PERFORMANCE TEST ON WATER TUBE STEAM BOILER

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Abstract - In the present scenario of energy demand overtaking energy supply top priority is given for energy conservation programs and policies. Most of the process plants are operated on continuous basis and consumes large quantities of energy. Efficient management of process system can lead to energy savings, improved process efficiency, lesser operating and maintenance cost, and greater environmental safety. With the growing need for energy conservation, most of the existing process systems are either modified or are in a state of modification with a view for improving energy efficiency. Any new proposal for improving the energy efficiency of the process or equipment should prove itself to be economically feasible for gaining acceptance for implementation. The focus of the present work is to study the effect of system modification for improving energy efficiency.

Key Words: Efficiency improvement, boilers, etc…

1. BOILERS

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care. The process of heating a liquid until it reaches its gaseous state is called evaporation. Heat is transferred from one body to another by means of radiation, which is the transfer of heat from a hot body to a cold body without a conveying medium, convection, the transfer of heat by a conveying medium, such as air or water and conduction, transfer of heat by actual physical contact, molecule to molecule.

The reference number should be shown in square bracket

[1]. However the authors name can be used along with the reference number in the running text. The order of reference in the running text should match with the list of references at the end of the paper.

Eg 1: As per Kong, the density of X increases with Y [9].

Eg 2: It is reported that X increase with Y [45].

1.1 Performance evaluation of boiler

The performance parameters of a boiler, like efficiency and evaporation ratio, reduces with time due to poor combustion, heat transfer surface fouling and poor operation and maintenance. Even for a new boiler, reasons such as deteriorating fuel quality and water quality can result in poor boiler performance. A heat balance helps us to identify avoidable and unavoidable heat losses. Boiler efficiency tests help us to find out the deviation of boiler efficiency from the best efficiency and target problem area for corrective action.

1.2 Efficiency of boiler

Thermal efficiency of a boiler is defined as “the percentage of (heat) energy input that is effectively useful in the generated steam.” There are two methods of assessing boiler efficiency:

The Direct Method: the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel

The Indirect Method: the efficiency is the difference between the losses and the energy input

2. HEAT EXCHANGER ANALYSIS

Heat transfer units that use steam to produce hot water are known as indirect heaters. They are often shell and tube type heat exchangers and are generally referred to as converters, hot water generators, and instantaneous heaters. The ASME Code for Unfired Pressure Vessels is the nationally recognized authority prescribing their construction for given temperatures and pressures. The term used varies with the heating medium and the manner of application. When these heaters use steam as the heat source they are usually called steam to water converters. In steam heated converters, the water to be heated circulates through the tubes and steam circulates in the shell surrounding the outside of the tubes. This results in condensate draining to the bottom of the heat exchanger shell as the steam gives up its latent heat.

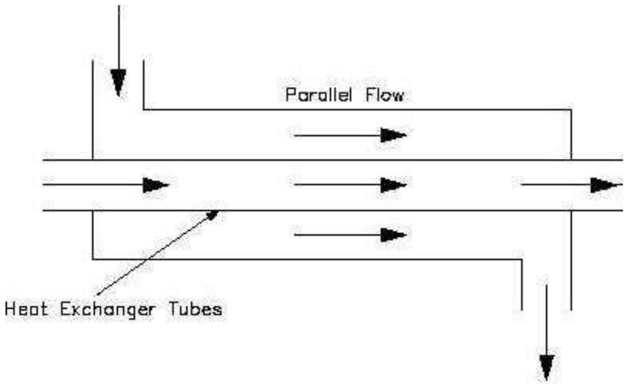


Fig – 1: Parallel flow heat exchanger

Water preheater:

Input data:

$T_1 = 212$

$T_2 = 146$

$t_1 = 102$

$t_2 = 145$ °C

Assume,

Outer dia of tube = 0.019m (14BWG) Internal dia of tube = 0.014m 0.025m inch square pitch Take $F_T = 0.8$

$$LMTD = \frac{(T_1 - t_1) - (T_2 - t_2)}{\ln(\frac{T_1 - t_1}{T_2 - t_2})}$$

$$LMTD = \frac{(212 - 102) - (146 - 145)}{\ln(\frac{212 - 102}{146 - 145})}$$

= 23.18 °C

= 296.33K

Determining heat transfer coefficient,

$$A = \frac{Q}{U_{assume} \times LMTD \times F_T}$$

$U = 2200 W/m^2K$ $Q = m \times Cp \times \Delta t$

$$= \frac{0.586 \times 2709 \times 339.15}{2200 \times 296 \times 0.8}$$

$= 1.033 m^2$ Calculating no. of tubes,

$$n_t = \frac{A}{\pi d_0 L_t}$$

$$\frac{hi * 0.014}{0.6850} * (\frac{0.000225 * 4250}{0.6850})^{-\frac{1}{3}}$$

A-Area of heat transfer in sq. meter

d_0-outer diameter of the tube in meter L_t-Length of the tube in meter

$$= \frac{1.033}{\pi \times 0.019 \times 6}$$

= 2.88

26 is the closest value in TEMA, so take nt = 26 Shell ID = 8 inch according to TEMA book

To calculate velocity of fluid through the tube,

$$R_e = \frac{4 m_c \left(\frac{n_{pass}}{n_{tubes}}\right)}{\pi \times d_i \times \mu_c}$$

$$= \frac{4 \times 6.93 \times \frac{2}{26}}{\pi \times 0.019 \times 0.000225} = 158768 > 10^4$$

Where,

R_e= Reynolds Number

m_c= mass flow rate of cold water

n_{pass}=no. of passes = 2

n_{tubes}=no. of tubes

d_i= inner diameter of the tube

μ_c=Dynamic Viscosity

$$\text{Velocity} = \frac{Re \times \mu(water)}{Di \times \rho}$$

$$= \frac{158768 \times 0.000225}{0.019 \times 945}$$

= 1.98 m/s

So the fluid velocity through the tube is in the optimum condition. So the best design parameters for tubes of water preheater is,

- ¾ inch Od of tube.
- Length of tube = 6 m
- Internal diameter(ID) = 0.584 inch
- Number of tube = 26
- Shell id = 8 inch

$$Jh = \frac{hi * di}{K} \left(\frac{\mu * cp}{k}\right)^{\frac{-1}{7}} \left(\frac{\mu}{\mu(water)}\right)^{-0.14}$$

Shell side assumption

- 25% cut segment baffles
- Baffle spacing, B=0.5”
- D_s (Half of shell diameter)=4 inch

Equivalent diameter for the shell side,

$$De = \frac{4(Pt^2 - \frac{\pi}{4}Do^2)}{\pi * Do}$$

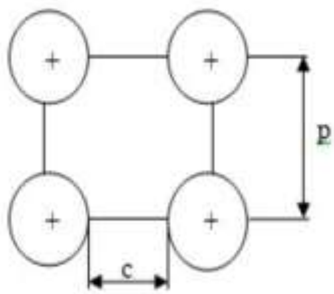
Pt = pitch of tube (1 inch)

$$De = \frac{4(0.025)^2 - \frac{\pi}{4}\times(0.019)^2}{\pi\times 0.019}$$

= 0.024m

Shell side cross flow area As =

$$\frac{CBDs}{Pt}$$



C = tube clearance

= Pt – Do

= 1 – ¾

= 0.25 inch = 0.00635m

$$As = \frac{0.00635\times 0.0127\times 0.101}{0.0254}$$

$= 5.13\times10^{-3}\ m^2$

Mass velocity of shell,

$$Gs = \frac{m_s}{As}$$

$$= \frac{0.586}{5.13\times10^{-3}}$$

$= 114.23 kg/m^2s$

$$Re = \frac{De * Gs}{\mu}$$

$$= \frac{0.024\times 114.23}{15.10\times10^{-6}}$$

$= 181557.6 > 10^4$ Assume jH = 130 for Re = 181557.6

$$\frac{ho * De}{k}\left(\frac{\mu * cp}{k}\right)^{\frac{-1}{3}}\left(\frac{\mu}{\mu(water)}\right)^{-0.14}$$

$$130 = \frac{ho\times 0.024\times 0.92}{0.03268}$$

$= 191.93\ W/m^2K$

Heat transfer coefficient of shell side = $191.93\ W/m^2K$

Pressure drop calculation of tube side,

$$At = \frac{no.of\ tubes * flow\ area\ /tube}{no.of\ passes}$$

$$= \frac{26*0.00017}{2}$$

$= 2.21\times10^{-3}\ m^2$

Tube side mass velocity Gt,

$$= \frac{m_w}{At}$$

$$= \frac{6.93}{26\times2.21\times10^{-3}}$$

$= 120.6\ kg/m^2s$

Frictional pressure drop = $\frac{fGt^2 LtnP}{7.5*10^{12}*Di*Sk*\emptyset t}$

$$= \frac{0.0002\times3135^2\times6\times2}{7.5\times10^{12}\times0.019\times0.9\times1}$$

= 0.017 Pascal

Return loss, ΔPrt = $1.334*10^{-13}*(2nP-1.5)\frac{Gt^2}{Sk}$

= Negligible value (2 pass)

Total tube side pressure drop,

$\Delta Pt = \Delta Ptf + \Delta Prt$

= 0.017 Pascal

Shell side pressure drop calculations,

Tube clearance, C = 0.25

Spacing B = 15.5 inch

$As = 5.13\times10^{-3}\ m^2$

Mass velocity $Gs = 114.23\ kg/m^2s$

Re = 181192

No. of baffles = $\frac{\text{Tube legth}}{\text{baffle spacing}}$

$$= \frac{6}{0.393}$$

= 15.26˜16

Shell side frictional pressure drop,

$$\Delta Pf = \frac{fGs^2 Ds(nB+1)}{7.5*10^{12} De*Sw*\emptyset}$$

$$= \frac{0.00009\times(114.23)^2\times0.203\times(16+1)}{7.5\times10^{12}\times0.024\times0.685\times1}$$ = Negligible value

Input data,

$T_1 = 212°C$

$T_2 = 111°C$

$t_1 = 27°C$

$t_2 = 110°C$

Mass flow rate of steam = 0.294 kg/sec Mass flow rate of air = 6.54 kg/sec

LMTD =

$$\frac{(T_1-t_1)-(T_2-t_2)}{\ln(\frac{T_1-t_1}{T_2-t_2})}$$

$$= \frac{(212-27)-(111-110)}{\ln(\frac{212-27}{111-110})}$$

= 35.24 °C

= 308K

Area of the tube ,

$$A = \frac{Q}{U_{assm}*LMTD*FT}$$

U of air = 25 W/m^{2}K Assume fouling factor FT = 0.8

$Q = m_s*Cs*(T_1-T_2)$

$$A = \frac{0.294\times2479\times374.15}{25\times308\times0.8}$$

= 44.26m^2

Calculating no. of tubes,

$$N_t = \frac{A}{\pi*Do*Lt}$$

$$= \frac{44.26}{\pi\times0.019\times8}$$

= 92.68

So take nt = 97 (according to TEMA book)

Reynolds no. of the fluid through the pipes,

$$Re = \frac{4*m(air)*(\frac{np}{nt})}{\pi*Di*\mu(air)}$$

np = No. of pass

nt = No. of tubes

Di = internal dia of shell = 13.25 inch(0.336m)

$\mu = 20.59\times10^{-6}$ Ns/m^2

$$Re = \frac{4\times6.54\times(\frac{1}{97})}{\pi\times0.336\times20.59\times10^{-6}}$$

= 12408.5

Velocity of the fluid through the tube,

$$= \frac{Re*\mu(air)}{Di*\rho(air)}$$

$$= \frac{12408.5\times20.59\times10^{-6}}{0.336\times1.029}$$

= 0.73 m/s

3. CONCLUSIONS

The objective of the study was to analyze the overall efficiency and the thermodynamic analysis of boiler. There are many factors, which are influencing the efficiency of the boiler. The fuel used for combustion, type of boiler, varying load, power plant age, heat exchanger fouling they lose efficiency. Much of this loss in efficiency is due to mechanical wear on variety of components resulting heat losses. Therefore, it is necessary to check all the equipments periodically. Moreover, it is noticed that the overall efficiency of any boiler depends upon the technical difficulties under unpredictable conditions. Hence, a viable study is carried out to assess the performance of boiler plant in this context. The paper set to show the weakness of depending on energy analysis only boilers as a performance measure that will help improve efficiency.

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