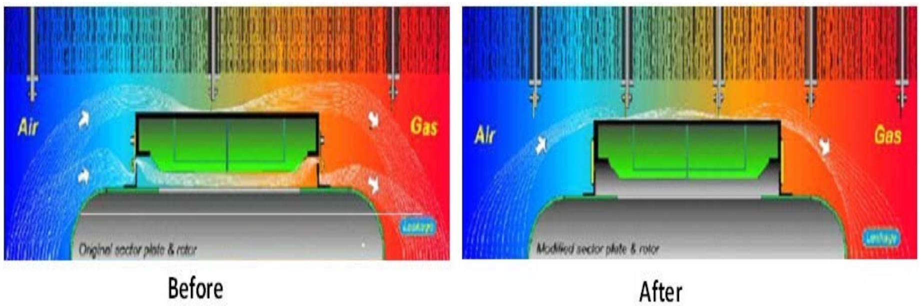

Figure 4: Before and After Sealing

Diaphragm Plate Protection Sheets

In the conventional air pre-heater, the hot end of the diaphragm plate is exposed to the gas flow. Due to erosive ash particles, the diaphragm plate edges erode fast. In course of time, the erosion extends to the radial seal fixing hole, thereby distributing the fixing and setting of radial seals. The diaphragm plate edge can be protected by the erosive resistant cover plates with the change of seals, these protective sheets also can be changed.

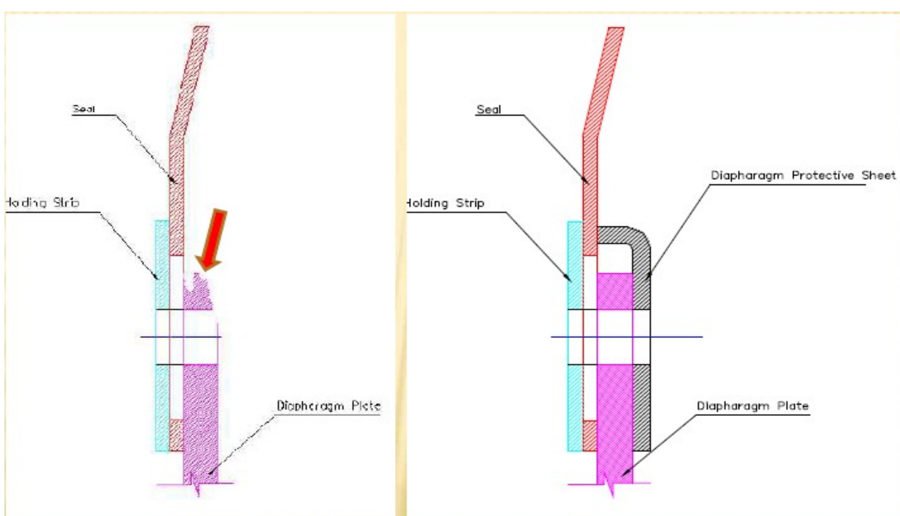

Figure 5: Diaphragm protection sheet

Cast 'T' Bar

Currently rolled 'T' bars are used for bypass sealing. This rolled 'T' has more variation in the radius. After setting it gives more leakage through bypass seal. Whatever correction is made at site could not control the radius variations. The cast 'T' bars keep the radius with controlled dimension, thus reducing the leakage across bypass seals.

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Rolled 'T' Bars more gap   Casted 'T' Bars less gap

Figure 6: Casted T Bars

Change of Profile for cold end Baskets

In old air pre-heaters, the cold end baskets are provided with 1.2 mm thick elements of NF6 profile. For Indian operating conditions, this can be changed to 0.8 mm DU profile. This will increase the heat transfer area, thereby reducing the flue as outlet temperature. It is calculated that by changing the profile as suggested, the as outlet temperature will decrease by 40C, that means 0.2% improvement in efficiency. This change has already been incorporated in the current design. Still some of the air pre-heaters are operating with cold end NF6 profile. This can be changed.

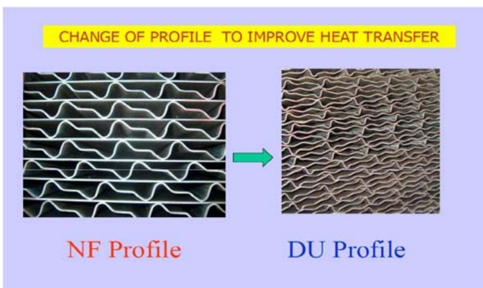

Figure 7: Heating Element Profiles

New Profiles

A highly efficient element profiles are available to improve the thermal performance. Case Study-I is presented to show the performance changes with the introduction of new profiles. With the introduction of new profile, the gas outlet temperature can be achieved to 135.60C.

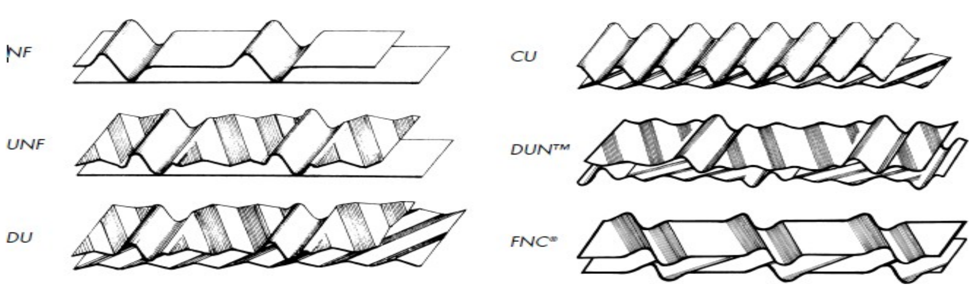

Figure 8: New Profiles

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VI. PROFIT GAINED AFTER MODIFICATION

Air preheater is modification then after saving of cost calculates as coal consumption and fans loading.

Table: Fans Current and others parameter

Sl. No	Parameter	Before Modification		After Modification	
		Fan A	Fan B	Fan A	Fan B
1.	Unit Load	205 MW		210 MW	
2.	Fuel consumption	126 MT		124MT	
3.	PA Fan	95Amp	93Amp	94Amp	92Amp
4.	FD Fan	58Amp	58Amp	57Amp	57Amp
5.	ID Fan	165Amp	164Amp	160Amp	158Amp

Coal cost saving

Coal consumption before modification = 126 T/Hr.

Coal consumption after modification = 124 T/Hr.

Coal consumption saving per hour = 126-124 = 2 T/Hr.

Coal cost per hour = 4265 * 2 = Rs.8530/-

Cost of coal saving per year = 8530 * 24 * 365 = Rs.7,47,22,800/-

Cost Benefit due to fan loading (Current)

Total fans current before modification = 633 Amp

Total fans current after modification = 618 Amp

Total saving fans current = 15 Amp

Power =1.732 * V I * CosΦ

Power saved =1.732 * (6.6 K) * 15 * 0.86 = 147.46 KWHr

Energy saved per year = 147.46 * 24 * 365 = 1282989.6 KWHr

Energy cost per unit =Rs 3.60

Energy cost saving per year =Rs.1282989.6 * 3.60 = Rs.4618762.56

Total cost saving per year =Rs.4618763 + Rs.74722800 **=Rs.79341563/-**

VII. CALCULATIONS OF AIR PREHEATER

The method determines air pre-heater as per this procedure is the volumetric method this is an empirical approximation of air heaters leakage with an accuracy of + or - 1%.

$$AL = \frac{(O_{2gl} - O_{2ge})}{(2l - O_{2gl})} \times 0.9 \times 100$$

Collected Data

AL – Air heater leakage

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O_{2ge} – Percentage of O2 in as leaving air heater: 5.0

O_{2gl} – Percentage of O2 in gas entering air heater: 3.5

Secondary air (SA) leaving air heater = 299^0c

Primary air (PA) leaving air heater = 304^0c

Calculations

$$\text{Air Leakage AL} = \frac{(5.0 - 3.5)}{(2l - 5.0)} \times 0.9 \times 100 = 8.437\ \%$$

Gas Side Efficiency

The gas efficiency is defined as the ratio of the temperature drop. Corrected leakage to the temperature head, expressed as a percentage. Temperature drop is obtained y subtracting the corrected gas outlet temperature from the gas inlet temperature. Temperature head is obtained y subtracting air inlet temperature from the gas inlet temperature. The corrected gas outlet temperature is defined as outlet gas temperature calculated for 'no air heater leakage' and is given y following equation.

$$T_{gnl} = [AL x C_{pa-} \frac{(T_{gl} - T_{ae})}{(100 x C_{pg})}] + T_{gl}$$

Collected Data

T_{gnl} – Gas outlet temperature corrected for no leakage.

C_{pa} – The mean specific heat between temperature T_{ae} and T_{gl} = 1.023 KJ / kg ^{0}k

C_{pg} - The mean specific heat between temperature T_{gl} and T_{ae} = 1.109 KJ / kg ^{0}k

T_{ae} – Temperature of air entering air heater = 40^0c

T_{ge} – Temperature of gas entering air heater = 331^oc

T_{gl} – Temperature of gas leaving air heater = 154^0c

Calculations

$$T_{gnl} = [AL x C_{pa-} \frac{(T_{gl} - T_{ae})}{(100 x C_{pg})}] + T_{gl}$$

$$T_{gnl} = [8.437 x 1.023 \frac{(154 - 40)}{(100 \times 1.109)}] + 154 = 162.87\ ^oc$$

Air heater Gas side efficiency

$$\text{Gas side efficiency GSE} = [\frac{(T_{ge} - T_{gnl})}{}] \times 100$$

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$$= \left[\frac{(T_{ge} - T_{ae})\ (331-162.87)}{(331 - 40)}\right] \times 100 = 57.77\%$$

X- Ratio

Ratio of heat capacity of air passing through the air heater to the heat capacity of flue gas passing through the air heater.

X-Ratio (X_r) = Gas Side Efficiency / Air Side Efficiency

Air Side Efficiency (SA & PA)

Ratio of air temperature gain across the air heater corrected from no leakage to the temperature head.

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})}\right] \times 100$$

Collected Data

T_{ae} – Temperature of air entering air heater = 40^0c

T_{al} – Temperature of air leaving air heater = 302^oc

T_{ge} – Temperature of gas entering air heater = 331^0c

Calculations

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})}\right] \times 100$$

$$\text{Air Side Efficiency} = \left[\frac{(302 - 40)}{(331 - 40)}\right] \times 100 = 90.03\%$$

X-Ratio (X_r) = Gas Side Efficiency / Air Side Efficiency

$$X_r = \frac{57.77}{90.03} = 0.641$$

Gas leaving temperature without leakage

$$T_{gl} = T_{ge} - X_r\,(T_{al} - T_{ae}) = 331 - 0.641\,(302 - 40) = 163.05^o c$$

Preheater Air Side Efficency (SA & PA)

$$\text{Air Side Efficiency (SA \& PA)} = \left[\frac{(T_{ge} - T_{ae})}{}\right] \times 100$$

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$$(T_{ge} - T_{ae})$$

$$= \left[\frac{(331 - 163.05)}{(331 - 40)} \right] \times 100 = 57.71\%$$

Secondary Air Side Efficiency

Collected Data

T_{ae} – Temperature of air entering air heater = 34^0c

T_{al} – Temperature of air leaving air heater = 299^0c

T_{ge} – Temperature of gas entering air heater = 331^0c

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})} \right] \times 100$$

$$= \left[\frac{(299 - 34)}{(331 - 34)} \right] \times 100 = 89.22\%$$

X-Ratio (X_r) = Gas Side Efficiency / Air Side Efficiency

$$X_r = \frac{57.77}{89.22} = 0.647$$

Gas leaving temperature without leakage

$$T_{gl} = T_{ge} - X_r (T_{al} - T_{ae}) = 331 - 0.647 (299 - 34) = 159.54^o c$$

Preheater Secondary Air Side Efficiency

$$\text{Secondary Air Side Efficiency} = \left[\frac{(T_{ge} - T_{gl})}{(T_{ge} - T_{ae})} \right] \times 100$$

$$= \left[\frac{(331 - 159.54)}{(331 - 34)} \right] \times 100 = 57.73\%$$

Primary Air Side Efficiency

Collected Data

T_{ae} – Temperature of air entering air heater = 46^0c

T_{al} – Temperature of air leaving air heater = 304^0c

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T_{ge} – Temperature of gas entering air heater = 331^0c

Calculations

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})}\right] \times 100$$

$$= \left[\frac{(304 - 46)}{(331 - 46)}\right] \times 100 = 90.52\%$$

X-Ratio (X_r) = Gas Side Efficiency / Air Side Efficiency

$$X_r = \frac{57.77}{90.52} = 0.638$$

Gas leaving temperature without leakage

$$T_{gl} = T_{ge} - X_r (T_{al} - T_{ae}) = 331 - 0.638(304 - 46) = 166.39^0c$$

Pre heater Primary Air side efficiency

$$\text{Primary Air Side Efficiency} = \left[\frac{(T_{ge} - T_{gl})}{(T_{ge} - T_{ae})}\right] \times 100$$

$$= \left[\frac{(331 - 166.39)}{(331 - 46)}\right] \times 100 = 57.75\%$$

VIII. CONCLUSION

We have detailed methods for improving the gross efficiency of the air pre heater and economizer by the solution minimizing heat losses during the process. Considerable increase in efficiency is achieved by improving the above parts on the design aspect. Even though it is importing these improvements in the generality boiler it would be highly appropriate if it is considered in the design of newly constructed boiler.

In this present work, energy analysis of a coal based thermal power plant is done by using the design data from 210 MW thermal power plants. Performance and analysis of air pre heater, in the air pre heater segment, notched flat profiles are replaced by double undulated profiles, and single seal are replaced by double seals, so heat loss in the air pre heater will be minimized. Hence the performance of air pre heater will increase. The main advantage of this proposed method is that, the heat transfer rate in the boiler will be increased.

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