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Design and Analysis of Heat Exchanger to Preheat the Boiler Feed Water by Blow Down Water

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Abstract - In present scenario, the energy crisis is the major problem faced by all the industries. The Cogeneration plant has two multi fuel boiler produces 170 Tons per hour of steam at a pressure of 86 kg/sq.cm at a temperature of 510˚C. The steam is used to produce electric power and the exhaust steam is being supplied to sugar plant to boil the sugarcane milk. Blow down water from the boiler has a temperature of 100 to 115 degree Celsius. This heat is transferred to the feed water by using shell and tube heat exchanger. In this project an attempt has been made to utilize the waste heat by a heat exchanger. By considering these design parameters namely outlet temperature of blow down, Inlet temperature of feed water, Mass flow rate of water, the shell and heat exchanger designed. Finally, the potential savings are presented by implement the newly designed heat exchanger. In heat exchanger, the cold water flows over the tube and the hot water flows inside the tube. In turns there is a scope for reduction in fuel consumption.

Index words - shell and tube heat exchanger, waste heat recovery, blow down water, feed water preheat.

I. INTRODUCTION

The co-generation boiler at Producing 170 Tons per hour of steam, at the pressure of 87 kg/sq.cm at the temperature of 510±5°C. The fuel is coal cum bagasse. The boiler is designed for 100% bagasse and 100% of coal firing. The rated capacity of fuel for the boiler is 130 Tonnes/day. This system is branched into 9atm and 3atm steam line at a temperature of 510±5°C. The 3atm steam is sent to sugar plant for crystal sugar making process. The above point was considered to design the heat exchanger to utilize the blow down water temperature to heat the feed water. Thus, the temperature of feed water is increased by 15°C to20°C. In turns, the outlet blowdown temperature is reduced to 30°C to 40°C.A heat exchanger is designed to transfer the heat from the blow down water to the feed water. While designing, the mass flow rate of the feed water will not be affected, because reduce in mass flow rate of the water will affect the effectiveness of the steam generation and thus the efficiency may reduce. So, the right design parameters are calculated without affecting the flow rate of feed water. By this, designing shell and tube heat exchanger is suitable to heat the water from the return blow down effectively. Since, the heat energy acquired by increasing the temperature from 15°C to 20°C, the fuel consumption is reduced in the boiler furnace. So, there is a scope in reduction in fuel consumption and increase the economy of power plant.

II. LITERATURE REVIEW

2.1 Alok Vyas[1]:

They experiment the tubular heat exchanger and also considered the various design factor that are to be taken while designing the tubes for the tubular heat exchanger. This paper experimented the analysis to predict the character difference in temperature and pressure reduction. In this paper number of tubes, baffles and baffles inclination are considered as a design factor. This paper shows how to improve the efficiency of heat exchanger.

2.2 Karan G. Gaya Wad [2]:

Waste heat can be generated by various methods i.e. by fuel combustion, by chemical reaction. The recovery of the waste heat is depending on the part of the waste heat temperature. The energy cannot be converted fully into a useful work but it recovers a maximum energy. Lots of heat energy is lost in the blow down water so it is need to recovery the heat by adding the heat exchanger. The waste heat can be utilized to heat the boiler water. The heat required to heat the boiler water is reduced. This blow down water can be used as feed water so the usage of boiler water is reduced.

2.3 J. Nityanandam [3]:

An experimental study of characteristics of heat transfer with or without insert by using shell and tube heat exchanger. Experiment effectiveness and overall heat transfer can be calculated using with or with our insert. Heat transfer should be effective in twisted tapes in heat exchanger.

The process variable like flow, pressure, level and temperature are the main parameters that are to be controlled. The heat transfer operation is important in the heat exchanger. The heat transfer may be liquid to liquid, gas to gas etc.,

2.4 S. Arunkumar[4] :

Steam generators are broadly utilized as a part of businesses for a few purposes like power creation, handling, warming and so forth. In industry steam generators are the real fuel customers. In an ordinary steam generator around 4% of high temp dilute is wasted as blow. Because of this, a lot of heat vitality is wasted. This venture plans to convey a heat recovery to minimize loses, so that a huge heat recovery can be made. So in this a heat recovery was intended to minimize the loses.

2.5 R .Keerthi[5]:

In this experiment analysis the boiler blowdown and energy savings has been carried out in and industrial establishment. Steam boilers need to be blow down to control the level of TDS in the boiler water. Feed water has a low TDS level then changes the discharge boiler water. The objective of this paper is the blow down analysis of water tube boiler in the plant and analyzed the annual savings. By conducting separated case studies on TDS measurement calculation on boilers, the savings that could be achievable in corrected systems and operations in the average TDS level. Since the system is being done manually without any actual online measurements, the boiler water TDS varies.

2.6 Rajagopal, Thundil Karuppa Raj and Srinath Ganne[6] :

They investigate the impacts of baffle inclination angles on shell and tube heat exchanger for fluid flow and the heat transfer characteristics. Three different baffle inclination angles namely 0°, 10° and 20° are taken. The simulation results for different shell and tube heat exchangers are compared for their performance. In this project various shell and tube heat exchangers, one with segmental baffles perpendicular to fluid flow and two with segmental baffles inclined to the fluid flow direction has been taken. The shell side design has been investigated numerically by modeling a shell and tube heat exchanger. This study concerns only single shell and single side pass parallel flow heat exchanger. For the baffle cut of 36%, the heat exchanger performance is investigated by varying mass flow rate and baffle incline angle. For the computational fluid dynamics simulation results outlet temperature, pressure drop, recirculation by baffles, optimal mass flow rate and optimal baffle inclination angle are investigated. It results that the shell and tube heat exchanger with 20° gives better performance.

2.7 Durgesh Bhat, Priyanka M Javhar[7]:

A heat exchanger is a device that is utilized to exchange heat energy (enthalpy) between two or more liquids, at various temperatures and in thermal contact. In this issue of heat exchange included the condition where different constructional parameters are changed for getting the performance under various conditions. The tube diameter, tube length, shell types are standardized and are available just in specific sizes and geometry. The design of shell and tube heat exchanger involves several trial and error removal procedures. Since a few combinations of the outline setups are conceivable, the designer needs an effective system to rapidly find the plan design having the minimum heat exchanger cost. In this specific issue the tube metallurgy and baffle spacing are being changed the outcomes are obtained. In current paper the baffle spacing and tube metallurgy are the parameters considering change and impact of the same of heat transfer coefficient have been considered.

2.8 A.GopiChand, A.V.L.Sharma, G.Vijay[8]:

In this paper, a simplified model for the investigation of thermal analysis of shell-and-tubes heat exchangers of water and oil sort is proposed. Shell and Tube heat exchangers are having special significance in boilers, oil coolers, condensers, pre-radiators. They are broadly used in part of process applications as well as the refrigeration and aerating and cooling industry. The strength and medium weighted shape of Shell and Tube heat exchangers make them perfectly suited for high pressure operations. In this paper the demonstration to done the heat investigation, the practical problem has been taken and designed using Pro-e. And it was analyzed using Floefd software. For simplification of theoretical calculations Matlab code is prepared for calculating the thermal analysis of shell and tube heat exchanger.

III. METHODOLOGY

The Boiler feed water (De-Mineralization make up water) inlet temperature 30°C. The quantity of makeup water is 450 MT/day. The continuous blow down water came from boiler at 270°C. And 86 kg/cm2 pressure. After flashing the flash vapour goes to De-aerator. The remaining quantity of blow down water is 40 MT/day at 115°C. In this project a heat exchanger is designed for utilizing the boiler continuous blow down water temperature to heat the feed water (De-Mineralization make up water) before entering the feed water tank. So we can able to extract the heat energy from this continuous blow down water before entering the feed water tank. At the same time the blow down water temperature reduced from 115°C to 80°C. and overall efficiency of the power plant will be increased.

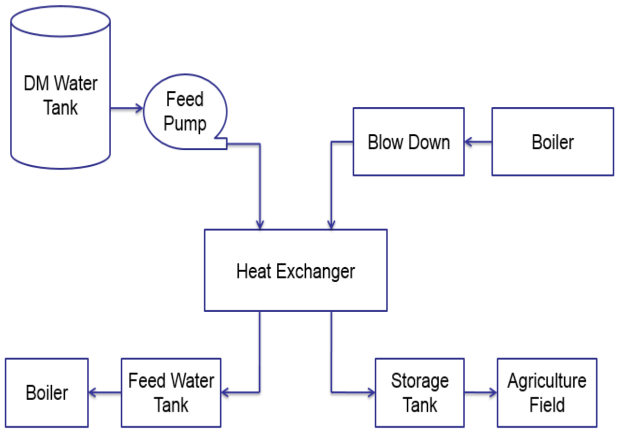

Fig.1, Flow Chart

IV. SHELL AND TUBE HEAT EXCHANGER

Shell and tube heat exchanger is heat exchanger in which the tubes are settled inside cylinder called shell. In that the hot and cold fluid flows inside the tube and flows over the tubes. Generally, shell and tube heat exchanger is well suited for pressure applications. Due to its simplicity of design and various applications, it is widely used all over the world.

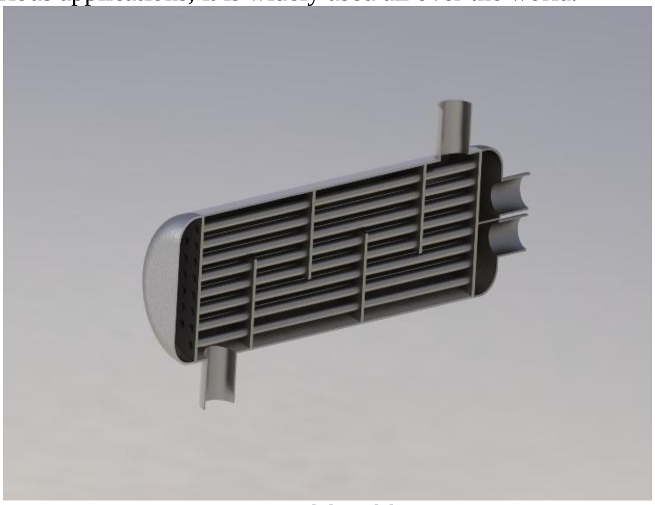

Fig.2, Solid Model

4.1 PARTS DESCRIPTION

The parts of the shell & tube heat exchanger are

- Tube sheet
- Baffle
- Shell
- Banks of tube
- Gaskets
- Connectors

4.1.1 TUBE SHEET

Tube sheet are the holed sheets in which the tubes are attached. It made the tube to arrange in order according to holes in it. The tube sheet made the fluid to flow inside the tube.

4.1.2 BAFFLE

Baffles are flow-directing parts inside the shell. It is generally meant for creating a circulation of water inside the shell. Due to that the Reynolds number increases. Thus heat transfer also increases. A baffle is designed to support tube bundles and direct the flow of fluids for maximum efficiency.

4.1.3 SHELL

Shell is the outer cover of the heat exchanger which guides and supports the outer fluid to move. The fluid moves in between the tube and the sheet. Shell also gives a mechanical support to the baffles. These shells prevent the heat loss from the fluid to the atmosphere and also from the atmosphere to the fluid. Shell materials have a low thermal conductivity or insulated to avoid the heat loss. It also has high corrosion resistance in fluid heat exchangers.

4.1.4 TUBES

Tubes are the small pipes carrying the hot or cold fluid inside. The heat energy transfer takes through the tubes. Conductive heat transfer takes place at the inside and outside surfaces of the tubes. The conductive heat transfer takes place across the cross section of the tube. The tube material should have high thermal conductivity and high corrosion resistance.

4.1.5 GASKETS

Gaskets are the leak preventive material. These gaskets are placed in between the tube sheets and the head. These materials also withstand the heat of the fluids.

4.1.6 CONNECTORS

Connectors are the pipe lines connectors, which connects the pipe lines to the shell or the head of the heat exchanger. These connections are welded with the shell and head of the heat exchanger. These connections are made up of temperature resistance material and high corrosive resistance material.

4.2 TYPES OF FLOW ARRANGEMENTS

Heat exchangers may be classified according to their flow arrangements. In parallel flow heat exchangers, the two fluids enter the exchanger at the same end, travelling in parallel to one another and exits at same end.

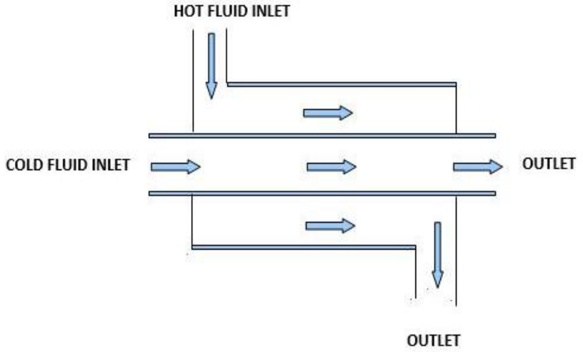

Fig. 3, Parallel flow heat exchanger

In the counter flow heat exchanger, the fluid enters the exchanger from opposite ends. The counter current design is most efficient, in that with can transfer the most heat.

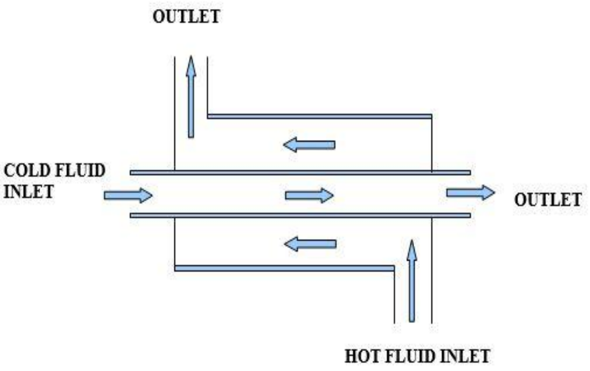

Fig. 4, Counter flow heat exchanger

In a cross flow heat exchanger, the fluid travel roughly perpendicular to one another through the exchanger. For efficiency, heat exchangers are designed to maximize the contact surface area between the two fluids, while minimizing resistance to fluid flow through exchanger. The exchangers performance can also be affected the addition of fins in one or both direction, which increase surface area and may channel fluid flow or induce turbulence.

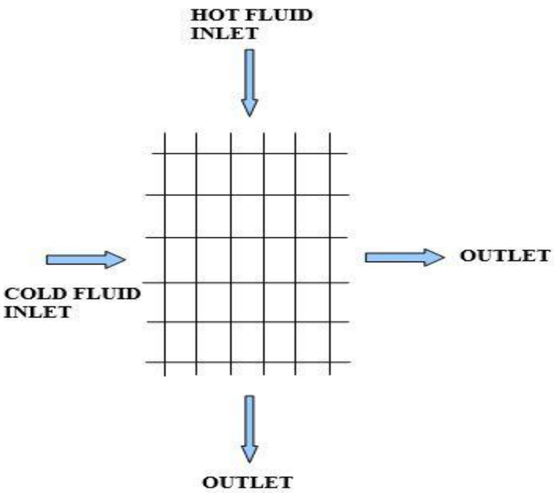

Fig.5, Cross flow heat exchanger

4.3 SHELL AND TUBE ARRANGEMENTS

In our project we are using BEM TEMA standard shell and tube configuration. In this type the shell has single pass flow and the tube has two pass flow.

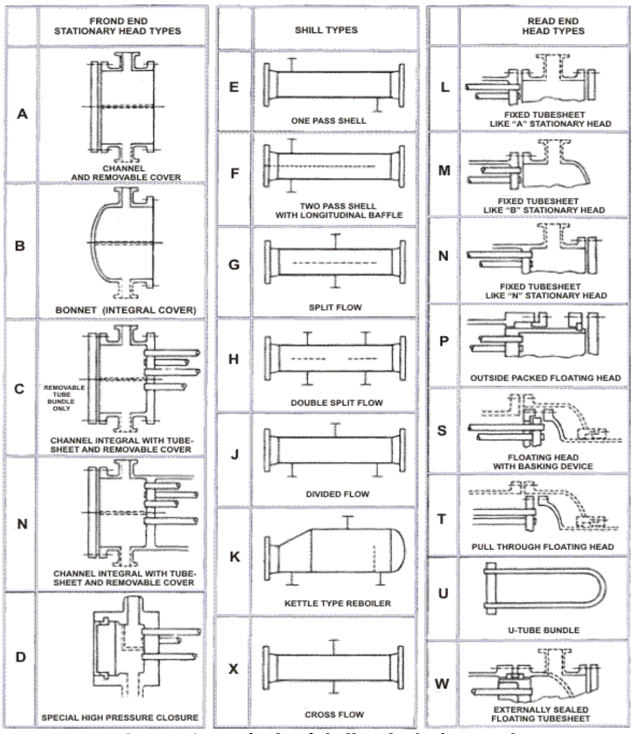

Fig. 6, TEMA standards of shell and tube heat exchanger

V. DESIGN & CALCULATION

NTU Method

$$NTU = \frac{UA}{C_{min}}$$

TO FIND THE AREA OF TUBE

Area of tube(A) = $\pi \times d \times l$

Where,

Diameter of the tube (d) =0.02 m

Length of the tube (l) = 1.00 m

Area of tube = π x 0.02 x 1.00

= $0.0628m^2$

We know that,

Heat loss in hot water = Heat gain in cold water

$Q_h = Q_c$

$Q_h = m_h \times C_{ph} (T_1 - T_2)$

$Q_c = m_c \times C_{pc} (t_2 - t_1)$

$m_h \times C_{ph} (T_1 - T_2) = m_c \times C_{pc} (t_2 - t_1)$

3 x 4241.5 (115 – T_2)=5.15 x 4178 (50 – 30)

$$T_2 = \frac{(1463317.5 - 430334)}{12724.5}$$

T_2=81.18° C

From **HMTdata** book

Heat transfer Q= UA $(\Delta T)_{lm}$

Where, U- Heat transfer co-efficient = 2900 W/m²k(From HMT data book pg.no. 156)

We know,

$$(\Delta T)_{lm} = \frac{(T1-t2)-(T2-t1)}{ln\left[\frac{(T_1-t_2)}{(T_2-t_1)}\right]}$$

$$= \frac{(115-50)-(81.18-30)}{ln\left[\frac{(115-50)}{(81.18-30)}\right]}$$

$$= \frac{(65-51.18)}{\ln\left[\frac{65}{51.18}\right]}$$

$$= \frac{13.82}{\ln(0.239)}$$

$$= \frac{13.82}{0.239}$$

$= 57.82°$ C

To calculate heating surface area

$Q = UA\ (\Delta T)_{lm}$

$$A = \frac{Q}{U \times (\Delta T)_{lm}}$$

$$= \frac{430334}{(2900 \times 57.82)}$$

$= 2.5664 m^2$

To Calculate Number of tubes

$$= \frac{\text{Total heating surface area}}{\text{Heating surface per tubes}}$$

$$= \frac{2.5664}{0.0628}$$

$= 40.86$

$= 41$ Nos

VI. SOLIDWORKS FLOW SIMULATON

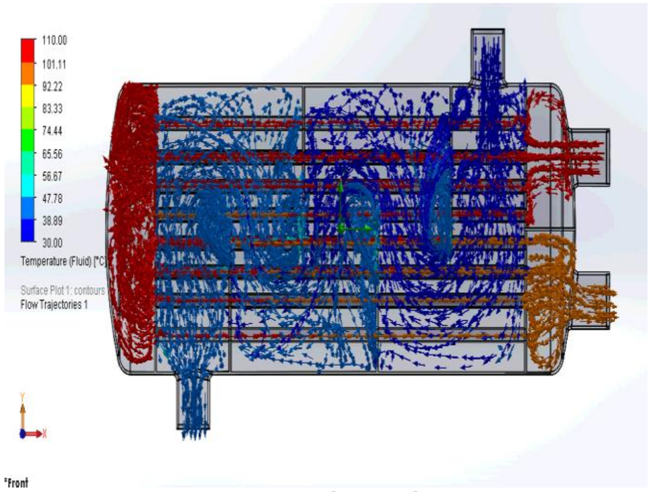

Fig .7, Flow Simulation

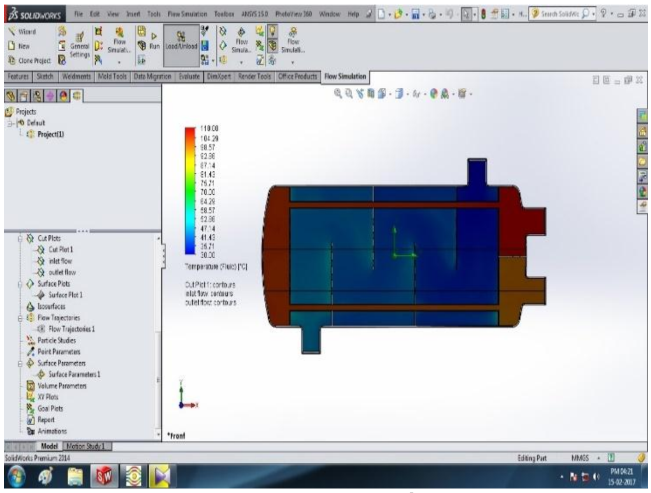

Fig. 8, Temperature Distribution

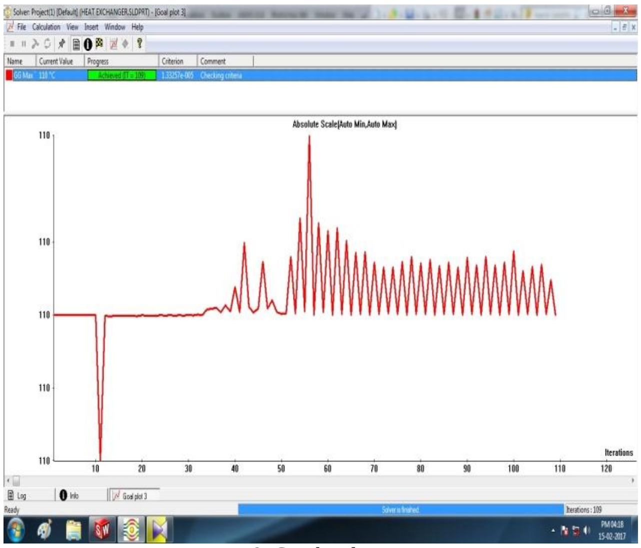

Fig. 9, Graphical Representation

VII. RESULTS AND DISCUSSION

Thus, the heat exchanger is designed to utilize the waste heat from the blowdown water to preheat the boiler feed water. The heat exchanger recovered some amount of heat energy from the blowdown water without wasting it to atmosphere. Thus, the energy saved from blowdown water is used for preheat the feed water. The feed water inlet air temperature gets increased and the blow down water temperature is reduced. The increased water temperature increases the effectiveness of the burning and reduces the fuel consumption. The reduced fuel consumption reduced the money spend for the fuel. Thus, it's an economical benefit of the company.

VIII. CONCLUSION & FUTURE WORK

In this project a methodology is developed to find heat transfer behavior of tube heat exchanger. The distribution of heat transfer co-efficient in shell is investigated. The result shows that there is an improvement in heat transfer in the tube heat exchanger. Finally, the numerically predicted heat transfer result is compared with theoretical result and the difference in heat transfer between shell and tube heat exchanger. The heat exchanger is designed for utilizing the boiler blow down water temperature to heat the boiler feed water before enter in to the feed water tank. So that the temperature is increased 20° C before the feed water tank. At the same time the blow down water temperature reduced from115°C to 80 ° C. In the heat exchanger feed water sent to the tube side at the same time blow down water is through the shell side. The temperature of feed water is increased. Thus the overall cycle efficiency is increased in boiler.

SCOPE FOR FUTURE WORK

The amount of heat transfer is based on the surface area in which the heat transfer occurs. So, in future the use of the fins on the external surface of the tube will increase the heat transfer area which increases the heat transfer rate.

Other types of heat exchanger are suggested to utilize the waste heat effectively.

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