iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** VI **Month of publication:** June 2023

DOI: https://doi.org/10.22214/ijraset.2023.54146

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

Statistical Analysis of Regenerative Air Preheater of Pulverized Coal Fired Boilers

D. Kulandaivel[1], M. Ravi Kumar[2], K. Ramesh[3]
[1]*Assistant Professor, Department of Mechanical Engineering, GCT, Coimbatore*
[2]*PG Student, Thermal Engineering, GCT, Coimbatore*
[3]*Professor, Department of Mechanical Engineering, GCT, Coimbatore*

Abstract: The data gathered from the field study and different parameter recorders connected to the data acquisition system of the distributed control system panel for measuring flow, pressure, and temperature are subject to typical systematic instrumentation measurement uncertainties with regard to the primary measuring elements, sensors, transducers, amplifiers, digital converters, and recorders, as well as the effects of the environment. The acceptability of data is statistically confirmed by taking into account the unpredictability of the inaccuracy in recorded parameters for temperature, pressure, and flow measurement. The statistical output on the measured and expected air flow through the APH (m_a) in relation to different AAT (T_{ae}) is summarized.
Keywords: Air Preheater, Ambient air temperature, mass flow rate, Air preheater Efficiency

I. INTRODUCTION

In pulverised coal fired power generation, moisture in coal is a major problem. Due to its hygroscopic nature, coal acquires a lot of surface moisture with seasonal changes. The performance of the pulverizer is impacted by coal moisture. Effective coal pulverisation and pneumatic transport depend on efficient coal drying. Traditional large pulverised coal-fired boilers use a coal drying mechanism that incorporates waste heat recovery from hot flue gas before discharge through stack by producing hot air stream (regenerative or recuperative APH) for coal drying purposes. Additionally, the need for cost- and energy-effective coal drying processes is critical because, in some cases, the combined weight of coal ash and moisture exceeds 50% of the coal "as received." Therefore, an appropriate and effective drying system on flue gas waste heat recovery will increase profitability while lowering the cost and emissions of power generation. The capacity for drying, however, is constrained by the hot primary air (PA) temperature and available hot airflow. The air preheater (APH) inlet flue gas temperature determines the PA temperature, which in turn limits the mill drying capacity. An increase in this temperature will reduce the boiler's overall efficiency, and too much hot PA may start a fire in the mill when the amount of coal fed is decreased to match a decrease in the demand for steam. Once more, any indirect heat exchange mechanism for coal drying within boiler combustion PA intake - preheating - combustion and exhaust circuit has an inherent limit on coal moisture removal capacity in the pulverising process that compromises overall boiler efficiency as heat of evaporating moisture is consumed from fuel energy. The heat retained in APH is consumed by the moisture from evaporated coal, and extra accessible heat from secondary air aids in achieving the furnace's combustion conditions. AAT also influences how much heat is available for steaming, which has an impact on how well APH works. The performance of the APH is impacted by the relative humidity (RH) and AAT, which determine heat loss resulting from moisture in the air.

II. REGENERATIVE AIR PREHEATER

In regenerative type APH thousands of high efficiency heat exchanging metal elements are closely spaced and compactly arranged within sector shaped compartments of a radial divided cylindrical shell called rotor. Heating elements are having corrugated profile and placed in closely packed baskets, which provide a medium for heat transfer. The gas side and air side in APH are separated by Sector plates and sealing arrangement. The housing surrounding the rotor is provided with duct connections at both ends and is adequately sealed by radial and circumferential sealing members forming secondary air passage through one (bi-sector) or primary and secondary air passage through two (trisector) sectors of the APH and a gas passage through another sector. Rotor rotates between these two sides. As the rotor slowly revolves theelements through air and gas passages, heat is absorbed by elements while passing through the hot flue gas stream and the same heat is released while passing through the air flowing passage(s) thus increasing the temperature of air used in combustion. The direction of flue gas and air are generally opposite.

Though the rotary APHs are superior to tubular APHs in terms of heat exchange effectiveness and surface area per unit volume [350 m^2/m^3 and volume per unit load (m^3/kW)], tip sealing is the source of severe air leaks from the air side (pressure: +6.5 to 7.5 kPa) to flue gas side (–0.3 to –0.8 kPa) as reported by Bhatt (2007). The air leakage to flue gas side of APH may cause fire hazard in presence of combustible in flue gas due to poor or delayed combustion in furnace. The leakage tramp air is unavailable for combustion though significant fan power is spent over it. Obviously, a minimum leakage of 5%–7% is unavoidable in regenerative rotary APH. In this paper, evaluation of performance is done only on the tri-sector regenerative type APH with respect to the variation of AAT.

The normal direction of rotation of the regenerative APH follows the direction of heat exchange from flue gas to PA pre-heating followed by secondary air preheating and this is suitable for high moisture coal drying. The direction of rotation need to be reversed for high volatile low moisture coal to prevent fire hazard in APH resulting from unburnt carbon in ash and undesirably high hot PA temperature at mill inlet.

III. STATISTICAL ANALYSIS

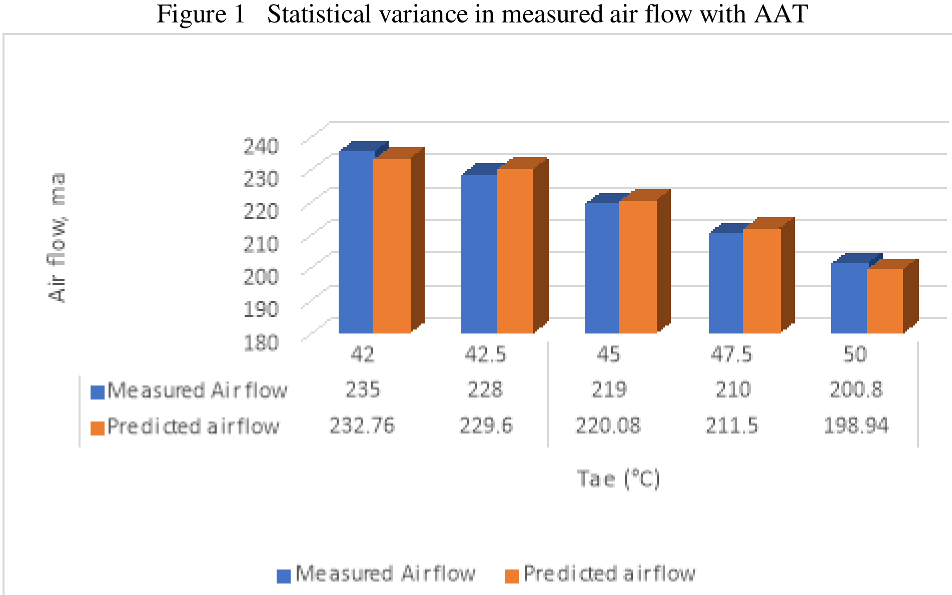
The data collected from the field study and various parameter recorders associated with data acquisition system of the distributed control system panel for measurement of flow, pressure and temperature are having usual systematic instrumentation measurement uncertainties with reference to primary measuring elements, sensors, transducers, amplifiers, digital converters and recorders including the environmental impacts.

Considering the randomness of the error in recorded parameters in temperature, pressure and flow measurement, the acceptability of data is statistically validated. The summary of statistical output on measured and predicted air flow (m_a) through APH with respect to various AAT (T_{ae}) is as given in Table 1 and graphically represented in Figure 1.

Table 1 Summary of statistical output (air flow in APH with AAT)

Regression statistics		*Observation*	*Measured air flow*	*Predicted air flow*	*Residuals*
Multiple R	0.990180449	1	235	232.76	2.238349878
R-square	0.980457321	2	228	229.6	–0.802022851
Adjusted R-square	0.973943094	3	219	220.08	–1.077533246
Standard error	2.252324765	4	210	211.5	–2.221455329
Observations	5	5	200.8	198.94	1.862661547

Figure 1 Statistical variance in measured air flow with AAT

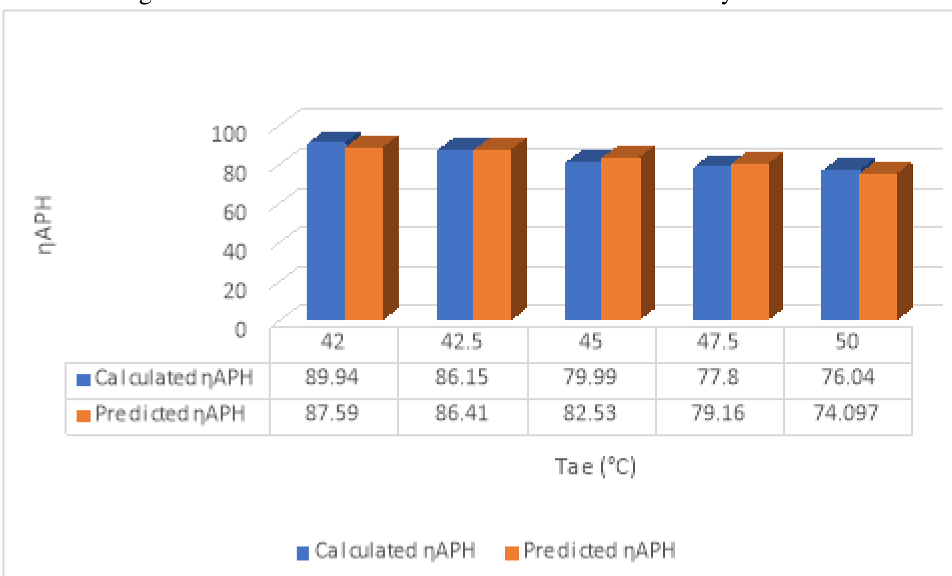


Similar to this, statistical analysis is conducted to assess uncertainties in variations of APH, with changes in AAT (Tae). The statistical output summary on calculated (on measured parameters) and predicted APH efficiency with maximum uncertainties at various AAT is provided in Table 2 and Figure 2.

Table 2 Summary of statistical output (efficiency of APH with AAT)

Regression statistics		*Observation*	Calculated η_{APH}	*Predicted* η_{APH}	*Residuals*
Multiple R	0.932453086	1	89.94	87.59	2.347808662
R-square	0.869468758	2	86.15	86.41	–0.26
Adjusted R-square	0.825958344	3	79.99	82.53	–2.544632235
Standard error	2.466089763	4	77.8	79.16	–1.360402514
Observations	5	5	76.04	74.097	1.946006989

Figure 2 Predicted maximum variation in APH efficiency with AAT



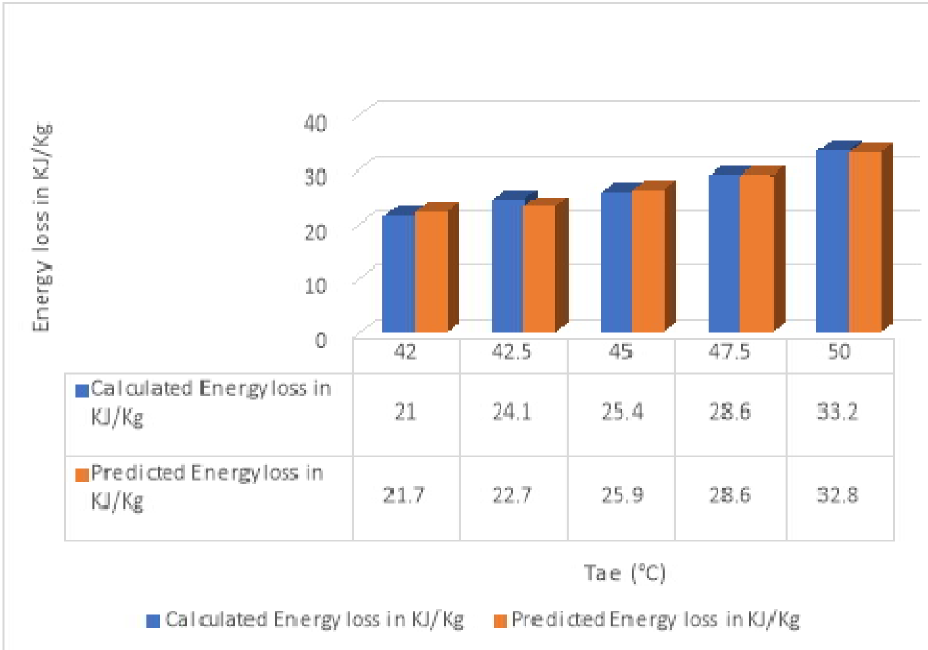
To verify the accuracy of the results, Figure 3 and Table 3 display the statistical analysis of uncertainties in fuel energy loss per kg of air to dry up at varied AAT at a RH of 40%.

Table 3 Summary of statistical output (fuel energy loss to dry air at 40% RH and variation of AAT)

Regression statistics		*Observation*	Calculated *energy loss*	*Predicted energy loss*	*Residuals*
Multiple R	0.979430851	1	20.95	21.7278	–0.780648637
R-square	0.959284792	2	24.08	22.6924	1.3876
Adjusted R-square	0.945713056	3	25.37	25.8617	–0.487783887
Standard error	1.07116565	4	28.6	28.6176	–0.017929989
Observations	5	5	33.18	32.7515	0.429266829

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

Figure 3 Predicted variation in fuel energy loss to dry air at measured AAT

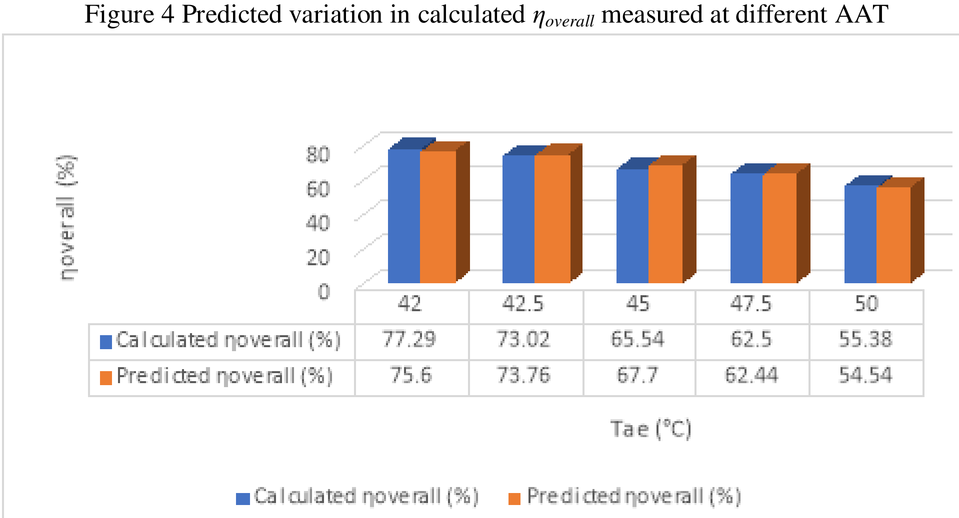


To assess the anticipated uncertainty in the computed APH overall efficiency and the anticipated excursions at various AAT, statistical regression analysis is used. Table 4 and Figure 4 provide the statistical output's summary. Figure 5 shows the highest variance of the estimated APH efficiency with the anticipated values taking uncertainties into account.

Table 4 Summary of statistical output ($\eta_{overall}$ with variation of AAT)

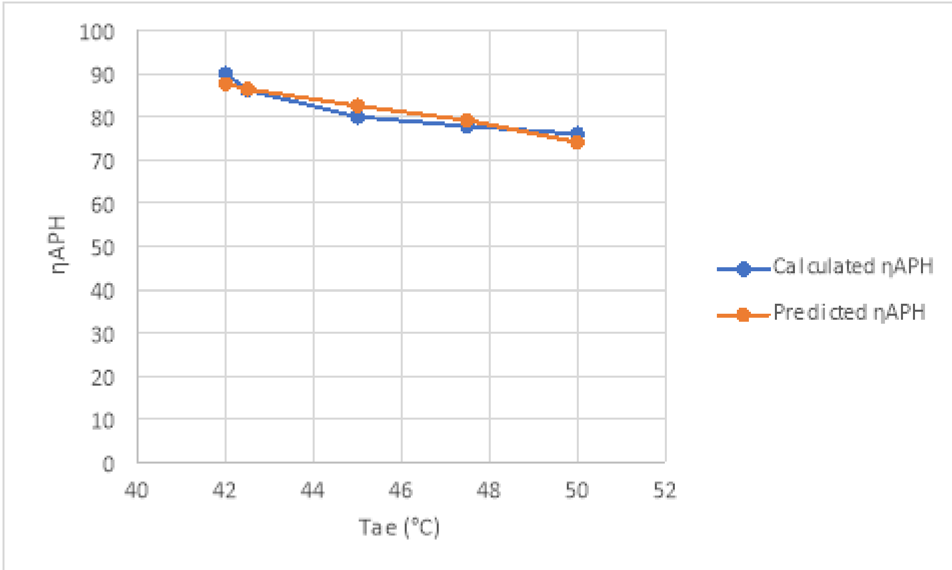
Regression statistics		*Observation*	Calculated $\eta_{overall}$	*Predicted* $\eta_{overall}$	*Residuals*
Multiple R	0.98611079	1	77.29	75.598	1.696388368
R-square	0.97241449	2	73.38	73.755	–0.375246182
Adjusted R-square	0.97241449	3	65.54	67.701	–2.158851442
Standard error	1.672859594	4	62.43	62.436	–0.006784201
Observations	5	5	55.38	54.54	0.844493457

Figure 4 Predicted variation in calculated $\eta_{overall}$ measured at different AAT



International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

Figure 5 Comparison of predicted values with calculated $\eta_{overall}$ measured at different AAT



Beside the randomness of error, certain site specific calibration is necessary, particularly for measurement of oxygen in flue gas at entry and exit of APH through sensors where pressure and temperature effect corrections are essential and in most cases are unavailable due to lack of calibration records as found in stated field study.
The equation to correct O_2 measurements for barometric pressure at any elevation is:

$$O_2\,\%_{actual} = O_2\,\%_{measured}\left[1-(100/P)*0.2095*(P_{measured} - P_{calibrated})\right] \qquad (1)$$

where P is the barometric pressure [kPa] at the given elevation and may be calculatedfrom:

$$P = 101.325 - 101.325*\{1-[1-(E/44,307.69,231)]\,5.25328\}\ \text{kPa} \qquad (2)$$

where E is elevation in meters.
Similarly, the effect of temperature correction in oxygen measurement by any sensor is to be taken care while probing APH for tramp air leakage measurement. The ideal gas law shows that gas concentration decreases by 0.34% (1 K / 293 K) for every 1ºC increase in temperature. Because air contains 20.95% O_2, a 1 ºC temperature increase results in a decrease of 0.07% O_2 per ºC (0.34% * 0.2095) increase in temperature. However, there is also an effect of temperature on the sensor, which causes the output to increase by approximately 0.10% O_2 per ºC temperature increase. This has an effect on the sensor's electronic device and it varies slightly from sensor to sensor. The net effect of the ideal gas law (–0.07%) and the sensor electronics (+0.10%) is an increase in the output of the sensor by 0.03% per ºC increase in temperature in dry air. For example, if an O_2 sensor were calibrated to read 20.95% O_2 at 25ºC then the sensor would read 21.10% O_2 at 30ºC [20.95 + 0.03 * (30 – 25)] and 20.80% O_2 at 20ºC [20.95 + 0.03 * (20 – 25)].
In accordance with ASME PTC 4.3, the non-availability of a measurement method for the distribution of air leakage for circumferential and radial seal degradation is a crucial factor in APH efficiency analysis. If there is no air ingress into the flue gas passage or moisture is not being added through a leaking steam coiled APH, an alternative method might be to analyse the fluid moisture content at various gas and air passages since moisture does not stratify like oxygen and specific humidity of air or flue gas does not change across the APH flow passage. More precise analysis of tramp airflow and heat rate lost due to bypassing of APH by air and flue gas will be provided by measuring changes in specific humidity on a basis of total air flow together with changes in oxygen concentration in flue gas flow through the APH.

The online humidity measuring sensors along with oxygen measuring sensors may be suitably utilised for the same. If L_{air} = volumetric air flow leakage in APH air side to flue gas side, V_{APHI} = Air/flue gas flow entering APH; V_{ag} = air/flue gas flow leaving APH; h_{ae} = Sp. humidity reading at APH passage inlet; h_{amb} = sp. humidity at AAT; h_{agl} = Sp. Humidity at APH passage outlet, then, this may be expressed as:

$$L_{air} = (h_{ae} - h_{agl})*V_{ag}/(h_{ae} - h_{amb}) \quad (3)$$

and

$$L_{air} * h_{amb} + V_{APHI} * h_{ae} = V_{ag} * h_{agl} \quad (4)$$

Where

$$V_{ag} = L_{air} + V_{APHI} \quad (5)$$

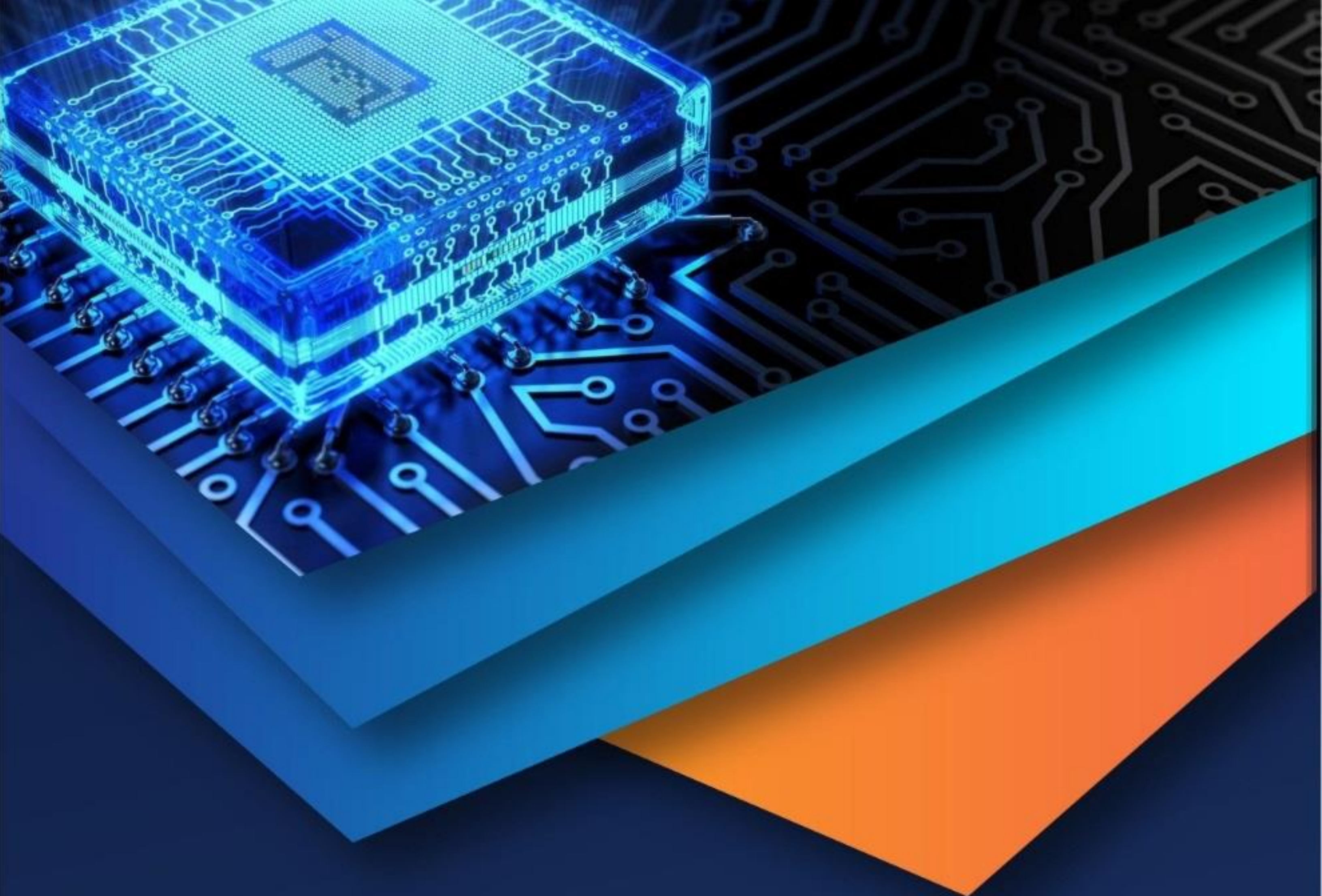
The above equations may be matched with the change in oxygen concentration in finalizing leakage air flow. A heat balance may only determine the APH bypass air quantity and change in dry flue gas loss to evaluate the efficiency of APH as a heat exchanger for air pre heating.

IV. CONCLUSION

Deterioration in APH performance invariably leads to loss of unit capability leading to commercial losses, loss of boiler efficiency due to incomplete combustion, along more of dry flue gas loss and ultimately higher energy consumption in the draft system. The leakage of air in the flue gas passage within APH causes loss of ID fan margin and rise in ID fan power consumption ultimately reduces availability of excess O_2 levels in the furnace for ensuring combustion completeness; which finally restricts unit capacity. Therefore, it is concluded that the use of regenerative APH in tropical countries with higher AAT is not an energy efficient option where RH of air is substantially high and considerable fuel energy is wasted to dry up air-moisture beside the high moisture low-rank coal used for pulverised coal fired power generation system. In fact, hot PA drying will increase the loss of available fuel energy as to dry up the low-rank high moisture content coal and thereby less of heat is available for steam generation. As such, high moisture coal drying can be more economically achieved through atmospheric fluidised bed drier using waste heat of flue gas downstream of ID fan and before exhaust through stack (Bhattacharya and Banerjee, 2011). The partial flue gas recirculation through pulveriser (PFGR) system can reduce the APH heat transfer loading, since coal drying capacity sometimes get restricted due to insufficient hot PA temperature and thereby causes power generation capacity restriction. Besides, a reduction in coal drying need in turn increases more secondary air temperature at APH ensuring better combustion with lower NO_x generation potential with less excess air.

REFERENCES

[1] Bhattacharya, C. and Sengupta, B. 'Effect of ambient air temperature on the performance of regenerative air preheater of pulverised coal fired boilers'.
[2] American Society of Mechanical Engineers (ASME) (1991) Air Heaters, Supplement to Performance Test Code for Steam Generating Units, PTC 4.1, ASME PTC 4.3-1968/ANSI PTC 4.3-1974; The American Society of Mechanical Engineers, New York.
[3] Bhatt, M.S. (2007) 'Effect of Air ingress on the energy performance of coal fired thermal power plants', Energy Conv. & Mgt.:, Vol. 48, pp.2150–2160, Elsevier.
[4] Bhattacharya, C. and Banerjee, N. (2011) 'Integrated drying and partial coal gasification for low NO_x pulverized coal fired boiler', Proc. of ASME 2011 Power-ICOPE Conference, Vol. 1, pp.293–300.
[5] Bhattacharya, C. and Mitra, A. (2007) 'Improving pulverizer output by partial flue gas recirculation', Proc. of International Conference on Advances in Energy Research:(ICAER – 2007), pp. 485–491, Macmillan.
[6] Bossong, J. (2012) 'Humidity measurement benefits in power applications', Proc. of Boiler Reliability Interest Group Meeting, Personal communication, USA.
[7] Nag, P.K. (2007) Engineering Thermodynamics, Tata McGraw-Hill Publishing Company Limited, New Delhi.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)