Heat & Water Recovery from Continuous Blowdown Water of AFBC Boiler of a Process Industry

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Abstract:

Heat is a Thermal form of Energy or in next word it's a Thermal Energy. So we can't envisage single activity or life without Energy. Consequently, it's our duty to save energy/heat or keep it in the usable form. However, we are wasting a lot of energy/heat in our daily routine life or in Industry either knowingly or unknowingly by habit. Specially in energy sector where Electric Energy (Electric Energy) are being generated by converting thermal energy (Fossil fuels like Coal, Biomass, Diesel, Furnace Oil etc.) in Electric Energy. One of the Energy waste was noted, in form of Boiler Blowdown water in Power Plant & Process Boilers while this Boiler blowdown water having some substantial heat/energy inside it. Usually Boilers having 1-4% of Blowdown water which consists of pure flash steam & hot water. These blow down water take away lots of heat (fuel) from system, as waste. So we can save a large amount of money & can protect our nearby land from these treated hot water by reusing it.

Keywords – Condensate, Flash steam, Blowdown water, TDS, Waste Heat

Introduction:

With the growing trend of increases in fuel prices over the past decades as well the rising concern regarding global warming, engineering industries are challenged with the task of reducing green- house gas emissions and improving the efficiency of their sites.

In this regard the use of waste heat recovery systems in industrial processes has been key as one of the major areas of research to reduce fuel consumption, lower harmful emissions and improve production efficiency.

So here in this Case we are focusing on saving of waste heat from Boiler Blowdown.

Boiler Blowdown are required to remove sediments & scale causing materials that is accumulated inside the Boiler from the feed water that is top up to it time to time or in continuous basis.

So Two methods of Blowdown are -

Intermittent Blowdown

Continuous Blowdown

Continuous Blowdown are done on regular basis & condensate water with flash steam are thrown away from Boiler into the drain tank or sewer.These Boiler water waste will have many impact on Economic & Environment.

Some are as following –

1.) Depletion of natural resources.

2.Contamination of nearby water resources.

3.Detoriation in Boiler Water Quality if more Top up done.

4.Wastage of flash steam, is purest form of water.

So we should have Boiler's Blowdown water recovery system by force to protect & enhance our economy & environment.

I. Boiler Details –

Coal Fired Boiler - The Boiler normally used in Industries are – Fire Tube type & Water tube type. Usually Water tube boiler are designed if fuel (coal or oil or gas) is required for running the Boiler.

Technical Details –

Type of Boiler (On the Basis of its Combustion)-

AFBC (Atmospheric fluidised Bed Combustion.

Type of Boiler on Basis of Drum Layout – Single steam Drum Bottom supported.

Boiler on Basis of Steam supply – Super heater type.

Technical Details of Boiler–
Design Pressure - 78 Kg/cm2
Design Flow rate - 40 x2 TPH
Furnace - 3 compartment,(4X3) fuel feed points
Steam Drum - Bottom Supported
Manufacturing year - 2017
Heating Surface Area -(1857 x 2)m2
Fuel Used-→ Coal
Boiler Eff.→ 81%

Steam Generated/ day –1440T/ day
Working Days→330 days/year
Required Blowdown -→2% of steam generation
Heat Exchanger Type-→ Plate Type

II. Proposed Idea–

1.Flash steam can be used directly in Deaerator.

2. Blowdown water(CBD) can be used in exchanging its heat from Makeup feed water & subsequently after polishing these blow down water in DM plant, can be used in Boiler water.

III. Difficulties for its application –

a.) Boiler Blowdown water having high phosphate (5-20 ppm), TDS (50-500 ppm) & hydrazine which must be removed before reusing.

Solution- When small amount of Blowdown water is mixed with huge amount of feed water then it's phosphate will come down <1 ppm of phosphate & TDS also. Meanwhile, to trap Silica of Boiler Blowdown water, water has to be filtered through Condensate polishing unit.

b.) How to exchange its waste heat in usable heat?

Solution-

Its heat can be exchanged by installing a PHE in between by following arrangement –

V. MODIFIED PROCESS

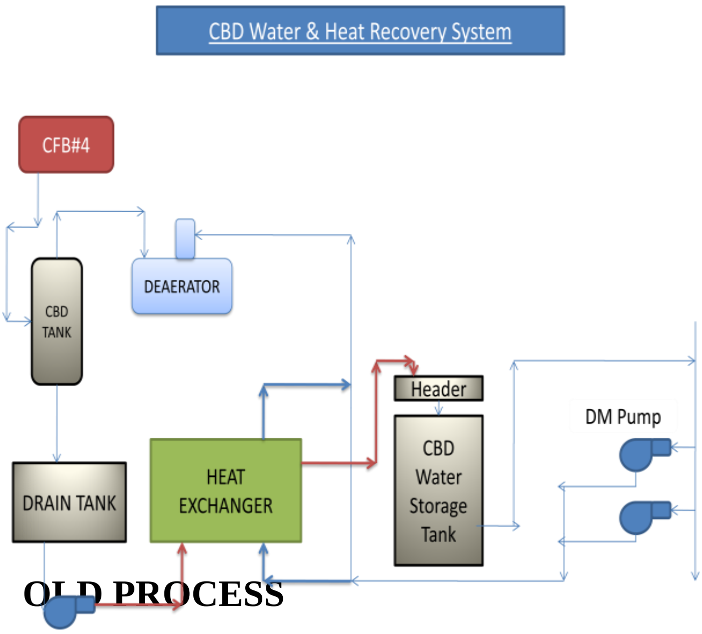

Figure 2

IV. OLD PROCESS

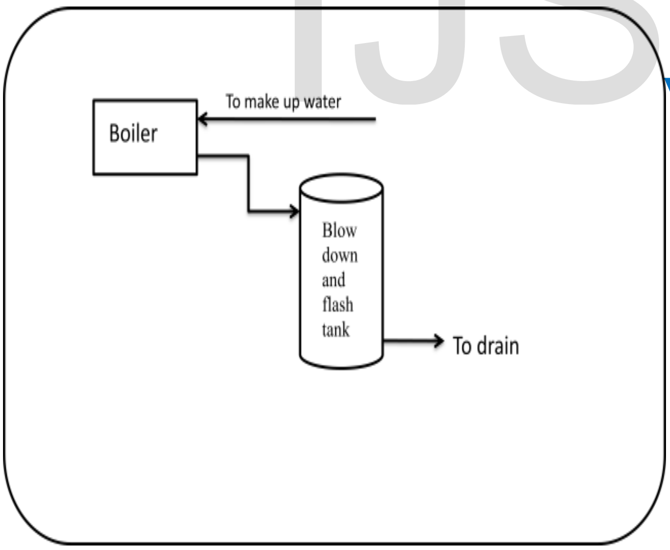

Figure 1

VI. Calculation –

Under study Boiler data –

Steam Drum pressure= 67-68 kg/cm2

So from Saturated Steam table (on basis of Pressure) –

hf1 = 298.7 Kcal/kg
hfg1=663.3 Kcal/kg
hg1 = 364.6 Kcal/kg

CBD Flash tank –

Steam pressure – 0.8 kg/cm2 (corresponding to Deaerator)
Hf2 – 117.2 Kcal/kg
Hfg2 – 645.33 Kcal/kg
Hg2 - 528.15 Kcal/kg

So flash steam % = (hf1-hf2/hfg2)

= (298-117)/528.15
= 34.2 %

Average Blow down per day of Boiler by **practical measurement = 2%**

=1440*0.02

=28.8 TPH

Then Flash steam quantity = 28.8 x 0.34

=9.8 TPH

Then Blowdown water quantity= 28.8-9.8

= 19 TPD

Heat recovered from Blowdown water only after using flash steam directly.

VII. PROPOSEDMETHODOLOGY

The approach of this project will use the underlying convection heat transfer equation Q= hA(dt) this equation willbe used to find out the change in enthalpy required to boil the water in the system. A boiler working at high pressure and high temperature will have to be selected. Most industrial application boilers operate at high pressures and temperature. Hence pressure of the boiler will be close or more than 60 kg/cm2. The variation in enthalpy needed to turn water into steam is very important at the boiler working pressure. Asteam pressure and steam temperature will have to be chosen perfectly to create the necessary heat flux in the heating element. Once heat fluxes have been calculated it could be used to calculate the conduction of heat through the heating element based upon conduction equations through a solid material. This will need an overall heat transfer coefficient due to the possibility of deposition of impurity forming on the heat transfer surfaces of the heating elements. When a temperature of surface is calculated based on the discussion above we can calculate the heat used to boil the feed water for boiler. The LMTD "Log mean temperature difference method" can be used to size this heat exchanger since this method can be used when a phase change is occurring.

After designing heat exchanger, we pass feed water intothe heat exchanger so this feed water get heat from drain water then feed water is passed into deaerator. In deaerator oxygen is removed from feed water and pump feed water to boiler by using boiler feed pump. In many power plant blowdown water is directly drain. If we drain blow down water lots of heat is loss. To recover this heat loss, we will pass this water into condensing polishing unit where we can reduce silica percentage from blow down water and this water can be used as feed water. If this water is used as feed water then we required less feed water to make up, so we reduce consumption of feed water.

By Convection formula –

Q=hA(dt)=UA(dt)=mCp(Tin-Tout)

Q= Total heat transfer in Kcal
h = Convection heat transfer coefficient
dt = Temp drop after heat transfer
U = Universal heat transfer co-efficient of Exchanger
m = mass of blowdown water fluid to exchange heat
Cp- specific heat transfers co-efficient
Tout = Blowdown water exchanger out temp
Tin = Blowdown water in temp.
Qb = Heat Transferred from Boiler Blowdown water

So,

U = 1300 W/m2K
Cp=4.1 Kcal/ (KG* °C)
Tin = 110 °C
Tout=40°C

m=Total CBD Qty. = 19 TPD

Qb= (19*1000*4.1*(110-40))

= 5453000 KCAL/Day

VIII. PHE design –

Now we have to calculate Logarithmic mean temperature difference(LMTD) –

$\Theta m = (\theta 1 - \theta 2)$
$(\ln \theta 1/ \theta 2)$

$\theta 1 = Th1\text{-}Tc1 = 110\text{-} x=70$
$\theta 2 = Th2\text{-}Tc2=40\text{-}30 = 10$

Now from Eqn – A

Qb= Qc
Mb*Cp*(th1 – th2) =Mc*Cp*(tc1 – tc2)
19*4.81*(110-40) =10*24*4.81*(x-30)
X = 35.5

Now

LMTD = (70 – 10)/ (ln (70/10))
= 30.83

Q = UAΘm
=1300*A*30.83
Qb=5453000 kcal/day

= 5453000* 4.8/ (3600*24)

A= 7.56 m2

Heat Transfer Area – 7.56 m2

Heat exchanger Effectiveness **=0.45**

IX. Installation of Heat Exchanger & Transfer Pump

Figure 3 **Heat Exchanger**

We collected one old one small PHE & one New PHE accordingly to fulfill the requirement of required heat surface area.

Table1 – Heat Exchanger Description -

S.No.	Description	
1.	No. of passes on Fluid1 side(Hot)	3
	No.of passes on Fluid side-2(Cold)	1
	Design press fluid to fluid	13 barg
	Design temp Fluid to fluid	120 degC
	Heat Transfer area	7.5
	Plate size (width & height)	320 x 920 mm
	No. of Plates	58
	Relative directions of fluid	Counter current
	Plate material/Thickness	Alloy 316 /0.5 mm
	Sealing Material	NBRP Clip on
	Design Code	ASME Section VIII,Div. 1U
	LMTD	30.83
	Heat Exchanged	227 Mcal/h

X. Other

difficulties which were vital concern during layout designing of this WHRS system was as following –

1. Boiler blow down water is being drained at higher pressure & temperature (Saturation temperature corresponding to Boiler drum pressure). So it's difficult to transfer it directly from boiler drain.
2. It's very difficult to design Heat exchanger of that much higher pressure & temp.
3. Blowdown water quality is comparatively not good as feed water so how to recycle it.
4. Need some type of Automation to control the level of drain tank or CBD tank to avoid dry running of pump
5. Capital cost of Blowdown tank, Control valve, Plate Heat Exchanger, Condensate tank, etc.
6. Lengthy Piping cost to reuse the condensate after polishing it.

After all we decided to keep this PHE near to DM transfer pump that we could check its performance on hourly basis. Simultaneously we made PHE bypass also to avoid any outage of Boiler due to PHE leakage or any type of Failure. As we know that Plate heat exchanger are prone get leak & choke frequently. Apart from this, PHE Heat transfer effectiveness are considered only 45% maximum.

XI. Solution of Problem(pointwise) –

1. We made CBD tank which will be collection tank also for Boiler Blowdown water & it will be used as flash tank. Flash steam will be transferred directly from CBD tank to Deaerator.
2. Pump arrangement done for condensate transfer on low pressure to Condensate tank via PHE, to avoid High pressure & temperature in PHE.
3. Condensate polish unit was installed for condensate polishing purpose.
4. So we are inculcating a control valve to control CBD tank level.
5. We used OLD PHE & it's plate also.
6. Investment payback period was calculated 3(Three) months only.

So we need following facilities to install & run WHRS & water recovery system –

XII. Facilities Required –

1. Plate Heat Exchanger
2. Blowdown transfer pump
3. Control valve
4. Condensate storage tank can be used or not.
5. Condensate polishing unit

XIII. Capital Cost of Project –

Sr. No.	Description	Cost (Rs.)
1.	Material Cost (PHE+PIPING+Control valve +PLC)	500000
2	Manpower cost	40000
3	Pump Cost(2 m3,40 m)	20000
4	Insulation Cost	5000
	Total Cost (Rs.)	565000 /-

XIV. Benefits/Outcome of WHRS project of Boiler CBD water -

Since Boiler Efficiency = 80%

Equivalent Energy, Qeqv. = 5453000/0.8

= 6816250 kcal/day

Coal GCV supplied = 4000 KCAL/kg

So Coal saving per day = (6816250/4000)

=1704 kg

= 1.7 Ton/day

Coal Cost per Ton = 4500 Rs. /Ton

So Ultimate saving from Coal Saving = 4500*1.7

=7668 Rs. /Day

Annual Saving from coal = 7668*330 (330 days operation)

= 25.30 Lacs per Year … (A)

Water Saving per Day-

By saving 19 TPD Blowdown water, 60 KL Raw water being saved.

DM water cost in coastal areas = 32 Rs. /KL

Total water saving per annum = 19x 330

= 6270 KL/year

SoRaw water saved for year = 6270 x 1.4

= 8778 KL/Year

Total Saving of DM water cost per day = 60*19

= 1140 Rs. /Day

Annual Saving from water = 1140 * 330

= 3.76 Lacs …. (B)

Total Savings = (A+B)
= 25.3 + 3.76
= 29 Lacs/Year (Except flashing steam)

-------------------C)

XV. Payback of Project –

From Eqn C

Saving per month from BHRS =29/12

= 2.41 Lacs/month

Total Investment – 5.65 lacs

So Payback period – 5.65/2.41

= 2.34

= 3 months.

Conclusion -

The proposed/studied Waste Heat Recovery system was constructed & commissioned successfully. It saved enormous energy with lots of water. So we must have Boiler Blow down recovery system to have following advantages / gain –

1.To protect Boiler pressure part from any scaling & sludging inside the water because water impurity will increase with Top up water quantity. So we should keep draining CBD from Boiler without overthinking of losses.

2. To eliminate the wastage & contamination of water resources which will could save substantial amount of water for our society. In this report 6270 KL/year while average drinking water consumption in India 2.38 Ltr/person hence we could fulfill drinking water requirement of

7983 peoples per day from one Boiler by saving these waste water from one Boiler only. So it's very imperative for Environment betterment.

3.To have substantial amount of money from heat recovery of high temperature condensate which could save enough Coal for Industries. These cost can impact profitability of Industries.

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