PERFORMANCE TEST OF COUNTER AND PARALLEL FLOW HEAT EXCHANGERS USING COPPER TUBES AND VARIABLE FLOW RATE OF COLLING FLUID

Course Title: Project and Thesis
Course Code: ME-400

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SEPTEMBER-2023

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DHAKA-1215, BANGLADESH

SEPTEMBER--2023

Declaration

It is declared hereby that this thesis paper or any part of it has not beensubmitted to anywhere else for the award of any degree.

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Md. Mehedi Hasan

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Md Polash Miah

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Md. Abu Jubaer Joy

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Pijush Sarker

Certification

This is to certify that this project entitled "**Performance Test of Counter and Parallel Flow Heat Exchangers Using Copper Tubes and Variable Flow Rate of Cooling Fluid**" is done by the following students under my direct supervision. This project work has been carried out by them in the laboratories of the Department of Mechanical Engineering under the Faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering.

<u>Supervisor:</u>

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ACKNOWLEDGENENT

Gratitude takes three forms a felling from heart, an expression in words and giving a return. We take this opportunity to express our heartfelt feelings.

This satisfaction and euphoria that accompany a successful competition of any task would be without the mention of the people incomplete without the mention of the people who made it possible, with whose constant guidance and encouragement crowned our efforts with success.

We consider it as our privilege to express our gratitude and respect to all those who guided and inspired in the completion of this project.

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ABSTRACT

Heat exchanger is equipment used to transfer heat from one fluid to another. It has extensive domestic and industrial applications. Extensive technical literature is available on heat exchanger design, operation and maintenance, but it is widely scattered throughout the industrial bulletins, industrial design codes and standard, technical journals, etc. The purpose of this thesis paper is to consolidate into basic background and concepts design of heat exchangers, operation, cleaning and green technology maintenance on heat exchanger closely related to the industrial practices. At the same time a fin-and-tube heat exchanger model performance is presented in this paper. It uses empirical heat transfer correlations identified in the literature. The model structure, its range of validity and accuracy are described in detail.

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Mathematical Symbols

L= Length

A= Area

D= Diameter

Q= Total Heat

U= Over all co-officiant of Heat Transfer

m_c= Mass of Cold Water

m_h= Mass of Hot Water

T_h= Temperature of Hot Water

T_c= Temperature of Cold Water

ΔT= Temperature Difference

LMTD= Logarithmic Mean Temperature Difference

CHAPTER -1

INTRODUCTION

1.1 INTRODUCTION

Heat exchanger is the one of the most important processes in engineering which transfers the heat between flowing fluids, means a process to transfer heat from one fluid to another fluid. To transfer internal thermal energy between two or more fluids at different temperatures heat exchanger is used. Usually fluids are not mixed in most of the heat exchangers. Mostly heat exchangers are used in petroleum, power, refrigeration and air conditioning, alternate fuels and automobile fields and day to day its uses are increasing. In a transient manner, heat transfer between fluids takes place through a separating wall or into and out of a wall in a heat exchanger. Fluids are separated by a heat transfer surface in many heat exchangers, and ideally, they do not mix or leak. Sometimes it referred to as a sensible heat exchanger if there is no phase change occurs in any of the fluids in the exchanger.

1.2 OBJECTIVE

Main objectives of this research work are given bellow:

1.2.1 To know about heat exchanger types.

1.2.2 To analyze the performance of copper tube heat exchanger for both counter and parallel flow.

1.2.3 Compare heat exchanger performance for both counter and parallel flow with different flow rates of cold fluid.

Chapter 2

HISTORY & LITERATURE

2.1 THE HISTORICAL DEVELOPMENT OF HEAT EXCHANGER

The historical development of heat exchangers can be traced back to the last century. The following is the historical development process of the heat exchanger.

The heat exchanger can be a separate device, such as a heater, cooler and condenser, etc.; it can also be a component of a process equipment, such as a heat exchanger in an ammonia synthesis tower.

Due to the limitation of manufacturing technology and scientific level, the early heat exchangers could only adopt simple structures, and the heat transfer area was small and the volume was large, such as the serpentine heat exchangers. With the development of the manufacturing process, a shelland-tube heat exchanger is gradually formed, which not only has a larger heat transfer area, but also has a better heat transfer effect. It has become a typical heat exchanger in industrial production for a long time.

Plate heat exchangers appeared in the 1920s and were used in the food industry. The heat exchanger made of plate instead of tube has compact structure and good heat transfer effect, so it has been developed into various forms one after another.

In the early 1930s, Sweden made the spiral plate heat exchanger for the first time. Then the British used brazing to produce a plate-fin heat exchanger made of copper and its alloy materials for the heat dissipation of aircraft engines.

At the end of the 1930s, Sweden produced the first plate and shell heat exchanger for use in pulp mills. During this period, in order to solve the heat exchange problem of strong corrosive media, people began to pay attention to heat exchangers made of new materials.

Around the 1960s, due to the rapid development of space technology and cutting-edge science, various high-efficiency and compact heat exchangers were urgently needed. Coupled with the development of stamping, brazing and sealing technologies, the heat exchanger manufacturing process has been further improved, which has promoted the vigorous development and wide application of compact plate surface heat exchangers.

In addition, since the 1960s, in order to meet the needs of heat exchange and energy saving under high temperature and high pressure conditions, typical shell-and-tube heat exchangers have also been further developed.

In the mid-1970s, in order to strengthen heat transfer, heat pipe heat exchangers were created on the basis of research and development of heat pipes.

After the 1980s, a new trend of independent development of heat transfer technology appeared in China, and a large number of enhanced heat transfer elements were introduced to the market.
Representative works during the climax of domestic heat transfer technology include baffle rod heat exchangers, new structure high-efficiency heat exchangers, high-efficiency reboilers, high-efficiency coolers, double-pass heat exchangers, plate heat exchangers, surface-based air coolers, etc.

After entering the 21st century, a large number of enhanced heat transfer technologies have been applied to industrial installations, and China's heat exchanger industry has achieved rapid improvement in the technical level, and plate heat exchangers have gradually risen. In recent years, China has also made major breakthroughs in large-scale shell-and-tube heat exchangers, large diameter threaded locking ring high-pressure heat exchangers, high-efficiency and energy-saving plate heat exchangers, and large-scale plate air preheaters.

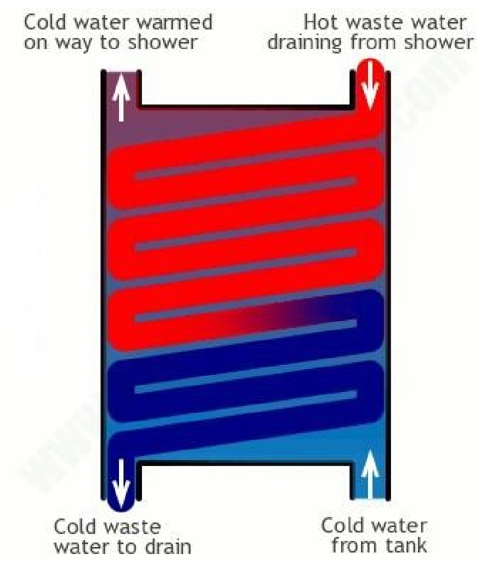


Figure1.1:- Concept of Heat-exchanger.

2.2 DEFINITION OF HEAT EXCHANGER

A heat exchanger is a device which allows for fast and efficient transfer of heat from one medium to another. It is used to heat or cool a particular medium using another in the vicinity. The process works based upon the basic science of flow of heat; from hot to cool medium. While anybody can decrease or increase the temperature of a medium; using physical contact or intermixing with another medium. A heat exchanger allows for the transfer of heat without actual contact in between.

It basically consists of segregated elements with high thermal conductivity to act as an element for heat transfer. They keep the two fluids separated from each other; while allowing efficient transfer of heat. Irrespective of the and shape of the exchanger; the actual heat transfer happen in response to the relative flow of liquid in these segregated elements.

2.3 DIFFERENT TYPES FLOW OF HEAT EXCHANGER

Mainly heat exchanger transfer of heat depend upon the three ways

2.3.1 Parallel flow

2.3.2 Counter flow

2.3.3 Cross flow

2.3.1 PARALLEL FLOW

Figure1.1 shows a fluid flowing through a pipe and exchanges heat with another fluid through an annulus surrounding the pipe. In a parallel-flow heat exchangerfluids flow in the same direction. If the specific heat capacity of fluids are constant, it can be shown that

2.3.2 COUNTER FLOW

Figure 1.2 shows a fluid flowing through a pipe and exchanges heat with another fluid through an annulus surrounding the pipe. In a counter-flow exchanger fluids flow in the opposite direction. If the specific heat capacity of fluids are constant,

2.3.3 CROSS FLOW

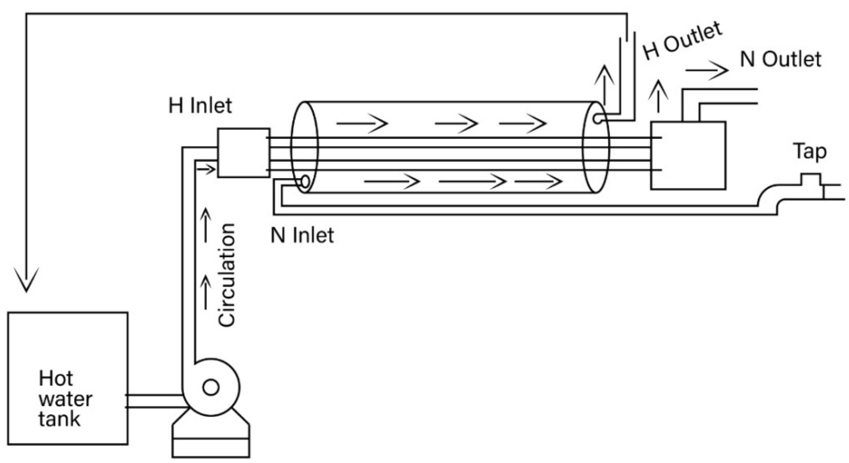
In a cross-flow exchanger the direction of fluids are perpendicular to each other. The required surface area, **A**cross for this heat exchanger is usually calculated by using tables. It is between the required surface area for counter-flow.

Chapter – 3

PROJECT OVERVIEW AND DESIGN METHODOLOGY

3.1 PROJECT OVERVIEW

Heat transfer performance of heat exchanger which is mostly used in corrosive environment was the main objective of this project. The space limitation is overcome by the use of straight configuration. It has greater corrosion resistance and zero fouling factors. So, we have designed and developed the straight tube in tube heat exchanger of copper material for the purpose, to know performance and utility.



DESIGN METHODOLOGY

3.2 FABRICATION OF SHELL

In the first case we collected hard PVC hollow tube from market, after that according to our design we cut the tube. Then attached transparent sheet on the both sides of the tube with bolt.

Shell Data Sheet:

- Diameter of shell 101.6 mm
- Height of shell 508 mm
- Thickness of shell 1.5 mm

Figure3.2:- PVC tube(Shell)

3.3 FABRICATION OF STRAIGHT COPPER TUBE

The heat exchangers coil is manufactured from copper material. The inner tube having dia. 6.4 mm and outer tube of dia. 12.5 mm. Pitch is of 30 mm . The cutting length of the tube is 610 mm. And there will be two tubes in same size. The end connections soldered at tube ends.

Figure 3.4: Fabrication of straight tube

3.4 REQUIRED FITTINGS

1. Transparent Sheet.
2. Nut Bolt.
3. Super Glue.
4. Water Sealent.
5. Hose Pipe.
6. Electric Water Heater.
7. Electric Socket.
8. Rubber Tube.

TRANSPARENT SHEET

Thin, clear material allowing light to pass through, often used for overlays, presentations, or protection.

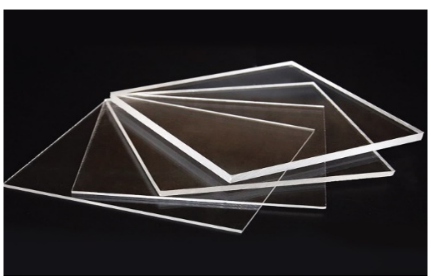


Figure 3.5: Transparent Sheet

NUT BOLT

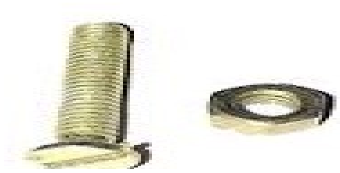


Figure3.6: Nut Bolt

Fastener used to join objects by threading and turning together.

SUPER GLUE

Strong adhesive bonds quickly, used for various materials, repairs, crafts.

Figure 3.7 : Super Glue

WATER SEALENT

Waterproof substance for sealing surfaces, preventing water infiltration and damage.

Figure 3.8 : Water Sealent

HOSE PIPE

Flexible tube for conveying water ofter used in garding task.

Figure 3.9: Hose Pipe

ELECTRIC WATER HEATER

Electric water heater heats water using electricity, providing hot water for various household needs

Figure 3.10 : Socket

ELECTRIC SOCKET

We use tank joint fittings at normal water tank create circulation line.

Figure 3.11: Electric Socket

RUBBER TUBE

A rubber tube is a flexible, cylindrical conduit made of rubber used for various fluid and gas transportation purposes.

Figure 3.12: Rubber Tube

3.5 REQUIRED ELECTRIC INSTRUMENT

1. **Dc pump**
2. **Adapter**

DC PUMP

Dc pump used to circulate cold water.

Figure 3.13: DC Pump

ADAPTER

Adapter use to run DC pump.

Figure 3.14: Adapter

3.6 REQUIRED MEASURING INSTRUMENT

1. **Digital Thermometer**

Thermometer used to measure temperature.

Figure 3.15: Digital thermometer

3.7 EXPERIMENT SET UP

The experimental setup for our thesis project involves a transparent tube (shell), capped at both ends with holes for two copper tubes. Tin boxes are attached to the copper tubes. Plastic pipes connect the water bucket to the tin boxes, creating a closed-loop system. To circulate cold water we installed a pump to the shell tube. The bucket, heated by an external source, circulates water through the tubes. Two additional holes in the tube facilitate water inlet and outlet. This setup is designed to test the heat transfer efficiency of the heat exchanger.

Figure 3.16: Experimental Setup of Straight Tube Heat exchanger

CHAPTER-4

4.1 PROCEDURE FOR TESTING COUNTER FLOW CONFIGURATION FOR STRAIGHT TUBE HEAT EXCHANGER

4.1.1 Close both inlet and outlet valves of Heat Exchanger.

4.1.2 Fill the hot water reservoir with the desired volume of hot water.

4.1.3 Fill the cold water reservoir with the required amount of cold water.

4.1.4 Begin by opening the hot water inlet valve of the Heat Exchanger.

4.1.5 Start the flow of hot water through the heat exchanger in a downward direction.

4.1.6 Simultaneously, initiate the cooling water pump to circulate cold water through the heat exchanger in an upward direction.

4.1.7 Record the following data:

4.1.7.1 Measure the mass flow rate of hot water: Collect hot water in a measuring flask over a specific period and record the time required to fill it. This will give you the flow rate in ml/sec.

4.1.7.2 Record the temperature of the hot water at both the inlet and outlet of the Heat Exchanger.

4.1.8. Monitor the system to ensure a stable and consistent flow of hot and cold water through the heat exchanger.

4.2 TEMPERATUE READING & CALCULATE DATA FOR COUNTER FLOW & PARALLEL FLOW

<u>COUNTER FLOW</u>

We will take the reading in two different mass flow rate:

Mass flow rate (Normal Water) 1 :

The volume water collected is 1000 ml

The density of water is 1000kg/m^3

Required time is 38 sec

So, Mass Flow Rate ≈ (1000 kg) / (38 seconds) ≈ 0.0263 kg/s

Mass flow rate for hot water :

The volume water collected is 1000 ml

The density of water is 1000kg/m³

Required time is 16 sec

So, Mass Flow Rate ≈ (1000 kg) / (16 seconds) ≈ 0.0625 kg/s

Table -4.2.1 Observation table for heat exchanger Counter flow & temperature data

Sr. No.	Initial temp (Hot water) ^{0}C (**TH Inlet**)	Final Temp (Hot water) ^{0}C (**TH outlet**)	Initial temp (cold water) ^{0}C (**TC Inlet**)	Final Temp (cold water) ^{0}C (**TC outlet**)	**(ΔT_1 =TH_I-TC_O)^{0}C**	**(ΔT_1 =$TH_O TC_I$)^{0}C**	**ΔTM ^{0}C**	Mass flow rate.(kg/s) (Cold Water)	Mass flow rate.(kg/s) (Hot Water)
1	52	40	32	32.5	19.5	8	12.93	0.0263 kg/s	0.0625 kg/s
2	51	40	32	32.9	18.1	8	12.31		
3	51	39	33	33.7	17.3	6	10.66		
4	48	37	33	34.5	13.5	4	7.80		
5	51	38	32	32.5	18.5	6	11.12		

Here

As per the definition and equation for Log Mean Temperature Difference (LMTD)

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{T_1}{T_2}\right)}$$

ΔT_1 → the temperature difference between hot and cold fluids at one end of the heat exchanger

ΔT_2 → the temperature difference between hot and cold fluids at the other end of the heat exchanger.
For counter current heat exchanger,

<u>For reading no 1</u>

ΔT_1 = TH1 - TC2 = 52– 32.5= 19.5 ^{0}C

ΔT_2 = TH2 - TC1 = 40 – 32 = 8 ^{0}C

Definition given above,

△T LMTD for counter current flow = (19.5- 8) / ln (19.5/8) = 11.5 / 0.8903 = 12.93^{0}C

For reading no 2

ΔT_1 = TH1 - TC2 = 51– 32.9= 18.1 ^{0}C

ΔT_2 = TH2 - TC1 = 40 – 32 = 8^{0}C

Definition given above,

△T LMTD for counter current flow = (18.1- 8) / ln (18.1/8) = 10.1 / 0.8188 = 12.31^{0}C

For reading no 3

ΔT_1 = TH1 - TC2 = 51– 33.7= 17.3 ^{0}C

ΔT_2 = TH2 - TC1 = 39 – 33 = 6^{0}C

Definition given above,

△T LMTD for counter current flow = (17.3 - 6) / ln (17.3/6) = 11.3 / 1.060= 10.66^{0}C

For reading no 4

ΔT_1 = TH1 - TC2 = 48– 34.5= 13.5 ^{0}C

ΔT_2 = TH2 - TC1 = 37 – 33 = 4^{0}C

Definition given above,

△ T LMTD for counter current flow = (13.5 - 4) / ln (13.5/4) = 9.5 / 1.216= 7.80^{0}C

For reading no 5

ΔT_1 = TH1 - TC2 = 51– 32.5= 18.5 ^{0}C

ΔT_2 = TH2 - TC1 = 38 – 32 = 6 ^{0}C

Definition given above,

△T LMTD for counter current flow = (18.5 - 6) / ln (18.5/6) = 12.5.5 / 1.123= 11.12^{0}C

Now △TM $_{average}$=∑△TM/No of △TM

=(12.93+12.31+10.66+7.80+11.12)/5

=10.96^{0}c

Now Tube length = 610*2 mm =1220 mm
= 1.22 m
Tube diameter d= 12.7mm
=0.0127m
Surface area A_s= ∏dl
=(3.1416×0.0127×1.22)
= 0.0486 m^2
Overall heat transfer coefficient U= 1200 W/m^2k

Heat transfer Q = $UA_s\Delta Tm_{avg}$
=(1200×0.0486×10.96)
=639.1872 W

Heat transfer rate Q^0=Q/T[Here T= 30 sec]
=639.1872/30
=21.306 Btu/hr

Mass flow rate (Normal Water) 2 :

The volume water collected is 1000 ml
The density of water is 1000kg/m^3
Required time is 14 sec
So, Mass Flow Rate ≈ (1000 kg) / (14 seconds) ≈ 0.0714 kg/s

Table -4.2.2 Observation table for heat exchanger counter flow & temperature data

Sr. No.	Initial temp (Hot water) ^{0}C (**TH Inlet**)	Final Temp (Hot water) ^{0}C (**TH outlet**)	Initial temp (cold water) ^{0}C (**TC Inlet**)	Final Temp (cold water) ^{0}C (**TC outlet**)	**(ΔT_1 =TH_I-TC_O)^{0}C**	**(ΔT_1 =TH_OTC_I)^0 C**	**ΔTM ^{0}C**	Mass flow rate.(kg/s) (Cold Water)	Mass flow rate.(kg/s) (Hot Water)
1	50	43	31	31.5	18.5	12	15.04		
2	49	43	32	32.6	16.4	11	13.57		
3	49	44	33	33.6	15.4	11	13.09	0.0714 kg/s	0.0625 kg/s
4	48	42	33	34.0	14	9	11.33		
5	50	42	32	32.5	17.5	10	13.40		

Here
As per the definition and equation for Log Mean Temperature Difference (LMTD)

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{T_1}{T_2}\right)}$$

ΔT_1 → the temperature difference between hot and cold fluids at one end of the heat exchanger

$\Delta T_2 \rightarrow$ the temperature difference between hot and cold fluids at the other end of the heat exchanger.
For counter current heat exchanger,

For reading no 1

ΔT_1 = TH1 - TC2 = 50– 31.5= 18.5 ^{0}C

ΔT_2 = TH2 - TC1 = 40 – 32 = 12 ^{0}C

Definition given above,

$\triangle$T LMTD for counter current flow = (18.5- 12) / ln (18.5/12) = 15.04^{0}C

For reading no 2

ΔT_1 = TH1 - TC2 = 49– 32.6= 16.4 ^{0}C

ΔT_2 = TH2 - TC1 = 43 – 32 = 11 ^{0}C

Definition given above,

$\triangle$T LMTD for counter current flow = (16.4- 11) / ln (16.4/11) = 13.57^{0}C

For reading no 3

ΔT_1 = TH1 - TC2 = 49– 33.6= 15.4 ^{0}C

ΔT_2 = TH2 - TC1 = 44 – 33 = 11 ^{0}C

Definition given above,

$\triangle$T LMTD for counter current flow = (15.4- 11) / ln (15.4/11) = 13.09 ^{0}C

For reading no 4

ΔT_1 = TH1 - TC2 = 48– 34= 14.0 ^{0}C

ΔT_2 = TH2 - TC1 = 42 – 33 = 9 ^{0}C

Definition given above,

$\triangle$ T LMTD for counter current flow = (14 - 9) / ln (14/9) = 11.33 ^{0}C

For reading no 5

ΔT_1 = TH1 - TC2 = 50– 32.5= 17.5 ^{0}C

ΔT_2 = TH2 - TC1 = 42 – 32 = 10 ^{0}C

Definition given above,

△T LMTD for counter current flow = (17.5 - 10) / ln (17.5/10) = 13.40 ^{0}C

Now $\triangle TM_{average} = \sum \triangle TM / \text{No of } \triangle TM$
=(15.04+13.57+13.09+11.33+13.40)/5
=13.29 ^{0}c

Now Tube length = 610*2 mm =1220 mm
= 1.22 m
Tube diameter d= 12.7 mm
=0.0127m
Surface area A_s= ∏dl
=(3.1416×0.0127×1.22)
= 0.0486 m^2
Overall heat transfer coefficient U= 1200 W/m^2k

Heat transfer Q = $UA_s\triangle Tm_{avg}$
=(1200×0.0486×13.29)
=775.073 W

Heat transfer rate Q^0=Q/T [Here T= 30 sec]
=775.073/30
=25.836 Btu/hr

PARALLEL FLOW

Reading taken in two different mass flow rate:
Mass flow rate (Normal Water) 1 :

The volume water collected is 1000 ml
The density of water is 1000 kg/m^3
Required time is 38 sec
So, Mass Flow Rate ≈ (1000 kg) / (38 seconds) ≈ 0.0263 kg/s

Mass flow rate for hot water :

The volume water collected is 1000 ml
The density of water is 1000 kg/m^3
Required time is 16 sec
So, Mass Flow Rate ≈ (1000 kg) / (16 seconds) ≈ 0.0625 kg/s

. **Table -4.2.3 Observation table for heat exchanger parallel flow and temperature data**

Sr. No.	Initial temp (Hot water) ^{0}C (**TH** Inlet)	Final Temp (Hot water) ^{0}C (**TH** outlet)	Initial temp (cold water) ^{0}C (**TC** Inlet)	Final Temp (cold water) ^{0}C (**TC** outlet)	**(ΔT_1 =TH_I-TC_O)^{0}C**	**(ΔT_1 =$TH_O TC_I$)^0 C**	**ΔTM ^{0}C**	Mass flow rate.(kg/s) (Cold Water)	Mass flow rate.(kg/s) (Hot Water)
1	50	44	32	32.3	17.7	12	14.69		
2	51	45	32	32.4	18.6	13	15.64		
3	51	46	33	33.3	17.7	13	15.26	0.0263 kg/s	0.0625 kg/s
4	48	44	33	34	14	11	12.4		
5	51	47	32	32.3	18.7	15	17.05		

Here
As per the definition and equation for Log Mean Temperature Difference (LMTD)

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{T_1}{T_2}\right)}$$

ΔT_1 → the temperature difference between hot and cold fluids at one end of the heat exchanger

ΔT_2 → the temperature difference between hot and cold fluids at the other end of the heat exchanger.
For parallel current heat exchanger,

For reading no 1

ΔT_1 = TH1 - TC2 = 50– 32.= 17.7 ^{0}C

ΔT_2 = TH2 - TC1 = 44 – 32 = 12 ^{0}C

Definition given above,

△T LMTD for parallel current flow = (17.7- 12) / ln (17.7/12) = 14.69 ^{0}C

For reading no 2

ΔT_1 = TH1 - TC2 = 51– 32.4= 18.6 ^{0}C

ΔT_2 = TH2 - TC1 = 45 – 32 = 13 ^{0}C

Definition given above,

△T LMTD for parallel current flow = (18.6- 13) / ln (18.6/13) = 10.1 / 0.8188 = 15.64 ^{0}C

For reading no 3

ΔT_1 = TH1 - TC2 = 51– 33.3= 17.7 ^{0}C

ΔT_2 = TH2 - TC1 = 46 – 33 = 13 ^{0}C

Definition given above,

△T LMTD for counter current flow = (17.7 - 13) / ln (17.7/13) = 15.26^{0}C

For reading no 4

ΔT_1 = TH1 - TC2 = 48– 34= 14 ^{0}C

ΔT_2 = TH2 - TC1 = 44 – 33 = 11^{0}C

Definition given above,

△ T LMTD for parallel current flow = (14 - 11) / ln (14/11) = 12.40^{0}C

For reading no 5

ΔT_1 = TH1 - TC2 = 51– 32.3= 18.7 ^{0}C

ΔT_2 = TH2 - TC1 = 47 – 32 = 15 ^{0}C

Definition given above,

△T LMTD for parallel current flow = (18.7 - 15) / ln (18.7/15) = 17.05^{0}C

Now △TM $_{average}$=∑△TM/No of △TM
=(14.69+15.64+15.26+12.4+17.05)/5
=15.008^{0}c

Now Tube length = 610*2 mm =1220 mm
= 1.22 m
Tube diameter d= 12.7mm
=0.0127m
Surface area A_s= ∏dl
=(3.1416×0.0127×1.22)
= 0.0486 m^2
Overall heat transfer coefficient U= 1200 W/m^2k

Heat transfer Q = $UA_s\Delta Tm_{avg}$
=(1200×0.0486×15.008)
=875.267 W

Heat transfer rate Q^0=Q/T[Here T= 30 sec]
=875.267/30
=29.175 Btu/hr

Mass flow rate (Normal Water) 2 :

The volume water collected is 1000 ml
The density of water is 1000kg/m³
Required time is 14 sec
So, Mass Flow Rate ≈ (1000 kg) / (14 seconds) ≈ 0.0714 kg/s

Table -4.2.4 Observation table for heat exchanger parallel flow and temperature data

Sr. No.	Initial temp (Hot water) ^0C (**TH Inlet**)	Final Temp (Hot water) ^0C (**TH outlet**)	Initial temp (cold water) ^0C (**TC Inlet**)	Final Temp (cold water) ^0C (**TC outlet**)	**($\Delta T_1 = TH_I - TC_O$)^0C**	**($\Delta T_1 = TH_O TC_I$)^0C**	**ΔTM ^0C**	Mass flow rate.(kg/s) (Cold Water)	Mass flow rate.(kg/s) (Hot Water)
1	50	47	31	31.2	18.8	16	12.93		
2	51	47	32	32.3	18.7	15	12.31		
3	51	47	33	33.3	17.7	14	10.66	0.0714 kg/s	0.0625 kg/s
4	48	45	33	34	14	12	7.80		
5	51	47	32	32.3	18.7	15	11.12		

Here

As per the definition and equation for Log Mean Temperature Difference (LMTD)

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{T_1}{T_2}\right)}$$

$\Delta T_1 \rightarrow$ the temperature difference between hot and cold fluids at one end of the heat exchanger

$\Delta T_2 \rightarrow$ the temperature difference between hot and cold fluids at the other end of the heat exchanger.
For counter current heat exchanger,

For reading no 1

ΔT_1 = TH1 - TC2 = 50– 31.2= 18.8 ^0C

ΔT_2 = TH2 - TC1 = 47 – 31 = 16 ^0C

Definition given above,

$\triangle$T LMTD for parallel current flow = (18.8- 16) / ln (18.5/16) = 17.5^0C

For reading no 2

ΔT_1 = TH1 - TC2 = 51– 32.3= 18.7 ^0C

ΔT_2 = TH2 - TC1 = 47 – 32 = 15 ^0C

Definition given above,

$\triangle$T LMTD for parallel current flow = (18.7- 15) / ln (18.7/15) = 17.13^0C

For reading no 3

ΔT_1 = TH1 - TC2 = 51– 33.3= 17.7 ^{0}C

ΔT_2 = TH2 - TC1 = 47 – 33 = 14 ^{0}C

Definition given above,

△T LMTD for parallel current flow = (17.7- 14) / ln (17.7/14) = 15.68 ^{0}C

For reading no 4

ΔT_1 = TH1 - TC2 = 48– 34= 14.0 ^{0}C

ΔT_2 = TH2 - TC1 = 45 – 33 = 12 ^{0}C

Definition given above,

△ T LMTD for parallel current flow = (14 - 12) / ln (14/12) = 13.07 ^{0}C

For reading no 5

ΔT_1 = TH1 - TC2 = 51 – 32.3= 18.7 ^{0}C

ΔT_2 = TH2 - TC1 = 47 – 32 = 15 ^{0}C

Definition given above,

△T LMTD for parallel current flow = (18.7 - 15) / ln (18.7/15) = 16.89 ^{0}C

Now $\triangle TM_{average}$=∑△TM/No of △TM
=(17.50+17.13+15.68+13.07+16.89)/5
=16.054 ^{0}c

Now Tube length = 610*2 mm =1220 mm
= 1.22 m
Tube diameter d= 12.7 mm
=0.0127m
Surface area A_s= ∏dl
=(3.1416×0.0127×1.22)
= 0.0486 m^2
Overall heat transfer coefficient U= 1200 W/m^2k

Heat transfer Q = $UA_s\triangle Tm_{avg}$
=(1200×0.0486×16.054) = 936.269 W

Heat transfer rate Q^0=Q/T [Here T= 30 sec]

=936.269/30

=31.209 Btu/hr

4.5 RESULT SUMMARY

Sl. no		△TM average	Heat transfer Q	Heat transfer rate Q^0
01	**Counter Flow and Flow rate: 0.0263 kg/s**	10.96	639.187	21.306
02	**Counter Flow and Flow rate: 0.0714 kg/s**	13.29	775.073	25.836
03	**Parallel Flow and Flow rate: 0.0263 kg/s**	15.008	875.267	29.175
04	**Parallel Flow and Flow rate: 0.0714 kg/s**	16.054	936.269	31.209

4.6 DISCUSSION

4.6.1 Copper tube provided better heat exchange in counter flow than parallel flow.

4.6.2 Copper tube provided better heat exchange with increased flow rate of cooling liquid for both counter flow and parallel flow.

CHAPTER 5

CONCLUSION

5.1 Conclusion:

To conclude, it is apparent that despite the contradiction with some of the literature, both the hot and cold mass flow rates had a positive impact upon the heat exchanger's performance, i.e. the higher the mass flow rate, the better the performance. However, it seems that there is a general limit of how high the mass flow rate can be set, as the effectiveness (as suggested by the literature) dropped when the mass flow rate was very high. The hot inlet temperature also had a positive impact upon the heat exchanger performance, however, there could be a limit from which point the performance worsens. Flow pattern of fluid flow showed great impact on heat transfer and it was observed that counter flow has higher heat transfer capacity than parallel flow heat exchangers. Lastly, the ambient temperature had almost no noticeable effect upon the heat exchanger's performance; however, this could have been because of the very low temperature range that was used for the investigation.

5.2 Recommendation for Future Work:

In the event that any future experiments take place to further assess the performance of heat exchangers, the following tests are recommended:

5.2.1 Investigation of the effect of cold inlet temperature on the performance of heat exchangers with temperatures ranging from 5ºC to 25ºC.

5.2.2 Investigation of the effect of ambient temperature on the performance of heat exchangers with temperatures ranging from 15ºC to 30ºC.

5.2.3 Investigation of the effect of insulation of the pipes on the performance of the heat exchangers, and the required critical radius of insulation to prevent heat loss to the environment.

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