DESIGN AND FABRICATION OF BLOW DOWN HEAT RECOVERY SYSTEM TO IMPROVE ENERGY EFFICIENCY IN STEAM BOILERS OF PETROLEUM REFINERIES

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ABSTRACT

Blow down water is the part of water that is purposely drained during the boiler operation to limit the level of impurities in boiler water to an acceptable level. So it is contains large quantity of heat energy. The aim of the present work is to improve energy efficiency of steam boilers in the south refineries company/Al-Basrah. This aim has been achieved through designed and manufactured of a heat exchanger consists of a shell and coiled tube unit to recover heat from surface blow down water and reducing indirect losses. The blow down water (hot fluid) is supplied to the heat exchanger at atmospheric pressure by passing it through the shell side and the feed water (cold fluid) in the coils tube side. These were done as counter flow. A flow control valve is used to control the flow rate of hot blow down water inside the heat exchanger. The experiments are done at the blow down water and feed water flow rates ranging between (0.06-0.14) m^3/h with 0.02 m^3/h interval, and between (0.1-0.5) m^3/h with 0.1m^3/h interval, respectively. The experimental results proved the effectiveness of the heat recovery system in improving the boiler efficiency where a percentage of 83.16% of the energy is lost with blow-down water that can be recovered using heat-recovery unit with an energy saving of 103411.8 MJ/day. Which will save a mass of fuel equals to 482.46 ton/ year. The heat recovery unit is proved to be a good solution for saving energy and reducing harmful emissions to the environment and it contributes to the maintenance of sewage pipes from damage caused by the heat of discharge water by cooling the water before discharging it into the sewer system.

Keywords: boiler blow down, heat exchanger, heat recovery system, energy efficiency, indirect losses.

1. INTRODUCTION

Energy efficiency has become an important feature of process industry with rising cost of energy and the more stringent environmental regulations being implemented worldwide, today the most prominent targets of modern technology to improve the efficiency of energy technology in industrial processes particular industries that generate their own steam need to optimize their energy generation and use by making all the measures are taken to reduce energy loss [1].Steam boiler is one of the largest equipment which consumes energy greatly, the boiler efficiency is dependent upon decreasing of various indirect losses of a boiler. Thus the quantity of energy entering the boiler by consumption of fuel can be maximum utilized for generation of steam and the cost of steam can be reduced ultimately through utilization of several methods to increase industrial boiler efficiency that can be implemented relatively easily by minimizing the indirect losses [2]. The main areas for improvement of boiler efficiency result from “reduction in blow down water and blow down heat recovery”. Boiler blow down water is water wasted from the steam boiler while the boiler is running to avoid concentration of impurities during continuing evaporation of steam [3]. Since the blow down process is carried out during the boiler operation so the blow-down water is at the same pressure and temperature of that the boiler. Blow down water is at boiler temperature; hence as it increases it means fuel wastage [4]. System of heat recovery is used to decrease energy losses that result from boiler blow down. Each boiler with continuous blow-down passing 5% of the steam rate is a perfect candidate for the introduction of waste heat-recovery system. Greater energy savings come with the use of heat-recovery system where they can recover up to 90% of the heat energy that would otherwise be lost down the drain [5].There are two types of blow down heat recovery systems depending primarily on boiler operating pressure, one simply includes heat exchanger arranged for counter flow with the continuous blow down on one side and makeup water on the other, and these are only employed with low pressure steam systems. For high pressure steam systems the blow down heat recovery equipment includes flash tank and heat exchanger. Heat recovery at high pressure boilers is used to heat boiler makeup water before entering the deaerator, while it is used to heat water inside the deaerator at low pressure steam boilers. This lowers the cost to operate the deaerator and improves the efficiency of steam boiler. Also, the heat recovery system achieves a typical requirement of reducing the temperature of the blow down water before it reaches the sewer drain, therefore eliminates the need to dilute blow down with cold-water before it enters the drainage system. Heat recovery systems provide fairly quick recovery depending on the volume of the blow down. Many boilers can be linked to a single heat recovery unit [6]. 90 percent of heat energy that would be lost down the drain can be recovered with the use of an efficient heat exchange unit. There are two types of blow-down, discontinuous (intermittent)and continuous: Discontinuous (intermittent) blow-down: is done by manually operating a valve connected to drainage line to adjust (suspended solids, TDS, pH, Silica and Phosphates concentration)

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inclusive of any sludge created in the boiler water within prescribed limits. Manual blow-down valve and discharge line are located at the bottom or low point of the boiler, where any sludge formed would tend to settle [7, 8].Continuous blow down: It is the continuous removal of water from the boiler to remove concentrations of minerals dissolved in the boiler water. It offers many features that are not provided by the use of intermittent blow down alone. Blow down water is discharged from the position of the highest dissolved solids in boiler water. The steam and water rising in the boiler are separated so the water at that point has the highest concentration of solids more than anywhere else in the boiler. By doing so, the TDS concentration can be held near the limit, that reduces the amount of blow down water and the amount of energy removed from the boiler through blow down process. As a result, the quality of boiler water can be maintained at suitable level of TDS at all times. Also, a maximum of dissolved solids may be discharged with minimal loss of heat and water from the boiler. Another main advantage of continuous blow down is the recovery of a large quantity of its heat content by using the blow down flash tanks and heat exchangers. Control valve settings must be regulated orderly to increase or decrease the blow-down with reference to control test results and to maintain close control of boiler water concentrations at all times [4, 7]. Several studies focused on blow down heat recovery systems. Gupta, *et al.* 2011 [9], They suggested an automatic blow-down system set up, which consisted of continuous monitoring for conductivity. This automatic system can save energy wasted by continuous system. D. Madhav, *et al.* 2013 [5], presented a design and mathematical modeling of the heat recovery system consists from flash vessel and a heat exchanger designed to minimize the heat losses. According to their studies, approximately (49)% of energy at boiler blow down can be returned. Sunudas and Prince 2013 [4], studied experimentally the optimization of bottom blow down and blow down heat recovery by installation of an automatic blow down system. The experimental analysis conducted in steam boilers in textile industries showed that nearly 1.5% of fuel was wasted through blow down and nearly an 85% of total wasted fuel was recovered. This recovered energy was supplied to feed water to raise the water temperature. S. Arunkumar, *et al.* 2014 [10], a system of heat recovery was designed to reduce the losses. The experimental measurements were carried out by using plate type heat exchanger, with 20 plates, design pressure of 10 kg/cm^2, and area of heat exchanger was 2.5 m^2, required 3% blow down of steam. The results showed that 6.61kJ/day total energy was saved in the process. Vandani, *et al.* 2015[11], they investigated the system of heat recovery on a power plant using the flash-tank to restore lost energy from blow-down water. Results showed that, the net generated power increased by 0.72% when a blow down recovery mechanism was used, and energy efficiency of the system raised by about (31.68-31.91) %. As well, the results showed that energy and exergy efficiencies of the system increased by 0.23 and 0.22 respectively, the exergy efficiency of a system reached (30.66%). Thus, the objective of the present work is to improve the energy efficiency of a steam boiler in the south refineries company located in Al-Basrah- Iraq. This has been achieved by designing and manufacturing of a heat recovery system includes special design of shell and coiled tube heat exchanger. It has been utilized to recover the heat from the surface blow down water and saving in fuel consumption for steam demand, in addition to environmental protection from blow down hot water that has been discharged to sewer system.

2. EXPERIMENTAL SETUP FOR HEAT RECOVERY SYSTEM

2.1 Experimental system

Figure-1 is a schematic diagram of the experimental rig. The main parts used in the experimental system are: boiler, feed water tank, feed water pump, electrical control panel, heat recovery unit, and automatic control system which consist of: conductivity monitor, throttle valve and automatic control circuit. The measuring devices are conductivity monitor, flow meter, temperature controller, thermocouples, an oscilloscope and a digital multimeter.

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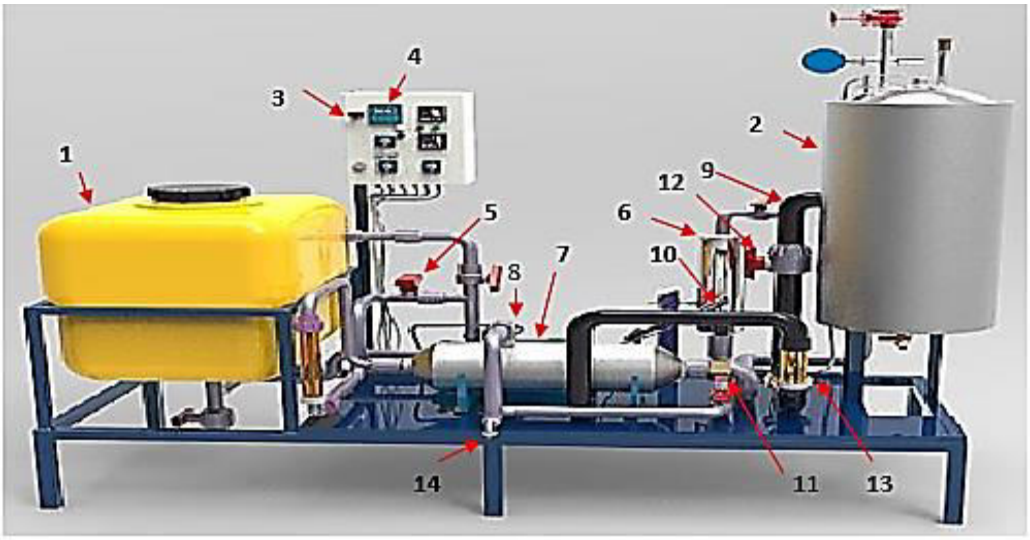

Fig. 1: schematic diagram of experimental rig

1- Feed water tank, 2- Boiler, 3- Electrical control Panel, 4- Online Conductivity monitor, 5- Flow regulating valve, 6- Sample cooling water, 7- Heat exchanger, 8- Feed water pump, 9- Surface blow down pipe, 10- Conductivity sensor probe, 11- Solenoid valve, 12-Throttling valve, 13- Water flow meter, 14- Blow down to drain.

The main parts assembling in the heat recovery system are:

Shell: Shell is the container for the coil tubes and liquid is distributed around the tube. It is created from tube or rolled sheet and soldered plate metal. For economical aspects, low carbon steel is commonly used; also other materials can be appropriate for maximum temperature or erosion resistance. Utilizing commonly obtainable shell pipe is of (24) inch diameter leads to reduced cost and facility at industrialization, partially because they generally are more completely round than rolled and soldered shells [12].

Coiled tube: Tube outside diameter of 3/4 and 1 inches are very common to design a compact heat exchanger. Coil tube designs can be an effective use of space in heat transfer applications as shown in Figure-2[12, 13].

Connecting pipes: Four pipes are connected for cold water inlet, cold water outlet, hot water inlet, and hot water outlets [12].

Thermocouple: It is a temperature measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit [12].

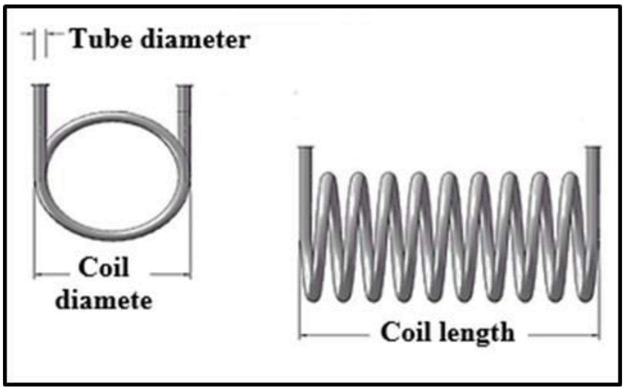

Figure-2. Coil tube configuration.

2.2 Design procedure for shell and coiled tube heat exchanger

A simple procedure to calculate the design equations for a shell and coiled tube heat exchanger shown in Figure-3, is used a differential cross section is considered for the coiled tube heat exchanger Figure-4. Then a counter current flow Logarithmic Mean Temperature Difference (LMTD) method is used to solve the design parameters. The liquid inflows are inside the coil and the annulus, heat transfer takes place through the coil wall [14].

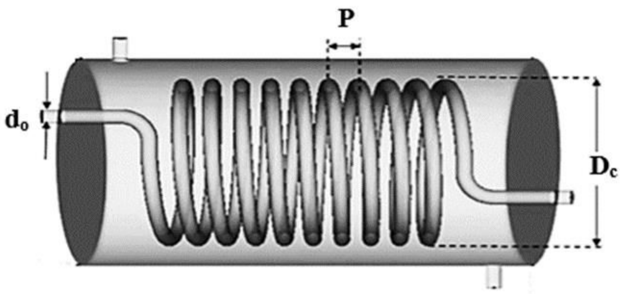

Figure-3. A heat exchanger (Shell and coiled tube) [15].

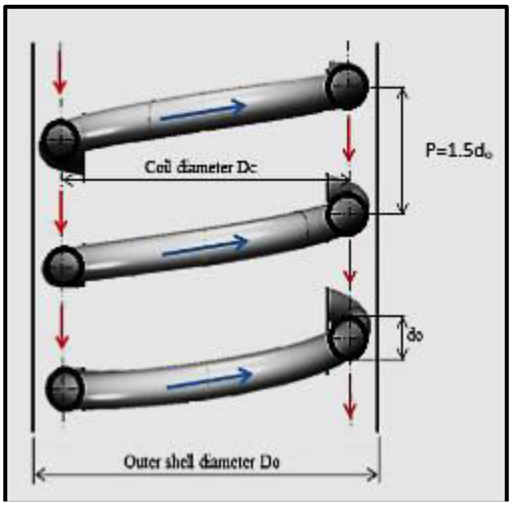

Figure-4. Schematic cross section view of coiled tube HE. [14].

To compute the coefficients of heat transfer at the coil and the annulus. The following transactions must be known [15], [16], [17]: Input and output temperatures for fluid are known. Consequently, relative values of viscosity (μ), thermal conductivity (k), isobaric specific heat capacity (Cp) and density (ρ) can be obtained from databases and then used to calculate the average values.

The quantity of heat transfer rate or heat potential is computed through utilization of the equations of energy balance:

$$Q=\dot{m} \times Cp\times (\Delta T) \quad (1)$$

Where: (Q) is the energy-absorbed (kJ/s), ($\dot{m}$) is the waste water quantity (kg/s), (Cp) is the specific-heat of water (kJ/kg.k), (ΔT) is the substance temperature rise ℃.

$$\dot{m} = \rho \times \dot{V} \quad (2)$$

Where: $\dot{V}$ is the volume flow rate in (m^3/h), and ρ is the density in (kg/m^3).

The coil length (L) necessary to make (N) turns:

$$L_c=N \times Dc\times\pi \quad (3)$$

Where: (N) is the number of coil turns, (P) is the tube pitch which represents the distance between consecutive coils turns measured from centre to centre in (mm) taken as:

$$p=1.5d_o \quad (4)$$

Where: (d_o) is the outside diameter of coiled tube (mm).

To calculate the curvature ratio:

$$\delta=d_i/D_c \quad (5)$$

Where: (d_i) is the internal diameter of coiled tube (mm).

The inside diameter of the tube being fixed, by knowing the mass- flow rate ($\dot{m}$), fluid average density, the average velocity (u) can be calculated from the following equation:

$$u_i=\dot{m}_i/\rho A \quad (6)$$

$$A_c= \pi/4\ d_i^2 \quad (7)$$

The Reynolds numbers for the cold and hot fluid can be calculating from equation:

$$Re_i=(\rho\ u_i d_i)/\mu \quad (8)$$

Where: (Re) is the critical Reynolds number (transition laminar/turbulent flow) for a helical tube.

$$Re_o= (\rho\ u_o D_h)/\mu \quad (9)$$

Where: (D_h) is the hydraulic diameter of shell side, can be calculated as:

$$D_h=(D^2-\pi D_c d_o^2\gamma^{(-1)})/ (D^2+ \pi D_c\ d_o\ \gamma^{(-1)}) \quad (10)$$

D is the shell diameter in (mm), γ is the non-dimensional pitch,

$$\gamma =p/ (\pi D_c) \quad (11)$$

Nusselt number:

$$Nu_i=0.023Re^{0.85}\ Pr^{0.4}\ (d_i/D_c)^{\ 0.1} \quad (12)$$

The coefficient based on internal diameter of the coil is obtained through:

$$h_i=(Nu_i\ .k)/d_i \quad (13)$$

Where: (hi) is the convective heat transfer coefficient of coiled tube (kJ/kg).

The Dean Number De: is dimensionless. Calculated from the following relation:

$$De=Re_i\ (d_i/D_c)^{0.5} \quad (14)$$

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To calculate the velocity of the fluid through shell side:

$$u_o = \dot{m}_o / (\rho A) \quad (15)$$

The Nusselt number is calculated from the relation:

$$Nu_o = 0.023 Re^{0.8} Pr^{0.4} \quad (16)$$

The overall heat transfer coefficient is calculated from the following equation:

$$Uo = Q_{average} / (A_o \times \Delta T_{lm}) \quad (17)$$

Where: $Q_{average} = (Q_{hot} + Q_{cold})/2$ (18)

$$A_o = \pi d_o L_{shell} \quad (19)$$

Ao: is the outside surface area of the heat exchanger.
ΔT_{lm} is the logarithmic mean temperature difference, calculated for a counter flow heat exchanger as:

$$\Delta T_{lm} = ((T_{h1} - T_{C2}) - (T_{h2} - T_{C1})) / \ln((T_{h1} - T_{C2}) / (T_{h2} - T_{C1})) \quad (20)$$

Where: (T_{h1}& T_{h2}) are the inlet and outlet temperatures of hot fluid in℃, and (T_{C1}&T_{C2}) are the inlet and outlet temperatures of cold fluid in℃.

The coefficient of convective heat transfer shell-side (ho) can be obtained from the following equation:

$$1/Uo = A_o / (h_i A_i) + A_o \ln(d_o/d_i) / (2\pi k L_{coil}) + 1/h_o \quad (21)$$

Where: (d_o) is the external diameter, and Lc is the coil length.

While (A_i and d_i) are the internal surface of the coiled tube and the internal diameter, and (k) the thermal conductivity of the material.
Area of the coil:

$$A = \pi\, d\, L_c \quad (22)$$

To determine the required area needed for heat transfer by overall heat transfer coefficient:

$$A = Q / U \Delta T_{lm} \quad (23)$$

To calculate the number of coil turns (N):

$$N = A / (\pi d_o (L/N)) \quad (24)$$

The actual number of coil turns needed n, is simple N rounded to the next highest integer.

To calculate the length of the shell L_{shell}:

$$L_{shell} = p\, .N \quad (25)$$

The volume of coil is calculated from equation:

$$V_{coil} = \pi/4\, d_o^2 . Lc \quad (26)$$

The volume of shell is calculated from equation:

$$V_{shell} = V_{coil} + V_a \quad (27)$$

Where:(V_a) is the volume of the annulus.

$$V_a = \pi / 4\, D_e d_o Lc \quad (28)$$

Where: (D_e) is the shell side equivalent diameter, calculated from equation:

$$D_e = (4\dot{m}/\pi \rho\, u)^{0.5} \quad (29)$$

To calculate the diameter of the shell:

$$D_{shell} = \sqrt{}\, 4V_{shell}/\pi Ls \quad (30)$$

To calculate the pressure drop:

$$\Delta P_D = 2 \times F \times Lc \times \rho \times u_i^2)/d_i \quad (31)$$

Where: F is the fraction factor, calculated by using Reynolds Number as in the following equation:

$$F = (7.2/ Re_i^{0.5}) \times (d_i / D_c)^{0.25} \quad (32)$$

2.3Assembly

Heat exchanger (shell and coiled tube) type is manufactured as shown in Figure-5 to be used for heat the make-up water that enters at near ambient temperature, and cools the blow down water before it is drained to sewer. the shell that is constructed from 316L stainless steel pipe with 13.6 cm inner diameter, 14 cm outer diameter, with 2 mm pipe thickness, and 43 cm length. Two holes were drilled in the shell with a diameter of 25 mm, for input and exit water (blow down water). Two nipples were welded in the holes have a diameter of 20 mm for connecting pipes. Two nipples were also welded in two flange plates for connecting pipes to the helical tube with a diameter of 25 mm for flow of cold water (feed water). Two coiled tubes (316L stainless steel), are inserted in the shell side. Each coiled tube has 10 mm outer diameter, 7 mm inner diameter and 1 mm thickness pipe. Both coil pipes have 30 cm length and 15 turns. The diameter of outer coil is 11 cm, while the diameter of inner coil is 8 cm. The distance between the two coils is 1.5 cm, with 20 mm pitch for each coil. In the present work the blow down water (hot fluid) flows in the shell side and make-up water (cold fluid) is supplied through coiled tube side. The heat exchanger was insulated by aluminum foil thermal insulation, with a thickness of 10 mm to reduce heat dissipating to the environment. Two flow meters are installed upstream of the heat exchanger to measure the flow rate of the hot stream and cold stream. Two PVC ball valves are used to control the flow rate of cold and hot water inside the flow meters. To measure the inlet and outlet temperatures of cold and hot water, four k- type thermocouples were inserted in the small holes drilled in the inlet and outlet tubes of heat exchanger and closed to prevent any leakage, thermocouples has been joined to

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digital temperature indicator, which is installed in the electrical control unit.

Figure-5. Experimental setup.

3. EXPERIMENTAL PROCEDURE

To operate and assess the pilot plant designed for heat recovery from blow down water. A number of experiments were carried out to recover the latent heat in the waste water discharged during the surface blow down process. The blow down water was supplied to the heat exchanger at atmospheric pressure. The experiments were conducted by passing feed water (cold fluid) through coils tube and the blow down (hot fluid) in the shell side; this was done for counter flow operation. Measuring the heat gained by feed water $Q_{\mathrm{F.W}}$ and heat lost by blow down water $Q_{\mathrm{B.D}}$ has been done by keeping the flow rates of feed water constant, while, blow down flow was changed from 0.06 m3/h to 0.14 m3/h with 0.02 m3/h interval. Next the flow rates of blow down water was kept constant and the flow rates of feed water was varied from 0.1 m3/h to 0.5 m3/h with 0.1m3/h interval. All of the data contained in this work are based on average values of five experiments conducted.

4. RESULTS AND DISCUSSIONS

4.1 Effect of flow rates on outlet temperatures of blow down water and feedwater

The experiments were carried out to measure the change in outlet temperature of feed water supplied to the steam boiler and outlet temperature of blow down water discharged to the sewer may be influenced by volumetric flow rates of feed water and blow down water through heat exchanger. Figure 6 shows the effect of variation of feed water volumetric flow rate on outlet temperature of blow down water for different volumetric flow rate of blow down water. It is clear that as the outlet temperature of blow down water decreases, the flow-rate of feed water increases, because of the increase in the heat transfer from hot water to cold water as the cold water flow-rate increases. Also it’s noted that, as the volumetric flow-rate of blow down water increases at specific volumetric flow-rate of feed water, the outlet temperature of blow down water increases. Figure-7 shows the effect of the flow rate of feed water on the feed water outlet temperature for different volumetric flow rates of blow down water. It is observed that feed water outlet temperature increases when volumetric flow-rate of the feed water increases because more cooling is generated by increasing volume flow-rate of cold-water leads to increase heat transfer rate to the cold water. The Figure shows outlet temperature of feed water initially increases and then decreases as the volumetric flow-rate of feed water increases. Figure-8 shows the outlet temperature of feed water with variation of volumetric flow-rate of blow-down water for different volumetric flow-rates of feed water. It is illustrated that the feed water outlet temperature increases when volumetric flow-rate of blow down increases inside the shell side for each corresponding volumetric flow rate of feed water. Therefore the rate of heat transfers increases when blow down water the volumetric flow rate increases. This leads to an increase in the outlet temperature of feedwater. Figure-9 illustrates the variation of the outlet temperature of blow down water with volumetric flow-rate of blow-down water for different feed water volumetric flow-rates. It’s observed that, outlet temperature of discharge water (blow down water) increases with increasing volumetric flow rate of blow down water. It also shows that when volumetric flow-rate of feed water is maintained at lower value of 0.1 m3/h, the outlet temperature of blow down water is maximum. But, when volumetric flow-rate of feed water increases, outlet temperature of blow down water decreases correspondingly until it reaches the lowest temperature at a flow-rate of feed water equals to 0.5 m3/h.

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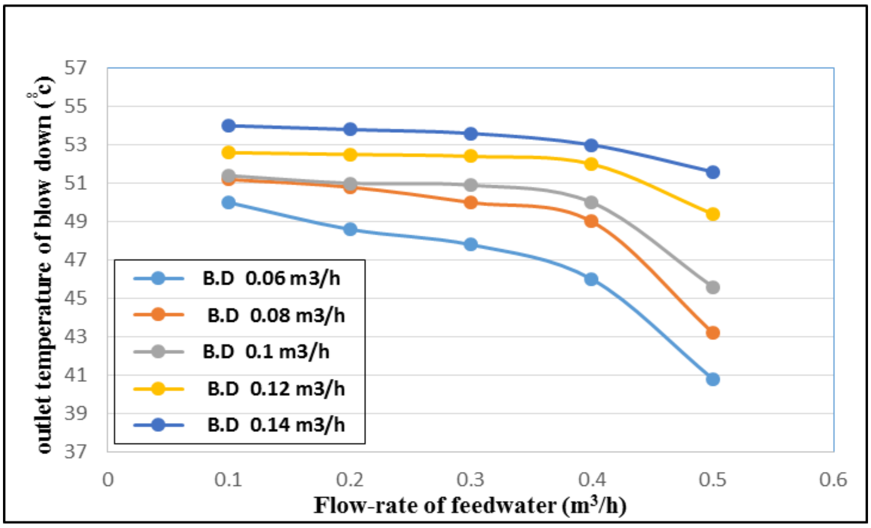

Figure-6. Difference of outlet temperature of blow down water withVolumetric flow-rate of feedwater at different volumetricflow ofblow down water.

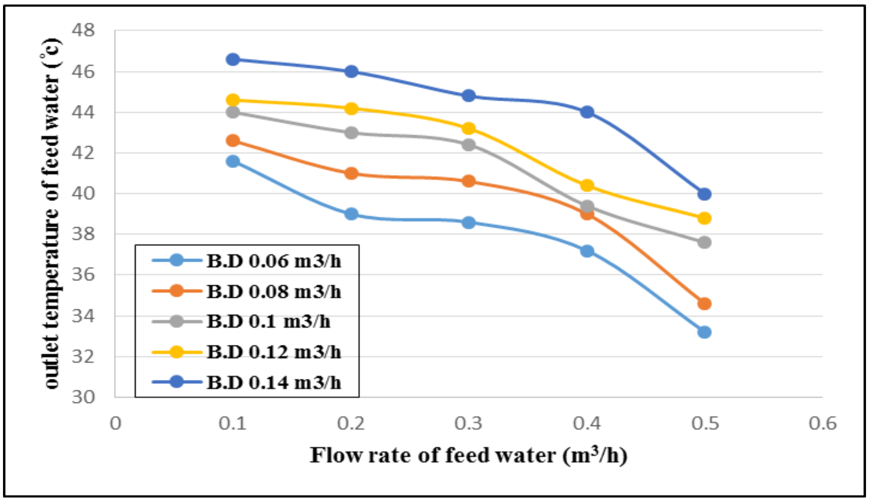

Figure-7. Difference of outlet temperature of feed water for volumetric flow-rate of feedwater at different volumetric flow-rate of blow-down water.

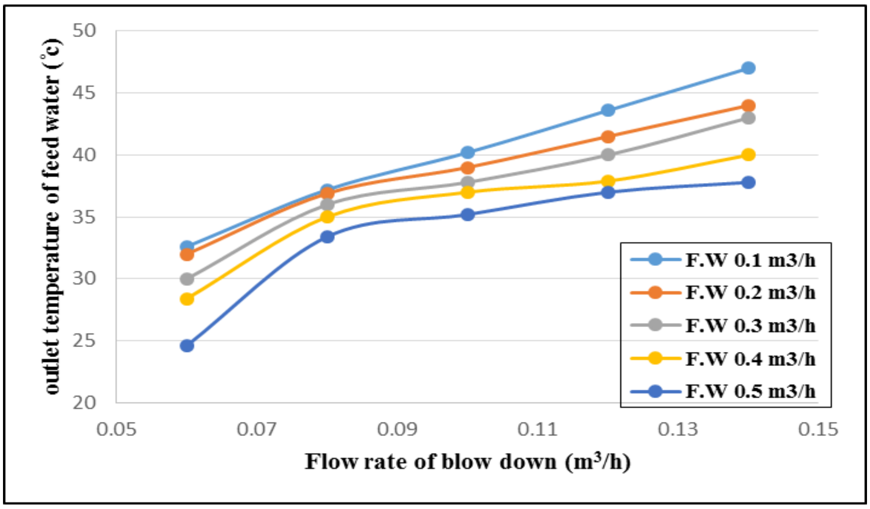

Figure-8. Variation of outlet temperature of feed water for volumetric inflow rate of blow down water at different volumetric flow rate of feed water.

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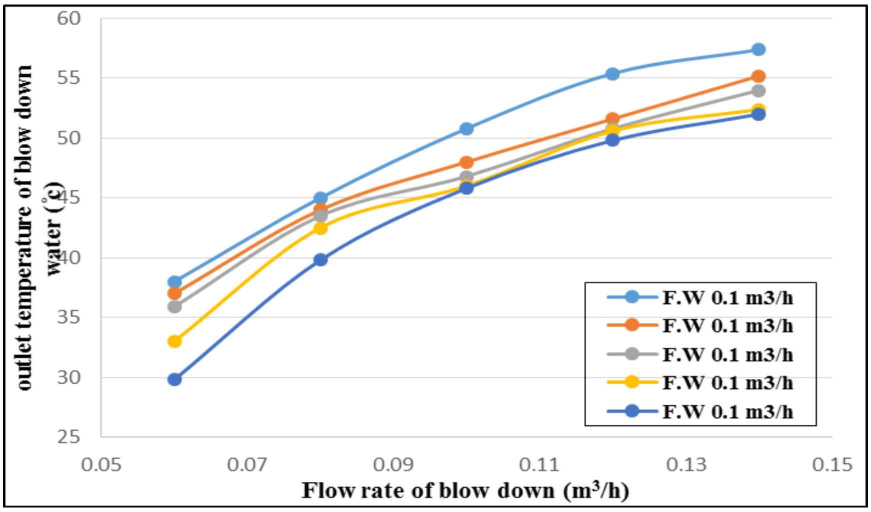

Figure-9. Variation of outlet temperature of blow down water for volumetric inflow rate of blow-down water atdifferent volumetric inflow rate of feed water.

Figure-10 shows the effect of variation volumetric flow rates of feed water on heat energy lost by the blow-down water when keeping the shell side flow rate is constant. It is observed that with increasing volumetric flow-rate of feed water rate, the heat energy lost from blow-down water increased because as the volumetric feed water increases there is more heat being transferred from the blow-down water. Figure-11 displays the effect of variation in the volumetric flow rate of blow-down water around (0.06 - 0.14) m^3/h with an interval of 0.06 on heat energy gained by the feed water$Q_{F.W}$. It is observed that the heat energy gained by feed water increases gradually with increasing volumetric inflow rate of blow-down water, because when the flow-rate of blow-down increases, there is a large amount of heat transferred to the feed water. Figures (12 and 13) show the relationship between the heat energy lost $Q_{B.D}$ and heat energy gained $Q_{F.W}$ with the volumetric flow rate of blow-down water and feed water. It's observed that the heat energy lost $Q_{B.D}$ and heat energy gained $Q_{F.W}$ increase when the flow-rates of blow-down water and feed water increases respectively, because a heat energy rate is a function of mass flow rate, when the mass flow rate increases it leads to increases in the heat energy rate.

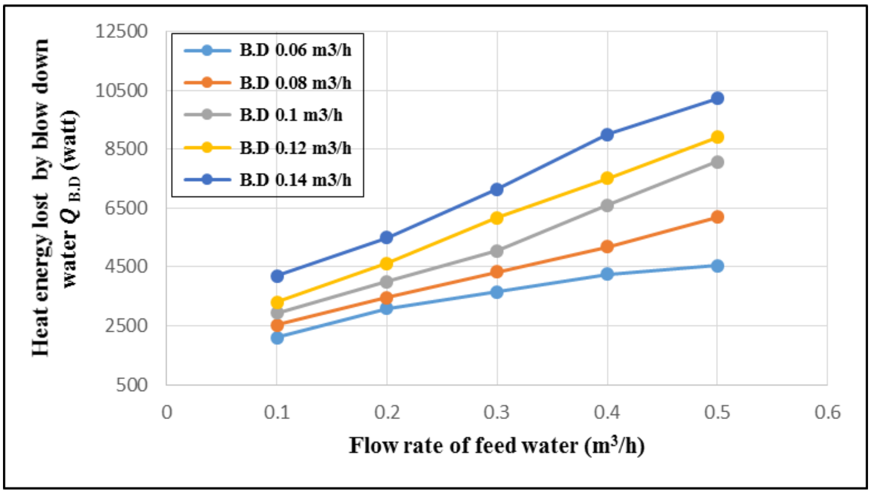

Figure-10. The effect of feed water flow rates on heat energy lost from blow down water $Q_{B.D}$ (watt).

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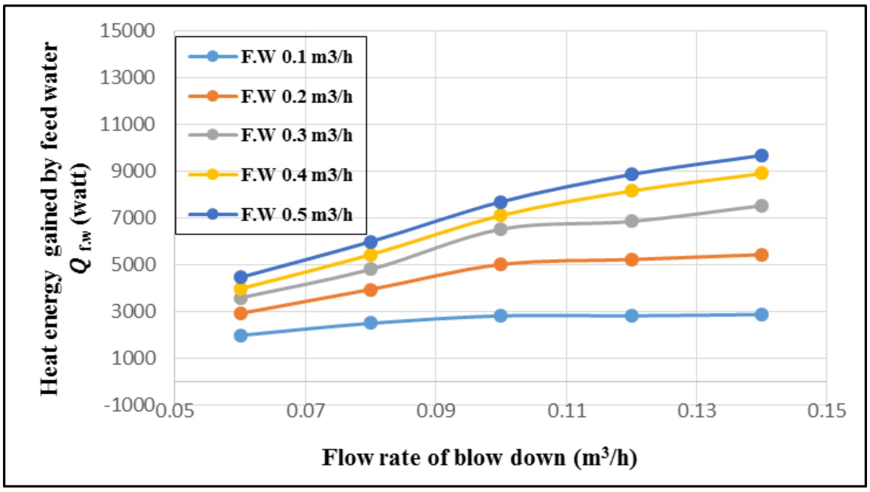

Figure-11. The effect of blow down water flow rates on heat energy gained by feed water $Q_{F.W}$ (watt).

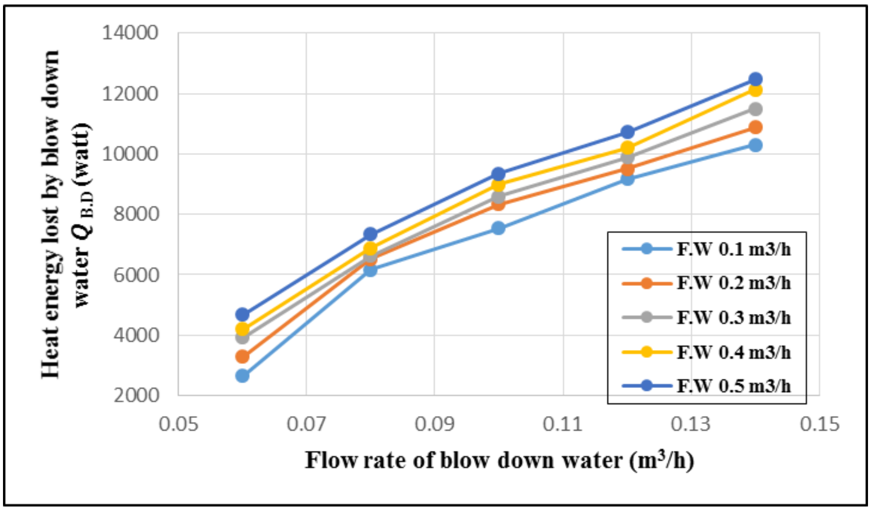

Figure-12. The effect of blow down water flow rates onheat energy lost $Q_{B.D}$ (watt).

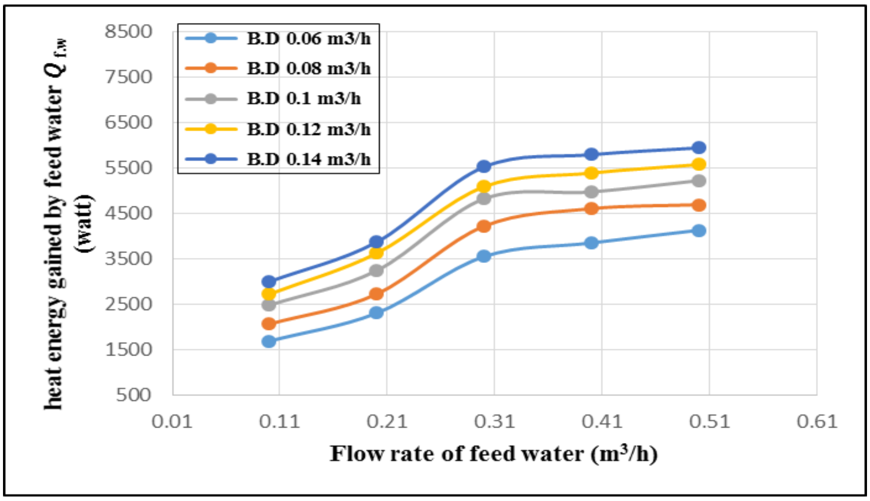

Figure-13. The effect of feed water flow rates on heat energy gained $Q_{F.W}$ (watt).

4.2 Effect of heat recovery unit utilization

According to the operating conditions in the south refineries company/AL-Basrah. A 21 m^3/h volumetric flow rate of blow down water is discharged from the bottom of flash tank to the drain at 90℃. By

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using the heat recovery system we can conserve the energy losses in the south refineries company.

The values of heat energy lost $Q_{B.D}$ and heat energy gained $Q_{F.W}$ were calculated by using equations (1) and (2). Where physical properties of water specific heat Cp (kJ/kg. k) and density ρ (kg/m3) are calculated at the atmospheric pressure:

Heat energy lost to the drains $Q = \dot{m} \times C_p \times \Delta T$ where ρ= 983.21 kg/m^3

$Q = (21\times 983.21) \times 4.182 \times (363 - 303)$

Blow down mass flow rate to drain ṁ = 20.64741 T/h.

Heat energy rate lost to the drain = 5180.848117 MJ/h

Heat energy recovered through the use of heat exchanger:

$Q = (21\times 980.56) \times 4.185 \times (363 - 313)$

Where ρ= 980.56 kg/m^3

Heat energy saving with heat recovery Q = 4308.825 MJ/h

Percentage of heat recovered= 4308.82578 /5180.848117 = 83.16%. Figure-14 shows the heat energy lost with blow down water by using the heat recovery unit and without the use of heat recovery unit. It is observed that the quantity of heat lost with blow down water has decreased with the use of heat recovery unit.

Amount of fuel saving with heat recovery system

Gross calorific value x mass of fuel = $\dot{m} \times C_p \times \Delta T$

Mass of fuel = [(21x994.8) x1x29)]/ 11000 = 55.075745 kg/h

Mass of fuel saving per day= 1321.81789 kg/day= 1.32181 ton/day which is equal to 482.460 ton/ year.

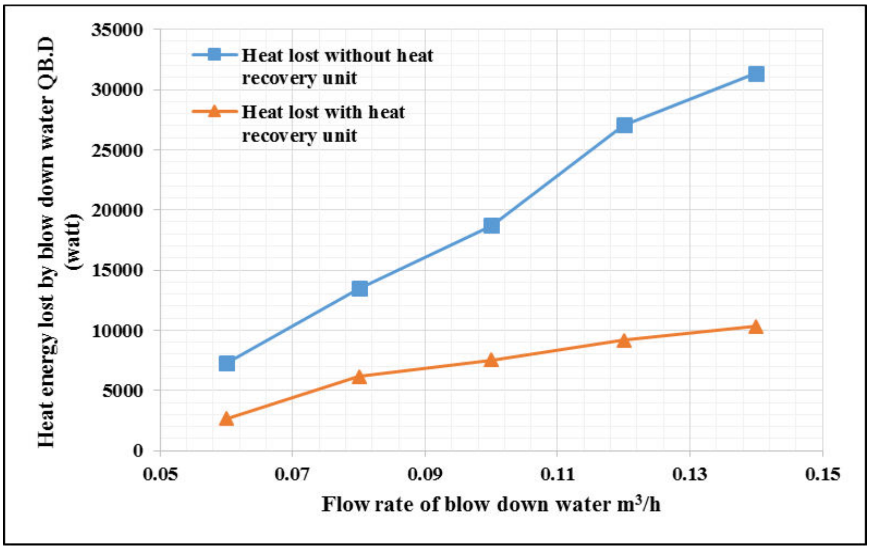

Figure-14. The heat energy lost with blow down water $Q_{B.D}$(watt) at feed water flow rate 0.1 m^3/hby using heat recovery unit and without using of a heat recovery unit.

5. CONCLUSIONS

From the obtained results it can be concluded that the best condition for volume flow rate of blow down water = 0.14 m^3/h and volumetric flow rate of feed water = 0.1 m^3/h. Where, at this level of flow rate for feed water and blow down water gave the highest value of heat exchange. Outlet temperature of blow down water decreases with increased the volumetric flow-rate of feed water. The output temperature of blow down water increased with increasing volumetric flow-rate of blow-down water. The heat energy gained by feed water $Q_{F.W}$ increased when the flow-rate of the side of coiled tube are fixed with a change in the volumetric flow rate of shell side. Outlet temperature of feed water decreased with increasing mass flow-rate of feedwater. The proposed design of the heat recovery unit which consists of a shell and coiled tube heat exchanger, contributed to recover nearly 83.16% of energy wasted with discharged blow down water from flash tank which is discharged at a temperature above 90℃. It means, 482.46 ton/ year in fuel (natural gas) can be saved. Reduction in fuel consumption means increased efficiency of boiler and reduced environmental pollution. It also neglects the need for blow down cooling before discharging to the sewer system.

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List of symbols

A_c Area of coiled tube (cm^2)

A_o Outside surface area of the helix (cm^2)

C_p Specific heat (J/kg.k)

d	distance (cm)
D_c	Helix diameter (mm)
De	Dean number
D_h	Hydraulic diameter (m)
d_i	Inside diameter of clean riser tube (m)
d_o	Outside diameter of coil (mm)
GCV	Type of fuel and gross calorific value of the fuel (kcal/kg)
L	Tube length (m)
L_c	Length of coil (m)
$\dot{m}$	Mass flow rate (Kg/s)
$\dot{m}_{B.D}$	Mass flow rate of B.D water (Kg/h)
N	Theoretical number of turns of coiled tube
D_e	Shell side equivalent diameter (mm)
P	Tube pitch (mm)
P B	Boiler operating pressure (N/m^2)
	Prprandtl number
Rc	The helix radius (mm)
Re	Reynolds number dimensionless
TDS	Total dissolve solid (ppm)
T_{h1}	Inlet temperature of hot fluid (℃)
T_{h2}	outlet temperature of hot fluid (℃)
U	overall heat transfer coefficient (w/m2.k)
u	Fluid average velocity (m/s)
V	Volume (m^3)
X	Thickness of coil wall (mm)
Q	Heat energy (watt)
T	temperature (Celsius)
ρ	density (kg/m^3)
$\dot{V}$	Volumetric flow rate (m^3/h)
Cp	Specific heat of water (kJ/kg.k)
B.D	Blow down
FW	Feed water
$Q_{B.D}$	heat energy lost (watt)
$Q_{F.W}$	heat energy gained (watt)
LMTD	Logarithmic Mean Temperature Difference

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