PERFORMANCE TEST OF HEAT EXCHANGER BY USING DIFFERENT MATERIAL TUBES.

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

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SONARGAON UNIVERSITY (SU)
DHAKA-1215, BANGLADESH

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Declaration

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

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Khairul Islam

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Certification

This is to certify that this project entitled "**PERFORMANCE TEST OF HEAT EXCHANGER BY USING DIFFERENT MATERIAL TUBES**." 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.

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....

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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 book chapter 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. A fin-and-tube heat exchanger model is presented in this paper. It uses empirical heat transfer and flow friction 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

$\boldsymbol{m_c}$= Mass of Cold Water

$\boldsymbol{m_h}$= Mass of Hot Water

$\boldsymbol{T_h}$= Temperature of Hot Water

$\boldsymbol{T_c}$= 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 is the process of transfer of heat from one fluid to another fluid. To transfer internal thermal energy between two or more fluids at different temperatures heat exchanger is used. In usually fluids are not mix most of the heat exchanger. Mostly heat exchangers are using petroleum power refrigeration and air conditioning, alternate fuels and automobiles field day to day its uses increases. 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 is direct transfer type, or simply recuperates heat exchangers are referred to as. In an indirect type of heat exchanger simply regenerator's thermal energy storage and release through the exchanger surface or matrix there is intermittent between the hot and cold fluids. Shell-and tube exchangers like automobile radiators, condensers, evaporators, air preheaters, and cooling towers due to pressure difference and matrix or valve switching usually having fluid leakage from one fluid stream to the other. 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 General criteria for materials selection:

A general procedure that could be used for identifying the most appropriate material for a specific heat exchanger application would consist of the following steps. – Define the heat exchanger requirements – Establish a strategy for evaluating candidate materials – Identify candidate materials – Evaluate materials in depth Special considerations which affect materials selection include:

1.3 Physical Properties:

High heat transfer coefficient (requiring high thermal conductivity for tube material) – Thermal expansion coefficient to be low and as compatible as possible with those of the materials used for tube sheet, tube support and shell to provide resistance to thermal cycling.

1.4 Mechanical Properties:

Good tensile and creep properties (High creep rupture strength at the highest temperature of operation and adequate creep ductility to accommodate localized strain at notches are important). – Good fatigue, corrosion fatigue and creep-fatigue behavior. – High fracture toughness and impact strength to avoid fast fracture.

1.5 Objective:

Main objective of our project is given bellow,

- To make a survey about heat exchanging rate for different types of tube.
- To know about cupper tube heat exchanging rate.
- To know about still tube heat exchanging rate.
- To know about aluminum tube heat exchanging rate.
- Choose best heat exchanging materials.

1.6 Research purposes:

The purpose of writing contained in the theme of scientific writing this time aims as follows: 1. Analysis of the heat transfer process that occurs in the shell and tube heat exchanger, 2. calculating the comparison of the influence of various mass flow velocities on the temperature of the hot water outlet on the tube

1.7 Methodology of the study:

• Creating an idea for Design and construction of water heat exchange. And designing a block diagram & circuit diagram to know which components need to construct it.

• Collecting the all components and hardware device to controlled the system.

• Assembling the whole block in a board and finally run the system & checking.

1.8 Classification of heat exchangers:

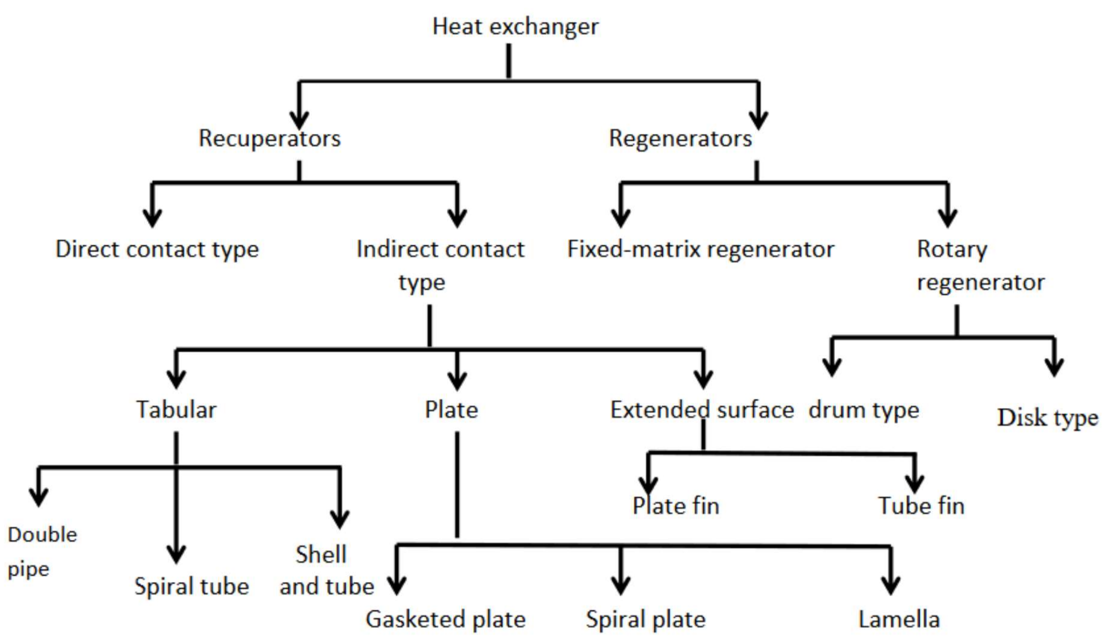

Figure 1.1: Classification of heat exchanger

1.8.1 Shell and Tube:

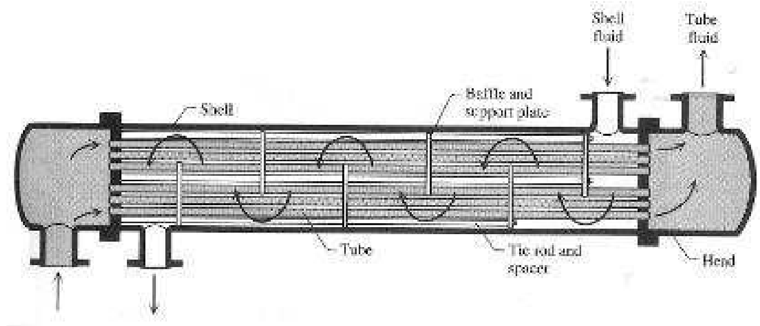

Figure 1.2: Shell and tube heat exchanger

This type of heat exchanger is normally built of a bundle of round tubes mounted in a cylindrical shell with the tube axis parallel to that of the shell. One of the streams flows along the tubes, while the other stream flows along the shell. The following components are used in a shell and tube heat exchanger:

Tubes: Round tubes of various shapes that are used as a means to flow by one of the streams. The tubes most commonly used in process and power industry exchangers are the tube bundles with straight and U-tubes. Nuclear exchangers on the other hand use more complicated shapes, such as sine-wave bend, J-shape and L-shape, because they allow for large thermal expansion of the tubes.

Shell: The shell is a cylindrical container with a circular cross section that allows for the flow of the second stream. The tubes are contained within the shell, and the heat exchange occurs between the tube stream and the shell stream.

Nozzles: The nozzles are the inlet and outlet for the streams in both the tubes and the shell. These are pipes of constant cross section that are used to distribute or collect the fluid uniformly on the shell and tube sides.

Front- and Rear-end heads: These are used as the entrance and exit by the tube fluid. The front-end is stationary, while the rear-end can eitherbe stationary (does not allow for thermal expansion) or floating (allows for thermal expansion.

Baffles: Baffles are classified into two types: transverse, and longitudinal. Transversal baffles can be further classified into plate baffles and grid baffles. Plate baffles are used to support the tubes during assembly and to direct the fluid in the tube bundle at an angle of approximately 90° to achieve higher heat transfer coefficients. They also increase the turbulence of the shell fluid and minimize tube to tube temperature differences and thermal stresses due to cross flow. Likewise, grid baffles are also used to support the tubes and increase the turbulence of the shell fluid, but unlike in plate baffles, the flow is parallel to the tubes. Grid baffles support the tube in such a way that they virtually eliminate flow induced vibrations.

1.8.2 Concentric:

This type of heat exchanger (also called a double pipe heat exchanger) has a much simpler design, consisting of two concentric pipes wherein one stream flows through the inner pipe, and the other stream flows through the outer pipe. The flow can be either parallel (both streams flow along in the same direction) or counter flowing (the two streams flow in different directions), with the former being ideal for applications needing constant wall temperature and the latter being ideal for the highest performance for the given surface area. Double pipe heat exchangers are generally used for small capacity applications where the total heat transfer surface area is less than 50m2 because the cost per unit area is much higher when compared to other types of heat exchangers.

Parallel flow

Counter flow

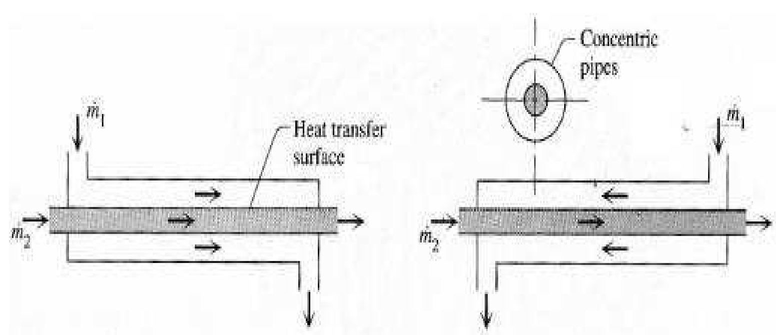

Figure 1.3: Concentric heat exchanger

This type of heat exchanger consists primarily of thin plates, which can either be smooth or corrugated. Plate heat exchangers can be classified as gasketed, welded, or brazed depending on the type of leak tightness required.

Gasketed exchangers consist of thin rectangular plates sealed around the edges by gaskets and held together in a frame (as shown in figure 3). The main advantage of this design is that the heat exchanger can be disassembled easily for maintenance and inspection purposes. One of the main applications of gasketed exchangers is that they can generate high heat transfer coefficients due to the breakup and formation of boundary layers, vortex flow generation, and small hydraulic diameter flow passes. Furthermore, high shear stresses, high turbulence and mixing due to plate corrugation patterns reduce fouling to about 10 to 25% of that of a shell and tube heat exchanger. Due to the high generation of heat transfer coefficients and low fouling, the surface area required for a plate heat exchanger is one half to one third that of a shell and tube heat exchanger, thus reducing the cost and overall volume of the heat exchanger. Gasketed plate heat exchangers also have high thermal capacity due to the high degree of counter flow that is achievable, and are unaffected by the flow induced vibrations, noise, thermal stresses, and entry impingement problems that are common in shell and tube heat exchangers.

However, gasketed exchangers also have disadvantages, one of them being that they are unable to handle high pressures (maximum possible being 3MPa). The gasket materials restrict their use in highly corrosive applications, and limit the maximum operating conditions to 260℃. Maintenance of this type of heat exchanger must also be regular as the gasket life is sometimes limited and must be replaced. To overcome the limitations of gasketed exchangers, for example in corrosive applications, welded or brazed heat exchangers can be used instead.

Welded exchangers have plates that are welded together instead of being held together in a frame, but with a loss of the disassembling flexibility available in gasketed exchangers. They are also constructed to be much bigger than gasketed exchangers so as to reduce the welding costs. The main advantage of this type of plate heat exchanger is that it can withstand higher limits of operating temperatures and pressure (usually about 350℃ and 4MPa).

1.9 Classification by Flow Arrangement:

1.9.1 Parallel Flow:

In a parallel flow heat exchanger, both streams enter together from one end, flow parallel to each other, and exit together at the other end. The temperature difference between the two streams is highest at the common entry and the lowest at the common exit, which leads to the average temperature of both streams staring relatively constant along the length of the heat exchanger. This type of flow arrangement has the lowest exchanger efficiency for overall thermal conductance, fluid heat capacity rates, and fluid inlet temperatures.

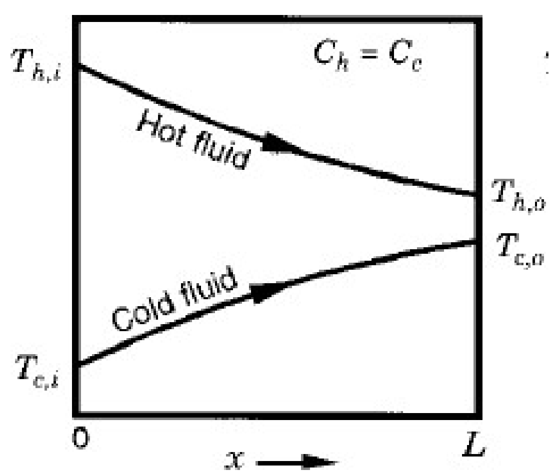

Figure 1.4: Temperature distribution of a parallel flow heat exchanger

The most common application of parallel flow heat exchangers is:

For temperature sensitive materials, highly viscous liquids, and metal recuperators with high inlet temperatures (excess of 1100°C) due to the relatively uniform longitudinal tube wall temperature distribution.

For when acid vapors are present in the exhaust gas, because the exchanger prevents condensation and thus eliminates the risk of corrosion of the metal surface. This is due to the lowest wall temperature of the parallel exchanger being higher than that of other flow arrangements. For situations that requires minimization of fouling, due to the highest wall temperature for a parallel exchanger being lower than that of other flow arrangements.

1.9.2 Counter Flow:

In a counter flow heat exchanger, the two streams flow parallel to each other but in opposite directions. This is the flow arrangement with the highest efficiency as it produces the highest temperature change in each fluid when compared to other flow arrangements for given thermal conductance, fluid flow rates, and fluid inlet temperatures. The maximum temperature difference across the exchanger wall thickness (between the wall surfaces exposed to the hot and cold sides) produces minimal thermal stresses in the wall when compared to other flow arrangements.

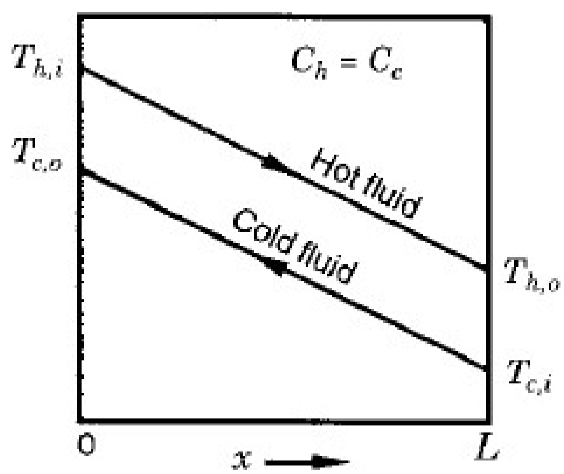

Figure 1.5: Temperature flow heat exchanger

Chapter-2

Literature Review

In 1920's, there appeared plate heat exchanger that was invented by Dr Richard Seligman [3] and revolutionized methods of indirect heating and cooling of fluids. Dr Richard Seligman founded APV in 1910 as the Aluminum Plant and Vessel Company Limited, as specialist fabricating firm supplying welded vessels to the brewery and vegetable oil trades [4]. The heat exchanger which is produced with plate pipe has compact structure and very good heat effect, subsequently it small by little developed into numerous forms. In the early 1930s, Sweden firstly made out spiral plate heat exchanger. Then Britain used the brazing approach to make out the plate fin heat exchanger which is developed from copper and alloy materials, and it was used for the cooling of aircraft engines.

In the late of 1930's, Sweden had produced the 1st shell heat exchanger, which is employed for the pulp plant. At the same time, in order to solve the heat exchanging issue of powerful corrosive medium, people began to be conscious of the heat exchanger are made of new materials. In about 1960's, on account of the rapid growth and development of space technology and advanced science, people are inside the urgent require for a range of high performance compact heat exchangers, and with the growth stamping, brazing and sealing technology, heat exchanger's manufacturing procedure has been further improved, thereby promoting the compact plate heat exchanger's rapid development and wide application. Moreover, since the 1960's, so as to adjust to the requirement of heat exchanging and energy saving underneath the high temperature and pressure conditions, the typical shell tube heat exchanger has as well been further developed [3].

At the middle of 1970's, in order to enhance heat transfer, based on researching and developing the heat pipe, folks have developed heat pipe heat exchanger [3]. Though the first detailed study in two phase flow was carried out by Lockhart and Martinelli in the year 1949. Bes Y Reitzel (1993) determined the thermal performance using a dimensionless approach that gave better results as the number of spirals in the unit increases. A through description of the exchanger geometry was published he provides the expressions to calculate spiral diameter, number of turns and length of the semicircles [5].

A wide range of researches are already done to study the flow characteristics and heat transfer in helical heat exchangers. The enhancement of the heat transfers in the helically coiled tubes is due to the centrifugal forces. A secondary flow field is produced due to the curvature of the tube with a circulatory motion, which causes the fluid particles to move towards the core region of the tube. The secondary flow enhances heat transfer rates by reducing the temperature gradient across the cross-section of the tube. Thus, there is an additional convective heat transfer mechanism occurs, perpendicular to the main flow, which does not exist in straight tube heat exchangers.

CHAPTER-3

EXPERIMENTAL DESIGN

3.1 Introduction of component:

SL.NO	Particulars	Specification	Qty.
1	Power Supply	12V	1
	Pump Motor	5V	1
2	Pump Motor	12 Volt	1
3	Temperature Meter	0 to 100 Degree Celsius	6
4	Water Cooling Heat Sink Block		1
5	Copper Tube		1
6	Aluminum Tube		1
7	Stainless steel Tube		1
8	PVC Pipe		1
9	Microcontroller		1
10	Switch		2

Table 3.1: List of Components

3.2 Pump Motor:

Figure 3.1: Pump Motor

DC 12V Water Pump Motor 700L/H

- Power:16.8W
- Max Flow Rate: 700 L/H
- Max Water Head: 5M Max
- Circulating Water Temperature: 60°C

Specification:
- Material: ABS (Acrylonitrile Butadiene Styrene) + Stainless Steel
- Overall Size: Approx. 80 x 48 x 63mm/3.15 x 1.89 x 2.48"
- Pump Inlet Diameter: 16mm (Outer), 12mm (Inner)
- Pump Outlet Diameter: 12mm (Outer), 6.9mm (Inner)
- Inlet/Outlet: 1/2" male thread
- Voltage: 6-12V DC
- Maximum Rated Current: 1.2A
- Power:16.8W
- Max Flow Rate: 700 L/H
- Max Water Head: 5M
- Max Circulating Water Temperature: 60°C

3.3 Temperature Meter:

A temperature meter is an instrument used to measure the temperature of beings or things. The most widely recognized temperature meter is a mercury thermometer used to measure the temperature of people.

Figure 3.2: Temperature Meter

Digital Temp Meter

- Digital Display -50C to +110C.
- Modeling simple, elegant, LCD panels inline connections, moisture-resistant.
- Strong anti-interference, applies to refrigerated cabinets, display counters and other needs of temperature measurement and display of various equipment.
- Remote wired probe can read temperature up to 3 feet away.
- No need to wire to any permanent power source. Size:48 x 28 x 15 mm.

3.4 Copper Tube:

Copper pipes are commonly used in the construction industry for water supply lines and refrigerant lines in HVAC (heating, cooling, and air-conditioning) systems. Copper pipes can be manufactured as soft or rigid copper and offer excellent corrosion resistance and reliable connections.

Figure 3.3: Coper Tube

3.5 Aluminum Tube:

Aluminum piping and tubing is silvery-white, soft, and ductile. The metal belongs to the boron group. Aluminum is the third most abundant element present on earth. Aluminum has low density. When exposed to corroding environments, aluminum forms a passivating coating on its surface, which helps it avoid further corrosion on its internal structure. Aluminum is mostly made into an alloy by elements like copper, manganese, zinc, magnesium, and silicon.

Figure 3.4: Aluminum tube

3.6 Stainless steel Tube:

Stainless steel pipe is primarily used in piping systems for the transport of fluids or gases. We manufacture steel pipe from a steel alloy containing nickel as well as chromium, which give stainless steel its corrosion-resistant properties. Stainless steel pipe resists oxidation, making it a low-maintenance solution that is suitable for high temperature and chemical applications. Because it is easily cleaned and sanitized, stainless steel pipe is also desired for applications involving food, beverages, and pharmaceutical applications.

Figure 3.5: Stainless steel tube

3.7 Block Diagram Parallel Flow:

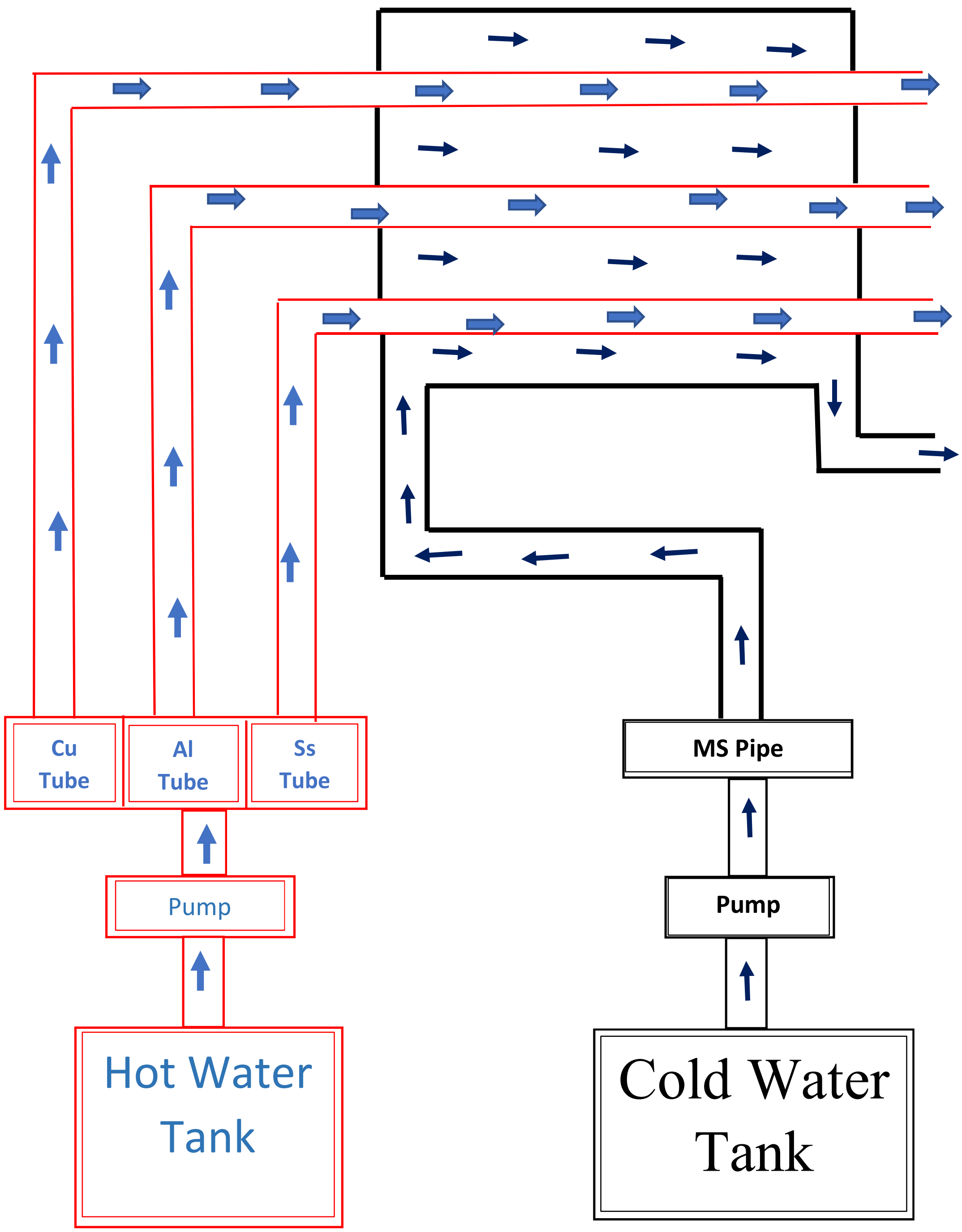

Figure 3.6: **Block Diagram of Parallel Flow.**

3.8 Working Principle:

So the plan of this project is there will be two water tank and both have temperature meter, then from the Hot Water Reserve Tank, hot water will be pass through the pump motor to copper pipe through the water cooling heat sink and to power up the Pump Motor we setup SMPS Power Supply, now water will go through the Aluminum, Copper & Stainless Steel Metal pipe, so the cool water will store in Recycle Water tank. We also setup a Temperature Meter on Recycle Water Tank, so we can measure the difference between the Hot water and Cold water.

3.9 Data table for three tubes:

3.9.1 For Parallel Flow

Copper Tube	Aluminum Tube	Stainless Steel Tube
Hot Water: T_h in = 60°C T_h out = 51°C **Cold Water:** T_c in = 22°C T_c out = 30°C	**Hot Water:** T_h in = 60°C T_h out = 53°C **Cold Water:** T_c in = 22°C T_c out = 29°C	**Hot Water:** T_h in = 60°C T_h out = 54°C **Cold Water:** T_c in = 22°C T_c out = 27°C

Table 3.2: Data Table for Parallel Flow

Chapter- 4

CALCULATION

4.1 Parallel Flow:

4.1.1 for Copper:

$L = 1\, m$

$D = 0.008\, m$

$m_{c\,=} 0.0125\, kg/sec$

$m_{h\,=} 0.023\, kg/sec$

$T_h\, in = 60^0$ C

$T_h\, out = 51^0$ C

$T_c\;\; in = 22^0$ C

$T_h\;\; out = 30^0$ C

$A = \pi$DL $= \pi \times 0.008 \times 1$

$= 0.025\, m^2$

$Q = \; m_{h\,\times} c_{p\,\times}(\;T_h\, in\, - \;\; T_h\, out\,)$

$= 0.023 \times 4.2 \times 10^3 \times (60 - 51)$

$= 869.4\, Watt$

$\Delta\, T_{cm}\; = \frac{(\;T_h\, in - \,T_c\;\, in\,) - (T_h\;\, out - T_c\, out\,)}{ln \frac{T_h\, in - \,T_c\;\, in}{T_h\;\, out - T_c\, out}}$

$= \frac{(\;60 - \;22\,) - (51 - 30\,)}{ln \frac{60 - 22}{51 - 30}}$

$= 28.66$ ℃

$Q = UALMTD$

$\Rightarrow U = \frac{Q}{A \times LMTD} \;\; = \frac{869.4}{0.025 \times 28.66}$

$U = 1213.40\, W/m^2$ ℃

4.1.2 For Aluminum:

$L = 1\,m$

$D = 0.008\,m$

$m_{c} = 0.0125\,kg/sec$

$m_{h} = 0.017\,kg/sec$

$T_h\,in = 60^0$ C

$T_h\,out = 53^0$ C

$T_c\;in = 22^0$ C

$T_c\,out = 29^0$ C

$A = \pi\text{DL} = \pi \times 0.008 \times 1$

$= 0.025\,m^2$

$Q = m_h \times c_p \times (T_h\,in - T_h\,out)$

$= 0.017 \times 4.2 \times 10^3 \times (60 - 53)$

$= 499.8\,Watt$

$$\Delta\,T_{cm} = \frac{(T_h\,in - T_c\;in) - (T_h\;out - T_c\,out)}{ln\frac{T_h\,in - T_c\;in}{T_h\;out - T_c\,out}}$$

$$= \frac{(60 - 22) - (53 - 29)}{ln\frac{60-22}{53-29}}$$

$= 30.47$ ℃

$Q = UALMTD$

$\Rightarrow U = \frac{Q}{A \times LMTD} = \frac{499.8}{0.025 \times 30.47}$

$U = 656.12\,W/m^2$ ℃

4.1.3 **For Stainless steel:**

$L = 1\,m$

$D = 0.008\,m$

$m_{c} = 0.0125\,kg/sec$

$m_{h} = 0.02\,kg/sec$

$T_h\,in = 60^0\,\text{C}$

$T_h\,out = 54^0\,\text{C}$

$T_c\;in = 22^0\,\text{C}$

$T_c\;out = 27^0\,\text{C}$

$A = \pi\text{DL} = \pi \times 0.008 \times 1$

$= 0.025\,m^2$

$Q = m_h \times c_p \times (\,T_h\,in - \;T_h\,out\,)$

$= 0.02 \times 4.2 \times 10^3 \times (60 - 54)$

$= 504\,Watt$

$$\Delta\,T_{cm} = \frac{(\,T_h\,in - T_c\;in\,) - (T_h\;out - T_c\,out\,)}{ln\frac{T_h\,in - T_c\;in}{T_h\;out - T_c\,out}}$$

$$= \frac{(60 - 22\,) - (54 - 2\quad)}{ln\frac{60-22}{54-27}}$$

$= 32.19\,°\text{C}$

$Q = UALMTD$

$\Rightarrow U = \frac{Q}{A \times LMTD} \quad = \frac{504}{0.025 \times 32.19}$

$U = 626.28\,W/m^2\,°\text{C}$

4.2.1 Graph of Parallel Flow:

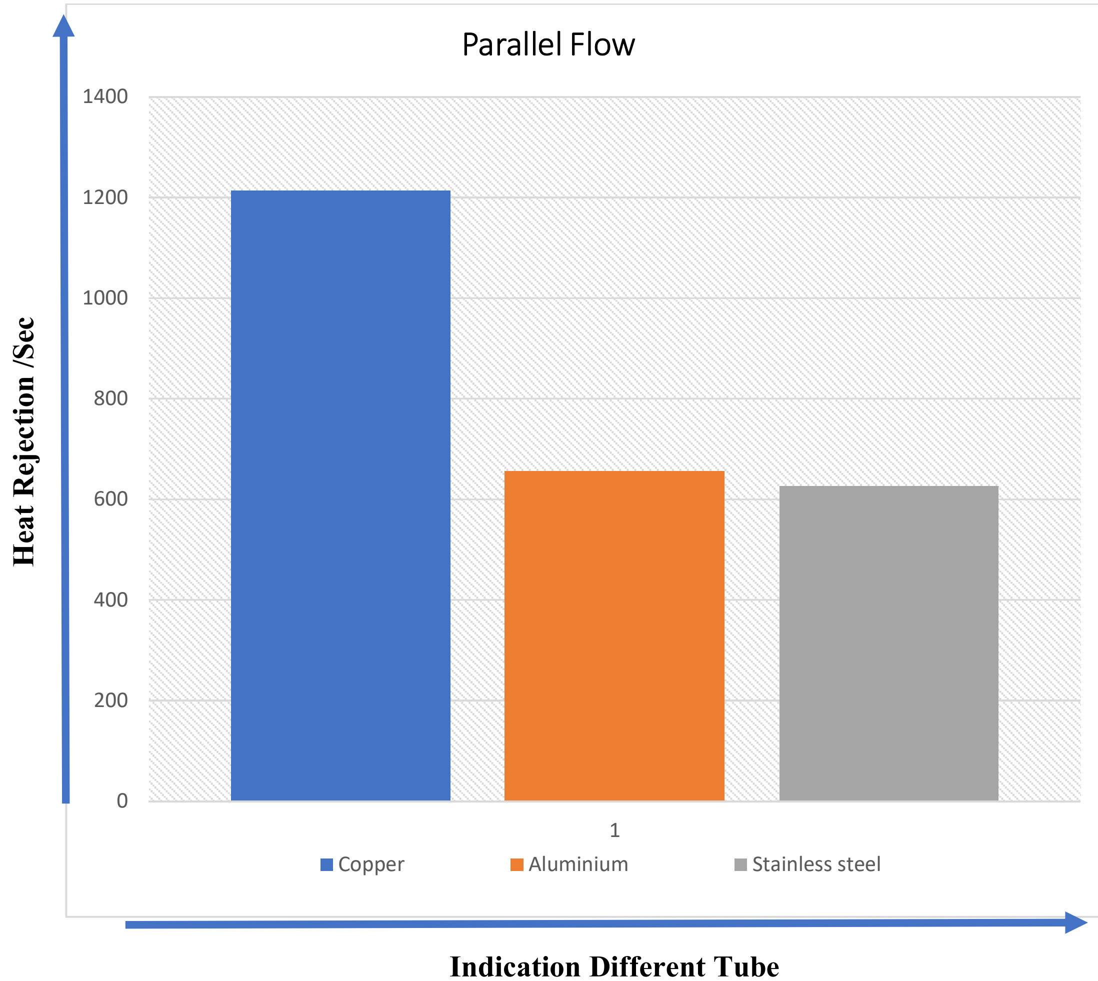

Figure 4.1: Graph of Parallel Flow

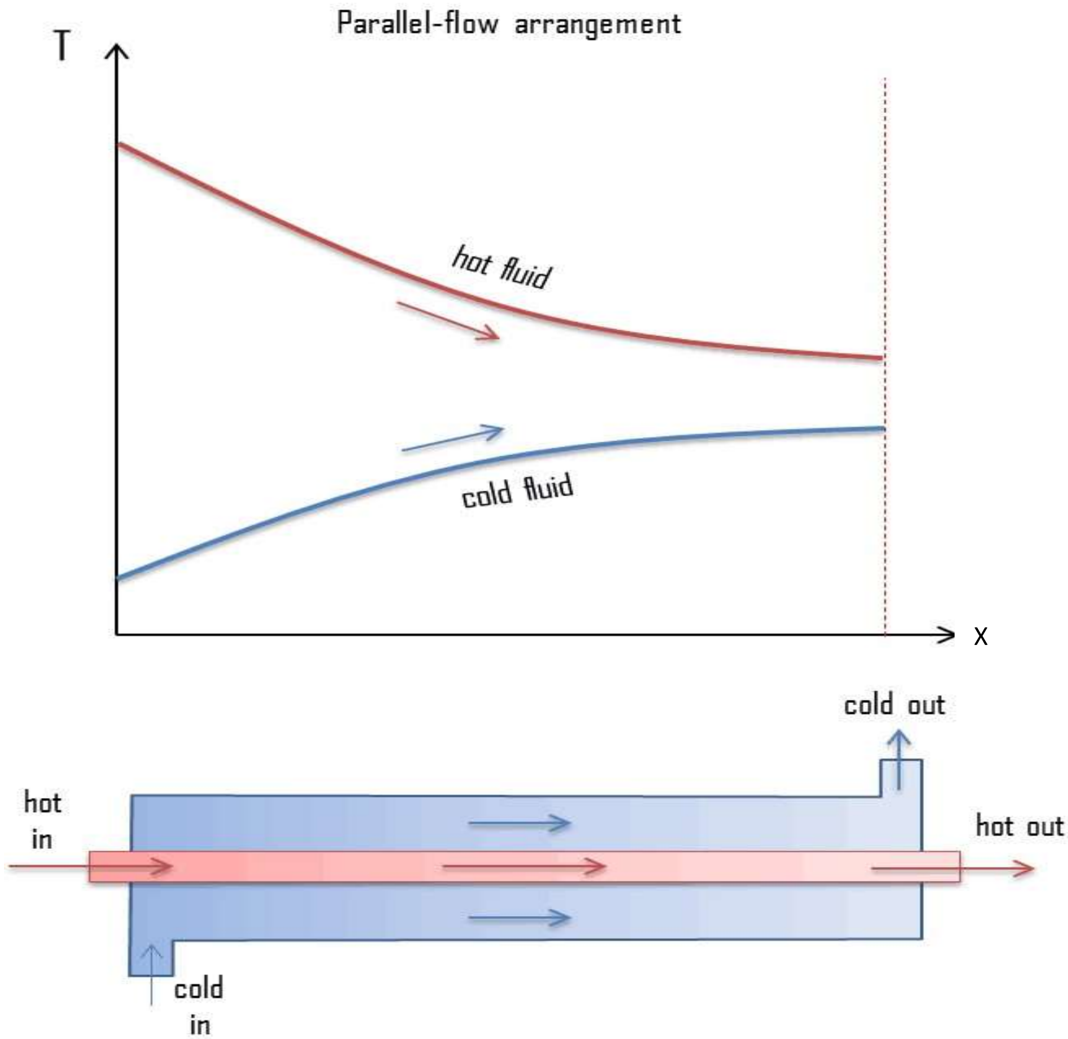

Figure 4.2: Parallel Flow Arrangement

4.2.2 Block Diagram of Counter Flow:

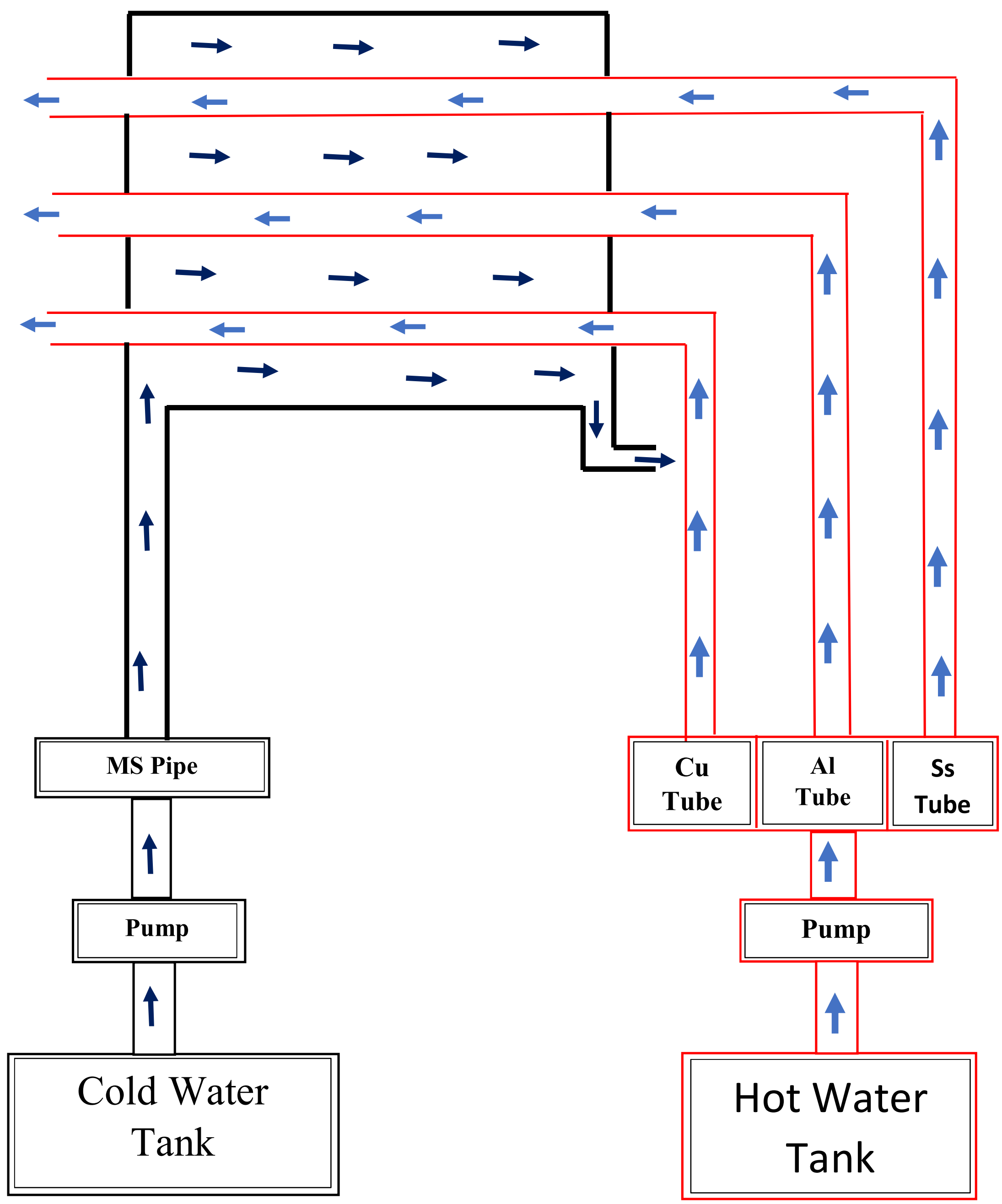

Figure 4.3: **Block Diagram of Counter Flow.**

4.3 Data Table of Counter Flow:

Copper Tube	Aluminum Tube	Stainless Steel Tube
<u>Hot Water:</u>	**<u>Hot Water:</u>**	**<u>Hot Water:</u>**
T_h in = 64℃	T_h in = 64℃	T_h in = 64℃
T_h out = 52℃	T_h out = 54℃	T_h out = 55℃
<u>Cold Water:</u>	**<u>Cold Water:</u>**	**<u>Cold Water:</u>**
T_c in = 22℃	T_c in = 22℃	T_c in = 22℃
T_c out = 32℃	T_c out = 30℃	T_c out = 27℃

Table 4.2: Data Table of Counter Flow

4.4 Counter Flow:

4.4.1 <u>For Copper:</u>

$L = 1\,m$

$D = 0.008\,m$

$m_c = 0.0125\,kg/sec$

$m_h = 0.02\,3kg/sec$

$T_h\,in = 64^0$ C

$T_h\,out = 52^0$ C

$T_c\ \,in = 22^0$ C

$T_c\ \,out = 32^0$ C

$A = \pi$DL $= \pi \times 0.008\times1$

$=0.025\,m^2$

$Q = \ m_h \times c_p \times (\ T_h\,in - \ T_h\,out\ )$

$= 0.023\times4.2\times10^3\times(64 - 52)$

$=1159.2\,Watt$

$$\Delta\,T_{cm} = \frac{(\ T_h\,in - T_c\ out\ ) - (T_h\ out - T_c\,in\ )}{ln\frac{T_h\,in - T_c\ out}{T_h\ out - T_c\,in}}$$

$$= \frac{(64 - 32\ ) - (52 - 22\ )}{ln\frac{64-3}{52-22}}$$

$= 30.98$ ℃

$Q = UALMTD$

$$\Rightarrow U = \frac{Q}{A\times LMTD} \quad = \frac{1159.2}{0.025\times30.98}$$

$U = 1496.71\ \ Watt/m^2$ ℃

4.4.2 For Aluminum:

$L = 1\,m$

$D = 0.008\,m$

$m_{c\,=} 0.0125\,kg/sec$

$m_{h\,=} 0.017\,kg/sec$

$T_h\,in = 64^0$ C

$T_h\,out = 54^0$ C

$T_c\;\,in = 22^0$ C

$T_c\;\,out = 30^0$ C

$A = \pi \mathrm{DL} = \pi \times 0.008 \times 1$

$= 0.025\,m^2$

$Q = \; m_{h\,\times} c_{p\,\times} (\; T_h\,in \text{ - } \; T_h\,out \;)$

$= 0.017 \times 4.2 \times 10^3 \times (64 \text{ - } 54)$

$= 714\,Watt$

$$\Delta\, T_{cm} = \frac{(\; T_h\,in - T_c\;\,out\;) - (T_h\;\,out - T_c\,in\;)}{ln\frac{T_h\,in - T_c\;\,out}{T_h\;\,out - T_c\,in}}$$

$$= \frac{(64 - 30) - (54 - 2\quad)}{ln\frac{64-3}{54-22}}$$

$= 32.98$ ℃

$Q = UALMTD$

$$\Rightarrow U = \frac{Q}{A \times LMTD} \quad = \frac{714}{0.025 \times 32.98}$$

$U = 865.98\;\; Watt/m^2$ ℃

4.4.3 For Stainless steel:

$$L = 1\ m$$

$$D = 0.008\ m$$

$$m_{c} = 0.0125\ kg/sec$$

$$m_{h} = 0.02\ kg/sec$$

$$T_h\ in = 64^0\ \text{C}$$

$$T_h\ out = 55^0\ \text{C}$$

$$T_c\ \ in = 22^0\ \text{C}$$

$$T_c\ \ out = 27^0\ \text{C}$$

$$A = \pi \text{DL} = \pi \times 0.008 \times 1$$

$$= 0.025\ m^2$$

$$Q = m_h \times c_p \times (\ T_h\ in - \ T_h\ out\ )$$

$$= 0.02 \times 4.2 \times 10^3 \times (64 - 55)$$

$$= 756\ Watt$$

$$\Delta\ T_{cm} = \frac{(\ T_h\ in - T_c\ \ out\ ) - (T_h\ \ out - T_c\ in\ )}{ln \frac{T_h\ in - T_c\ \ out}{T_h\ \ out - T_c\ in}}$$

$$= \frac{(64 - 27) - (55 - \quad)}{ln \frac{64 - 27}{55 - 22}}$$

$$= 34.96\ ℃$$

$$Q = UALMTD$$

$$\Rightarrow U = \frac{Q}{A \times LMTD} \quad = \frac{756}{0.025 \times 34.96}$$

$$U = 864.98\ \ Watt/m^2\ ℃$$

4.5 Graph of Counter Flow:

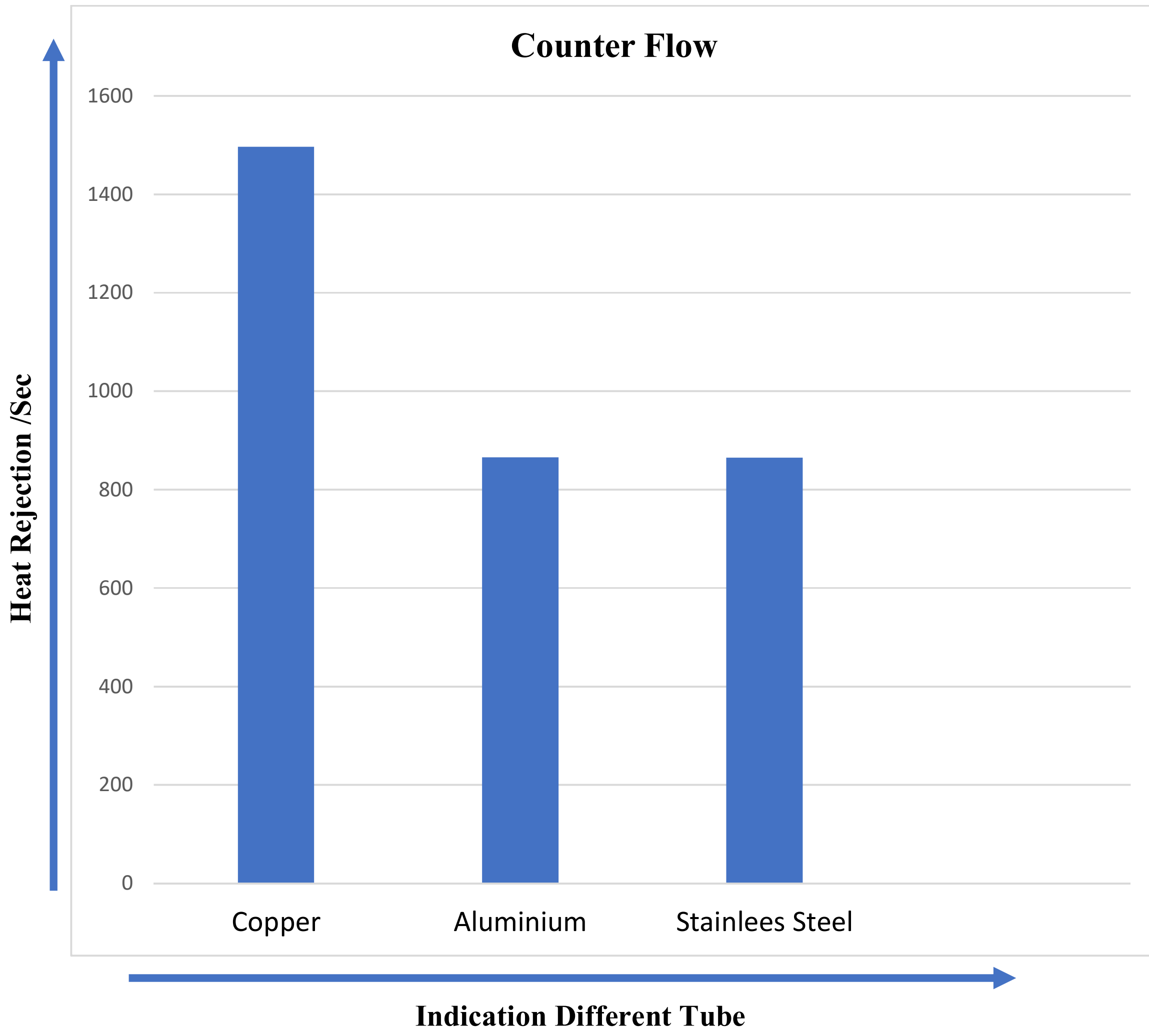

Figure 4.4: Graph of Counter Flow

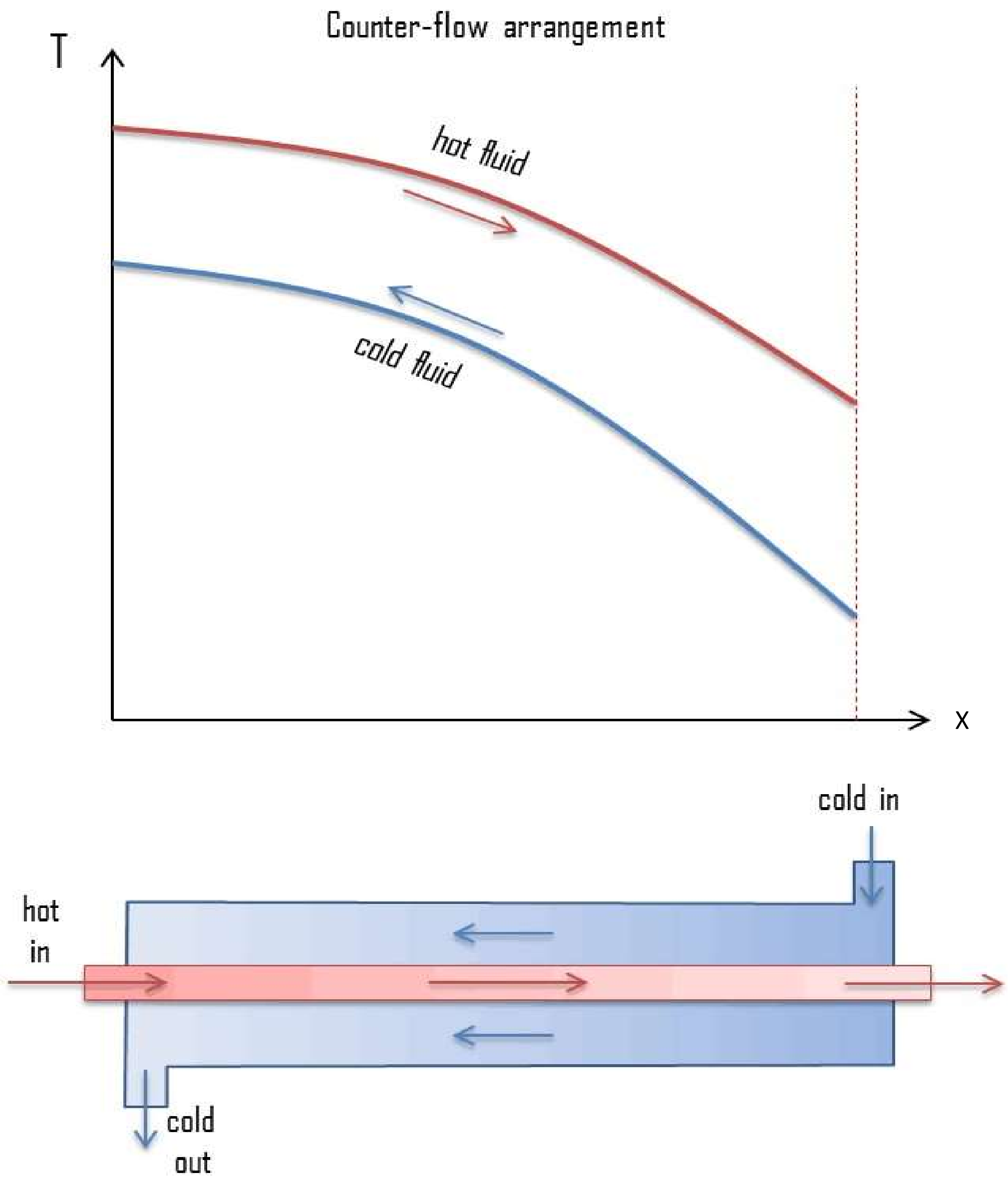

Figure 4.5: Counter Flow Arrangement

4.6 Result and discussion:

Result of Parallel Flow:

$$U_{cu} = 1213.40 \ watt/m^2 \,°C$$

$$U_{Al} = 656.12 \ watt/m^2 \,°C$$

$$U_{SS} = 626.28 \ watt/m^2 \,°C$$

Result of Counter Flow:

$$U_{cu} = 1496.71 \ watt/m^2 \,°C$$

$$U_{Al} = 865.98 \ watt/m^2 \,°C$$

$$U_{SS} = 864.98 \ watt/m^2 \,°C$$

Discussion:

- **Copper tube is better in parallel flow.**
- **Again, copper tube is better in counter flow.**
- **Copper tube is better in both parallel flow and counter flow but give best result in counter flow.**

Chapter 5

CONCLUSION

5.1 Conclusion:

To conclude, it transpired that the plate heat exchanger was the device with the best performance when compared to the shell and tube heat exchanger and the concentric heat exchanger. Even though the heat exchange areas for all the devices were the same, the design of the plate heat exchanger is such that it had the highest rates of heat transfer, effectiveness, and heat transfer coefficients during all the investigations that were carried out. 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. Varying the flow arrangement showed that the counter flow arrangement yields better results than the parallel flow, and this is because the average temperature difference between the hot and cold streams is muchmore uniform when undergoing counter flow as opposed to parallel flow. 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:

- Investigation of the effect of cold inlet temperature on the performance of heat exchangers with temperatures ranging from 5ºC to 25ºC.
- Investigation of the effect of ambient temperature on the performance of heat exchangers with temperatures ranging from 15ºC to 30ºC.
- 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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