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AN ANALYTICAL APPROACH TOWARDS ECONOMISER DESIGN WITH FINNED & BARE TUBE ECONOMIZER

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An analytical approach towards economizer design with finned & bare tube economizer

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Abstruct - A brief historical overview on economizer design & optimization is given. Main economizer design methodologies available in literature are described and their advantages and disadvantages. The main advantage of the proposed method is that it permits a better understanding of influence of the design parameters on the cycle performance.

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1. INTRODUCTION

Economizer tubes are employed in power plants to preheat the boiler feed water before it is introduced into the boiler drum and to recover some of the heat from the flue gas leaving the boiler. The economizer is located in the boiler near gas pass below the rear horizontal super heater. Each section is composed of a number of parallel tube circuits. Feed water is supplied to the economizer inlet via feed stop and check valves from the outer header. Feed water is pumped to the drum via economized links. Steaming in the economizer is prevented by controlling the economizer outlet feed water temperature. The operating temperature of the economizer tubes lies below 3990C suggest that the occurrence of creep of the tube material which is generally mild steel is not expected. Therefore tensile properties at the operating temperature range rather than stress rupture properties have much importance in predicting the remaining life of these tubes. Generally premature failures of economizer tubes take place due to several reasons mainly flue gas erosion, low temperature water corrosion, fatigue, oxygen pitting, mechanical failures of the joints etc.[1]

Economizer is a heat exchanger which resist the temperature of feed water leaving the highest pressure feed water heater to about saturation temperature corresponding to the boiler pressure. This is done by hot flue gaseous exiting the last super heater or reheater at a temperature varying from 3700C to 5400C. The term economizer was used historically because the throwing away of such high temp gaseous involved great deal of energy loss. By utilizing these gaseous heating feed water, higher efficiency and better economy were achieved and hence the heat exchanger was called economizer.

2. TRADITIONAL STRATEGIES FOR ECONOMIZER DESIGN

Economizer surface types bare tube: The most common and reliable economizer design is the bare tube, in-line, cross flow type. When coal is fired, the flyash creates a high fouling and erosive environment. The bare tube, in-line arrangement minimizes the likelihood of erosion and trapping of ash as compared to a staggered arrangement. It is also the easiest geometry to be kept clean by soot blowers. However, these benefits must be evaluated against the possible larger weight, volume and cost of this arrangement. Extended surfaces:

To reduce capital costs, most boiler manufacturers have built economizers with a variety of fin types to enhance the controlling gas-sideheat transfer rate. Fins are inexpensive parts which can reduce the over- all size and cost of an economizer. However, successful application is very sensitive to the flue gas environment. Surface clean ability is a key concern. In selected boilers, such as coal-fired units, extended surface economizers are not recommended because of the peculiar fly ash characteristics. [1]

Stud fins: Stud fins have worked reasonably well in gas-fired boilers. However, stud finned economizers can have higher gas-side pressure drop than a comparable unit with helically-finned tubes. Studded fins have performed poorly in coal-fired boilers because of high erosion, loss of heat transfer, increased pressure loss and plugging resulting from flyash deposits.

Longitudinal fins: Longitudinally-finned tubes in staggered cross flow arrangements, have also not performed well over long operating periods. Excessive plugging and erosion in coal-fired boilers have resulted in the replacement of many of these economizers. In oil and gas-fired boilers, cracks have occurred at the points where the fins terminate. These cracks have propagated into the tube wall and caused tube failures in some applications. Plugging with flyash can also be a problem (tight spaces).

Rectangular fins: The square or rectangular fins, arranged perpendicular to the tube axis on in-line tubes have been used occasionally in retrofits. The fin spacing typically varies between 13 and 25 mm and the fins are usually 3.18 mm thick. There is a vertical slot down the middle because the two halves of the fin are welded to either side of the tube. Most designs are for gas velocities below 15.2 m/s. However, because of the narrow, deep spaces, plugging with fly ash is a danger with such designs.

Velocity limits: The ultimate goal of economizer design is to achieve the necessary heat transfer at minimum cost. A key design criterion for economizers is the maximum allowable flue gas velocity (defined at the minimum cross-sectional free flow area in the tube bundle). Higher velocities provide better heat transfer and reduce capital cost. For clean burning fuels, such as gas and low ash oil, velocities are typically set by the maximum economical pressure loss. For high ash oil and coal, gas-side velocities are limited by the erosion potential of the fly ash. This erosion potential is primarily determined by the percentage of A1203, and SiO2 in the ash, the total ash in the fuel and the gas maximum velocity.

3 PERFORMANCE ANALYSIS OF ECONOMIZER

Economizer heat transfer rate is calculated as per following formula

q = U x A x (LMTD) [5] (1) q = mg x cp x Tg = mg x cp x (T'- T) (2) q = m x H (3) where,

$h_{rg} = h_r' x K x Fs$ (11) v = specific

$Fs = (A - A_p)/A$ (12) G = mass fl

q = heat transfer rate, Kcal/hr

U = overall heat transfer coefficient

LMTD = log mean temperature difference, °C

mg = gas mass flow rate, Kg/hr

cp = mean specific heat of gas, KJ/Kg K

T' = gas temperature leaving economizer, °C

T = gas temperature entering economizer, °C T" = economiser water outlet temp, °C

T1 = economiser water inlet temp, °C

The heat transfer by convection and intertube radiation is:

qci = q - qr (4)

where,

q = total heat transfer rate. Kcal/hr qr = cavity radiation Kcal/hr

Gas temperature leaving the economizer can

be determined by :

T' = T - ((qci)/(mg x cp) (5) Counter flow heat exchanger, the log mean temp difference is :

LMTD = ((T - T") - (T'- T1)) / (ln((T – T")/ (T'-T1))) (6) Average gas temperature can be determined by:

Tf = ((T1 + T")/2 +(LMTD/2)) (7)

Gas mass flux :

Gg = mg / Ag (8) Reynolds number:

Re = Kre x Gg (9) K Re = Gas properties factor, m2 hr/ Kg

Gas film heat transfer coefficient:

hcg = hc' x Fpp x Fd x Fc (10) Fpp = Physical properties factor

Fd = Heat transfer depth factor

Fc = Arrangement factor

hc' = Geometry factor

Gas side radiation heat transfer coefficient:

Overall heat transfer coefficient:

U = hcg + hrg (13)

Finned tubes: As a general guideline, the overall heat transfer coefficient can be approximated by the following relationship for most types of economizer fins:

U = 0.95(hg x kf) (14) Kf = surface effectiveness factor hg = gas-side heat transfer coefficient for the heat transfer across finned tube bundles..

Gas-side resistance: The gas-side pressure loss across the economizer tube bank can be evaluated using the crossflow correlations. The pressure loss should be adjusted for the number of tube rows using the correction factors provided. The gas-side

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resistance across the in-line finned tube banks is approximately 1.5 times the resistance of the underlying bare tubes. Water-side pressure drop:

If the calculated water-side pressure drop is excessive, the number of parallel flow paths must be increased. If the flue gas velocity can be increased, the water-side pressure drop can also be reduced by increasing the tube size, usually in increments of 3 mm. The dynamic pressure drop is inversely proportional to the fifth power of the inside tube diameter.

Total pressure loss is calculated (Pt):

Pt = Pf + Pl + Pz (15)

Where,

Pf = friction pressure loss

Pl = sum of local losses

Pz = static head loss

Pf = f x L/De x v (G/105)2 (16)

where,

Pf = fluid pressure drop,kg/cm2

f = friction factor

L = length,m

De = equivalent dia of flow channel,m

hr' = Radiation heat transfer coefficient

K = Effect of fuel on radiation heat transfer

coefficient

Pl = Nv x (30/B) x ((T+460)/(1.73 x 105)) x (G/103)2 (17) Where,

Nv = number of equivalent velocity heads

dimensionless

Pl = pressure drop in wg

B = barometric pressure, mm Hg

T = air temp. °C

Pz= (g/gc)L sin (18)

g = acceleration of gravity (m/s2)

gc = 1 kg m/ N s2

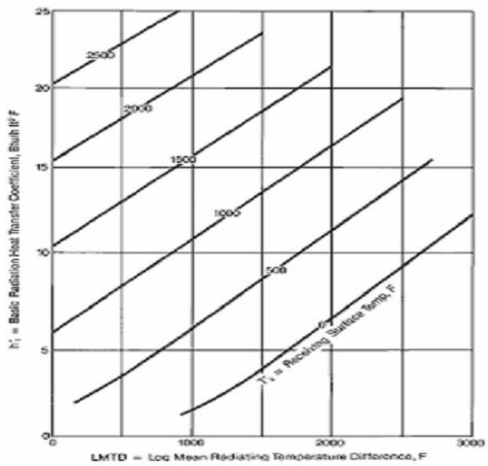

Fig.1 Basic radiation heat transfer coefficient

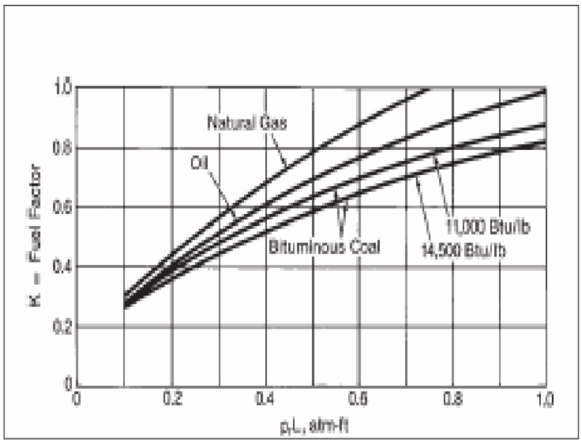

Fig. 2 Effect of fuel, partial pressure and mean radiating length on radiation heat transfer coefficient

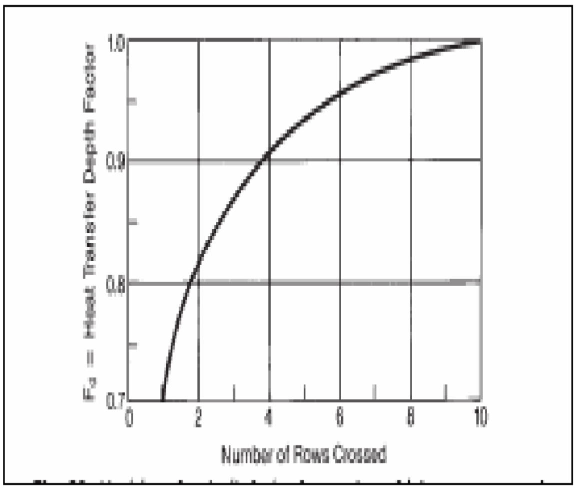

Fig. 3 Heat transfer depth factor for number of tube rows

4 CFD ANALYSIS OF ECONOMIZER

Input parameter: Air inlet mass flow rate = 160 Kg/s Flue gas inlet Temperature = 800 0C Back pressure at outlet = -150 mmWC Gas composition (volume fractions)

H_2O 13.81 % N_2 68.65 % CO_2 11.45 % O_2 5.09 %

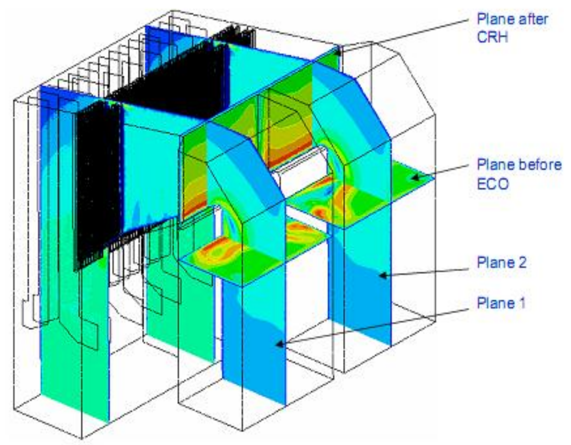

Fig. 4 Plane location

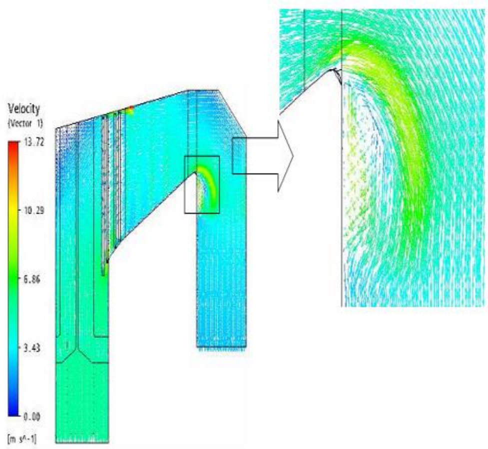

Fig. 5. Velocity vector on plane

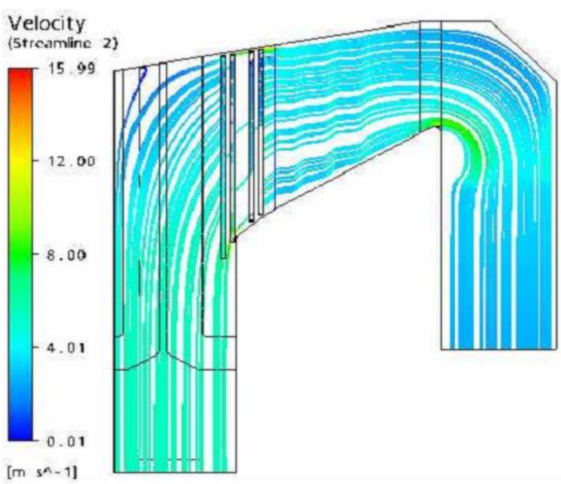

Fig. 6. Velocity streamlines on plane

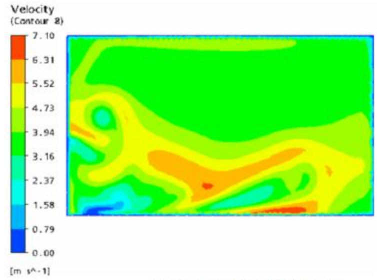

Fig. 7. Velocity contours on plane before eco

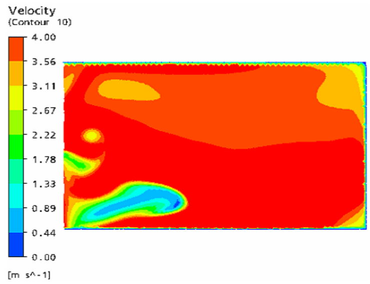

Fig. 8. Velocity contours on plane before eco

CONCLUSION

The most common and reliable economizer design is the bare tube, in-line, cross flow type. When coal is fired, the flyash creates a fouling and erosive environment. The bare tube, in-line arrangement minimizes the likelihood of erosion and trapping of ash as compared to staggered arrangement. It is also easiest geometry to be kept clean by soot blowers. To reduce capital costs, most boiler manufacturers have built economizers with a variety of fin types to enhance the controlling gas-side heat transfer rate. Fins are inexpensive parts which can reduce the overall size and cost of an economizer. However, successful application is very sensitive to the flue gas environment. Surface clean ability is key concern. In selected boilers, such as coal-fired units, extended surface economizers are not recommended because of the peculiar flyash characteristics. Stud fins have worked reasonably well in gas-fired boilers. However, stud finned economizers have higher gas side pressure drop than a comparable unit with helically-finned tubes. Studded fins have performd poorly in coal-fired boilers because of high erosion, loss of heat transfer, increased pressure loss and plugging resulting from flyash deposits

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