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The University of Jordan

School of Engineering

Chemical Engineering Department

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Experiment Number (5+6)

Shell and tube heat exchanger

Concentric tube heat exchanger

Type of the report : short report

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Abstract

Heat exchanger is a device that allows heat from a fluid to pass to a second fluid with out the two fluids having to mix together or come into direct contact. Thus, devices like Shell and Tube Heat Exchanger and concentric tube heat exchanger are used to conduct this experiment which consists of two flow patterns co-current and counter current flow.

The objectives of this experiment are to investigate the heat transfer capabilities of a shell and tube heat exchanger and concentric tube heat exchanger , to obtain the effect of flow rate on the overall heat transfer coefficient to get the differences and similarities between co- and counter-current operations clear and to obtain the performance of a heat exchanger, the best convergence of Qc and Qh (the ratio of Qc/Qh is nearest to 1.0).

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Results:

For shell and tube heat exchanger

Table (1): Specifications for shell and tube heat exchanger

heat transmission area (m^2)	0.0182
heat transmission length (m)	1.008
cold water flow rate (l/min)	1.664
cold water flow rate (m^3/s)	2.773*10^-5

- Co-current flow

Table (2): raw data for co current flow in shell and tube heat exchanger

hot water flow rate (l/min)	hot water flow rate (m^3/s)	T hot in (C)	T hot out (C)	T cold in (C)	T cold out (C)	ΔT max	ΔT hot	ΔT cold
3	0.00005	59.6	55.8	26.5	32	33.1	3.8	5.5
4	6.66667E-05	60	56.9	27.1	33	32.9	3.1	5.9
4.7	7.83333E-05	59.9	57	27.1	33.5	32.8	2.9	6.4
5	8.33333E-05	59.8	57.1	27.2	33.8	32.6	2.7	6.6
6	0.0001	59.8	57.4	27.2	34.3	32.6	2.4	7.1

Table (3.a): parameters for co current flow in shell and tube heat exchanger

cold stream Avg temp (K)	density cold (Kg/m³)	Cp cold (J/Kg.K)	Cold mass flow rate (Kg/s)	hot stream Avg temp (K)	density hot (Kg/m³)	Cp hot (J/Kg.K)	Hot mass Flow rate (Kg/s)
302.25	995.62	4180	0.0276	330.7	984.44	4190	0.0492
303.05	995.7	4180	0.0276	331.45	984.06	4190	0.0656
303.3	995.62	4180	0.0276	331.45	984.06	4190	0.0771
303.5	995.56	4180	0.0276	331.45	984.06	4190	0.0820
303.75	995.49	4180	0.0276	331.6	983.98	4190	0.0984

Table (3.b) parameters for co current flow in shell and tube heat exchanger

Q absorbed (W)	Q emitted (W)	Q loss (W)	ΔT_1	ΔT_2	ΔT_{lmt}	U (W/m².K)	η overall (%)	η cold (%)	η hot (%)	η exchanger (%)
634.72	783.71	148.99	33.1	23.8	28.2	1527.0	81.0	16.6	11.5	14.0
680.94	852.13	171.19	32.9	23.9	28.16	1662.7	79.9	17.9	9.4	13.7
738.58	936.66	198.07	32.8	23.5	27.89	1845.3	78.9	19.5	8.8	14.2
761.62	927.72	166.10	32.6	23.3	27.69	1840.9	82.1	20.2	8.3	14.3
819.26	989.49	170.23	32.6	23.1	27.577	1971.5	82.8	21.8	7.4	14.6

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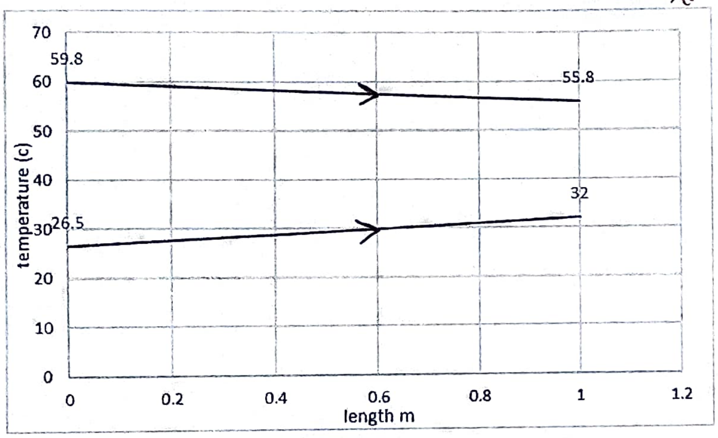

Figure (1):temperature profile in co-current shell and tube

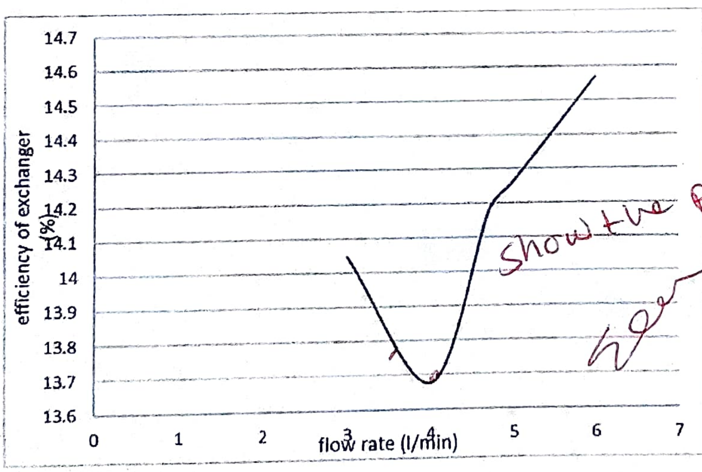

Figure (2):efficiency vs hot water flow in co-current shell and tube

➢ Counter current flow

Table (4) raw data for counter current flow in shell and tube heat exchanger

hot water flow rate (l/min)	hot water flow rate (m^3/s)	T hot in (C)	T hot out (C)	T cold in (C)	T cold out (C)	ΔT max	ΔT hot	ΔT cold
3	0.00005	60.1	56.3	27.2	33.2	32.9	3.8	6
4	6.66667E-05	60.2	57.1	27.3	34	32.9	3.1	6.7
5	8.33333E-05	59.9	57.2	27.3	34.5	32.6	2.7	7.2
6	0.0001	60	57.7	27.4	35	32.6	2.3	7.6

Table (5.a): parameters for counter current flow in shell and tube heat exchanger

cold stream Avg temp (K)	density cold (Kg/m^3)	Cp cold (J/Kg.K)	Cold mass flow rate (Kg/s)	hot stream Avg temp (K)	density hot (Kg/m^3)	Cp hot (J/Kg.K)	Hot mass flow rate (Kg/s)
303.2	995.65	4180	0.0276	331.2	984.19	4190	0.0492
303.65	995.52	4180	0.0276	331.65	983.96	4190	0.0656
303.9	995.44	4180	0.0276	331.55	983.01	4190	0.0819
304.2	995.35	4180	0.0276	331.85	983.86	4190	0.0984

Table (5.b): parameters for counter current flow in shell and tube heat exchanger

Q absorbed (W)	Q emitted (W)	Q loss (W)	ΔT_1	ΔT_2	ΔT_{lmt}	U ($W/m^2.K$)	η overall (%)	η cold (%)	η hot (%)	η exchanger (%)
692.44	783.51	91.07	32.9	23.1	28.2	1526.6	88.38	18.24	11.55	14.89
773.13	852.04	78.92	32.9	23.1	28.16	1662.5	90.74	20.36	9.42	14.89
830.76	926.73	95.98	32.6	22.7	27.89	1825.7	89.64	22.09	8.28	15.18
876.83	948.15	71.32	32.6	22.7	27.69	1881.4	92.48	23.31	7.06	15.18

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27.99
27.96
27.59
27.57

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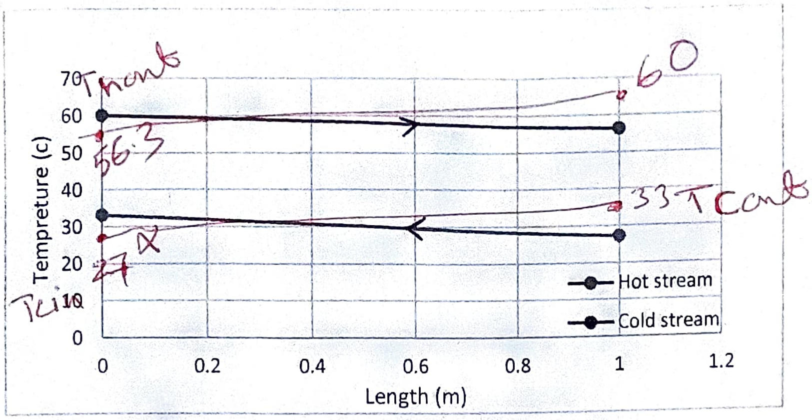

Figure (3) temperature profile in counter current shell and tube

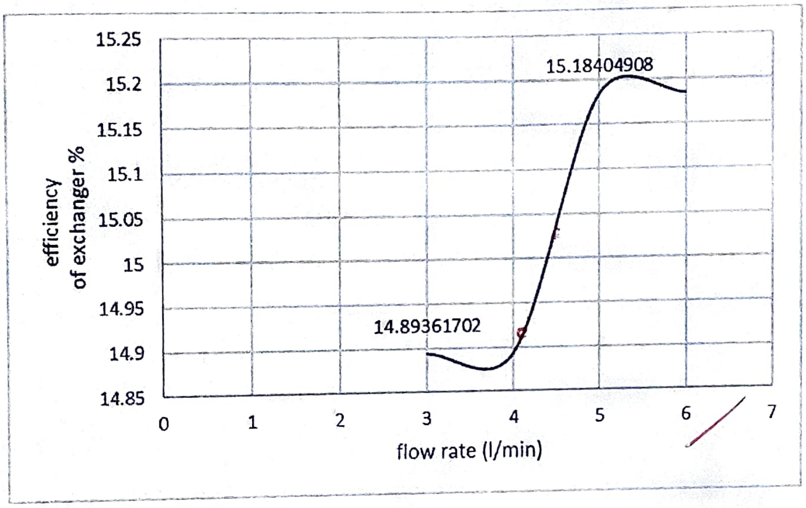

Figure (4)):efficiency vs hot water flow in counter current shell and tube

Results:

For concentric tube heat exchanger

Table (6): Specifications for concentric tube heat exchanger

Tube outer diameter	Shell outer diameter	Insulation thikness	Heat transfer length	Heat transfer area	Cold water flow rate	Cold water flow rate
15*0.7 wall	22*0.9 mm wall	20 mm wall	1.5 m	0.067 m2	1300 cm^3/min	2.16666E-5 m^3/s

- Co-current flow

Table (7): Raw data for co current flow in concentric tube heat exchanger

Hot water flow rate (cm3/min)	Hot water flow rate (m3/s)	T hot ,in	T hot ,out	T cold ,in	T cold, out	T max	T hot	T cold
1000	1.67E-05	58	48	27	34	31	10	7
1500	2.50E-05	60	50	27	37	33	10	10
2000	3.33E-05	60	51	27	40	33	9	13
2500	4.17E-05	60	52.5	27	41	33	7.5	14

Table (8.a): parameters for co current flow in concentric tube heat exchanger

cold stream Avg temp (K)	density cold (Kg/m^3)	Cp cold (J/Kg.K)	Cold mass flow rate (Kg/s)	hot stream Avg temp (K)	density hot (Kg/m^3)	Cp hot (J/Kg.K)	Hot mass Flow rate (Kg/s)
303.5	995.56	4180	0.0216	326	986.73	4180	0.0164
305	995.1	4180	0.0216	328	985.77	4180	0.0246
306.5	994.62	4180	0.0216	328.5	985.53	4190	0.0329
307	994.45	4180	0.0215	329.25	985.16	4190	0.0410

Table (8.b): parameters for co current flow in concentric tube heat exchanger

Q absorbed (W) (cold fluid)	Q emitted (W) (hot fluid)	Q loss (W)	ΔT_1	ΔT_2	ΔT_{lmt}	U ($W/m^2.K$)	η overall (%)	η cold (%)	η hot (%)	η exchanger (%)
631.15	687.42	56.27	31	14	21.39	479.76	91.81%	22.58%	32.26%	27.42%
901.23	1030.13	128.90	33	13	21.47	716.14	87.49%	30.30%	30.30%	30.30%
1171.03	1238.81	67.78	33	11	20.03	923.32	94.53%	39.39%	27.27%	33.33%
1260.90	1289.94	29.05	33	11.5	20.40	943.98	97.75%	42.42%	22.73%	32.58%

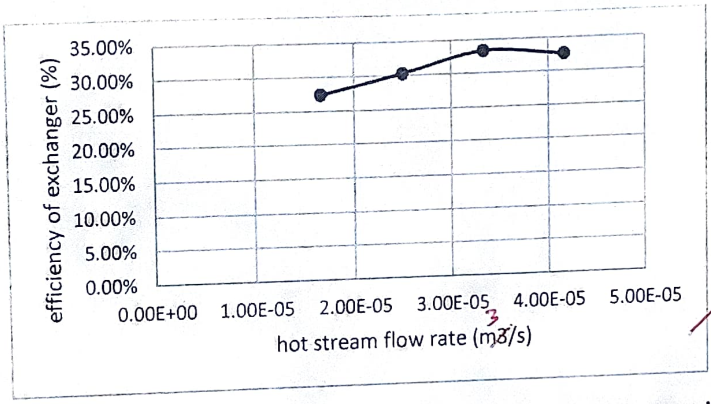

Figure (5)):efficiency vs hot water flow in co-current concentric tube

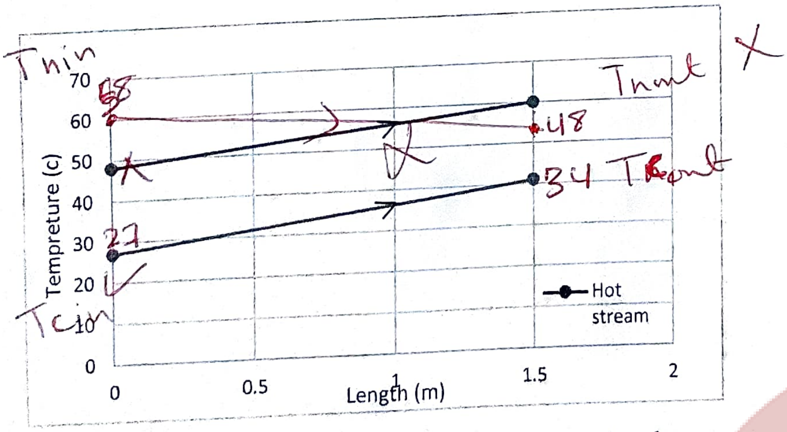

Figure (6): temperature profile in co-current concentric tube

- Counter current flow

Table (9): Raw data for counter current flow in concentric tube heat exchanger

Hot water flow rate (cm3/min)	Hot water flow rate (m3/s)	T hot ,in	T hot , out	T cold ,in	T cold ,out	T max	T hot	T cold
1000	1.67E-05	60	47	27	36	33	13	9
1500	2.50E-05	60	49	27	38	33	11	11
2000	3.33E-05	60	50	27	39	33	10	12
2500	4.17E-05	60	51	27	40	33	9	13

Table (10.a): parameters for counter current flow in concentric tube heat exchanger

cold stream Avg temp (K)	density cold (Kg/m^3)	Cp cold (J/Kg.K)	Cold mass flow rate (Kg/s)	hot stream Avg temp (K)	density hot (Kg/m^3)	Cp hot (J/Kg.K)	Hot mass Flow rate (Kg/s)
304.5	995.26	4180	0.0216	326.5	986.49	4180	0.0164
305.5	994.94	4180	0.0216	327.5	986.01	4180	0.0247
306	994.78	4180	0.0216	328	985.77	4180	0.0329
306.5	994.45	4180	0.0215	328.5	985.53	4190	0.0411

Table (10.b): parameters for counter current flow in concentric tube heat exchanger

Q absorbed (W) (cold fluid)	Q emitted (W) (hot fluid)	Q loss (W)	ΔT_1	ΔT_2	ΔT_{lmt}	U (W/m^2.K)	η overall (%)	η cold (%)	η hot (%)	η exchanger (%)
811.24	893.43	82.19	33	11	20.03	665.90	90.80%	27.27%	39.39%	33.33%
991.19	1133.42	142.23	33	11	20.03	844.77	87.45%	33.33%	33.33%	33.33%
1081.13	1373.51	292.38	33	11	20.03	1023.71	78.71%	36.36%	30.30%	33.33%
1170.83	1548.51	377.68	33	11	20.03	1154.15	75.61%	39.39%	27.27%	33.33%

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21.

21.98

2.94

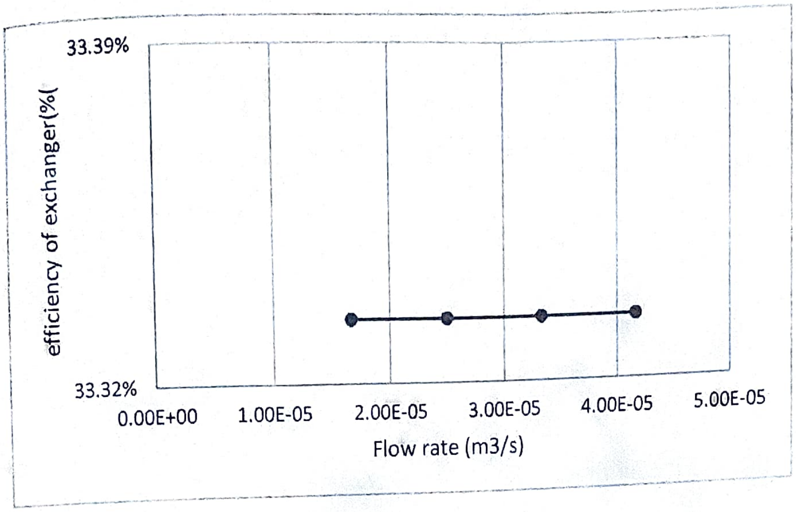

Figure (7)):efficiency vs hot water flow in counter current concentric tube

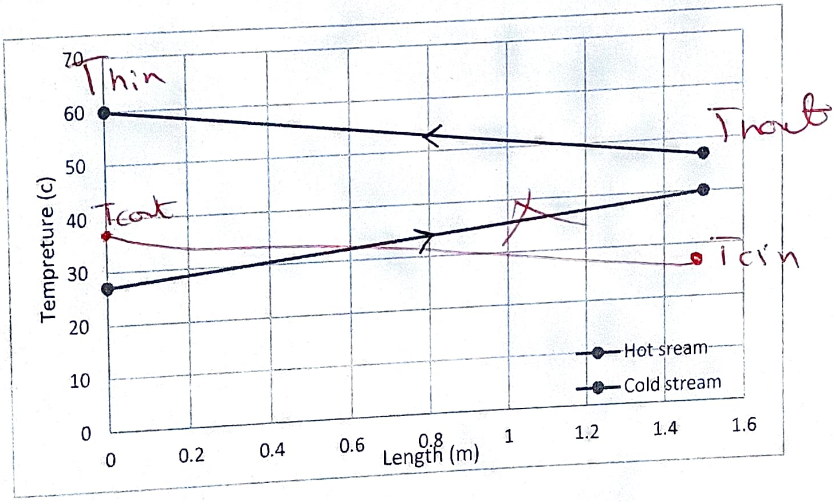

Figure (8) temperature profile in counter current concentric tube

Discussion

Shell and tube exchanger

As we can see in figure 2 * that the greater the flow, the greater the efficiency, especially the flow of hot water. Why? Because we are improving the heat exchange by increasing the flow, the flow increases the turbulent, and this enhances the heat exchange, so the higher the flow, the higher the efficiency .

We conclude that in the counter - current the efficiency is better because the heat exchange is better

Concentric tube exchanger

Increasing hot water temperature increases the overall heat transfer coefficient and that leads to increase the rate of heat transfer

The higher the flow rate of the fluids flowing in the heat exchanger, the higher the rate of heat transfer, thus the better the performance of the heat exchanger.

In counter current the temperature difference between the hot and cold water is higher, that means the rate of heat transfer is higher and the efficiency is better.

Conclusion

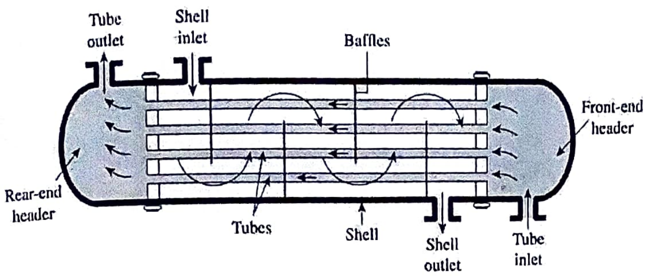

Figure (9):shell and tube heat exchanger

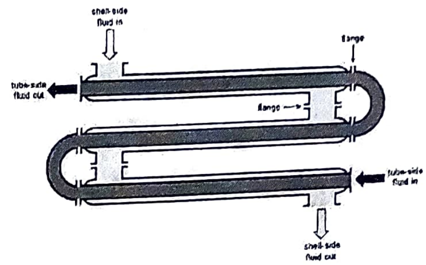

Figure (10):concentric tube heat exchanger

Heat exchangers are devices that transfer energy, in the form of heat, from one working fluid to the next, whether that be solids, liquids, or gases. These devices are essential for refrigeration, power generation, HVAC, and more, and come in many shapes and sizes that can both introduce heat or remove it

the fundamental point of heat exchangers is to pass a hot fluid through a cold fluid without mixing them, so that only their heat is transferred. The above diagram shows two inlets and two outlets, where each fluid starts at their respective inlet and exits the device at their outlets.

In shell and tube exchanger the tube-side flow passes through the tube bundle (secured by metal plates known as tube sheets or tubeplates) and exits the tube outlet. Similarly, the shell-side flow starts at the shell inlet, passes over theses tubes, and exits at the shell outlet. The headers on either side of the tube bundle create reservoirs for the tube-side flow and can be split into sections according to specific heat exchanger types.

In concentric tube exchanger there will be an inner tube through which the hot water will pass and an outer tube surrounding it through which the cold water will pass through .

Increasing the volumetric flow rate will increase the power emitted and absorbed for both counter current flow and co-current flow that will surely affect in decrease of the power lost for each of the volumetric flow rate.

The efficiency for a counter current flow is greater than co-current flow making the flow is a better option for a heat exchanger system. Besides, heat transfer coefficient is also change when the volumetric flow rate is increased.

Overall counter current flow has a better heat exchanger performance factor when it comes to compare with co-current flow

References

Website :: https://www.haarslev.com/products/shell-tube-heat-exchanger/

Website : All About Shell And Tube Heat Exchangers - What You Need To Know (thomasnet.com)

https://www.engineeringtoolbox.com/amp/water-density-specific-weight-d_595.html

https://www.researchgate.net/profile/Zoubair_Boulahia/post/In_heat_exchanger_does_heat_transfer_between_fluids_increases_or_decreases_if_flow_rates_of_both_the_fluids_are_increased/attachment/59d6472179197b80779a20a3/AS:461217782341633@1486974296791/download/Chapter+4.pdf10/08/2022

Coulson Richardson_s_Chemical_Engineering__vol_1 6th edition chapter 9

Appendix

sample of calculation

& For which Exchanger

co-current :

& shell? CO

flow first row :

cold water mass flow rate =ρ*Q/s =995.62 kg/m^3*2.77*10^-5m^3/s =0.0275kg /s

Qabs =mc *cpc*(Tout-Tin) =0.0275*4180*(32-26.5)=632.2 W

hot water mass flow rate =ρ*Q/s =984.44*2.77*10^-5 =0.0492 kg/s

Qemit =mh *cph *(Tout-Tin)=783.4

Qloss=Qemit-Qabs =783.4-632.2=151.2W

overall heat transfer efficancy = Qabs/Qemit=632.2/783.4=81%

ΔTcold=Tcold out-Tcold in =32-26.5=5.5

ΔThot =Thot in -Thot out =59.6-55.8=3.8

ΔTmax =Thot in -Tcold in =59.6-26.5=33.1

ηcold =ΔTcold/ΔTmax=(5.5/33.1)*100=16.6%

ηhot=ΔThot/ΔTmax =(3.8/33.1)*100=11.5

ηexchanger =(ΔThot-ΔTcold)/2 =14%

....

ΔT1=Thot in -Tcold in =59.6-26.5=33.1

Δt2=Thot out -Tcold out

55.8-32=23.8

ΔT1m=ΔT1-Δt2/Ln(ΔT1/Δt2) =28.2

Area =dmL=5.77*10^-3*1.008=0.0182 m^2

overall heat transfer coefficient (U)=Qemit/A*ΔT1m 283.4/(0.0182*28.2)

Where is the Sample of Calculation For Concentric tube heat Exchanger

Shell and Tube Heat Exchanger Data Sheet

T1 hotout
T2 hot in
T3 coldin
T4 coldout

Cold water flow rate: [illegible]

Co-current flow:

Hot water flow rate (Liter/min)	$T_{hot,in}$ (°C)	$T_{hot,out}$ (°C)	$T_{cold,in}$ (°C)	$T_{cold,out}$ (°C)
3	59.8	55.8	26.5	32.0
4	59.9	56.9	27.1	33.0
5	59.8	57.1	27.2	33.8
6	59.8	57.4	27.2	34.3

Counter-current flow:

Hot water flow rate (Liter/min)	$T_{hot,in}$ (°C)	$T_{hot,out}$ (°C)	$T_{cold,in}$ (°C)	$T_{cold,out}$ (°C)
3	60.1	56.3	27.2	33.2
4	60.2	57.1	27.3	34.0
5	59.9	57.2	27.3	34.5
6	60.0	57.7	27.4	35.0

Rula Mustafa
3/8/2022

Instructor signature:
Date:

Concentric Tube Heat Exchanger Data Sheet

Heat transfer area: _____________

Heat transfer length: _____________

Cold water flow rate: 1300cm³/min

Co-current flow:

Hot water flow rate (cm^3/min)	$T_{hot,in}$ (°C)	$T_{hot,out}$ (°C)	$T_{cold,in}$ (°C)	$T_{cold,out}$ (°C)
1000	58	48	27	34
1500	60	50	27	37
2000	60	51	27	40
2500	60	53.5	27	41

Counter-current flow:

Hot water flow rate (cm^3/min)	$T_{hot,in}$ (°C)	$T_{hot,out}$ (°C)	$T_{cold,in}$ (°C)	$T_{cold,out}$ (°C)
1000	60	47	27	36
1500	60	49	27	38
2000	60	50	27	39
2500	60	51	27	40
	60			

Instructor signature: Rula Mustafa

Date: 3/8/2022