Performance Analysis of Blowdown Heat Recovery System

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Abstract— Unfortunately the global conventional fuels in reserves are running out while the world energy consumption is increasing very fast. All scientists agreed that optimization of boiler system is one of the best solutions for save energy and reduce the pollutions. The efficiency improvement of blow down is one of the major factors to save energy. Blow down is necessary in the boiler but it is also important to recover the maximum heat energy from blow down which can reduce overall fuel consumption of boiler. Thus, solving this is a key issue to develop efficient blow down heat recovery system.

Key words: Blowdown Heat Recovery Systems, Plate Heat Exchangers, Performance Analysis of the Systems, Heat Transfer Coefficient, Pressure Drop

I. INTRODUCTION

All steam boilers must blow down to reduce the amount of TDS in the boiler water. Blow down However, along with the solids, boiler chemicals and thermal energy is lost; blow down heat recovery systems cannot recover the chemicals, but they do recover up to 90% of the heat energy that would otherwise be lost down the drain. There covered heat is use to pre-heat boiler make-up water before it enters the deaerator, and for low pressure steam to heat water inside the deaerator, which reduces the cost to run the deaerator and improves overall boiler efficiency. Reducing the temperature of the blow down before it reaches the sewer drain is a typical Code requirement. Therefore, a heat recovery system also eliminates the need to dilute blow down with cold water before it enters the sewer. Blow down heat recovery systems offer a fairly rapid payback, depending on blow down volume. Several boilers can be connected to a single heat recovery unit, reducing capital costs. A blow down heat recovery system should be considered when:

1) 5% of boiler water is make-up (smaller boilers; lower percentage for larger boilers)
2) 500 lbs/hour steam is blown-down
3) Continuous blow down systems of at least 1 gpm

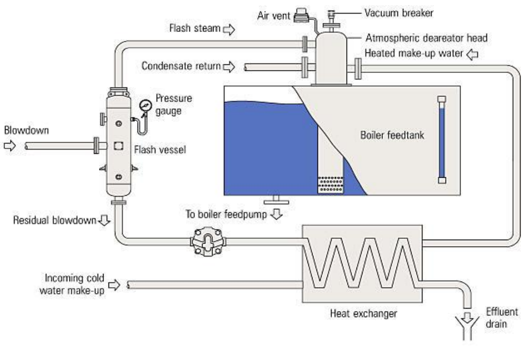

Fig. 1: Blowdown Heat Recovery System

Boiler Operating Pressure (psig)	Total Dissolved Solids (ppm)	Total Alkalinity (ppm)	Total Suspended Solids (ppm)
0-50	2500	2500	8
51-300	3500	3500	15
301-450	3000	3000	10
451-600	2500	2500	8
601-750	1000	1000	3
751-900	750	150	2
901-1000	625	125	1

Table 1: Maximum Permissible Concentrations (ABMA)

– Types of Blowdown

1) Surface blowdown
2) Bottom blowdown

A. *Surface Blow Down:*

Surface blow down continuously bleeds off a low volume of water from within the boiler as a means of ridding the boiler of dissolved impurities. It is most effective to remove water with the highest level of impurities; and such water is found where steam separates in the steam drum at the top of the boiler.

B. *Bottom Blow Down :*

Some boiler water treatment cause precipitation of impurities as insoluble particles anticipating those particles will settle to the bottom of the boiler before they become entrained in water circulating past the heat exchange surfaces. These water treatments often include compounds forming sludge to entrap such particles; and boilers intended for such water treatment include a structure called a mud drum at the lowest part of the

Krum semkoy[1] carried out study for the evaluation of the potential heat energy saving through technology optimization and improved heat recovery. Heat network analysis is carried out using redesign of the technology based on process integration.The heat network analysis have characteristics of; quick estimation of the potential saving ,limited system analysis requirements, process integration , local and output exergy reduction, low grade heat recovery. A case study shown that overall impact of the improved technology results in 30% heat saving and about 2.7 times reduction of NO_x emission and 70˚c hot water can be generated from the recovered heat.

Dong-hun kwak[2] discussed about techno-economical analysis of the key technologies for the energy recovery and reuse it in the boiler feed water heating. Evaluation of the process modeling used for identifies the optimal integrated configuration of the technologies.A Case study carried out for utilization of the low grade of heat energy between ambient and 523K.which is often wasted. Total side analysis (TSA) is used to integrate the energy system of different process in site, provides an overall picture of the steam. Analysis of the stream data includes initial temperatures, target temperature and heating/cooling demands. Composite curve and grand curve used with the pinch analysis to determine the minimum hot and cold utility requirements of the each process. A boiler 160kg/s of steam and condensate return is 80%, flow rate of makeup water which can be preheated using waste heat is 32kg/s. low grade heat is available between 111.1 and 140˚c. to calculate the heat exchanger and fuel cost the overall heat transfer co efficient(u) is assumed 500W/m^2.Fuel cost is reduced up to 3.6% and cooling water cost is reduced up to 8.6% .The added heat exchanger cost are 1.94m$. After optimization the addition of the boiler feed water heating is reduced 3.1% of cost

Subodh Panda[3] analyzed that neural network proves to be an efficient modeling system for calculation and optimization of the Blow down. It significantly reduces the frequency of deviations and the degree of deviation of the TDS that can reduce indirect losses.

A case study shown that if we use the normal controller then the tripping of boiler during the load fluctuation which is undesirable. The result has shown the operational difference between various controllers.

It is shown that for the optimization of the blow down system and reduces the tripping problem during the loads; ANN (artificial neural network) controller is more suitable rather than conventional PI (proportional integral) controller. The ANN model is more accurate and efficient making the system robust and reliable as compared to the former

Lanbinlium[5] explained about two different kind of heat pump (an electrical heat pump and absorption heat pump) in the heat recovery system .In both type system will use drain wastage water. When the drain water reaches some certain volume heat pump will begin working and recycling heat.

The electric heat pump system consists of storage tanks, electric heaters, water pool, filters, heaters, pumps and electric heat pump. When waste water drain into the water pool, the heat pump starts. From the water to water heat exchange the cold water is heated from 12˚c to 25˚c and excluded wastewater temperature drops from 30˚c to 17˚c.

From the experiment it shown that exhaust heat recovery with the electric heat pump and boiler for heat supplement needs 2.6 year and absorption heat pump system needs 2.1 year to recover investment. It found that absorption heat pump has lower energy consumption, less pollution and lower operating cost

Cheng-liange chen[6] developed the comprehensive mathematical models for the operational optimization and retrofits of industrial system. The maximizing the cost reduction given by annual operating cost minus the annualized investment cost of retrofits is formulated as mixed integer non linear program (MINLP).

A case study carried out on the base of mathematical model for analysis and design of the power plant, design problem is formulated as a mixed integer non linear programs (MILP).

A result from case study shown that existent layout limits the steam utilization performance, retrofits strategy adopted to break this limits and site performance can be improved .significant reduction has achieved in operating cost by 13.8%. By applying the integrated technique, the corresponding cost saving is up to 15.1%. The payback time of the retrofits system is lower than 0.5 year.

Mousas.mohsen[7] studied on the potential of industriawastewater reuse in thermal power plant. Carried out the review on process involved, industrial waste generation and water requirement.

A case study shown that amount of waste water is reduced by the water treatment system, blow down heat recovery system and using sewage treatment plant effluent as water. It can show that water and energy can very likely conserved by good operating conditions, cleaning techniques using minimum water

Petre stehilk[8] described and discussed about the characteristics and specific features of heat transfer is important process in waste-to-energy system. Example evolved of heat exchanger for heat recovery system, their design, arrangement and optimization CFD (computational fluid dynamics) is used for improved design and troubleshooting in Heat transfer equipment and the heat exchangers experiment. A shopestigated support based on a computational and modeling for improved or optimize the design of heat exchangers method was as below;

1) Simulation based on energy and mass balance
2) Thermal and hydraulic calculation of heat exchangers
3) CFD (Computational fluid dynamics) approach
4) Optimization
5) Heat integration

From the case study it was observed that a computational support which unambiguously belongs to efficient tool of up to date heat design , Through the example result it is shown that benefits of using CFD is both for improved design or optimize design and troubleshooting of the problems.

Quci tian[9] presented a passage arrangement method for minimizing the cumulative heat load to bring convenience for passage arrangement and to improve the heat transfer coefficient .the optimal design is important for structure improvement and performance enhancement.

Two different methods are generally used in the passage arrangement of multi stream fin plate heat exchangers

1) The cold passage and hot passage are arranged alternatively.i.e. A cold passage is separated by hot passage and a hot passage is separated by two cold passages.
2) The passage of the same stream is arranged relatively together.

A result of case study shown that passage arrangement method is carried out based on the heat transfer simulation

1) By using the passage arrangement method the mean square error of cumulative local heat load is reduced by 2.9%.
2) Distributed parameter is useful for obtain accurate temperature profile.

II. NEW METHODS OF THE BLOWDOWN HEAT RECOVERY SYSTEMS

The common procedure is to use a valve to reduce the pressure of the blow down water in the tank to 10-15 psig. In which blow down valve is installed before heat recovery system. The pressure of saturated water decrease due to the adiabatic expansion and part of the blow down water evaporates generating flash steam. The flash steam and the temperature of remaining water declines to the temperature of the saturation at the new pressure.

The blow down of low-pressure steam generator contains a small amount of flash steam.The heat energy of the blow down water is transferred to the make-up water in two steps.

First, the flash steam is condensed on the surface of the heat exchanger shell, which provides heating of the make-up water. The blow down water fraction, mixed with flash steam condensate, flows through the tubes of the tube bundle (sub-cooling section), providing the initial heating of the make-up water. In this option the condensing tube bundle may be unnecessary.

The heat and mass rates of the condensing and sub-cooling sections, as well as the temperature distribution are calculated from the heat balance equations by the in-house computer pro

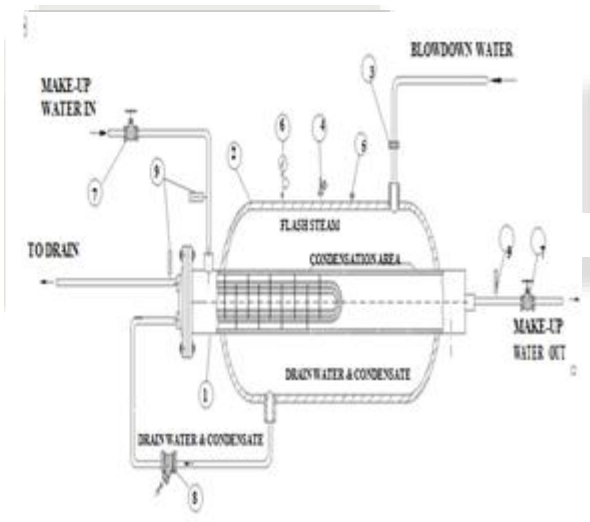

Fig. 2: Ahlstrom Blow down Heat Recovery System for Low Pressure Steam Generators where the Flash Steam condenses on the Inner Shell

No	Description
1	Heat Exchanger
2	Flash steam Separator
3	Orifice
4	Safety Valve
5	Vacuum Breaker
6	Pressure Gauge
7	Gate Valve
8	Strainer
9	Thermometer

Table 2: Specification Table

III. CONCLUSION OF LITERATURE REVIEW

From the litrature review based on experimental and analytical it is concluded that

1) Exergy analysis of the system gives the qualitative energy and quick estimation of potential saving, limited system analysis requirement, process integration, local and output energy reduction, low grade heat recovery.
2) Boiler with continuous surface water blow down exceeding 5% of the steam generation rate is a good candidate for blow down waste heat recovery. And blow down is affected by the quality of the feed water and the water treatment system.
3) The automatic blow down system is the one of the best way for the optimization of boiler with the comparison of the manual blow down system.
4) The numeral network analysis is efficient for the modeling and optimization of the blow down system. Significantly reduces the frequency of deviations and the degree of deviation of the TDS that can reduce indirect losses.
5) Combined cycle of two systems is very efficient operation and reduces the losses.
6) Experimental studies on highly efficient equipment gives the better operation and reduce the energy.

Performance analysis of the plate heat exchangers which is used in the blowdown system

Plate material	dimensions
Plate thickness(mm)	0.6
Chevron angle(◦c)	30
Total number of plates	117
Enlargement factor	1.25
Number of passes	1
Tptal effective area	$58m^2$
All port diameter(mm)	200
Compressed plate pack length (l_c)m	0.38
Vertical port diameter(l_v)	1.33
Horizontal port distance(l_h)	0.48

Table 3: Specification of Plate Heat Exchangers

ITEMS	HOT FLUID	COLD FLUID
Fluid	blowdown water	dm water
Flowrate kg/s	3.125	4
Tem.inlet(◦c)	140	80
Temp.outlet(◦c)	25	55
Maximum permissible pressure drop(kg/cm^2)	1	1
Total fouling resistance(m^2-k/w)	0.00005	0
Specific heat(kj/kg-k)	4.183	4.183
Viscocity(N-s/ m^2)	5.11×10^{-4}	7.68×10^{-4}
Thermal conductivity(w/m-k^2)	0.635	0.616
Density(kg/m^3)	986	985
Pradalt number	3.32	5.21

Table 4: Fabricational Data Received From Atul for Plate And Frame Type Heat Exchanger

IV. CALCULATIONS

A. Blowdown:

$$B = \frac{E \times S}{C - S} \qquad 1)$$

E=steam generation rate
S=amount of solids
B = blowdown
C= maximum permissible concentration of solids

B. Calculation of Flash Steam:

$$m_{sf} = \frac{hi \times hf}{hfe} \tag{2}$$

$=1.48 kg/cm^2$
hi=initial liquid enthalpy (kj/kg)
hf= final liquid enthalpy (kj/kg)
hfe= enthalpy of evaporation (kj/kg)

C. Logarithmic Mean Temperature Difference of Plate Heat Exchangers:

Hot water inlet temperature (th_1): 140◦c
Hot water outlet temperature (th_2) :80◦c
Cold water inlet temperature (tc_1) :25◦c
Cold water outlet temperature(tc_2): 55◦c
Now , T_1 =80◦c -55◦c
=55◦c
T_2 =140◦c -55◦c
=85◦c
Now, LMTD(T_M)

$$T_M = \frac{85-55}{0.43}$$

T_M=69.76◦c

D. Heat Load Calculation:

$$Q_h = mc_p(t_1-t_2) \tag{3}$$

=3.125×4.183×60
=784.312KW
Q_C =4×4.183×30
=501.96KW

E. The Effective Number Of Plate:

$$N_e=N_2-2 \tag{4}$$

=115

6. Plate pinch

P =0.0033m

F. Determine The Mean Channel Flow Gap:

$$b=p-t \tag{5}$$

=0.0033-0.0006
=0.0027m
One channel flow area:
$A_{ch}=b \times l_w$
=0.0027×0.63
$=0.0017 m^2$

G. The Single Plate Heat Transfer Area

$A_r=a_e/n_e$
=58/115
$=0.504 m^2$

H. The Projected Plate Area

$A_P=L_P \times L_W$
=(1.33-0.2) ×0.63
$=0.711 m^2$

I. Enlargment Factor Can Be Varied

$$Ø = \frac{0,504}{0.711}$$

=0.708

J. Calculate Channel Equivalent Diameter:

$$D_e = \frac{2b}{Ø}$$

=0.0077m

K. Number Of Channel Per Pass:

$$N_{cp} = \frac{Nt-1}{2Np}$$

=57

L. Mass Flow Rate Per Channel

$$M_{ch} = \frac{58}{57}$$

$=0.052 kg/cm^2$

M. Mass Velocities

$$G_h = \frac{1.97}{0.0017}$$

$=1158 kg/m^2$-s

N. Hot Fluid And Cold Fluid Renolds Number

$$R_{eh} = \frac{g_h}{u_h} \times d_e$$

$$= \frac{1158 \times 0.0077}{5.11 \times 10}$$

= 17447.31

And,

R_{ec}= 11610.21

O. Overall Heat Transfer Coefficient

$$\frac{1}{u_e} = \frac{1}{h_e} + \frac{1}{h_h} + \frac{t}{k_w}$$

U_e= 9870 $W/m^2 k$

P. Fouled Overall Heat Transfer Coefficient

$$\frac{1}{u_f} = \frac{1}{u_e} + r_{fh} + r_{fc}$$

u_f =6607 $W/m^2 k$

Q. The corresponding cleaning factors:

$$CF = \frac{u_f}{u_e}$$

=0.67

Simulations of plate heat exchangers using HTRI

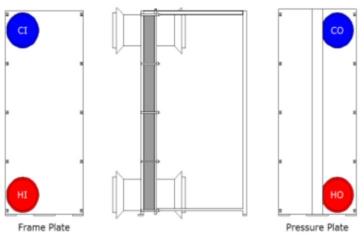

Fig. 3: Drawing of Plate Heat Exchangers

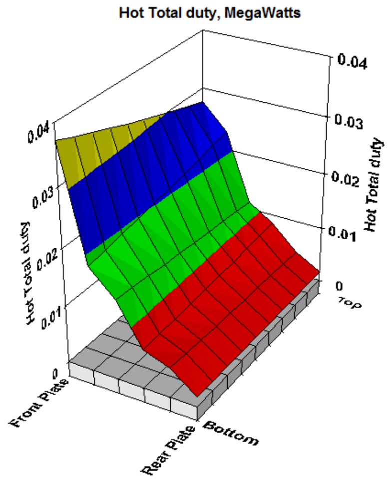

Fig. 4: Total Heat Duty of The Plate Heat Exchangers

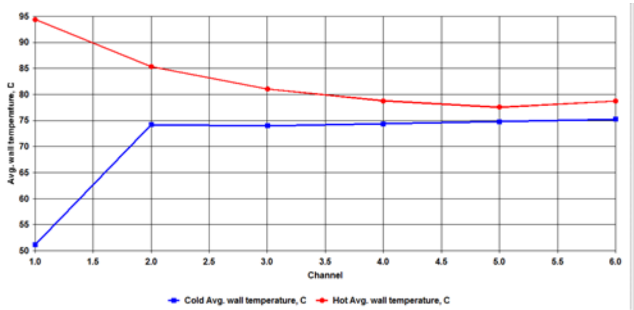

Fig. 5: Average Temp. Vs Channel

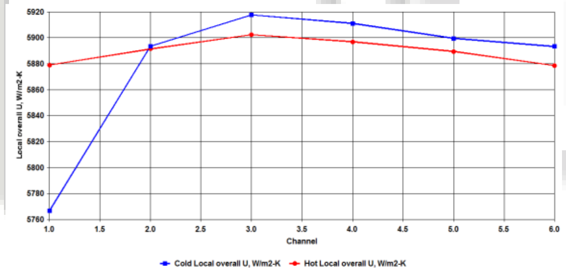

Fig. 6: Local Overall U Vs Channel

V. CAD MODEL

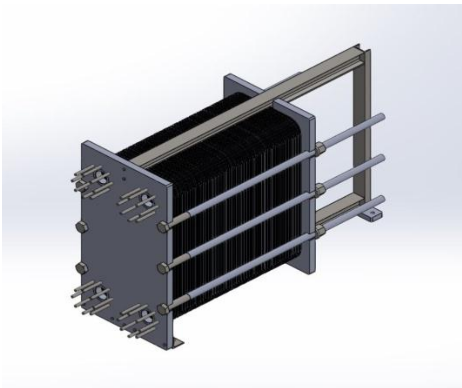

Fig. 7: Cad Assembly

VI. PLATE DESIGN

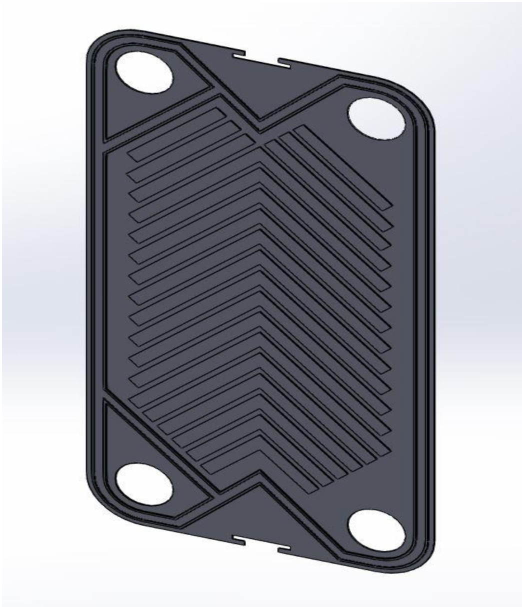

Fig. 8: Plate Design

VII. CONCLUSION

From this simulation results I am able to understand the thermal behavior of the fluid (water) at the different point of the plate heat exchanger. also concluded that considerable energy can be saved with the use of blowdown heat recovery system. Variation in number of plate is mainly effect the outlet temperature .recovery of the energy from the flash steam to deareter can give the benefits of the saving cost.

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