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Reduction of low pressure steam consumption in deaerator of coal fired boiler

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ABSTRACT

ITC PSPD (Bhadrachalam) is one of the biggest and renowned paperboard manufacturers in India. The unit has integrated pulp mill and 7 no's paper and board manufacturing machines powered by its own thermal power plant of installed capacity of 140 MW with a network of 6 turbines and a battery of 9 boilers, which include 3 no's Soda recovery boilers and 5 no's Atmospheric Fluidized bed combustion (AFBC) type and 1 no Circulating Fluidized bed combustion (CFBC) type coal-fired boilers. AFBC and CFBC boilers generate high-pressure steam with 62 ata, 102 ata and temperature 480^{0}C, 525^{0}C respectively. One of the AFBC Boiler of capacity 90 TPH consumes Low-pressure steam 0.150 Tons per Tons of High-pressure steam (Specific LP Steam) which is very high. This can leads to an increase in the cost of HP steam generation. Higher specific low-pressure steam consumption in boilers is a serious concern for the organization because of the low-pressure steam cost is nearly Rs 750/ton. The reason for High LP steam consumption is Low Feed Water temperature which is coming to Deaerator. So we would like to increase the temperature of DM water by recovering heat from a process which is venting to the atmosphere.

Keywords— *Coal fired Boiler, Deaerator, Shell and tube heat exchanger, Kern method, Heat and mass balance, TG condensate, Hot condensate*

1. INTRODUCTION

One of the AFBC boiler (of capacity 90 TPH) HP Steam Generation cost is high due to high low-pressure steam consumption in the Deaerator. Deaerator is an equipment used to remove dissolved gases from the feed water. These dissolved gases expelled out through the vent of the deaerator by heating the feed water up to saturation point, heating is done by using low-pressure steam if the feed water inlet temperature is less, then the steam required to raise the temperature is more. If the feed water temperature is high, obviously the steam required to raise the temperature up to saturation point is less. Hence steam consumption can be reduced if we maintain feed water inlet temperature high. In order to increase the temperature of DM water by recovering heat from a process which is venting to atmosphere

2. THEORETICAL ANALYSIS

Fish-Bone Analysis tool is utilized to find out the solutions to reduce the LP steam consumption in Deaerator of Coal-fired the boiler.

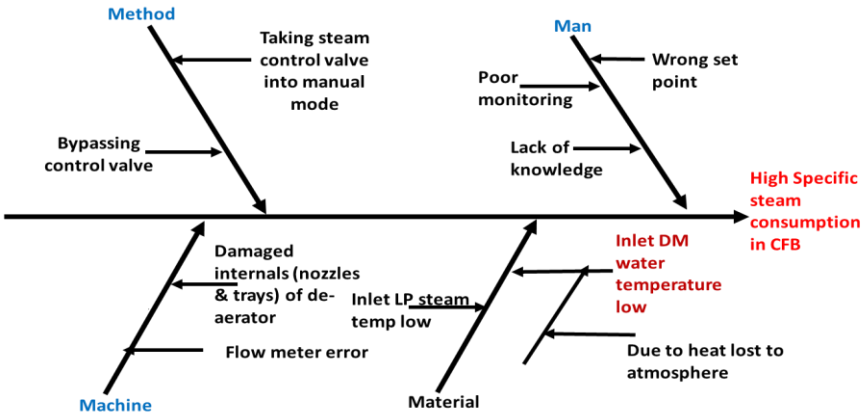

Fig. 1: Fishbone analysis

At present TG condensate to Deaerator inlet temperature is 35^0 C and DM water from DM plant is 45^0C, In Deaerator feed water to be heated with LP steam to remove dissolved gases, it consumes 13.65TPH low-pressure steam and specific LP steam consumption is 0.152 tons/ton of HP steam.

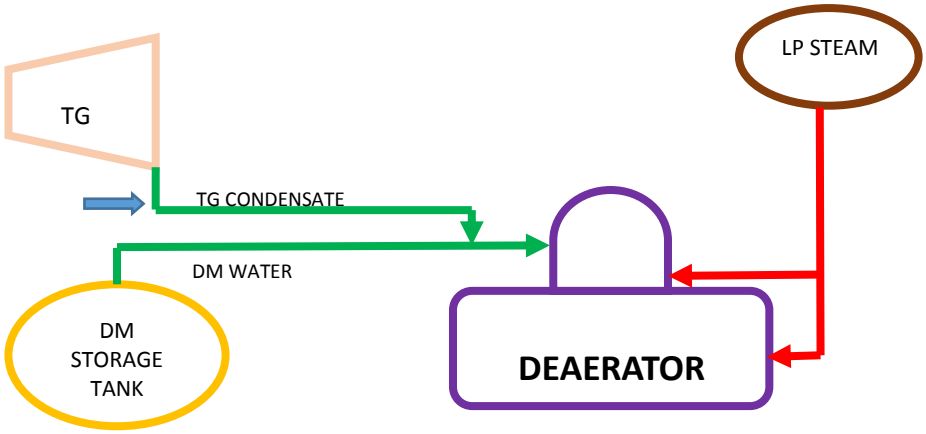

Fig. 2: Present Feed water system to Deaerator

There are some areas in the industry where heat is being vented to atmosphere. Most probably to trap the heat potential we would need a heat exchanger, piping, and pumping energy. The investment would be minimum. By using heat from waste heat venting to atmosphere we can increase the temperature.

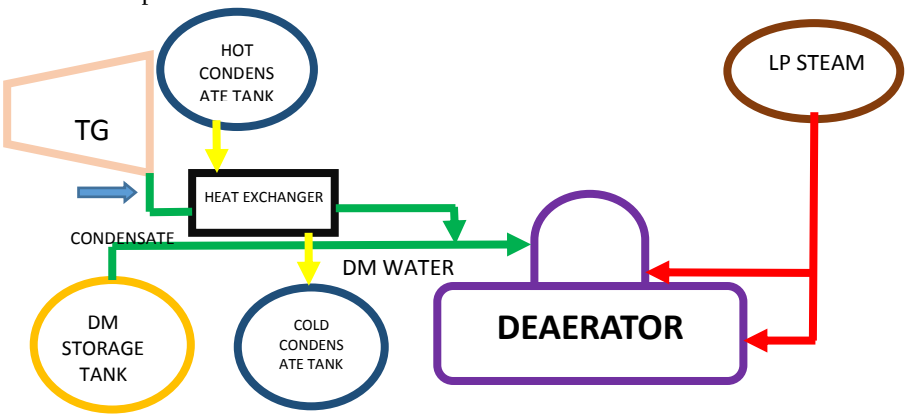

Fig. 3: Proposed feeding system to Deaerator

By installing the heat exchanger we would recover heat from hot condensate 95^0C and converted into cold condensate to temperature 50^0C, As well as Increase of TG condensate which is going to Deaerator from 35^0C to 60^0C, Hence LP Steam required to do heating of feed water to remove dissolved gases will be minimum.

3. SHELL AND TUBE HEAT EXCHANGER DESIGN

Shell and tube type heat exchangers are designed normally by using Kern's method [2]. Kern's method [2] [6] is mostly used for the preliminary design. In this paper, we have designed a simple shell and tube type heat exchanger to heat TG condensate from 35℃ to 60℃ by using waste heat at 95℃ temperature by using Kern's method [2]. The steps of designing are described as follows:

a) First, we consider the energy balance to find out the values of some unknown temperature values. Certainly, some inputs like hot fluid inlet and outlet temperatures, cold fluid inlet temperature, and mass flow rates of the two fluids are needed to serve the purpose. The energy balance equation may be given as:
   $Q = mhCph\ (th1\text{-}th2) = mcCpc\ (tc2\text{-}tc1)$ [1]
b) Then we consider the LMTD expression to find its Value:
   $LMTD = (\Delta T1 - \Delta T2) / \ln (\Delta T1/\Delta T2)$
   Where, $\Delta T1 = th1\text{-}tc2$ and $\Delta T2 = th2\text{-}tc1$
c) Our next step is to calculate the area required of the heat exchanger (on the basis of assumed U0), a number of tubes, tube bundle diameter, the diameter of the shell and its thickness with the help of following expressions:
   $A = Q / (Uo\Delta T)$
   $Nt = A / (\pi dtol)$
   $Db = dto\ (Nt / K1)1/n1$
   $Di = Db$ + additional clearance
   $Do = Di + 2 \times$ thickness
d) Then we calculate the proper baffle dimension viz. its diameter, thickness and baffle spacing [3].
e) Our next step is to find out heat transfer coefficients on the inner and outer surface of the tubes using the following correlation:
   $1/U = (1/Ui) + (/Uo)$
f) Then by the values obtained by the above equation, we calculate the actual value of heat transfer coefficient and check whether the actual value is greater than the assumed one or not.

g) After rigorous mathematical calculations we have found out following values of interest:
mh = 4.63 kg/sec
mc = 7.28 kg/sec
th1 = 95℃
th2 = 50℃
tc1 = 35℃
tc2 = 60℃.
A = 52m2
Dto = 47.6 mm
Dti = 38.1 mm
Nt = 73
T_L = 6000mm
Di = 734 mm
Do = 758 mm
Number of baffles = 19
Baffle spacing = 294mm.

4. EXPERIMENTAL ANALYSIS

4.1 Low-pressure steam consumption as per heat and mass balance sheet before modification

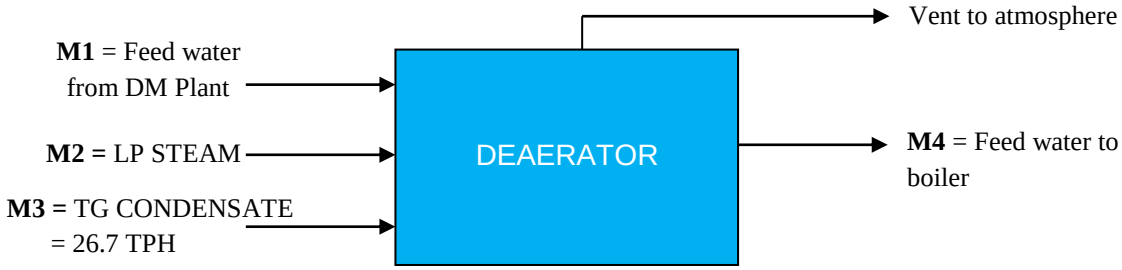

Fig. 4: Schematic of Deaerator without heat exchanger

M4= Mass of Boiler feed water as per design 1.5% of Boiler capacity (90TPH)

M4= 90 + (0.015 X 90)
= 90+1.35
M4= 91.35TPH

T1= Temperature Feedwater inlet to Deaerator (45°C)
T2= Temperature of Low-Pressure Steam Inlet to Deaerator as per Design (160°C)
T3= Temperature of TG condensate (35^0C)
T4= Temperature of Feed Water Outlet to the boiler as per design (134°C)

From steam tables
H1= Enthalpy of Feed Water at 45 degrees = 45kcal/kg
H2= Enthalpy of Low Pressure steam at 4.5kg/cm2 160degrees = 660kcal/kg
H3= Enthalpy of TG condensate at 35 degrees = 35kcal/kg
H4= Enthalpy of Feed water to boiler at 134degrees=134kcal/kg

M1+M2+M3= M4
M1+M2+26.7= 91.35
M1+M2= 91.35 – 26.7
M1+M2= 64.65
M1= 64.65 – M2
M1.H1) + (M2.H2) + (M3.H3) = M4.H4
((64.65 – M2) XH1) + M2.H2 + M3.H3= M4.H4
(64.65X45) – (M2X45) + M2X660= (91.35x134) – (35x26.7)
2909.25 + 615.M2 + 934.5= 12240.9
615. M2= 8397.15
M2= 13.65 TPH
Mass of LP steam (M2) = 13.65 TPH
M1= 64.65 – M2
M1= 64.65 - 13.65
M1= 50.99 TPH

Mass of DM Water to be supplied from DM plant to Deaerator (M1) = 50.99 TPH
Mass of LP steam (M2) = 13.65 TPH

4.2 Low-pressure steam consumption as per heat and mass balance sheet after modification

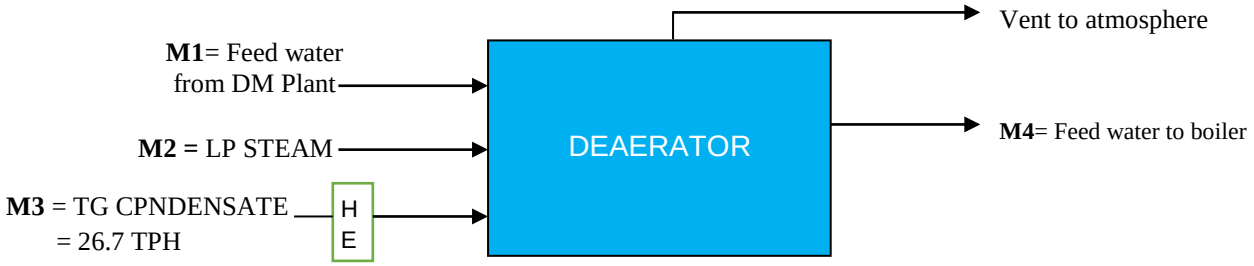

Fig. 5: Schematic of Deaerator with heat exchanger

M4= Mass of Boiler feed water as per design 1.5% of Boiler capacity (90TPH)

M4= 90 + (0.015 X 90)
= 90+1.35
M4= 91.35TPH

T1= Temperature of DM Feedwater inlet to Deaerator from DM Plant (45°C)
T2= Temperature of Low-Pressure Steam Inlet to Deaerator as per Design (160°C)
T3= Temperature of TG condensate (60^0C)
T4=Temperature of Feed Water Outlet to the boiler as per design (134°C)

From steam tables
H1= Enthalpy of Feed Water at 45 degrees = 45kcal/kg
H2= Enthalpy of Low Pressure steam at 4.5kg/cm2 160degrees = 660kcal/kg
H3= Enthalpy of TG condensate at 60 degrees = 60kcal/kg
H4= Enthalpy of Feed water to the boiler at 134degrees =134kcal/kg

M1+M2+M3= M4
M1+M2+26.7= 91.35
M1+M2= 91.35 – 26.7
M1+M2= 64.65
M1= 64.65 – M2
(M1.H1) + (M2.H2) + (M3.H3) = M4.H4
((64.65 – M2) XH1) + M2.H2 + M3.H3= M4.H4
(64.65X45) – (M2X45) + M2X660= (91.35X134) – (26.7X60)
2909.25 + 615.M2= 10638.9
615. M2= 7729.65
M2= 12.57 TPH
Mass of LP steam (M2) = 12.57 TPH
M1= 64.65 – M2
M1= 64.65 - 12.57
M1= 52.08 TPH

Mass of DM Water Inlet required from DM plant to Deaerator (M1) = 52.08 TPH
Mass of LP steam required (M2) = 12.57 TPH

5. CONCLUSIONS

By using Heat Exchanger TG condensate temperature increase from 35 degrees C to 60 degrees C, Thereby LP steam consumption reduced from 13.65 TPH to 12.57 TPH variance of 1.08 TPH, annually it will be 9331.2 tons.
One ton of LP steam cost is Rs 750/- Annual saving in terms of money will be 69.98 lac/annum.

- Saving in steam means saving in coal as steam is produced from coal in our power plant. Hence reduction in natural resource consumption or reduction in depletion of a natural resource with reduced consumption.
- Saving in steam means saving in water, which is again a reduction in consumption of the natural resource.

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