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IMPROVING BOILER EFFICIENCY BY USING AIR PREHEATER

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Abstract: *Air pre-heater is a heat transfer surface in which air temperature is raised by transferring heat from other media such as flue gas .Hot air is necessary for rapid combustion in the furnace and also for drying coal in milling plants. So an essential boiler accessory which serves this purpose is air pre-heater. The air pre-heater are not essential for operation of steam generator, but they are used where a study of cost indicates that money can be saved or efficient combustion can be obtained by their use. The decision for its adoption can be made when the financial advantages is weighed against the capital cost of heater in the present paper we have taken up the operation and performance analysis of LJUNGSTROM AIRPREHEATER27VITM 1900 of 2x210 MW capacity Rayalaseema Thermal Power Plant, Kalamala and compare with Rothemuhle air pre-heater. In analysis of performance preventive measures for corrosion of heating elements has been studied, and also air heater leakage, corrected gas outlet temperature and finally gas efficiency has been calculated.*

Key words: *Thermal power plant, energy, air pre heater, Rothemuhle air pre-heater*

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1. INTRODUCTON

The place where the heat energy of fuel is converted into Electrical Energy is called Thermal Power Plant.

Energy Conversion: This part of the lesion outlines the various conversion processes which are carried out at power station indicating where possible the efficiency of the conversion process or in other words, indicating how successful the operation is of converting one form of energy into another. Remember, energy cannot be destroyed, but its conversion incurs difficulties, which results in not all the energy being usefully converted

Chemical Energy to Heat Energy: Chemical energy is stored in coal is converted into heat by the process known as combustion. The carbon and other combustible elements in coal are made to unite with Oxygen of air in furnaces. This process converts chemical energy into heat energy. Many pieces of equipment are used for this first conversion, including chain grate stroke, pulverized fuel furnaces, forced and induced draught fans, chimney stacks and many other items of boiler house plant.

2. WORKING PRINCIPLE

As the name implies the tri-sector pre-heater design has three sections. Use for flue gas. One for primary air (used for drying and transport of coal through mill to the burner) another for secondary air (additional air for combustion around the burners). These helps in avoiding wastage of heat pick up by air due to primary air flow and also help in selecting different temperatures for primary air and secondary air. Whatever is not utilized in primary air can be picked up by secondary air stream. Thousands of these high efficiency elements are spaced compactly arranged with in 12 sectors shaped compartments for heater size from 24.2 to 27 inches, and 24 sector shaped compartments for heater size from 28 to 33 of radially divided cylindrical shell called the rotor. The housing surrounding the rotor is provided with duct connections at both ends and is adequately sealed by radial and axial sealing members forming an air passage through one half of the pre-heater and a gas passage through the other. As the rotor slowly revolves the mass of the elements alternatively through the air and gas passage, heat is absorbed by the element surfaces passing through the hot gas stream. These are the same surfaces are carried through the air stream. They released the stored up heat thus increasing the temperature of the incoming combustion or process air.

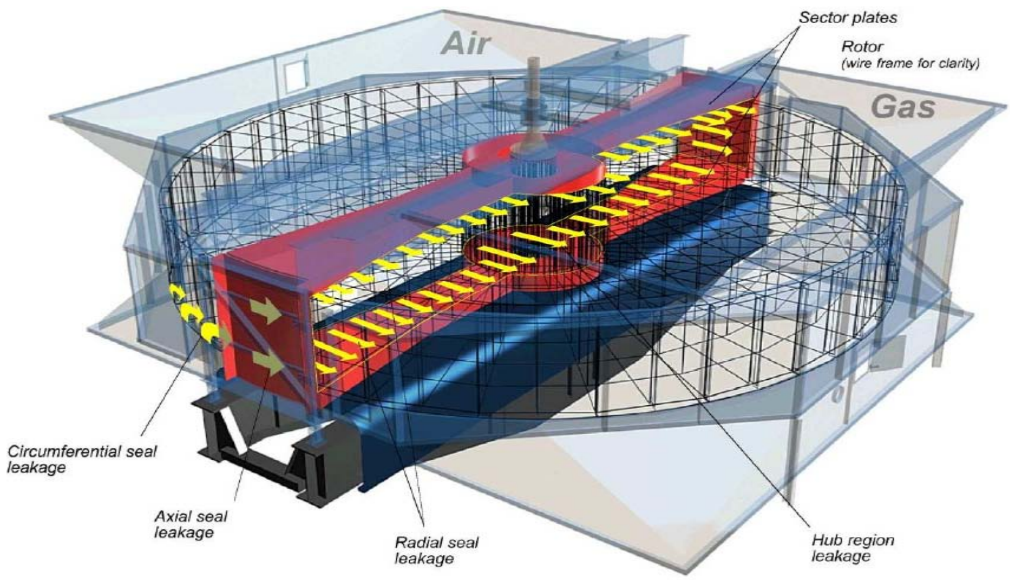


Figure 1: 3-D View of Ljungstrom Air pre-heater

The Ljungstrom air pre-heater is more widely used than any other type of heat exchanger for comparable service. The reasons for this world wide acceptance are its proven performance and reliability, effective leakage control, and its adaptability to most, any fuel burning process. It is both designed and built to operate over extend periods with durable, uninterrupted service. Simplicity of design also makes it easy and economical to maintain while in operation and at scheduled outages.

Applications of Air Pre-Heaters: Available in a broad range of sizes, arrangements and materials, LJUNGSTROM Air pre-heaters are custom engineer to meet the specific requirements and operating conditions of a variety of applications.

- Electric power generating plants
- Fluidized bed and marine boilers
- Package and large industrial boilers
- Hydro-carbon and chemical processes
- Flue gas and other re heating systems
- Heat transfer surface

3. 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.

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 2: Incorporation of soft touch seal

Figure 3: View of soft touch seal

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 e protected by the erosive resistant cover plates with the change of seals, these protective sheets also can be changed.

Figure 4: Installation of soft touch seal

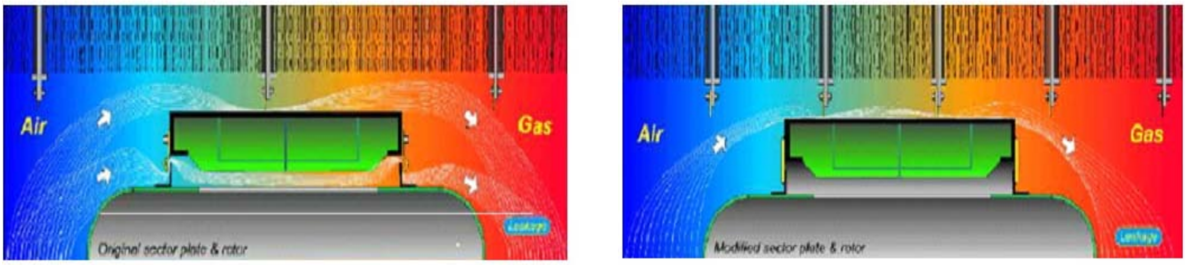


Figure 5: Before and After sealing

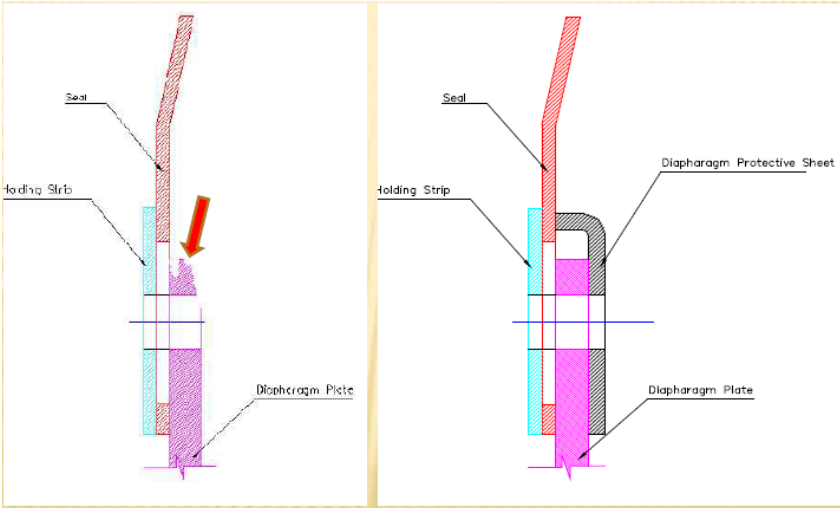


Figure 6: Insertion of diaphragm protection sheets

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.

Figure 7: Reducing gaps by 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 4^0C, 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.

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 135.6^0C.

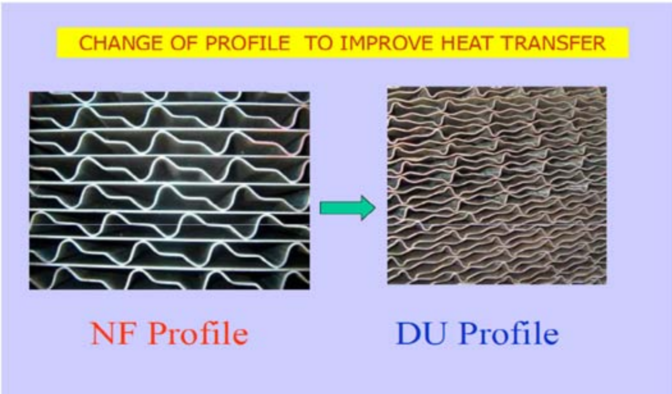


Figure 8: Change of profiles

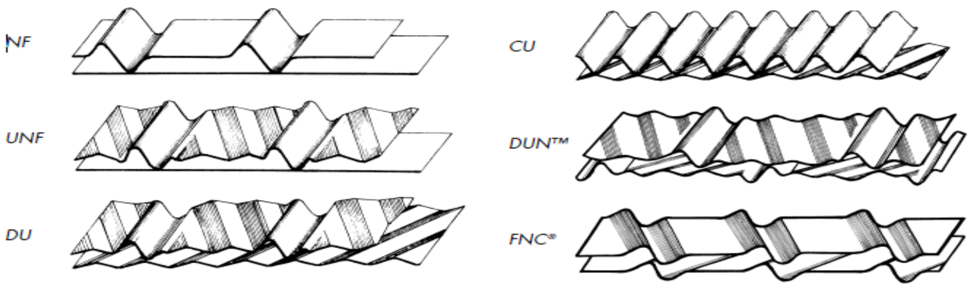


Figure 9: New profiles

4. OVERHAULING OF THE PLANT AFTER INCORPORATING SOFT SEALS:

OVERHAUL PERIOD - (15/11/2012 - 15/12/2012)						
S.No.	PARAMETERSUNITS		BEFORE OVERHAUL		AFTER OVERHAUL	
			APH-A	APH-B	APH-A	APH-B
1.	UNITLOAD	MW	205	-	210	-
2.	Fuel consumption	T/hr	115.3	-	113	-
3.	PD fan current	amps	198	178	181	188
4.	FD fan current	amps	171	164	157	141
5.	ID fan current	amps	278	311	236	238

4.1 Profits Gained After Overhauling

A) Cost saving per hour:

1. Fuel saving = 115.3 - 113 = 2.3 T/Hr
2. Assuming coal cost as = Rs 2000 per MT
3. Cost saving per hour = 2000 X 2.3 = Rs 4600
4. Cost of fuel saving per year = 4600X24X365 = Rs 40, 29,600

B) Cost benefit due to fan loading:

1. Total fan loading before overhauling = 1300 amps
2. Total fan loading after overhauling = 1141 amps
3. Total saving in current = 159 amps
4. Power saved = 1.73 X 3.3 X 159 X 0.86
   = 782.00KWhr = 0.782MWhr
5. Energy saved per year = 6,850,320
6. Power cost = Rs 2.60 per unit
7. Saving per year = 6850320 X 2.60 = Rs 1,78,10,832

C) Total savings per year = 4,02,96,000 + 1,78,10,832
= Rs 5,81,06,832

5. COMPARING LJUNGSTROM WITH ROTHEMUHLE

Calculations of Ljungstrom air pre-heater

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 + / - 1%.

$$AL = \frac{(O_{2gl} - O_{2ge})}{(21 - O_{2gl})} \times 0.9 \times 100$$

Collected Data:

AL – Air heater leakage

O_{2gl} – Percentage of O_2 in gas entering air heater: 3.5

O_{2ge} – Percentage of O_2 in as leaving air heater: 5.0

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

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

Calculations:

Air leakage $AL = \frac{(5.0-3.5)}{(21-5.0)} \times 0.9 \times 100$ = 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.

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

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^{0}c

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

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

Calculations:

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

$$T_{gnl} = \left[8.437 \times 1.023 \times \frac{(154-40)}{(100 \times 1.109)} \right] + 154$$ = 162.87^{0}c

Air heater Gas side efficiency:

Gas side efficiency $GSE = \left[\frac{(T_{ge} - T_{ngnl})}{(T_{ge} - T_{ae})} \right] \times 100 = \left[\frac{331-162.87}{331-40} \right] \times 100$ = 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 = 302^0c

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

Calculations:

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

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) = 163.05^0c

Pre heater Air side efficiency (SA & PA):

$$\text{Air side efficiency (SA \& PA)} = \left[\frac{(T_{ge} - T_{ae})}{(T_{ge} - T_{ae})}\right] \times 100 = \left[\frac{(331 - 163.05)}{(331 - 40)}\right] \times 100 = 57.71\%$$

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

Calculations:

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})}\right] \times 100 = \left[\frac{(299 - 34)}{(331 - 34)}\right] \times 100 = 89.22\%$$

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

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

Gas leaving temperature without leakage

$T_{gl} = T_{ge} - X_r (T_{al} - T_{ae}) = 331 - 0.647(299 - 34) = 159.54^0$c

Pre heater Secondary Air side efficiency:

Secondary Air side efficiency = $\left[\frac{(T_{ge}-T_{ae})}{(T_{ge}-T_{ae})}\right]\times 100$ = $\left[\frac{(331-159.54)}{(331-34)}\right]\times 100$ = 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

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

Calculations:

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

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

Pre heater Primary Air side efficiency:

Primary Air side efficiency = $\left[\frac{(T_{ge}-T_{ae})}{(T_{ge}-T_{ae})}\right]\times 100$ = $\left[\frac{(331-166.39)}{(331-46)}\right]\times 100$ = 57.75%

5.1 Rothemuhle air pre-heater:

The heating plate elements in this type of regenerative air pre-heater are also installed in a casing, but the heating plate elements are stationary rather than rotating. Instead the air ducts in the pre-heater are rotated so as to alternatively expose sections of the heating plate elements to the up flowing cool air. As indicated in the adjacent drawing, there are rotating inlet air ducts at the bottom of the stationary plates similar to the rotating outlet air ducts at the top of the stationary plates. Stationary-plate regenerative air pre-heaters are also known as Rothemuhle pre-heaters.

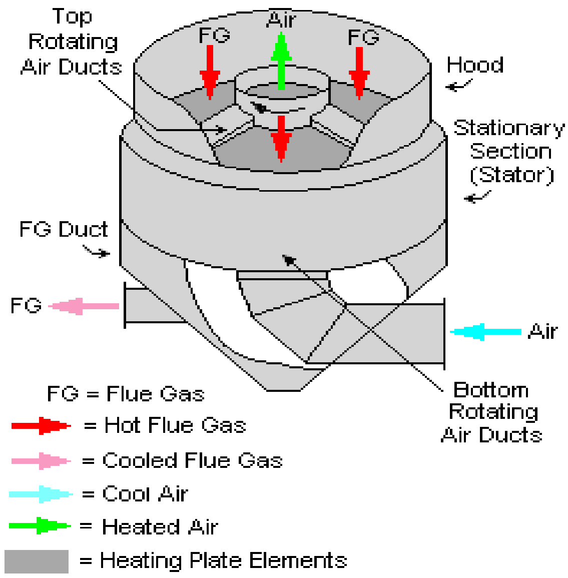


Figure 10: Rothemuhle air pre-heater

Calculations of Rothemuhle Air Pre-Heater:

Collected data:

AL – Air heater leakage

O_{2gl} – Percentage of O_2 in gas entering air heater: 3.5

O_{2ge} – Percentage of O_2 in as leaving air heater: 7.0

Air leaving air preheater = 295^0c

Air leakage (AL) = $\left[\frac{7.0-3.5}{21-5.0}\right]\times 0.9\times 100$ **= 22.5%**

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 by subtracting the corrected gas outlet temperature from the gas inlet temperature. Temperature head is obtained by 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 by following equation.

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

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 = 331^0c

T_{gl} – Temperature of gas leaving air heater = 175^0c

Calculation:

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

$$T_{gnl} = \left[22.5 \times 1.023 \times \frac{(175 - 40)}{(100 \times 1.109)} \right] + 175 = 203^0\text{c}$$

Air heater Gas side efficiency:

Gas side efficiency $GSE = \left[\frac{(T_{ge} - T_{ngnl})}{(T_{ge} - T_{ae})} \right] \times 100 = \left[\frac{331 - 203}{331 - 40} \right] \times 100$ = **43.92^0c**

Air Side Efficiency (SA & PA):

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

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 = 295^0c

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

Calculation:

Air Side Efficiency = $\left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})} \right] \times 100 = \left[\frac{295 - 40}{(331 - 40)} \right] \times 100$ = **87.62%**

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

$$X_r = \frac{43.92}{87.62} = 0.5$$

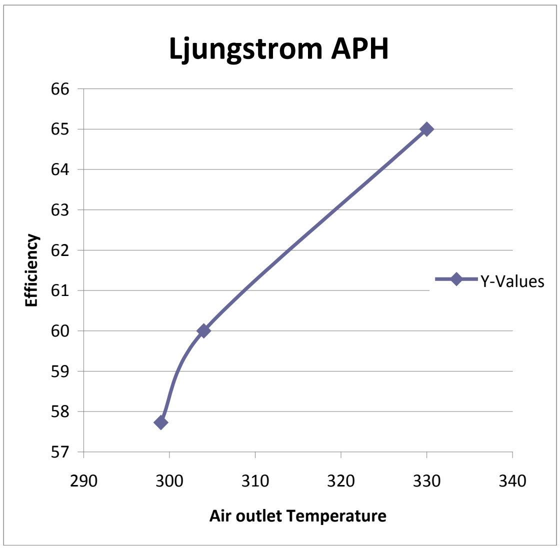
Gas leaving temperature without leakage

$T_{gl} = T_{ge} - X_r (T_{al} - T_{ae})$ = 331 – 0.5(295– 40) = 203.5^0C

Pre heater Air side efficiency (SA & PA):

$$\text{Air side efficiency (SA \& PA)} = \left[\frac{(T_{ge} - T_{al})}{(T_{ge} - T_{ae})}\right] \times 100 = \left[\frac{(331 - 203.5)}{(331 - 40)}\right] \times 100 = \mathbf{43.8\%}$$

From this comparison air leakages in Rothemuhle are higher than Ljungstrom and air side, gas side efficiencies are less in Rothemuhle



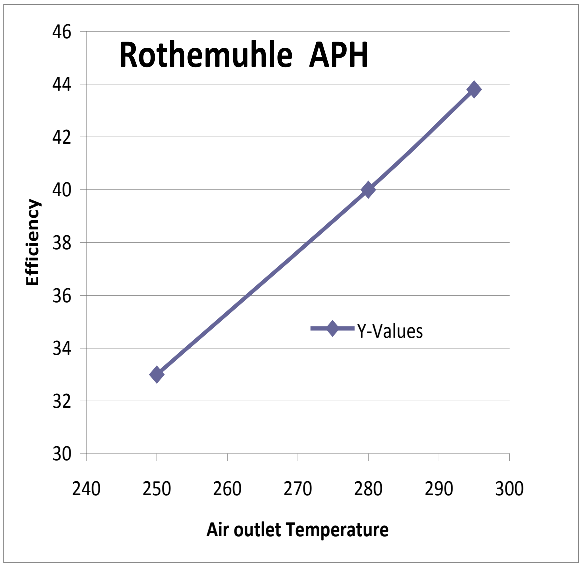


Figure 11: Pre heater Air side efficiency

CONCLUSIONS

- The Thermal performance of the air preheater is improved
- Load on the fans are reduced thus power consumption is reduced and cost is reduced
- Fuel consumption is also reduced, thus fuel is saved and cost is reduced
- By comparing Rothemuhle with Ljungstrom air leakages are more, gas side efficiency and air side efficiencies are less in Rothemuhle air pre-heater
- The Thermal performance of the Ljungstrom air pre-heater is better than Rothemuhle

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