Rover Publications
United International Journal of Engineering and Sciences (UIJES)
An International Peer-Reviewed (Refereed) Engineering and Science Journal
Impact Factor:7.984(SJIF) Volume-4, Special Issue-3; ISSN: :2582-5887

An Intense Study on The Efficiency and Effectiveness of Gilled Tube Economizer in Thermal Power Plant by Using LMTD And NTU Methods

Kolahalam. Sai Babu[1*], T. N.Charyulu[2]
[1*]Lakireddy Bali Reddy College of Engineering, Mylavaram, Andhra Pradesh-521230, India
[2]RK College of Engineering, Kethanakonda, Vijayawada, Andhra Pradesh-521456, India
Corresponding author mail id: kolahalamsaibabu332@gmail.com
DOI:10.53414/UIJES:2024.43.23

***Abstract* – An economizer is an apparatus in which waste heat of flue gases is applied for heating the feed water. Usage of economizer increments boiler efficacy. For each $6^{0}C$ increment in the temperature of feed water boiler efficacy increases by 1%. By reason of growth in boiler efficacy, must be utilised the economizer as a mounting also overall plant efficacy rises. In this analysis of economizers, several things for economiser are depicted. In which by using the initial data from the power plant several analyses are carried out. Those are efficiency of economizer, heat grown by steam, heat loss by flue gases, effectiveness of economizer by LMTD method, effectiveness of economiser by NTU method. Effectiveness of economizer by LMTD method is 0.438 and effectiveness of economizer by NTU method is 0.775.**

***Keywords* – Economizer, Boiler, Power plant, LMTD, NTU, Effectiveness, Efficiency, Heat energy**

I. INTRODUCTION

Energy nothing but capacity to do the work. Heat energy from boiler is converted to rotational energy at the turbine. The turbine is attached to the generator on common shaft, where the rotational energy is converted to electrical energy. The generator works on the principle of electromagnetic induction. The generated voltage at our nearest power plant figure 1 is 15.75 kV rated for 210 MW.

Fig. 1 Power plant

1.1 Energy transformation

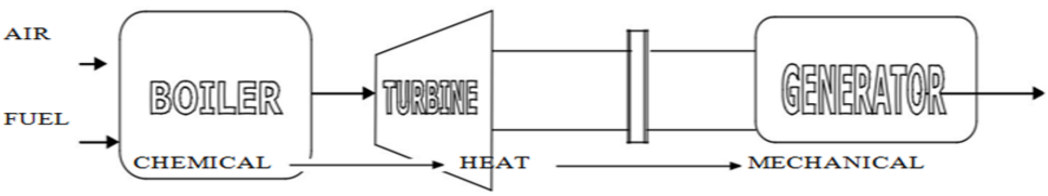

Fig. 2 Energy Transformation

Thermal power plant is a habitation here the heat energy of fuel is transformed into electrical energy. The principle is as shown in figure 2.

1.2 Economizer

The economizer is a feed water heater originating hotness from the flue fumes quitted from the boiler. Extreme element of heat loss in a boiler is hotness passed out by flue fumes up the stack. Less quantity of the hotness being passed by the flue fumes, perhaps recuperated and directed return into the boilers. In the economiser if the route of feed liquid is positioned in the passage of flue fumes in amid the going away from the boiler and enter to the stack the hotness from the flue fume is shifted to the feed liquid. By this the fuel is economized and the same steam rate is augmented

As a part of this research work, lot of literature survey has done. This survey not only on the economisers but also on the boilers, power plants and materials which are utilised for economisers. The corresponding literature has been mentioned below.

Celep et. al (2016) analysed the steam boiler. With the help of outcomes, it exposed that energy redeemable quantity as natural gas was 21,7248 m^3/year. Therefore, smearing of the economizer in a revenue of near 7760 dollar per annum and a decrease of 2713 tons CO_2 discharge each annum [1]. Asmaa S Hamouda (2019) had founded that the heat transmission proportion has been heightened and this thermal energy is transported to H_20 passing in the conduit. Thus, like that easily understood the augmented heat transmission and upsurge fuel redeemable by 1 %, which provide supreme boiler efficacy [2]. Aziz et. al (2012) offered a method for enlightening the act of economizer heat archetypal utilising bond graph and genetic algorithm. The abilities of the projected technique to progress archetypal presentation are revealed after simulation outcome equivalence to the intended data [3]. S. Park et. al (2018) analysed the cooling-energy redeemable possessions taking the EA-recirculation and supply-air (SA)-heat circumstances when straight and unintended air-side economisers were functional to a information located in Korea [4]. Nikola J. Budimir et. al studied to utilise excess heat from EFG at 165˚C and lesser its heat to 120˚C earlier send-off to the environment. Attained thermal power employment is 120 kW, because plant is releasing 209 kg per hour a smaller amount steam in boiler. Through ECO, complete efficacy of CHP is progressed after presently 74.5% to 78% [5]. Ahmad Mahmoudi Lahijani and Eris E Supeni (2018) studied the various losses occurred in boiler operation and found the effect of using economizer to increase the temperature of feed water and thereby improving the efficiency of fire tube steam boiler [6]. Anees U Malik et. al (2018) discussed regarding three different case studies provided various causes for failure of economizer tubes and their combating techniques [7]. Kamlesh Dewangan et. Al (2017) have reported the CFD analysis for eradicating the erosion effects on water tube boilers [8]. Marcin Trojan, and Mariusz Granda (2018) have presented their design and thermal performance analysis of economizer with various fin shapes of different radii using solid works software [9].

The above literature accomplished a review of numerous investigates. So, the review revealed the importance and effectiveness of economiser. By installing the economiser, not only increment in the boiler but also increment in the plant efficiency.

II. MATERIALS AND METHODS

By analyzing the economizer some important methods were used like LMTD, NTU. By using these methods there is a scope to evaluate the overall heat transfer coefficient, average heat etc., are calculated. However, there are two types of economizers, those are plain tube and gilled tube type economizers. This study has focused on the gilled tube type economizers.

2.1 Gilled tube economizer

A decrease in economizer dimension composed with rise in spread of heat can be attained by moulding quadrangular grills on the bare pipe walls cast iron grilled tube economiser can be utilised about 50 bar and such economiser are easily obtainable. At higher pressure (> 50 bar) steel pipes are utilised in its place of cast iron. 80 fins/m were utilised when dehydrated hard fuels were utilised and 120 fins/m were utilised when oils were utilised. Fin thickness varieties beginning 0.5mm to 5mm. The economiser used in power plant is gilled bare tube. The arrangement of gilled bare tube economiser as show in figure 3.

Fig. 3 Gilled Tube Type Economisers

2.2 Specifications

S.No.	Parameter	Specification
1.	Type	Gilled tube
2.	Over-all heat exterior area	7911 m^2
3.	No. of blocks	2 No's
4.	Size of Economiser	25 m^3

Table. 1 Specifications of economiser in power plant as per manual

III. RESULTS AND ANALYSIS

The impartial results and their analysis as mentioned below. The entire analysis was focussed on the gilled tube in real power plant only.

3.1 Data collection for economiser

Required hot and cold fluid data is collected from the power plant and the same presented below. Where the working fluid is water and the boiling point for the water is 100^{0}C.

3.1.1 Cold fluid data

Mass of feed water evaporator/kg of fuel (M_W) = 697TPH
Specific heat of feed water (C_{pw}) = 4.949 kJ/kg K
Temp of feed water entering economiser (T_1) = 241.9^{0}C
Temperature of feed water leaving economiser (T_2) = 304^{0}C

3.1.2 Hot fluid data

Mass of flue gases/kg of fuel (M_f) = 668TPH
Specific heat of flue gases (C_{pf}) = l.151 kJ/kg K
Temperature of flue gas entering economiser (T_{fl}) = 427.6°C
Temperature of flue gas leaving economiser (T_{f2}) = 337.3°C
No. of tubes in economiser (n) =2x100
Outer dia of the pipe (Do) = 0.0455m
Length of the pipe (L) = 282.9m

3.2 Calculations and results for economiser

Corresponding calculations based on the standard formulae and theorems [10, 11] and obtained results were mentioned below.

3.2.1Efficiency of economiser (η)

Economiser efficacy proportion between the growth in temperature of the water and the fall in temperature of the gases.

$$\eta = \frac{Mw \times Cpw \times (T2 - T1) \times 100}{Mf \times Cpf \times (Tfl - Ta)} \quad (1)$$

$$\eta = \frac{697 \times 4.949 \times (304 - 241.9) \times 100}{668 \times 1.151 \times (427.6 - 31)}$$

Efficiency of economiser, η = 70.24%

3.2.2 Heat gained by steam

Steam is a derived supply of energy as it is formed from water by burning of any kind of principal resource of fuel in a boiler.

$$\text{Heat gained by steam } (Q_c) = \frac{Mw \times Cpw \times (T2 - T1)}{3600} \quad (2)$$

$$(Q_c) = \frac{697 \times 4.949 \times (304 - 241.9)}{3600} \times 1000$$

Heat gained by steam (Q_c)=59503.06 kW

3.2.3 Heat lost by flue gases

Flue gas losses are the primary root of heat loss in boilers. They arise when heated gas leaves the boiler through the stack.

$$\text{Heat lost by flue gases } (Q_h) = \frac{Mf \times Cpf \times (Tf1 - Tf2) \times 1000}{3600} \quad (3)$$

$$(Q_h) = \frac{668 \times 1.151 \times (427.6 - 337.3) \times 1000}{3600}$$

Heat lost by flue gases (Q_h) =19221.7 kW

3.3 Effectiveness

The effectiveness (ϵ) of a heat exchanger is relation of the actual transfer of heat to the utmost probable transfer of heat. However, in this analysis effectiveness is expressed in the methods of LMTD and NTU.

3.3.1 Effectiveness by LMTD method

The LMTD is a logarithmic mean of the temperature variation amid the warm and cold feedstuffs at every finish of the double tube exchanger. Usually there are two types of flows. Those are parallel and counter flow, however, this analysis is focussed on counter flow as shown in figure 4.

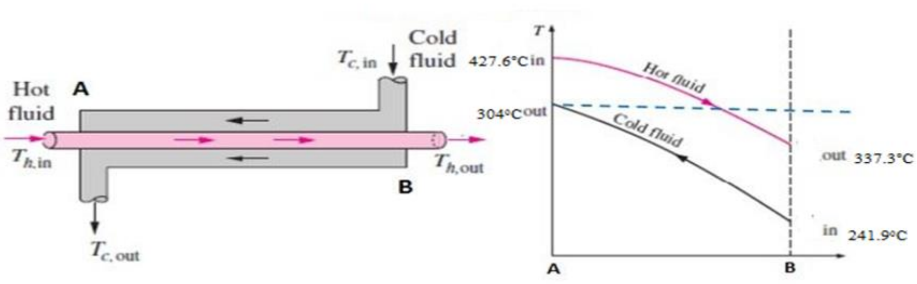

Fig. 4 Representation of counter flow

$$LMTD = \frac{DT1 - DT0}{\ln\left(\frac{DT1}{DT0}\right)} \quad (4)$$

Where,

$$DT_1 = T_{f1} - T_2 \quad (5)$$

$$= 427.6 - 304 = 123.6°C$$

$DT_0 = T_{f2}-T_1$ (6)

$= 337.3-241.9 = 95.4°C$

$$LMTD = \frac{123.6-95.4}{\ln\left(\frac{123.6}{95.4}\right)} = 108.89°C$$

$$\text{Avg heat } (Q) = \frac{Qc+Qh}{2} \quad (7)$$

$$= \frac{59503.06+19221.7}{2} = 39362.7 \text{ kW}$$

Surface area $(A_0) = n×\pi×D_0×L$ (8)

$= 2×100×\pi×0.0445×282.94 = 7911m^2$

$$\text{Overall heat transfer coefficient } (U_0) = \frac{Q}{A_0 \times LMTD} \quad (9)$$

$$U_0 = \frac{39362.7}{7911 \times 108.89} = 0.0456 \text{ kW/m°C}$$

$$\text{Heat capacity of hot the fluid } (C_h) = \frac{Mf \times Cpt \times 1000}{3600} \quad (10)$$

$$C_h = \frac{Mf \times Cpt \times 1000}{3600} = \frac{668 \times 1.5 \times 1000}{3600} = 213.571 \text{ kW/°C}$$

$$\text{Heat capacity of cold the fluid } (C_c) = \frac{Mw \times Cpw \times 1000}{3600} \quad (11)$$

$$C_c = \frac{Mw \times Cpw \times 1000}{3600} = \frac{697 \times 4.949 \times 1000}{3600} = 958.19 \text{ kW/°C}$$

$$\text{Effectiveness by LMTD method } (\epsilon): = \frac{Tf1-Tf2}{Tf1-T1} \quad (12)$$

$$= \frac{427.6-337.3}{427.6-241.9} = 0.438$$

By the above calculation by using the predefined data and standard formulae the effectiveness by LMTD method is 0.438, also the over-all heat transfer co-efficient is 0.0456 kW/m°C and logarithmic mean temperature difference is 108.89°C and all the values are tabulated below.

S.No.	Parameter	Value
i.	LMTD	108.89°C
ii.	Average heat	39362.7 kW
iii.	Overall heat transfer coefficient	0.0456 kW/m°C
iv.	Effectiveness	0.438

Table. 2 Representation of outcomes by LMTD method

3.3.2 Effectiveness by NTU method

The number of transfer units technique is utilised to compute heat transfer rate in heat exchangers mainly counter flow exchangers. To describe the effectiveness of a heat exchanger, require to calibrate the utmost probable hotness transmission which suppositionally obtained in a counter-movement heat exchanger of inestimable span. The effectiveness is the relation amid the actual heat transmission rate and the utmost probable heat transmission rate.

$$NTU\ (N) = \frac{Uo \times Ao}{Cmin} \quad (C_h < C_c) \quad (13)$$

$$N = \frac{Uo \times Ao}{Ch} = \frac{0.450 \times 7911}{213.574} = 1.68$$

$$\text{Ratios of heat capacities (R)} = \frac{Cmin}{Cmax} \tag{14}$$

$$= \frac{213.574}{958.19} = 0.222$$

$$\text{Effectiveness by NTU method: NTU}(\epsilon) = \frac{[1-e(-N(1-R))]}{[1-R\,e(-N(1-R))]} \tag{15}$$

$$\text{NTU}(\epsilon) = \frac{[1-e(-1.68(1-0.222))]}{[1-0.22\,e(-1.68(1-0.222))]} = 0.775$$

From the above fair outcomes, effectiveness by NTU method is 0.775 and heat capacities ratio is 0.22. All the values are tabulated below.

S.No.	Parameter	Value
i.	NTU	1.68
ii.	Ratio of heat capacities	0.222
iii.	Effectiveness	0.775

Table. 3 Representation of outcomes by NTU method

IV. CONCLUSIONS

Economisers helped to a raise in the temperature of feed water, if 6^0C of temperature rise then improve the boiler efficacy by 1%. Economisers are normally positioned between the last super heater & air pre-heater. At few situations, small temperature economiser was sited afterwards the air pre-heater such an economiser is named a stack cooler & acts like small pressure feed liquid heater except that the heating arrangement is the flue gas substitute of steam to bleed from turbine. By the analysis, the genuine conclusions were mentioned below.

- The Efficiency of economiser is 70.24% so by fitting the economiser in the plant, plant efficacy can be augmented.
- Economiser needs regular maintenance for effective running.
- Heat gained by steam is 59503.06 kW.
- Heat loss by flue gas is 19221.7 kW.
- The phase variation in economiser is not accessible.
- By using the economiser heat assortment between several portions of the boiler is decreased, which in decrement of stresses due to unequal extension.
- Effectiveness of economiser by LMTD method is 0.438.
- Effectiveness of economiser by NTU method is 0.775.
- Evaporative capacity of the boiler is increased.

REFERENCES

[1] Gamze Karanfil Celep and Selmin Ener Rusen, "Application Of Economizer For Waste Heat Recovery From Exhaust Flue Gas In Steam Boiler: A Case Study In A Biscuit Factory", 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016. PP 439-444.

[2] Asmaa S. Hamouda, "Boiler Efficiency Improvement and Energy Saving by Optimizing Economizer Design for Better Performance –Pre-Feasibility Study", International Journal of Science Technology & Engineering (IJSTE), Volume 5, Issue 8, February 2019, ISSN (online): 2349-784X.

[3] A.N. Aziz, P. Siregar, Y.Y. Nazaruddin and Y. Bindar., "Improving the Performance of Temperature Model of Economizer Using Bond Graph and Genetic Algorithm", Improving the Performance of Temperature Model of Economizer Using Bond Graph and Genetic Algorithm, 2012, PP 57-61.

[4] Seonghyun Park and Janghoo Seo, Analysis of Air-Side Economizers in Terms of Cooling-Energy Performance in a Data Center Considering Exhaust Air Recirculation, Energies 2018, 11, 444, PP 1-14.

[5] Nikola J. Budimir, Marko S. Jaric, Igor Martic, Aleksandar Maslarevic and Nenad Mitrovic., "Application and Design Of An Economizer For Waste Heat Recovery in A Cogeneration Plant" Thermal Science · January 2015. PP 1-10.

[6] Ahmad Mahmoudi Lahijani and Eris E Supeni, "Evaluating the Effect of Economizer on Efficiency of the Fire Tube Steam Boiler", Innovative Energy & Research, Lahijani and Supeni, Innov Ener Res 2018, Volume 7, Issue 1.

[7] Anees U. Malik, Saleh A. Al-Fozan, M. Mobin1 and Mohammad Al-Hajri., "Studies on the Failure of Economizer Tubes Involving Acid Dew-Point Corrosion in High Pressure Boilers", International Journal of Scientific & Engineering Research, Volume 4, Issue 9, September-2013, PP 1726-1736.
[8] Kamlesh Dewangan, Saurabh Kumar and Ruman Singh, Analysis and Optimization of Boiler Tube Failure Due To Erosion Using CFD Package, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 11, November 2017, PP 21462-21470.
[9] Marcin Trojan, and Mariusz Granda, "Modeling of the boiler economizer", MATEC Web of Conferences 240, 2018. PP 1-7.
[10] Heat and Mass Transfer by P. K. Nag, McGraw Hill Education; 3rd edition (26 April 2011); McGraw Hill Education (India) Private Limited.
[11] Heat Transfer by J. P. Holman, McGraw Hill Education; 10th edition (1 July 2017)