Waste Heat Recovery from Turbine Exhaust to Improve the Boiler Efficiency in Sugar Industry

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Abstract— In sugar factory, the exhaust condensate from process house taken to the boiler feedwater tank (storage tank) then by transfer pump it pumps to deaerator. After deaeration, through boiler feed pump, pumps to boiler. But in modified system, the exhaust condensate from process house to direct deaerator eliminating the feed water tank and transfer pump which saves water flashing, vapour loss and also saves energy of pump operation. By implementing the new method by eliminating the feedwater water tank and feedwater transfer pump, the exhaust steam saved up-to 2.057 MT/hr, as well as deaerator water temperature will be increased up to 106 to 107 oC and save the water flashing, vapour loss and also saves energy of pump operation and finally boiler efficiency increased about 3.98%.

Keywords: Deaerator, Exhaust Condensate, Feed water Transfer Pump, Boiler Feed Pump

I. INTRODUCTION

In the sugar industry a power turbine exhaust steam after generation at power is supplied to process house to boil cane juice to form a crystal sugar in a step by step boiling process (1). The exhaust steam which is supplying to process house is having temperature about 120^{o}C and pressure-2.5 ata. The exhaust steam after applying to juice boiling it loses its temperature and juice gains the temperature. The exhaust steam after losing latent heat it condenses and this condensate is called condensate water (3). This condensate is good quality regain feed to boiler through condensate pump to feedwater tank and again feedwater tank to deaerator then deaerator to boiler through boiler feed pumps.

At present practice, the direct exhaust condensate water injected to the deaerator tank by eliminating the feedwater tank, the water flashing at feed tank is eliminated and water temperature become 106-107^{o}C, actually at exhaust condensate tank water temperature 112^{o}C. While travelling from process house (at exhaust condensate tank) to boiler it loses around 4-5^{o}C temperature. So at deaerator water temperature is around 106-107^{o}C (requirement is 105^{o}C). By implementing the above new method by eliminating the feedwater water tank, feedwater transfer pump, by doing so, increase the water temperature in the deaerator to remove the non condensable gases, Steam conservation up to 2.057t/h, increasing in the additional crushing rate, to save the energy of pump operation by eliminating the feedwater tank and increase the boiler efficiency up to3.98%.

A. Deaerator steam consumption

The deaerator steam consumption is equal to the steam required to heat the feed water to its saturation temperature, plus the amount of vapour vent with the non condensable gases (2). The vent rate is function of the deaerator size, type and amount of makeup water. The operating vent rate is at its maximum with the introduction of cold, oxygen rich makeup water.

B. Pressure Fluctuation

Sudden increase in free or flash steam may cause spike in deaerator vessel pressure, as a result re-oxygenation of feed water (3). So for that pressure regulating valve should be providing to maintain the deaerator at a constant pressure.

II. OBJECTIVES

The direct exhaust condensate water injected to the deaerator tank by eliminating the feedwater tank. The water flashing at feed tank is eliminated and water temperature become 106-107 ^{o}C, actually at exhaust condensate tank water temperature 112^{o}C. While travelling from process house (at exhaust condensate tank) to boiler it loses around 4-5^{o}C temperature. So at deaerator water temperature is around 106-107^{o}C, (requirement is 105^{o}C). By implementing the above new method by eliminating the feedwater water tank, feedwater transfer pump, by doing so,

- Increasing the water temperature in the deaerator to remove the non condensable gases.
- Steam conservation up to 2.057 TPH.
- Increasing in the additional crushing rate.
- Increasing in boiler performance.
- To eliminate the water flashing at feed tank.
- Vapour loss eliminated.
- To save the energy of pump operation by eliminating the feedwater tank.

III. METHODOLOGY

To raise water temperature 105^{o}C from 95-97^{o}C to good deaeration as well as to increase boiler performance we need extra amount of steam. To heat 135 tonne of water from 94^{o}C to 105^{o}C, the 2.057 t/h steam is required. To save above 2.057 t/h exhaust steam which will help to full fill the process demand we adopted direct exhaust condensate water to deaerator tank, eliminating feedwater tank. To take exhaust condensate to deaerator, at deaerator spray nozzles this requires high head water to create spray as well as atomisation of water.

To create high head, high head pumps are installed for exhaust condensate water pump and higher specification pipe line to with stand of pressure 9 kg/cm^{2} is installed; earlier low head pumps and pipe lines are replaced. At deaerator station, the high water temperature water is injected to deaerator through control valves which help to maintain the deaerator water level inside the deaerator tank.

By all above, the exhaust condensate water injected to deaerator tank by eliminating the feedwater tank. By doing so, the water flashing at feed tank is eliminated and water temperature becomes 106-107^{o}C actually at exhaust

condensate tank water temperature 112°C. While travelling from process house (at exhaust condensate tank) to boiler it loses around 4-5°C temperature. So at deaerator water temperature is around 106-107°C. (requirement is 105°C). By implementing above new method by eliminating the feedwater water tank, feedwater transfer pump, the exhaust steam can be saved up to 2.057 MT/hr as well as deaeration water temperature will be increased up to 106 to 107 °C.

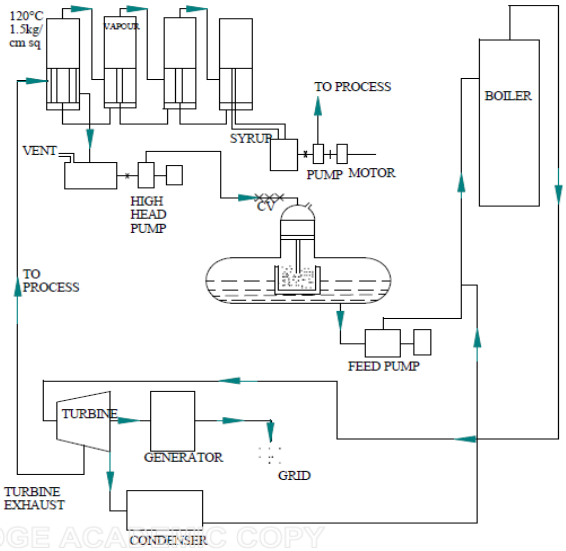

Fig. 1: Direct Exhaust Condensate Water to the Deaerator

A. Probable reason for not achieving water temperature in deaerator

At present practice, is to take exhaust condensate from process to feedwater tank by pump, at feedwater tank condensate water flashes due to its high content of heat. i.e. 112°C (above boiling point) due to this flash huge quantity of vapours are venting out to atmosphere, with this vapour we are also loosing huge amount of boiler feedwater quality water while flashing with this flash vapour condensate water also loses its temperature, tremendously about 15-20°C temperature loosed by water.

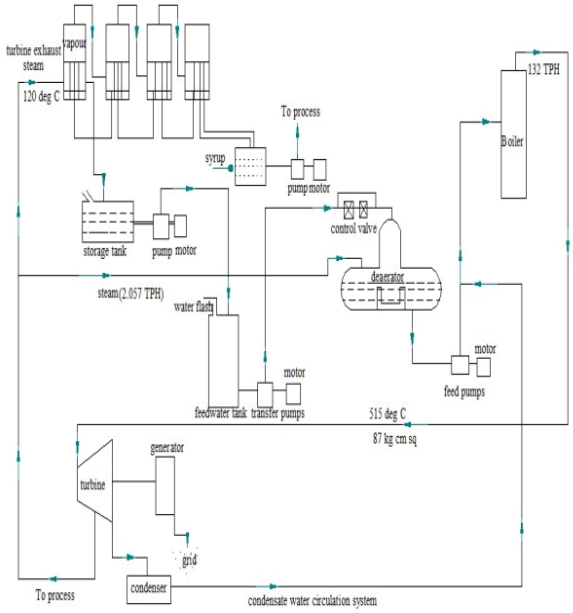

Fig. 2: Before Modification

B. Different Methods to Increase Water Temperature in Deaerator

Based on theoretical observation the following are the best possible methods to achieve the desired deaerator water temperature.

- Adopted direct exhaust condensate water into deaerator by eliminating feedwater tank.
- Blowdown water from the boiler drums through the flash vessel and heat exchanger into the deaerator. (Flash steam becomes available for recovery at flash vessel).
- By installing the HP heater in between turbine and deaerator.

IV. CALCULATION

$T_c = T_s - 0.4(T_s - T_j)$
$= 120 - 0.4(120 - 100) = 112^oC$

A. Exhaust steam requirement

$$\frac{\text{feedwater capacity (feedwater after heating}-\text{before)}}{\text{latent heat}}$$

$$= \frac{135\,(105-97)}{525} = 2.057 \text{ TPH}$$

By providing above exhaust steam to process house, we can increase the crushing rate more. So additional cane crushing by this exhaust steam is,

$= \frac{2.057}{0.35} = 5.87$ MT/hr.

(Steam requirement for process is 35%).

= 140.88 MT/day

B. Flashing vapour

1) Before

Quantity of water = 135 TPH (135000 kg/hr)

Vapour loss = $\frac{135\,(112-97)}{530}$ = 3.820 TPH

2) After

Temperature of deaerator water = 107 °C

Vapour loss = $\frac{135\,(112-107)}{530}$ = 1.273 TPH

Saving the vapour flash = 2.546 TPH

C. Power saving from feed water transfer pump

1) Before

Capacity of pump is 165 m^3/hr and pump is running in range of 80 to 82% (because 135*100/165) continuously so the power consumption is around,

= 1.3×55 = 71.5 HP

(Because 1HP = 0.735kw therefore 1/0.735 =1.3)

Maximum current for motor = 71.5×1.3 = 92.95 ampere

And pump is running at range of 80 to 82% load, therefore load on motor is,

= 92.95×0.80 = 75 ampere

D. Power saving

= V×I×cosφ
= 440×75×0.80 = 26.40 kW/hr (units)
= 26.4×2 = 52.8 kW/h or 1.26 MW/day (because no. of pumps 2).

E. After Modification

Power consumed per day = 26.4 kWh or 633.6 units/day.

F. Fuel saving

$= \frac{100\ (t-t1)}{T+32-t1}$ = 3.37 TPH

G. Boiler efficiency

$= \frac{Q\ (H-h)}{q \times GCV}$

1) Before

At 87 kg/cm^2 and 510^{0}C enthalpy of steam (H) is = 810 kcal/kg

$= \frac{132\ (810-105)}{60 \times 2250}$ = 70.5 %

2) After

Fuel firing rate (q) = 56.63 TPH

Enthalpy of feed water temperature (h) = 107^{o}C

$\eta_b = \frac{132\ (810-107)}{56.63 \times 2250}$ = 74.48 %

V. Result & Discussions

Description	Units	Before	After
Deaerator water temperature	^{0}C	97	107
Vapour flashing	TPH	3.820	1.273
Power exported/day	MW	26	26.63
Fuel firing rate	TPH	60	56.63
Boiler efficiency	%	70.50	74.48

Table.1: Before & After Modification

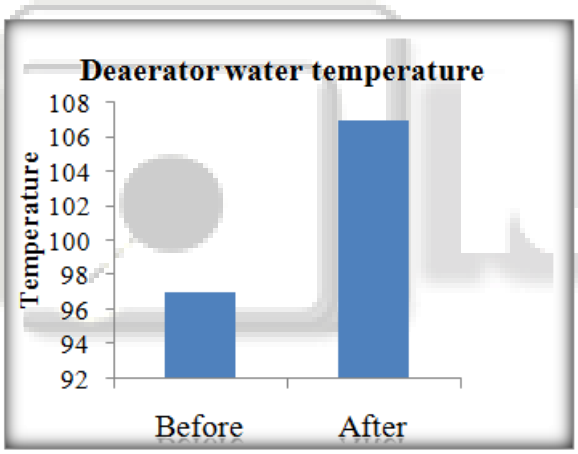

Fig. 3: Deaerator Water Temperature

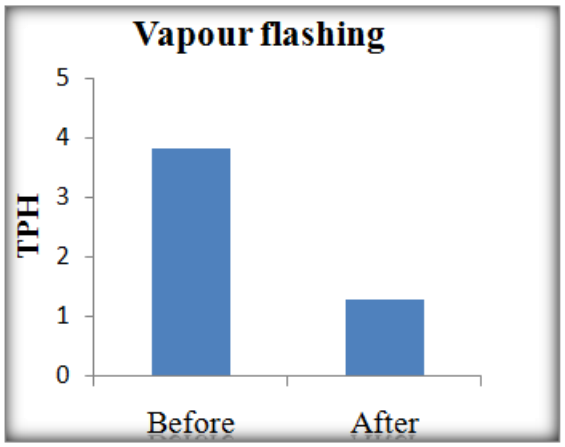

Fig. 4: Vapour Flashing

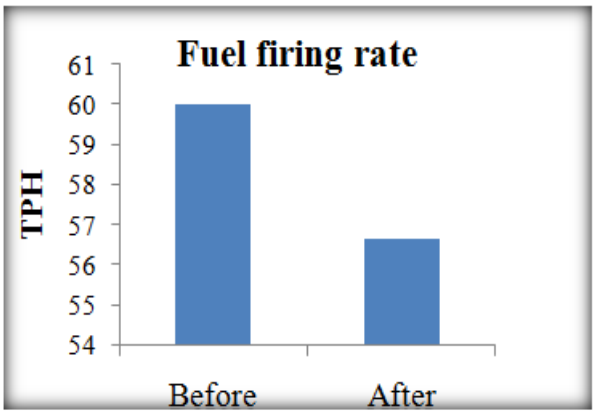

Fig. 5: Fuel Firing Rate

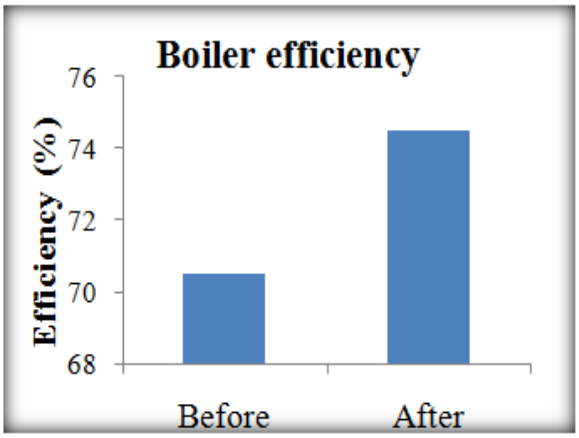

Fig. 6: Boiler Efficiency

VI. Conclusion

After adopting the above method the following improvements are observed.

- Injecting the exhaust condensate water to deaerator tank by eliminating the feedwater tank, the water flashing at feed tank is eliminated and achieve the water temperature about 106-107^{o}C.
- By implementing above new method, the exhaust steam saved up to 2.057 MT/hr.
- Save the energy of pump operation up to 26.40 kilo watt per hour, its mean that saving of power per day is 633.6 units.
- Before adopting method the fuel firing rate will be 60 TPH. So after adopting direct exhaust condensate method, fuel firing rate will be 56.63 TPH. Therefore fuel conservation up to 3.37 TPH.
- Boiler efficiency increases up to 3.98 %.

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