The Performance of the U Shape Double pipe heat exchanger under effect of using Active Techniques

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Abstract. The main aim from this research experimentally studied the effect of external power effect like use the active technique which is represented as an air bubble injection on shell side of U shape double pipe heat exchanger and in this investigations was used a suitable U shape heat exchanger with different position angle of the U shape Exchanger like position (U shape , ∩ Inverse U shape) in additionally used a system which has all the equipments that measuring flow rates and parameters, the vortex generation due to the curvature of bending shell and tube has strong effect to increase the performance of exchanger. The results with this injection inside the shell side demonstrated that the optimize position of exchanger with best performance of parameter was with (∩) Inverse and the exchanger enhancement was (24.4%) due to the different shape of diffuser which was used it with inverse U shape exchanger. the air bubble injection as active technique it suggested that the effect cause by the bubble increment the agitation of flow and due to the motion of fluid and air as mixing turbulence flow motion and increased the heat transfer rate and performance parameter of exchanger

Key words: active techniques, passive techniques, heat Transfer enhancement, heat exchangers.

Introduction:

Heat exchangers is important advice which is used in many factory in the world. The area space today very important for most of factory and companies so the mean aims from modern study how reduce the area space to design small exchanger with high performance Thorough investigation of U shape exchanger, the active Technique used as air bubble injection which is required the external energy supply to augment the heat transfer rate Heat transfer enhancement due to air bubble injection into a horizontal double pipe heat exchanger [1], Bubbling Generation on the Shell Side[2], air injection effect on the performance of horizontal shell and multi-tube heat exchanger with baffles[3], Effect of air bubble injection on the performance of a horizontal helical shell and coiled tube heat exchanger[4], heat transfer rate in a shell and tube heat exchanger with air bubble injection[8], Numerically Investigation on Heat Transfer[5], heat transfer enhancement in heat exchanger due to air bubbles injection[6], vertical shell-coiled tube heat exchanger with air bubble injection into shell side[7], Evaluation of Nusselt number and effectiveness for a vertical shell-coiled tube heat exchanger with air bubble injection into shell [8], experimental study for enhancement of heat transfer by using air bubbles injections inside a shell and coiled tube [9],exergy analysis of a double pipe heat exchanger under air bubble injection[10], Effect of air bubbles on heat transfer coefficient in turbulent convection flow[11], The effect of bubble on pressure drop reduction in helical coil[12], Temperature Distribution Measurements along Helical Coiled Tube Heat Exchanger with Effect of Air Injection[13].The main reason from this study to enhance the performance parameter of U shape exchanger with different positions of the exchanger under effect of Active and passive

Techniques the experimental condition was in Kirkuk technical college lab march 2021.

2. Material and Method:

2.1Theoretical Analysis :

Heat transfer rate can be calculated by using the following equation[13].

Qh= ṁhCPh(Thi-Tho) or Qc= ṁcCPc(Tco-Tci) .....(1)

And

$$Qave= (Qh + Qc) /2 \quad ......(2)$$

Where:

ṁh= mass flow rate of hot fluid

ṁc = mass flow rate of hot fluid

CPh , CPc = specific heat of hot and cold fluids respectively. Th,=hot fluid temperature

Tc = the cold fluid temperature .

The subscripts (i) and (o) represent the inlet and outlet hot and cold temperature respectively.

Effectiveness –P NTU method is the versatile and powerful method for designing and analyzing parallel coupling parallel coupling with tube fluid in series exchangers and can be calculated by: [14].

Consider the U shape and inverse U shape half symmetrical exchanger one half has counter flow and other has parallel flow So, due to this case symmetrical assumed that n=2 to represent as two exchanger connected to gather as parallel coupling with tube fluid in series.

$$Rt = \frac{C1}{C2/2} \quad .....(3)$$

Where

$$C1=Cmin= \dot{m}_h \times CP_h \quad ......(4)$$

$$C2=Cmax= \dot{m}_c \times \quad ......(5)$$

$$R_{1\,p}= 2\times R1 \quad ......(6)$$

$$Pt = \frac{Cmin}{C1} \times \varepsilon$$

Where:

$$C1=Cmin \quad ....(7)$$

$$\therefore Pt= \varepsilon = \frac{Q\ actual}{Q\ max} = \frac{T1_{h\,i}-T1_{h\,o}}{T1_{h\,i}-T2_{C\,i}} \quad ....(8)$$

$$Pt = \frac{\Delta T}{\Delta T_{Max}} = \frac{T1_{h\,i}-T1_{h\,o}}{T1_{h\,i}-T2_{C\,i}} \quad ......(9)$$

$$P_{1,p} = 1-(1-p_t)^{\frac{1}{n}} \quad .....(10)$$

Where

Pt = ε =Effectiveness of overall exchanger.

$P_{1,p}$ = Individual Effectiveness .

Compute the $NTU1_p$ from the table (3.6) Eq (III.I.2) [29].

$$NTU_t = \frac{1}{E}\ln\frac{2-p_t(1+R_{1\,p}-E)}{2-p_t(1+R_{1\,p}+E)} \quad ......(11)$$

Where

E= $(1+R^2)^{\frac{1}{2}}$

$$NTU_t = \sum_{i=1}^{2} NTU_{1p} \quad .....(12)$$

$$NTU_t= UA/Cmin \quad .....(13)$$

∴ UA=NTU_t ×Cmin

Where

NTU_t =(number of transfer units) is indicative of the size of the heat exchanger .

UA=Overall heat transfer Coefficient W/m^2C

3.Exergy Analysis :

Exergy as maximum work can be got it from system once equilibrium the system with environment condition. The Exergy (X) can be detemined from relation [17].

$$\sum X_i = \sum X_o - \sum X_{product} \quad ....(14)$$

Where

Xi=inlet Exergy

Xo=outlet Exergy

X product=amount of Exergy product in system.

Due to the some heat transfer rate as heat flux transport from the outer surface of shell side that mean the heat loss from hot side and heat gain from cold side are not equal[2].

Q h≠ Qc

Qh= ṁhCPh(Thi-Tho)

Qc= ṁcCPc(Tco-Tci)

So the Exergy losses for Exchanger under the steady condition can be computed [17].

$$X=Xh+Xc \quad ......(15)$$

Where

Xh= Exergy for hot side

Xc=Exergy for cold side

The Exergy change for hot and cold side can be illustrate Mathematically [2].

$$X_h = T_e[m_h(S_{ho}-S_{hi})] \text{ and } X_h = T_e[m_h(S_{ho}-S_{hi})] \quad ......(16)$$

Where

T_e = Environment Temperature and for this study used Te=12 c room temperature.

By using the Entropy change due to the temperature difference and with neglected the effect of losses caused by pressure drop the Entropy can be evaluated [2].

$$S_o - S_i = cp\ln(\frac{T_o}{T_i}) \quad ....(17)$$

Where

So=outlet Entropy

Si=inlet Entropy

By substituting the equations (15,16 and 17) we obtained Exergy losses as

$$X = T_e[m_h\, cp\ln\left(\frac{T_{ho}}{T_{hi}}\right) + T_e[m_h\, cp\ln\left(\frac{T_{co}}{T_{c_i}}\right) \quad ......(18)$$

4. Experimental Procedure and Instrumentation:

In this experiential study the first step was to design the U shape heat exchanger as schedule (1) show that the specific material which is used for this design heat exchanger.

Schedule (1) specific material design of heat exchanger.

U shape Heat Exchanger Length	150 Cm
Shell Diameter (Iron)	61.5 mm
Tube Diameter (Cupper)	19.05 mm
Tube Thickness	1.067mm
Air Injection Tube(plastic) Diameter for ∩ Inverse U shape position	60 mm
Holes of Air Injection in plastic Tube for ∩ inverse U shape	Average 0.5-100 micro meter
Air Injection Tube(plastic) Diameter for U shape position	25 mm
Holes of Air Injection in plastic Tube for U shape	Average 0.5-100 micro meter
Curvature bend of U Shape Exchanger	(R=40 cm)

Figure 1: Illustrate TQ equipment system

The second step was prepare the test system (TQ equipment system) as Fig(1) which is contain the small boiler and mass flow rate controller and indictors for hot and cold fluids .the operation fluid was water used for this investigation for both side tube and shell, The shell was insulated by Glass insulator to prevent the heat loss to surrounding. The system was connecting with the air compressor and air flow rate controller to supply air to air diffuser as mention in Fig(2) for inverse U shape and fig (5) diffuser for position U shape which spotted in side shell. to form the bubble between the tube and shell. The air injection through the diffuser and formed the bubbles of air and the bouncy force of bubble increase the motion to move the bubble up to top of exchanger . as mentioned in Fig (3)
system contain with ∩ Inverse U shape exchanger. And Fig (4) system contain U shape exchanger. In this test was used the water as fluid operation with constant mass flow rate of hot side (1) (L/min) or (0.016457 kg/sec) and kept temperature constant with (60℃) respectively. and cold side in shell with flow rate (1-5) (L/min)or (0.016457 -0.083103333) kg/sec and with each change flow in shell side use air injection rate (1 – 4) L/min.

Figure 2: Air Diffuser of Inverse U shape

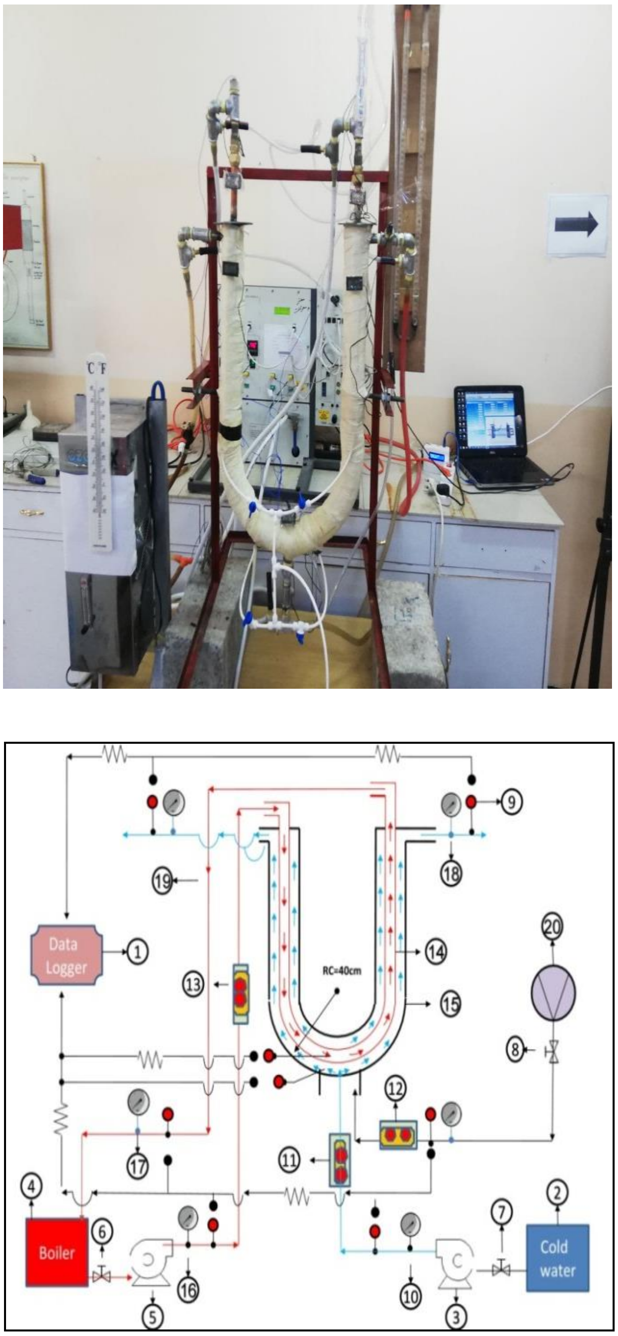

Figure 3: Illustrate ∩ inverse U shape
See Appendix A Schedule 2 further information

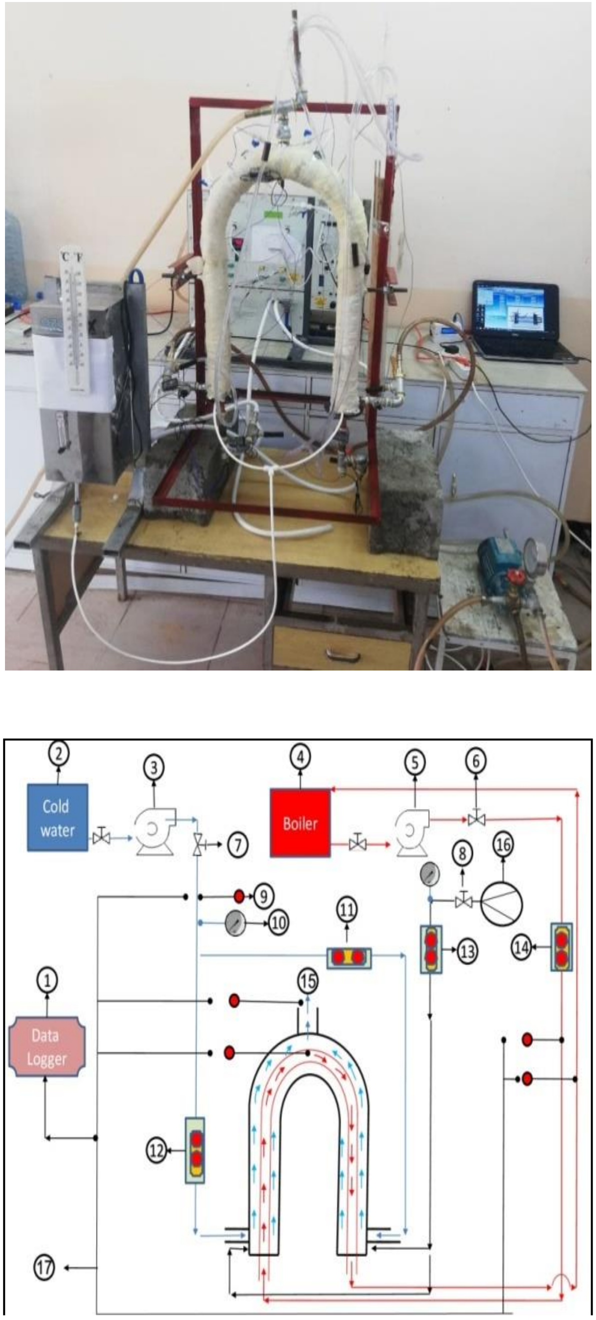

Figure 4: Illustrate U shape
See Appendix A Schedule 2 further information

Figure 5: Air Diffuser of U shape

5. Results and Discussion:

This investigation experimentally studied the effect of air bubble injection on the performance parameter for different position of heat exchanger either U shape exchanger type and (∩) Inverse U shape type the each picture illustrates denote the relationship between the air injection rate for different position U shape and inverse U shape either with or without air bubble injection. the heat exchanger performance of active with two position of exchanger show that the best position of heat exchanger was (∩) Inverse U shape type with enhance around (3-4%) the data was better than U shape position and the heat transfer rate increase with use air injection rate till air flow rate (4 L/min) after this flow rate the performance will be stable and no strong temperature difference .

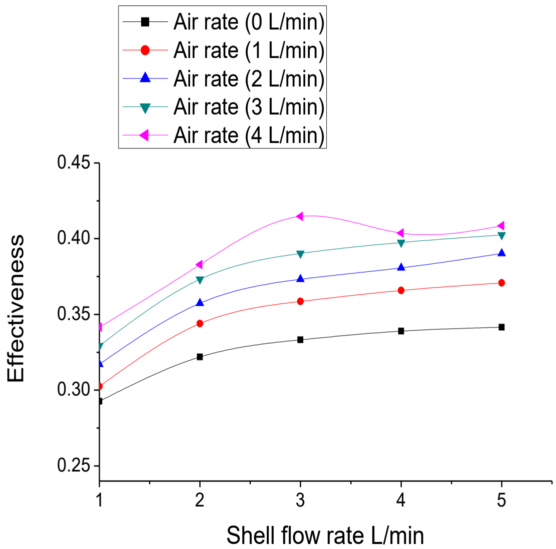

Figure 6: U shape the relationship between the Air injection rate and the Effectiveness

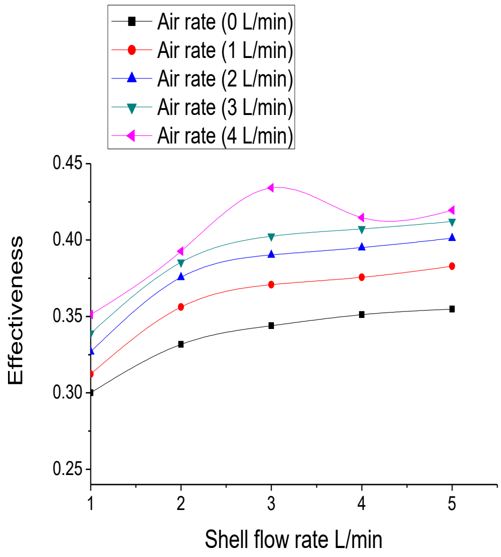

Figure 7: Inverse U shape the Relationship between the Air injection rate and the Effectiveness

Fig(6-7) show that relationship between the air injection rate and the Effectiveness for two position U shape and inverse U shape and the relation demonstrated that the Effectiveness increase with increase the air injection specially with air rate (3-4) L/min,The effectiveness enhancement was increase to (26%) with inverse U shape and the shell flow rate after reach the 5 L/min with air rate (3-4) the performance of effectiveness step by step decrease because may be the effectiveness reaching the maximum value of this type exchanger.

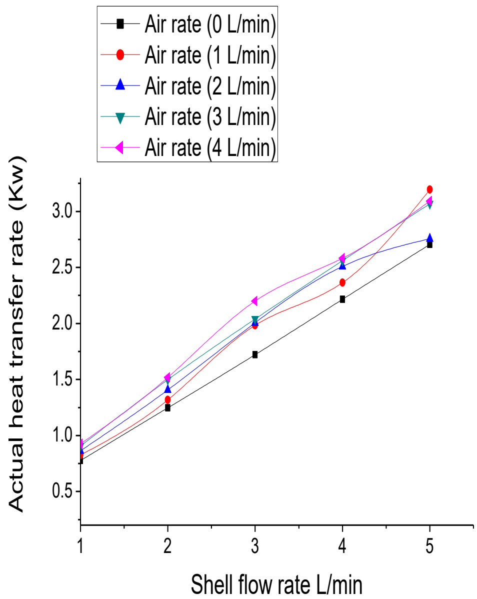

Figure 8: U shape the Relationship between the Air injection rate and the Actual heat transfer rate

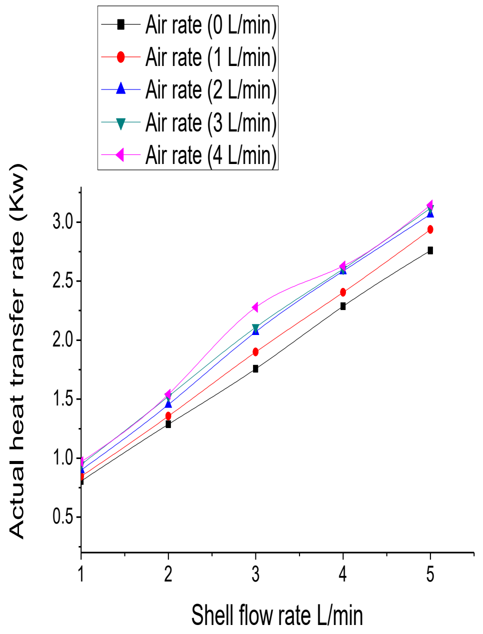

Figure 9: Inverse U shape
the Relationship between the Air injection rate and the Actual heat transfer rate

Fig(8-9) show that the relationship between the air injection rate and the actual heat transfer rate either use the U shape or Inverse U shape exchanger the result of experimental show that the heat transfer rate of exchanger increase with increase the air rate bubble injection and the maximum enhance actual heat transfer for this investigation was (29.7%) with inverse U shape and air flow rate 5 L/min.

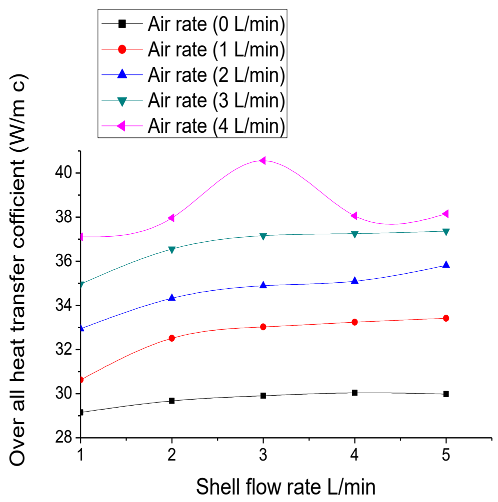

Figure 10: U shape the Relationship between the Air injection rate and the overall heat transfer coefficient

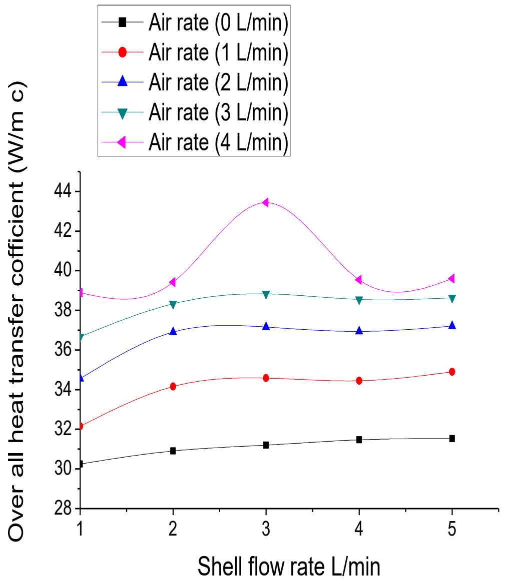

Figure 11: Inverse U shape
the Relationship between the Air injection rate and the overall heat transfer coefficient

Fig(10-11) demonstrated that the relation between the air rate bubble injection and overall heat transfer coefficient and the figure demonstrated that the when use active technique as air injection with both position of exchanger the overall heat transfer coefficient was strong enhance (39%) especially with first shell flow rate and air rate 3 (L/min).

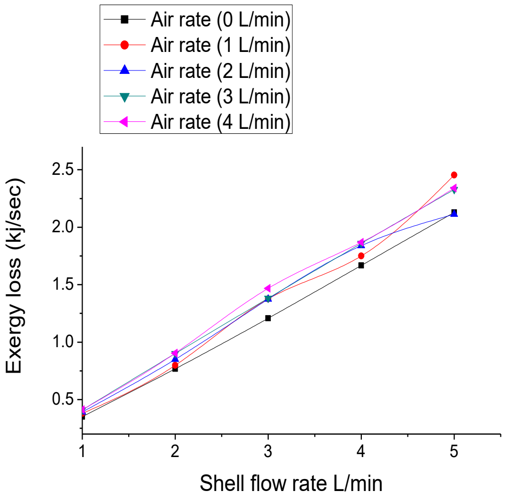

Figure 12: U shape the Relationship between the Air injection rate and the Exergy loss

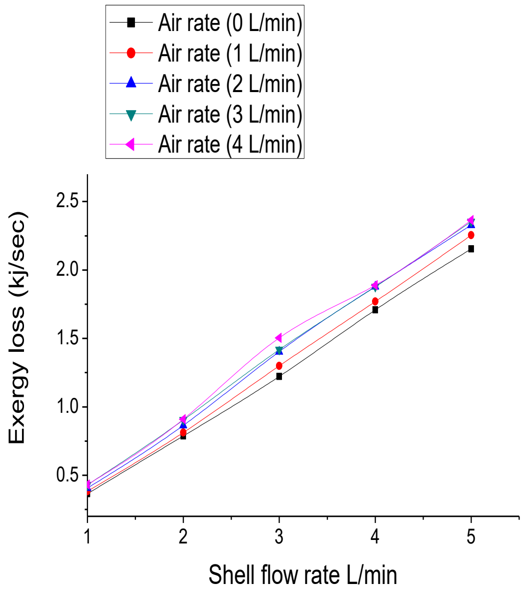

Figure 13: Inverse U shape
the Relationship between the Air injection rate and the Exergy loss

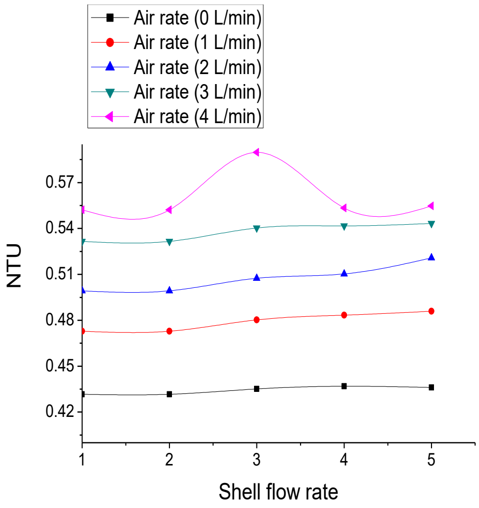

Figure 14: U shape
the Relationship between the Air injection rate and the Number of transfer unit

Figure (12-13) demonstrated that the two position of exchanger with using the air rate and fig (12-13) the relations with the exergy loss the exergy loss was increased with increased the air rate bubble injection in shell side and due to use external power which represented as air
injection inside shell side and increment the exergy loss (22%).with neglect the
pressure drop and friction while calculate the exergy loss.

Fig(14-15) demonstrated that the two position of exchanger with using the air injection rate with relation with the number of transfer unit and the result show that the NTU increment with raise the air rate injection and the strong enhancement was (39%) that is because the air bubble increase NTU.and the data with flow rate of shell (3-4 L/min) step by step move down and get stable with air flow rate (3-4) L/min.

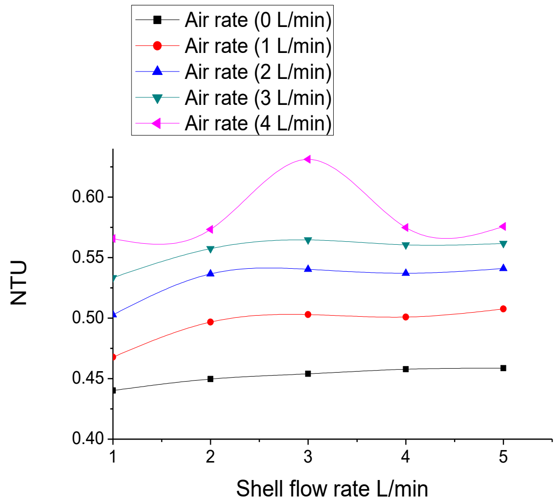

Figure 15: U shape
the Relationship between the Air injection rate and the Number of transfer unit

6. Conclusion

The data analysis of experimental study show once use varies rate of shell side with varies rate of air bubble injection with two different position of exchanger U shape and inverse U shape the flowing conclusions of this experimental study.

1. The best position of exchanger was inverse U shape due to the type of air bubble diffuser which use with this position it was little bit bigger than the U shape .

2. Once increase the air rate bubble injection the Effectiveness and NTU parameter enhance (26%, 39%) respectively.
3. A ctual heat transfer rate and overall heat transfer coefficient increase to (29.7%,39%) Respectively.
4. Exergy loss was increase with increase the air rate that is because use external power as air rate and the exergy loss was calculate by different temperature and neglect the effect of pressure drop and friction.

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Appendix A

Schedule 2 information about layout of Fig (1)

Information U shape	NO	Information U shape	NO
Cold water tank	2	Data Logger	1
Boiler and Tank	4	Cold water pump	3
Hot water valve	6	Hot water pump	5
Air valve	8	Cold water valve	7
Pressure gauge	10	Thermo couples	9
Air flow rate	12	Cold water flow meter	11
Inner tube	14	Hot water flow meter	13
Pressure gauge hot in side	16	Outer tube of shell	15
Pressure gauge hot out side	18	Pressure gauge hot out side	17
Air compressor	20	System body	19

Schedule 3 information about layout of Fig (4)

Information ∩ shape	NO	Information ∩ shape	NO
Cold water tank	2	Data Logger	1
Boiler and Tank	4	Cold water pump	3
Hot water valve	6	Hot water pump	5
Air valve	8	Cold water valve	7
Pressure gauge	10	Thermo couples	9
Cold water flow meter	12	Cold water flow meter	11
Hot water flow meter	14	Air flow rate	13
Air compressor	16	Water outlet	15
		System body	17