Design and Fabrication of a U tube type BFU Heat Exchanger

A thesis submitted to the
Department of Mechanical Engineering



SONARGAON UNIVERSITY (SU)

A Thesis submitted By

Md. Nesar Uddin	**ID NO: BME1601008244**
Ahsan Habib	**ID NO: BME1502006116**
Md. Golam Kabria	**ID NO: BME1601008088**
Md. Sakil Adnan	**ID NO: BME1501005067**

SUPERVISED BY

Pronoy Chowdhury
Lecturer and Assistant Coordinator
Department of Mechanical Engineering
Sonargaon University (SU)

January 2020

DEPARTMENT OF MECHANICAL ENGINIEERING, SONARGAON UNIVERSITY (SU)

DHAKA-1215, BANGLADESH

DECLARATION

Course Title: **Project and Thesis**

This is to certify that the thesis work entitled **"Design and Fabrication of a U-tube type BFU Heat Exchanger"** have been carried out by Md. Nesar Uddin, Ahsan Habib, & Md Golam Kabria, Md. Sakil Adnan in the department of Mechanical Engineering, Sonargaon University (SU). We also declare that neither this thesis work nor any part of the paper has been submitted elsewhere for any degree.

Submitted By

Md. Nesar Uddin	**ID NO :BME1601008244**
Ahsan Habib	**ID NO: BME1502006116**
Md. Golam Kabria	**ID NO: BME1601008088**
Md. Sakil Adnan	**ID NO: BME1501005067**

Supervised by

PRONOY CHOWDHURY

Lecturer and Assistant Coordinator
Department of Mechanical Engineering
Sonargaon University (SU)

ACKNOWLEDGEMENT

The authors are very much grateful to the Almighty Allah for the good health and wellbeing that were necessary to complete this book.

We would like to express gratefulness, regard, gratitude and sincere thanks to supervisor **Pronoy Chowdhury**, Lecturer and assistant coordinator, Department of Mechanical Engineering, Sonargaon University, for his guidance and valuable counsel in execution and completion of the study without which it would be impossible to carry out the work.

Finally, the authors are grateful to the teachers who helped us directly or indirectly which was very necessary to complete the project work.

"Authors"

ABSTRACT

A heat exchanger is an equipment used for transferring heat from one medium to another. There is a wide application of u tube type heat exchanger in the field of industrial applications for its enhanced heat transfer characteristics and compact structure. Lots of researches are going on to improve the heat transfer rate of the heat exchanger. Here, we have fabricated the shell and tube heat exchanger with selecting the materials on the primary objective of enhancing the heat transfer effectiveness. We casted the tube in the u tube shape with different materials as Stainless steel and Copper. Then we compare the heat transfer Effectiveness between this u tubes. We are intended to show the merits of u tube type Shell and Tube heat exchanger to that of the conventional counter flow heat exchangers.

Table of Contents

ACKNOWLEDGEMENT 3
ABSTRACT 4
CHAPTER 1: INTRODUCTION 8
1.1 Introduction 9
1.2 Importance of this study 10
1.3 Origin of the Report 10
1.4 Rational of the study 10
1.5 Objectives 10
1.6 Scope of this study 11
1.6 Limitation of this study 11
CHAPTER 2: LITERATURE 12
2.1 Previous Study 13
2.2 Classification of heat Exchanger 14
2.2.1 Classification by Transfer Process 14
2.2.2 Classification according to Compactness 15
2.2.3 Classification by Construction Type 15
2.2.4 Classification by Flow Arrangement 17
2.2.5 Classification by Function 19
2.2.6 Classification by Heat Transfer Mechanism 20
2.3 Factors of Considering for Heat Exchanger Analysis 21
2.3.1 Convection 21
2.3.2 Conduction 21
2.3.3 Surface Area 22
2.3.4 Resistance of heat transfer 22
2.3.5 Contact Resistance 22
2.3.6 Application 22-23
CPTER 3: METHODOLOGYHA 24
3.1 Proposed Model 25
3.2 Material and Measurement 25-26
3.3 Individual parts of U tube (BFU) Heat Exchanger 26-28
3.4 Dimension in MMGS of U tube (BFU) Heat Exchanger 28-29

3.5 My project view 29-31
3.6 Assumption 31
3.7 Formulation 31
CHAPTER 4: FABRICATION 33
4.1 Experimental Setup 34
4.4 Data Collection Board 35
4.4 Pump 35
4.2 Temperature Control 36
4.3 Thermocouple Sensor 36-37
4.4 Water Heater 37
CHAPTER DATA COLLECTION AND CALCULATION 38
4.1 Data Collection Method 39
4.2 Data 39
4.2 Calculation 39-42
CHAPTER 6: RESULT AND DISCUSSION 43
6.1 Result 44
6.2 Discussion 44
CHAPTER 7: CONCLUSION 45
7.1 Conclusion 46
REFERENCES 47-48

LIST OF FIGURES

Figure 1.1: U-tube heat exchanger 9

Figure 2.1: Heat Exchanger 14

Figure 2.2: Tubular heat exchanger 15

Figure 2.3: Plate heat exchanger 16

Figure 2.4: Plate-fin heat exchanger 16

Figure 2.5: Tube-fin heat exchanger 17

Figure 2.6: Parallel flow 17

Figure 2.7: Counter flow 18

Figure 2.8: Cross flow arrangement 18

Figure 2.9: Multi-pass flow heat exchanger 18

Figure 2.10: Regenerative Heat Exchanger 19

Figure 2.11: non-generative heat exchanger 19

Figure 2.12: Regenerative and non-generative heat exchanger 20

Figure 3.1: U-tube heat exchanger 25

Figure 3.2: Individual parts of U-tube heat exchanger 26

Figure 3.3: Dimensions and views 28

Figure 3.4: B-type front header 30

Figure 3.5: F-type shell 30

Figure 3.6: U- Heat Exchanger 31

Figure 3.9: Experimental set up 34

CHAPTER 1
INTRODUCTION

1.1 Introduction

Heat exchangers are devices that facilitate heat transfer between two or more fluids at different temperatures. In most heat exchangers, the fluids are separated by a heat transfer surface and ideally they do not mix. Heat exchangers are used in process, petroleum, power, transportation, refrigeration, air conditioning, cryogenic, heat recovery, alternate fuels and other industries.

In U-tube (BFU) heat exchanger one of the fluids flows through a bundle of U shaped tubes enclosed by a shell. The term BFU is a designation system authorized by TEMA (Tubular Exchanger Manufacturing Association). The first letter describes the front header type, the second letter the shell type and the third letter the rear header type.

B-Type front header

This is the cheapest type of front header. It is more suitable front header for high pressure duties because the header has only one seal. A disadvantage is that to gain access to the tubes requires disturbance to the pipe work in order to remove the header.

F-Type shell

This is generally used when pure countercurrent flow is required in a two tube side pass unit. This is achieved by having two shells side passes—the two passes being separated by a longitudinal baffle. The main problem with this type of unit is thermal and hydraulic leakage across this longitudinal baffle unless special precautions are taken.

U tube

This is the cheapest of all removable bundle designs, but is generally slightly more expensive than a fixed tube sheet design at low pressures. However, it permits unlimited thermal expansion, allows the bundle to be removed to clean the outside of the tubes, has the tightest bundle to shell clearances and is the simplest design. A disadvantage of the U-tube design is that it cannot normally have pure counter flow unless an F-Type shell is used. Also, U-tube designs are limited to even numbers of tube passes.

This type of arrangement is employed where reliability and heat transfer effectiveness are important. With the use of multiple U shaped tubes heat transfer rate is simply improved due to increased surface area. It is simple to design and has effective and advantageous application in cooling hydraulic fluid and oil in engines, transmissions and hydraulic power packs.

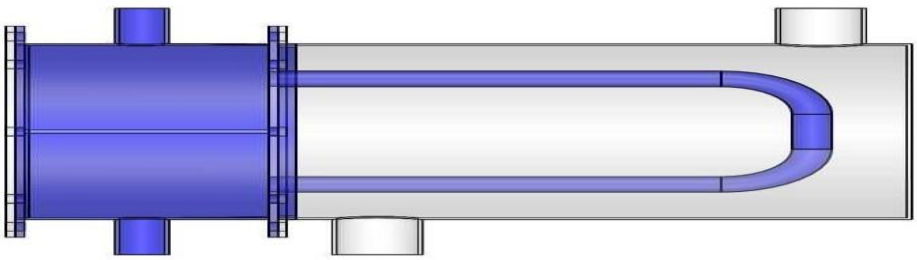


Figure 1.1: U-tube heat exchanger

1.2 Importance of the study

Shell and tube heat exchangers are the most common and popular type of heat exchanger due to the flexibility they allow for a wide range of pressure and temperature. It has U shaped tubes which are enclosed by a shell. One fluid flows inside the tubes while the other liquid flows over the outside walls of the tubes which, basically, are the shell. It's highly recommended for places where there's a need for high heat transfer coefficient and unlimited thermal expansion. Due to its unique shape, it finds use in high pressure applications.

1.3 Origin of the report

As a Mandatory part the Department of Mechanical Engineering of the degree of Bachelor of Science (B.SC) in Mechanical Engineering. Report ,all the Students of the thesis report with an objective of gaining practical knowledge about & quot "**Design and Fabrication of a U-tube Type BFU Heat Exchanger**" By Coducting this Study ,we can enhance our knowledge and skill to apply various research methods in professional life or higher educational life. By doing we can boost our acceptability in job market and develop our real life knowledge.

1.4 Rational of the study

The report is assigned by us supervisor "Pronoy Chowdhury" Lecturer Department of Mechanical Engineering, Sonargaon University . The topic of the report is "**Design and Fabrication of a u-tube type BFU Heat Exchanger**" By conducting this Study. We can enhance our knowledge and skill to apply various research in professional life or higher educational life. By doing we can boost our acceptability in job Market a develop our real life knowledge.

1.5 Objectives

- To design and fabricate a U tube heat exchanger.
- To find the amount of heat exchanged between two fluids.
- To find the log mean temperature difference, overall heat transfer coefficient and effectiveness of the heat exchanger.

1.6 Scope of the study

The U-tubes permit unlimited thermal expansion, the tube bundle can be removed for cleaning and small bundle to shell clearances can be achieved. However, since internal cleaning of the tubes by mechanical means is difficult, it is normal only to use this type where the tube side fluids are clean. Some application of U tube heat exchangers are as follows:

- Domestic hot water
- Oil temperature cooling
- Liquid and gas cooling
- Water heating with steam
- Condensate cooling
- Boiler feed water
- preheating Cooling tower
- Trim cooling Glycol cooling
- Oil cooling

1.7 Limitation of the study

- Assuming no conduction and radiation heat loss occurred from shell.
- Assuming constant overall heat transfer coefficient.
- Constant specific heat for cold and hot fluid.
- Temperatures are assumed uniform at any section.

CHAPTER 2
LITERATURE REVIEW

2.1 Previous study

A lot of research work has been done about designing heat exchangers, and especially shell-and-tube heat exchangers. Than et al. [1] evaluated their data for heat transfer area and pressure drop and checking whether the assumed design satisfies all requirement or not. The primary aim of their design was to obtain a high heat transfer rate without exceeding the allowable pressure drop.

Mukherjee et al. [2] explained the basics of heat exchanger thermal design, covering various topics like STHE components; classification of STHEs according to construction and according to service; data needed for thermal design; tube side design; shell side design. The basic equations for heat transfer and pressure drop in tube side and shell side along with. correlations for the optimal condition were also focused and explained with some tabulated data. Their research provided an overall idea to design optimal shell and tube heat exchanger.

Yusuf et al. [3] produced a computer-based design model for the preliminary design of shell and tube heat exchangers with single-phase fluid flow both on shell and tube side. The program regulated the overall dimensions of the shell, the tube bundle, and optimum heat transfer surface area required to meet the specified heat transfer duty by calculating minimum or allowable shell side pressure drop. They found that circulating cold fluid in the shell-side tube has some advantages rather than the hot fluid in the shell-side tube.

Andre et al. [4] presented a study about the design optimization of shell-and-tube heat exchangers. They formulated problem consists of the minimization of the thermal surface area for a certain service, involving discrete decision variables. Their obtained results illustrated the capacity of the proposed approach to direct the optimization towards more effective designs.

Tinker [6]. He suggested a schematic flow pattern, which divided the shell-side flow into a number of individual streams.

Baghban et al. [7] analyzed the thermal behavior of the shell-side flow of a shell-and-tube heat exchanger using theoretical and experimental methods. The experimental method provided the effect of the major parameters of the shell-side flow on thermal energy exchange.

Gopi Chand et.al. [8] has proposed a simplified model for the study of thermal analysis of shell-and-tubes heat exchangers of water and oil type.

From this above study it is learnt that analysis of U- tube heat exchanger can be done both experimentally and theoretically. Experimental analysis of heat exchanger involves analysis of its thermal performance and its pressure drop performance as both this factors are the main

selection criteria for a heat exchanger. It is obtained that performance analysis of a heat exchanger generally involves two type of problem:

- Performance problem
- Design problem

The objective in performance problem is to predict the outlet temperature of the two fluids and heat transfer rate for a heat exchanger of known construction and flow arrangement. The flow rate and inlet temperatures are usually known in this class of problem.

On the other hand, the objective in design problem is to design a U tube heat exchanger that will provide a specified outlet temperature of one of two fluids or transfer a specified heat rate between two fluids. Such problems do not have unique answers since the objective can be accomplished by an infinite number of heat exchanger.

2.2 Classification of Heat Exchanger

Heat exchangers are made in so many sizes, types, configurations, and flow arrangement.

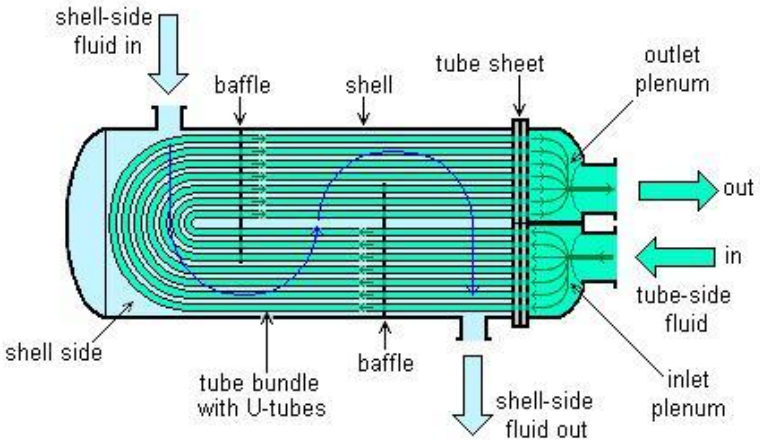


Figure 2.1: Heat Exchanger

Classify heat exchangers are based on-

1. The transfer process.

2. Compactness.

3. Construction type.

4. Flow arrangement.

5. Function.

6. Heat transfer mechanism.

2.2.1 Classification by Transfer Process

Heat exchangers can be classified as-

a) Direct contact: in the direct contact type heat transfer takes place between two immiscible fluids, such as a gas and a liquid, coming into direct contact. For example,

cooling towers, jet condensers for water vapor, and other vapors utilizing water spray are typical examples of direct-contact exchangers.

b) Indirect contact: in the indirect contact type of heat exchangers, such as automobile radiators, the hot and cold fluids are separated by an impervious surface, and they are referred to as surface heat exchangers. There is no mixing of the two fluids.

2.2.2 Classification according to compactness

Density in the range of 70 to 500 m2/m3, are not considered compact. The definition of compactness is quite arbitrary matter. The ratio of the heat transfer surface area on one side of the heat exchange to the volume can be used as a measure of the compactness of heat exchangers. A heat exchanger having a surface area density on any one side greater than about 700 m2/m3 quite is referred to as a compact heat exchanger regardless of its structural design. For example, automobile radiators having an area density on the order of 1100 m2/m3and the glass ceramic heat exchangers for some vehicular gas turbine engines having an area density on the order of 6600 m2/m3 are compact heat exchangers.

On the other extreme of be compactness scale, plane tubular and shell-and-tube type exchangers, having an area

2.2.3 Classification by Construction Type

Heat exchangers also can be classified according to their construction features, as-
a) Tubular heat exchangers: Tubular heat exchangers are widely used, and they are manufactured in many sizes, flow arrangements, and types. They can accommodate a wide range of operating pressure and temperatures. The easy of manufacturing and their relatively low cost have been the principal reason for their widespread use in engineering applications.

The character of the fluids may be 1iquid-to- liquid, liquid-to-gas, or gas- to-gas. Liquid- to liquid exchangers have the most common applications. Both fluids are pumped through the exchanger, hence the heat transfer on both the tube side and the shell side is by forced convection. Since the heat transfer coefficient is high with liquid flow, generally. There is no need to use fins.



Figure 2.2: Tubular heat exchanger

The liquid-to-gas arrangement is also commonly used; in such cases, the fins usually are added on the gas side of the tubes, where the heat transfer coefficient is low. Gas to gas exchangers is used in the exhaust-gas and air preheating recuperate for gas turbine systems, cryogenic gas liquefaction systems and steel furnaces. Internal and external fins generally are used in the tubes to enhance heat transfer.

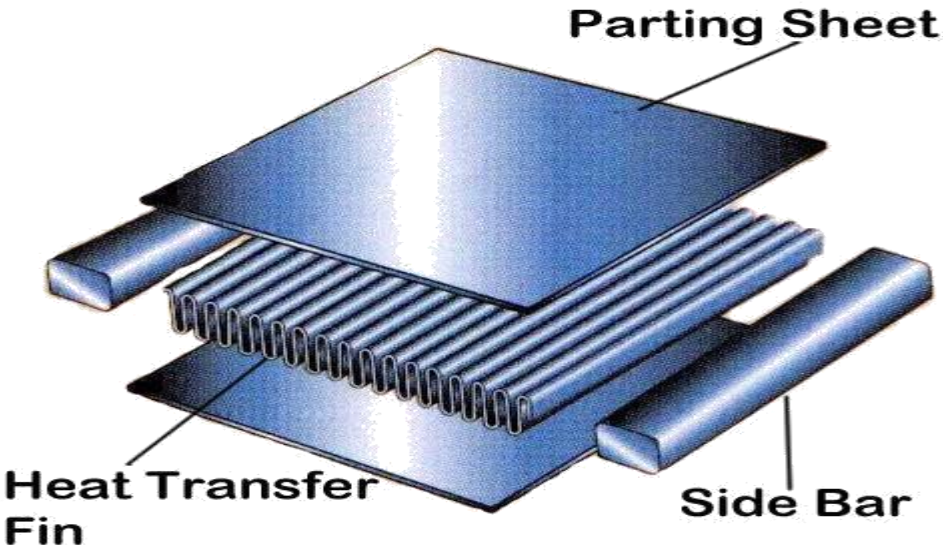


Figure 2.3: Plate heat exchanger

b) Plate heat exchanger: Plate heat exchanger is composed of multiple, thin, slightly separated plates that have very large surface areas and fluid flow passages for heat transfer. The plates may be smooth or may have some form of corrugation. This stacked plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical. Since the plate geometry cannot accommodate as high pressure and/or temperature differentials as a circular tube, they are generally designed moderate temperature and/or pressure the compactness factor for plate heat exchangers range from 120 to 230 m2/m3.

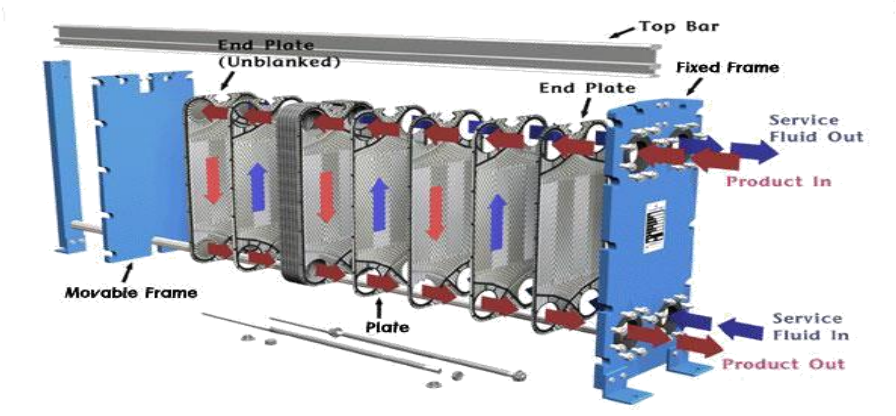


Figure 2.4: Plate-fin heat exchanger

c) Plate-fin heat exchanger: The compactness factor can be significantly improved (i.e. up to about 6000 m2/m3) by using the plate tin type of heat exchanger. Louvered or corrugated tins are separated by flat plates. Cross-How, counter flow or parallel flow arrangements can be obtained readily by properly arranging the fins on each side of the plate. Plate-fin exchangers are generally used for gas-to-gas applications, but they are used for low-pressure applications not exceeding about 10 atmospheres. The maximum operating temperatures are limited to about 800 °C. Plate-fin exchangers also have been used for cryogenics applications.



Figure 2.5: Tube-fin heat exchanger

d) Tube-fin heat exchanger: when a high operating pressure or an extended surface is needed on one side, tube fin heat exchangers are used. Tube-fin heat exchangers can be used for a wide range of tube fluid operating pressure not exceeding about 30 atmospheres and operating temperatures from low cryogenic applications to about 870°C. The maximum compactness ratio of about 330 m^2/m^3 is less than that obtainable with plate-fin exchangers.

2.2.4 Classification by Flow Arrangement

Numerous possibilities exist for flow arrangement in heat exchangers. We summarize here the principle ones.

a) **Parallel flow heat exchanger:** The hot and cold fluids enter at the same end of the heat exchanger, flow through in the same direction, and leave together at the other end, as shown in Fig.

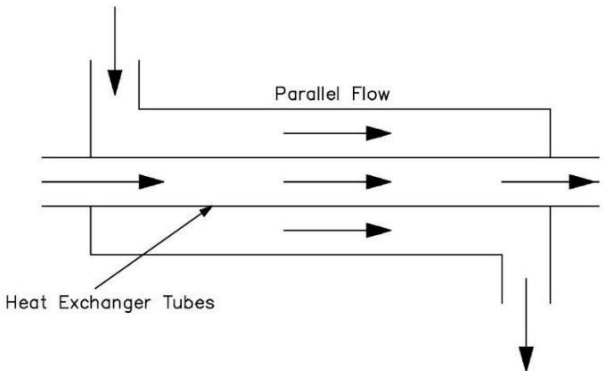


Figure 2.6: Parallel flow

b) Counter flow heat exchanger: The hot and cold fluids enter in the opposite ends of the heat exchanger and flow through in opposite direction, as shown in Fig.

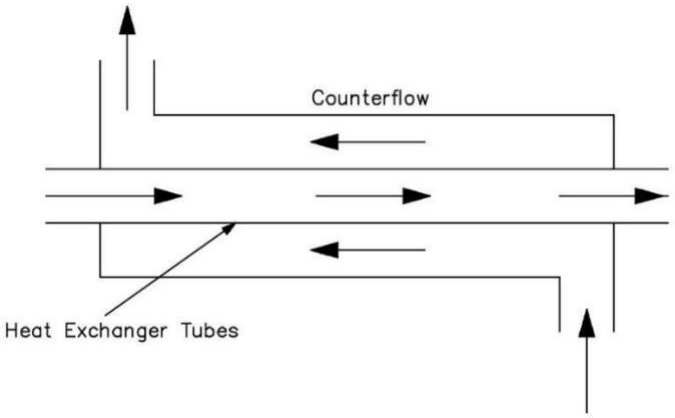


Figure 2.7: Counter flow

c) Cross flow heat exchanger: In the cross flow exchanger, the two fluids usually flow at the right angles to each other, as shown in Fig. In the cross-flow arrangement, the flow may be called mixed or unmixed, depending on the design.

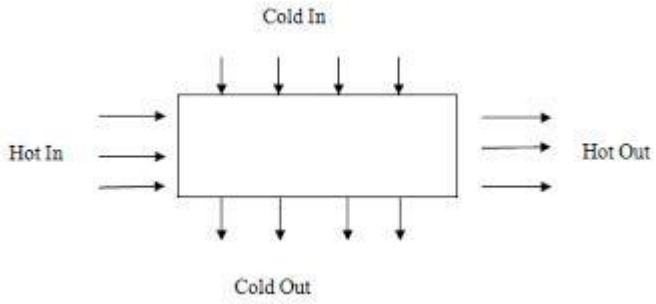


Figure 2.8: Cross flow arrangement

d) Multi-pass heat exchanger: The multi-pass flow arrangements are frequently used in heat exchanger design, because multi-passing increases the overall effectiveness over individual effectiveness. A wide variety of multi-pass flow arrangements are possible.

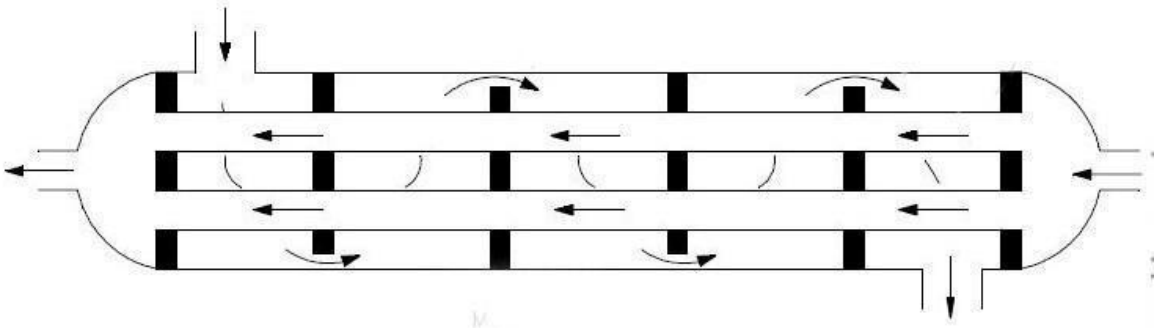


Figure 2.9: Multi-pass flow heat exchanger

2.2.5 Classification by Function

Heat exchangers are also classified by their function in a particular system. One common classification is-

a) Regenerative: A regenerative heat exchanger is one in which the same fluid is both the cooling fluid and the cooled fluid, as illustrated in Figure. That is, the hot fluid leaving a system gives up its heat to "regenerate" or heat up the fluid returning to the system. Regenerative heat exchangers are usually found in high temperature systems where a portion of the system's fluid is removed from the main process, and then returned. Because the fluid removed from the main process contains energy (heat), the heat from the fluid leaving the main system is used to reheat (regenerate) the returning fluid instead of being rejected to an external cooling medium to improve efficiency.

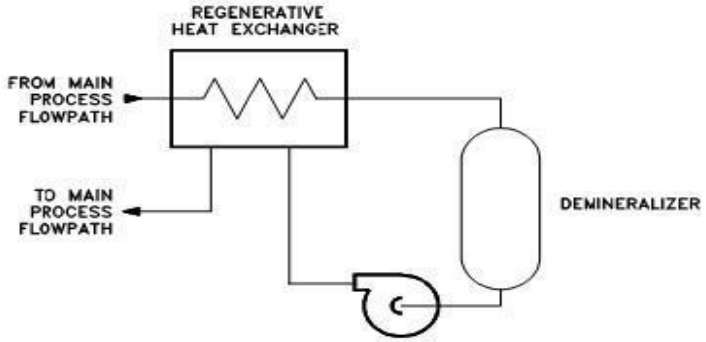


Figure 2.10: Regenerative Heat Exchanger

b) Non regenerative: In a non-regenerative heat exchanger, the hot fluid is cooled by fluid from a separate system and the energy (heat) is not removed.

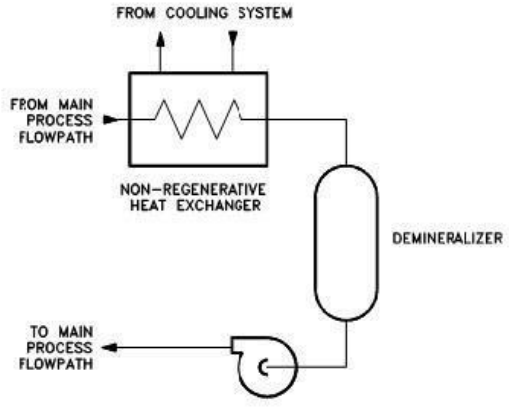


Figure 2.11: non-generative heat exchanger

The relation between regenerative and non-generative heat exchanger:

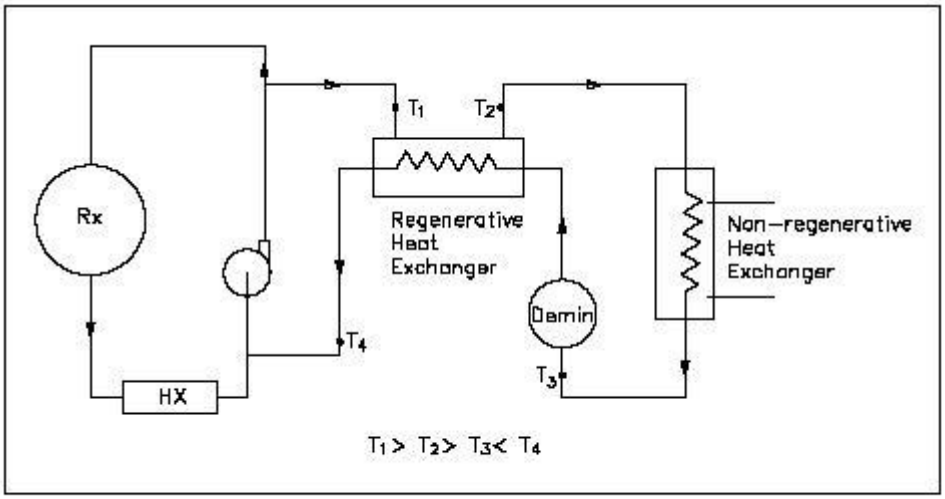


Figure 12 Regenerative Heat Exchanger

Figure 2.12: Regenerative and non-generative heat exchanger

2.2.6 Classification by Heat Transfer Mechanism

The possibilities for the heat transfer mechanism include a combination of any two of the following:

- Single-phase forced or free convection.
- Phase change (boiling or condensation)
- Radiation or combined convection and radiation.

For all the case discussed earlier we considered single-face forced convection on both sides of heat exchanger. Condensers, boilers and radiators for space power plants including the mechanisms of condensation, boiling and radiation, respectively, on one of the surface of the heat exchanger.

Condensers are used for such varied application as steam power plants, chemical processing plants, and nuclear electric plants for space vehicles. The major types include the surface condensers, jet condensers and evaporative condensers. The most commons the surface condenser, which has the advantage that the condensate is returned to the boiler through the feed water system.

Boilers Steam boilers are one of the earliest applications of heat exchangers. The term steam generator is often applied to the boilers in which the heat source is a hot fluid stream rather than the product of combustion. An enormous variety of boiler types exist, ranging from small units for house heating applications to huge, complex, expensive Limits for modern power stations.

Radiators for space power plants the rejection of waste heat from the condenser of a powerplant intended to produce electricity for the propulsion, guidance, or the

communication equipment of a space vehicle poses serious problems even for a power plant producing only a few kilowatts of electricity. The only way the waste heat can be dissipated from a space vehicle is by thermal radiation by taking advantage of the fourth-power relationship between the absolute temperature of the surface and the radiative-heat flux.

2.3 Factors considering for Heat Exchanger Analysis

The design of heat exchanger is a complicated matter. Heat transfer and pressure drop analysis, sizing and performance estimation, and the economic aspects play important roles in the final design. In heat exchanger as the energy is transferred from one fluid to another across a solid surface, heat exchanger analysis and design therefore involve both convection and conduction. Heat transfer will occur by convection to the outside of the inner tube, by conduction across the tube and by convection to the cooler fluid from the inside tube surface Radiative transfer between the exchanger and the environment can usually be neglected unless the exchanger is uninsulated and its external surfaces are very hot. Two important problems in heat exchanger analysis are (i) rating existing heat exchangers and (ii) sizing heat exchangers for a particular application. Rating involves determination of the rate of heat transfer, the change in temperature of the two fluids, and the pressure drop across the heat exchanger. Sizing involves selection of a specific heat exchanger from those currently available or determining the dimensions for the design of new heat exchanger, given the required rate of heat transfer and allowable pressure drop.

2.3.1 Convection

When fluid flows over a solid body or inside a channel while temperatures of the fluid and the solid surface are different, heat transfer between the fluid and the solid surface takes place as a consequence of the motion of fluid relative to the surface; this mechanism of heat transfer is called convection. The term natural convection is used if this motion and mixing is caused by density variations resulting from temperature differences within the fluid. The term forced convection is used if an outside force, such as a pump, causes this motion and mixing. The transfer of heat from a hot water radiator to a room is an example of heat transfer by natural convection. The transfer of heat from the surface of a heat exchanger to the bulk of a fluid being pumped through the heat exchanger is an example of forced convection. Thermal radiation by taking advantage of the fourth-power relationship between the absolute temperature of the surface and the radiative heat flux.

2.3.2 Conduction

Conduction is the mode of heat transfer in which energy exchange takes place from the region of high temperature to that of low temperature by the kinetic motion or direct impact of molecules, as in the case of fluid at rest, and by the drift of electrons, as in the case of metals. In a solid, which is good electric conductor, a large number of free electrons move about in the lattice; hence materials that are good electric conductors are generally good heat conductors.

2.3.3 Surface Area

Increasing a common surface area between two fluids will increasing the overall heat transfer rate between two fluids. This could be accomplished by using more tubes in a shell and tube heat exchanger, by using fins in plate-tin exchangers etc.

2.3.4 Resistance of heat transfer

The ability to transfer heat from one fluid to another through some form of solid wall is depends on following factors:

- The surface area between two fluids.
- Rate of heat transfer through a dividing wall, which separates the two fluids.
- Rate of heat transfer from one layer to the next (if more than one layer is present) in the dividing wall.
- Rate of heat transfer from the hot fluid to the dividing wall. Rate of heat transfer from the dividing wall to the cold fluid.

2.3.5 Contact Resistance

Contact resistance occurs between two surfaces that are fitted together or joined together in some way. A simple case would to be considering two flat plates laying each other. Imagine a hot fluid above the top plate and the top plate, which rests upon a lower plate. This lower plate is either a different metal or the same metal. At the microscopic level there exists a certain roughness between the two plates; such that there is not a perfect contact between them this roughness inhibits heat conduction for a variety of ways. Actually there is several heat transfer mechanism occurring such as conduction between that portion of the plates which are in contact, convection between the small amount of air between the two plates, and radiation from a hot surface to a cold surface. What is done in analysis is to assume that the combination of convection, conduction radiation between the surface discontinuities provides a given degree of resistance to the conduction.

2.4 Application

Significant industries in which heat exchangers are used extensive:

- **HVACR {Heating- Ventilation- Air Conditioning- Refrigeration}**

Heat transfer is one of the most important industrial processes. Throughout any industrial facility, heat must be efficiently added, removed or moved from one process stream to another. In massive organizations human comfort is the big thing to tackle with in order to obtain maximum output from their employees. For employee's comfort all industries no matter whether it's small or big, install HVACR (Heat- Ventilation- Air Conditioning- Refrigeration).

- **Power industry**

As we already mentioned Heat transfer is one of the most important industrial processes so be it power generation from coal power plant, oil power plant or gas power plant. In power industry we burn the fuel- coal, oil or gas in order to generate heat and then that heat is used to run the turbine and power our houses. During the whole process a lot of heat losses occur. To minimize that heat loss & in other way to optimize great yield output, heat exchangers plays major role at various stages of energy conversion process. In fact, Boilers are one kind of heat exchanger. Apart from Boilers many more type of heat exchangers are used in Power Industry.

- **Food & agriculture**

Heat exchangers are extensively used for drying process involved in Food & Agriculture. Achieving the desired taste, a stable shelf life and commercial sterility of food products is reliant upon tight control of process timing and temperatures as well as careful and correct raw ingredients and materials.

- **Chemical / petrochemical**

Plate heat exchangers have been successfully employed for decades in the chemical industry in the most diverse sectors, such as the cooling and heating of base, intermediate and final products, heat recovery or also the tempering of containers, reactors and autoclaves.

- **Marine**

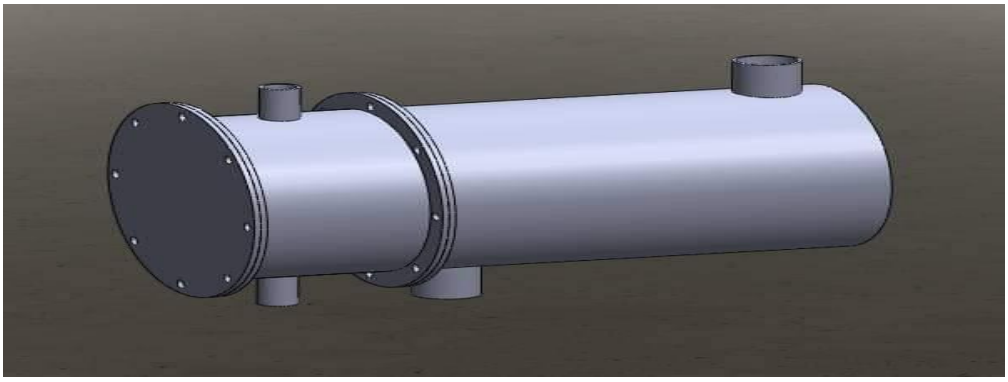
When conditions are tough, crew and equipment are really put to the test. The main engine oil cooler and central fresh water cooler simply have to work. There is no room for compromise when the sea is rough and the harbor far away.

CHAPTER 3

METHODOLOGY

3.1 Proposed Model

This model has been proposed because of its having certain advantage as compared to the conventional heat exchanger. It is possible to open it part by part which will aid in cleaning effectively and manually. It is one of the most needed things for heat exchanger handling dirty fluid. Using U shaped tubes will allow more heat to be exchanged because of having increased surface area and heat transfer can be further increased by increasing the number of tubes. We used two types of material for made up U tube. Cooper and Stainless steel has been selected for made up this tube. As a result, we can compare heat transfer rate by applied two types of U tube.



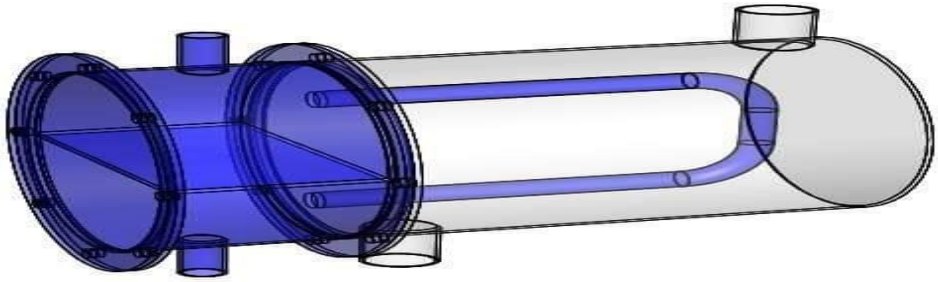


Figure 3.1: U tube Heat Exchanger

3.2 Material and Measurement

Mainly stainless steel has been selected for manufacture the U tube heat exchanger. But for U tube's material selection, there are two types of material used for comparison heat transfer efficiency.

F-type shell

Material: Stainless Steel
Length: 685.8 mm
Diameter: 203.2 mm
Thickness: 1.5 mm

B-type front header:

Material: Stainless steel
Length: 127 mm
Diameter: 101.6 mm
Thickness: 1.5 mm

U tube

Material: Stainless steel and Copper
Length: 1140 mm (Two tube pass)
Diameter: 45 mm

3.3 Individual parts of U tube (BFU) Heat Exchanger

To design something, first of all the individual parts which all together make it up must be assumed and according to the shape and size they need to be designed. Similarly, all the individual parts of U tube heat exchanger have been designed to make it easy to manufacture. It gives important idea about what type of and what amount of materials needed for manufacturing those components. Using solid works all these parts have been designed.

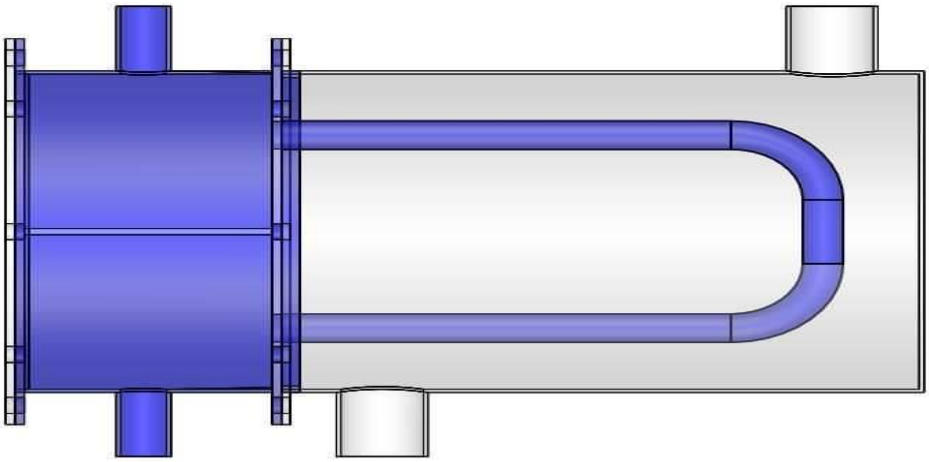


Fig (a): F-type shell

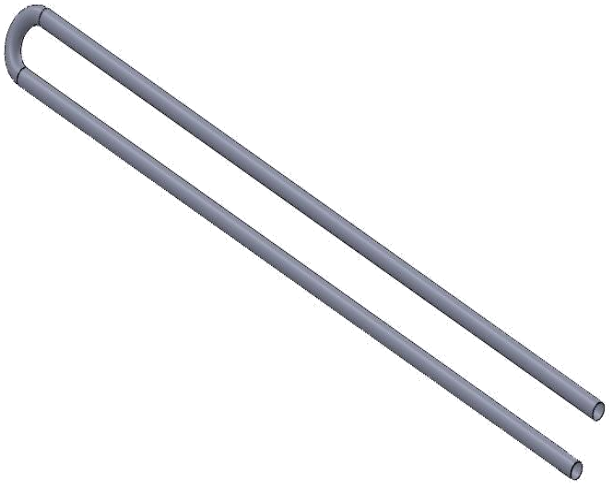


Fig (c): U tube

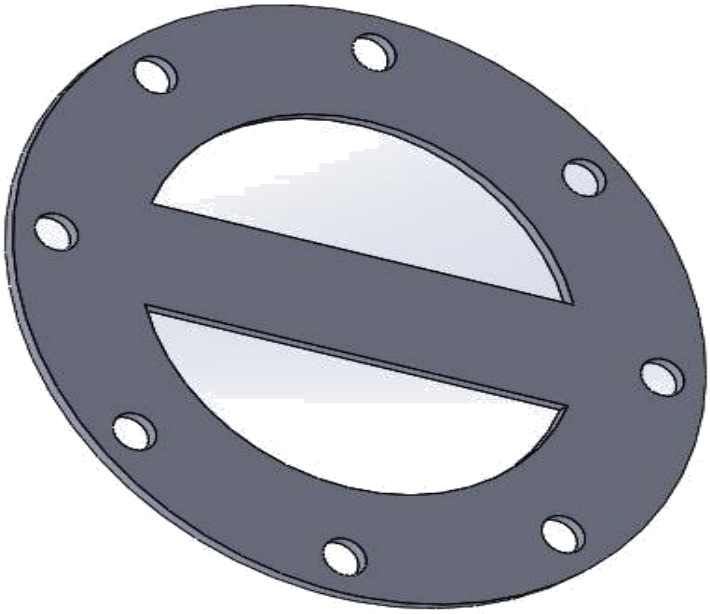


Fig (e): Header gasket

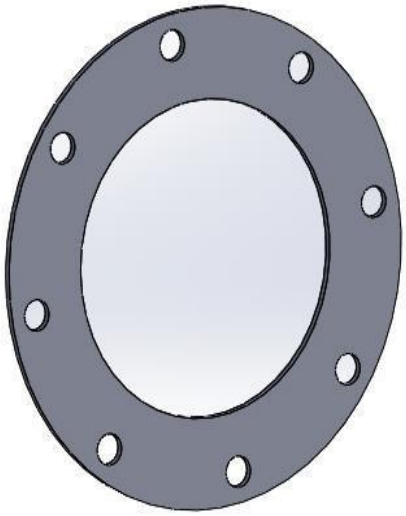
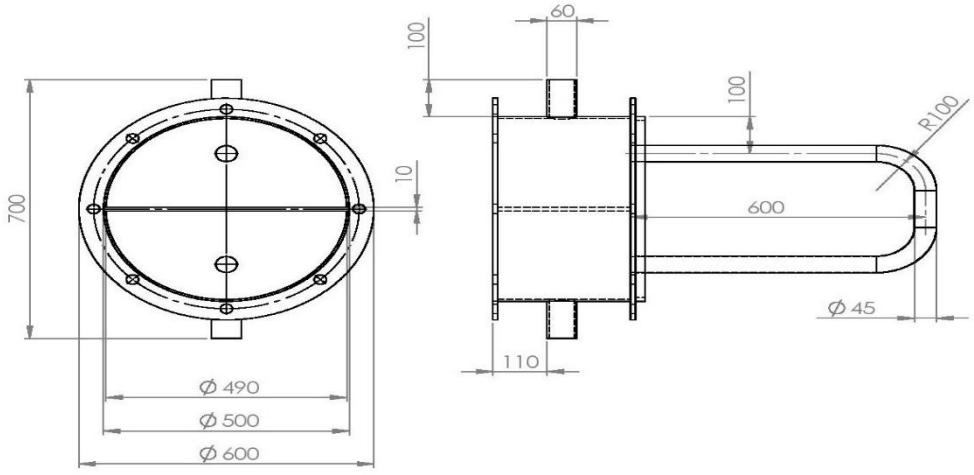


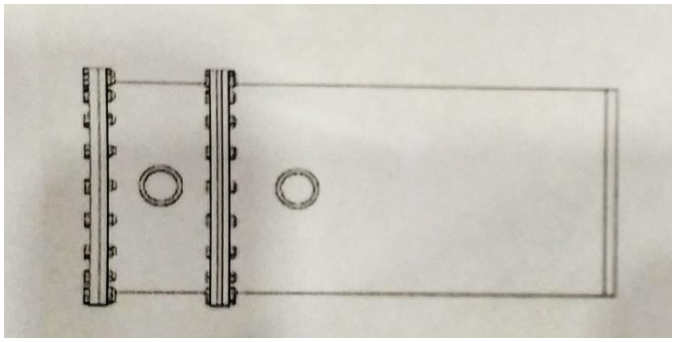
Fig : Flange gasket

3.4 Dimensions in MMGS unit of U tube (BFU) Heat Exchanger and various views

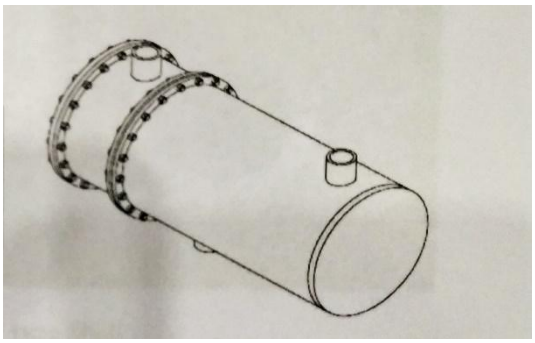
An engineering drawing must be properly dimensioned in order to convey the designer's intent to the end user. Dimensions and various views provide the information needed to specify the size and location of every feature on the object. A properly dimensioned drawing helps ensure that the part produced in the manufacturing phase matches the part which have thought and asked for. So Dimensions of U tube heat exchanger and various views have been created so that it can be manufactured perfectly according to the designed size and shape.



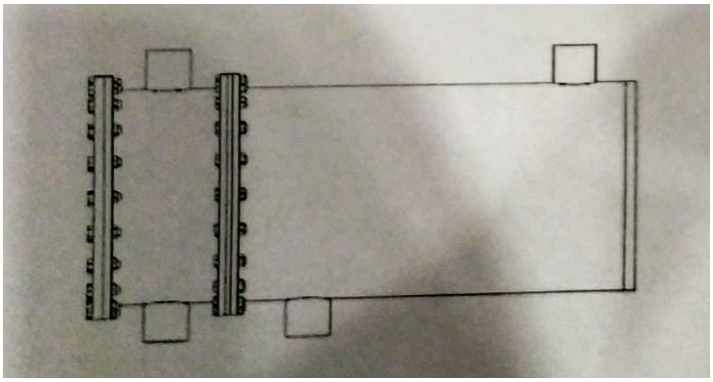
Section View



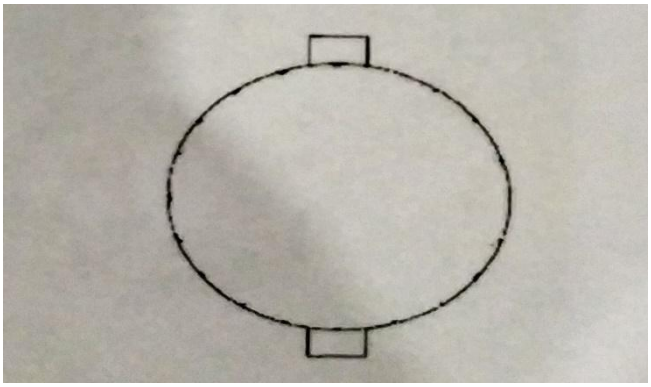
Top view



Isometric View



Front View



Right Side view

Figure 3.3: Dimensions and view

3.5 My project view

All the parts of U tube heat exchanger have been manufactured according to the designed shape and size using stainless steel and copper. Gasket has been used to make it leak proof and rubber gasket has been used. Double set, two U shaped tubes have been used and it can be increased according to the requirement. Eleven fastener bolts with washer have been used to attach the removable parts of the heat exchanger. Increased numbers of stainless steel bolts have ensured it to be leak proof also along with gaskets. Gaskets have been used in each junction of removable parts.

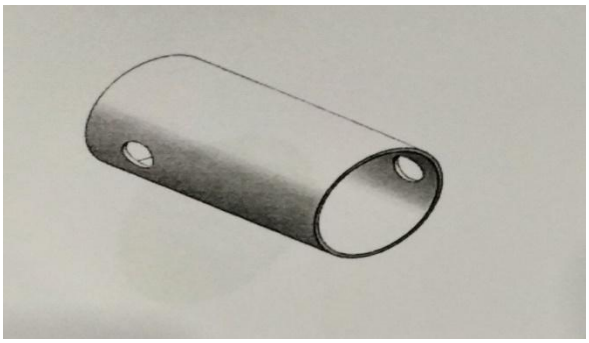


Figure 3.4: F-type Shell

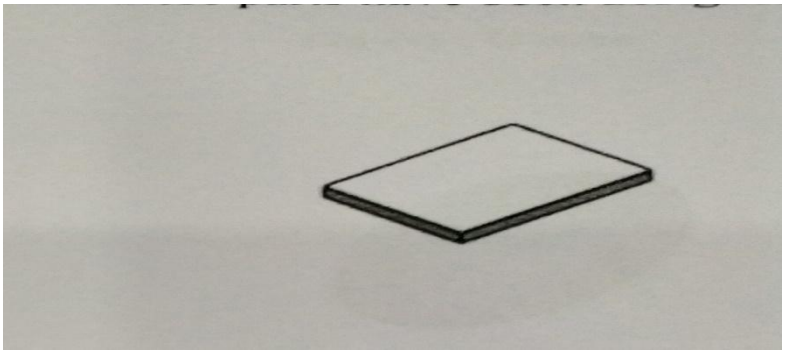


Figure: Header Shell separator

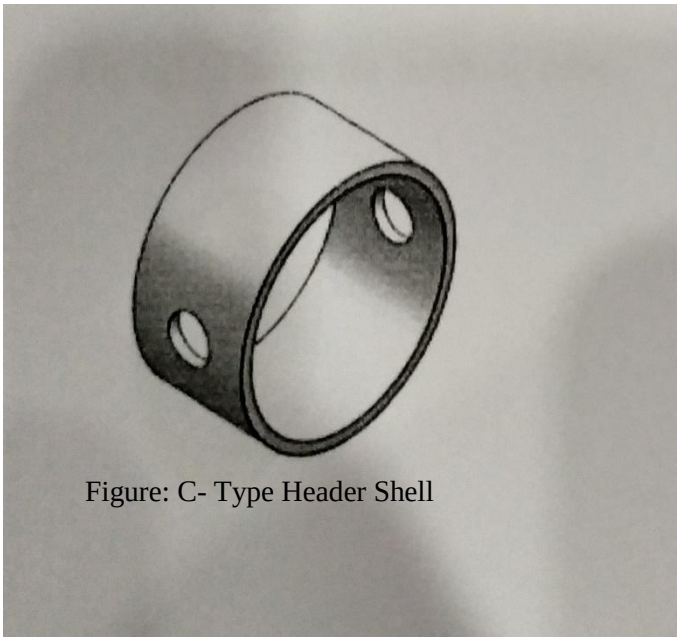


Figure: C- Type Header Shell

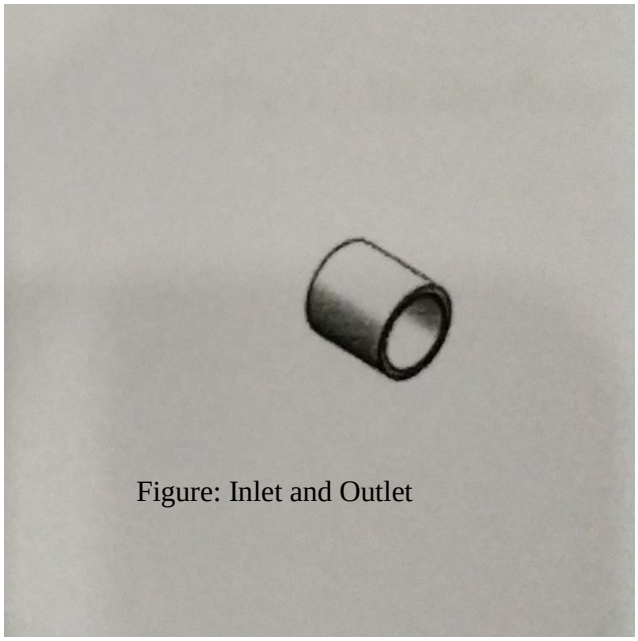


Figure: Inlet and Outlet

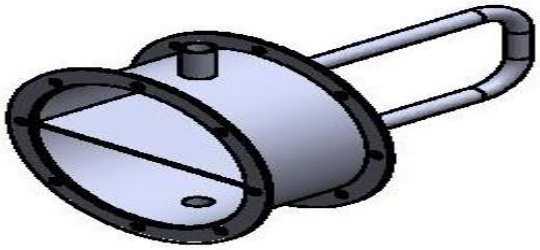


Figure: U- Heat Exchanger

3.6 Assumption

- No axial flow conduction through fluids, tube and shell.
- No heat loss from the shell to the surroundings.
- No changes in potential and kinetic energy.
- Constant overall heat transfer coefficient.
- Constant specific heat of the cold and hot fluids.
- Temperature of each fluid is uniform at any section.
- Negligible pressure drops in both fluids.
- No phase change.

3.7 Formulation

A heat exchanger can be designed by the LMTD when inlet and out let conditions are specified. When the problem is to determine the inlet and outlet temperatures for a particular heat exchanger, the analysis is performed more easily by using a method based on effectiveness of the heat exchanger and number of transfer units (NTU).

The heat exchanger effectiveness is defined as the ratio of actual heat transfer to the maximum possible heat transfer.

The actual heat transfer rate Q can be determined by energy balance equation,

The fluid capacity rate C:

$m_h c_{ph}$= hot fluid capacity rate

$m_c c_{pc}$= cold fluid capacity rate

c_{min} = the minimum fluid capacity rate (c_h or c_c)

c_{max}= the maximum fluid capacity rate (c_h or c_c)

Where,

U = Overall heat transfer coefficient in W/m^2.
^oC A = Surface area in m^2

The effectiveness, = (−) (−)

The governing equations for design problem are usually given as follows:

Heat rate,

$Q= C_h(t_{hi}-t_{ho}) = C_c(t_{co}-t_{ci})$

Where,

Q=heat duty of heat exchanger, W

C_h= specific heat of the hot fluid, J/kg ^oC

C_c= specific heat of the cold fluid, J/kg ^oC

T_{hi}= temperature of the hot fluid inside, ^oC

T_{ho}= temperature of the hot fluid outside, ^oC

T_{ci}= temperature of the cold fluid inside, ^oC

T_{co}= temperature of the cold fluid outside, ^oC

Where heat capacity rate for hot or cold fluid

$C= m_{cp}$

Where,
m = mass flow rate, kg/sec

C=heat capacity

CHAPTER 4
FABRICATION

4.1 Experimental Setup

In order to measure the effectiveness, log mean temperature difference, overall heat transfer co-efficient of U tube heat exchanger an experimental set up was made. Hot water, cold water, Aluminum Oxide and Copper Oxide have been used to measure those parameters. We supplied hot fluid through the header side of U tube and cold fluid was passed through the shell side of U tube. Two Bucket were connected to the inlets of hot fluid and cold fluid to carry fluid. Here can also use rubber tube which connected to the inlets and outlets to carry water. A gas stove was used to heat the water to make it considered to be hot water. Normal tap water was used as cold water. The household buckets were used for carrying water. The water was supplied to the heat exchanger using the force of gravity without using pump. the nanoparticles were measured by a digital weight machine. The temperatures were measured using digital thermometers.

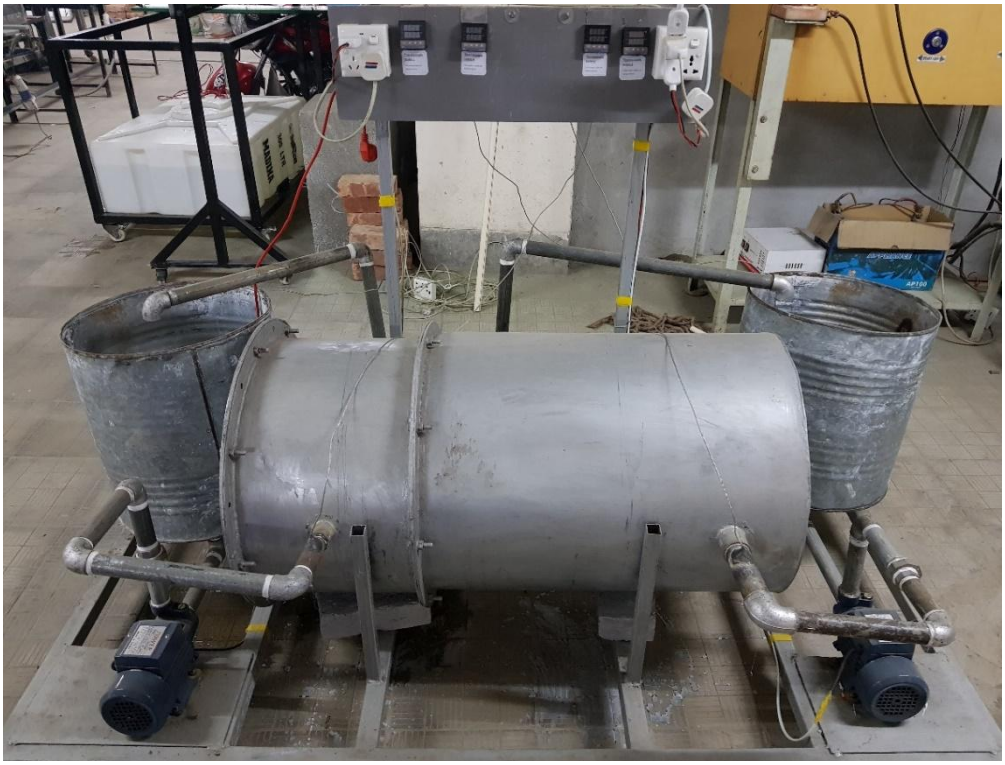


Figure:Experimental Setups

Data Collection Board:

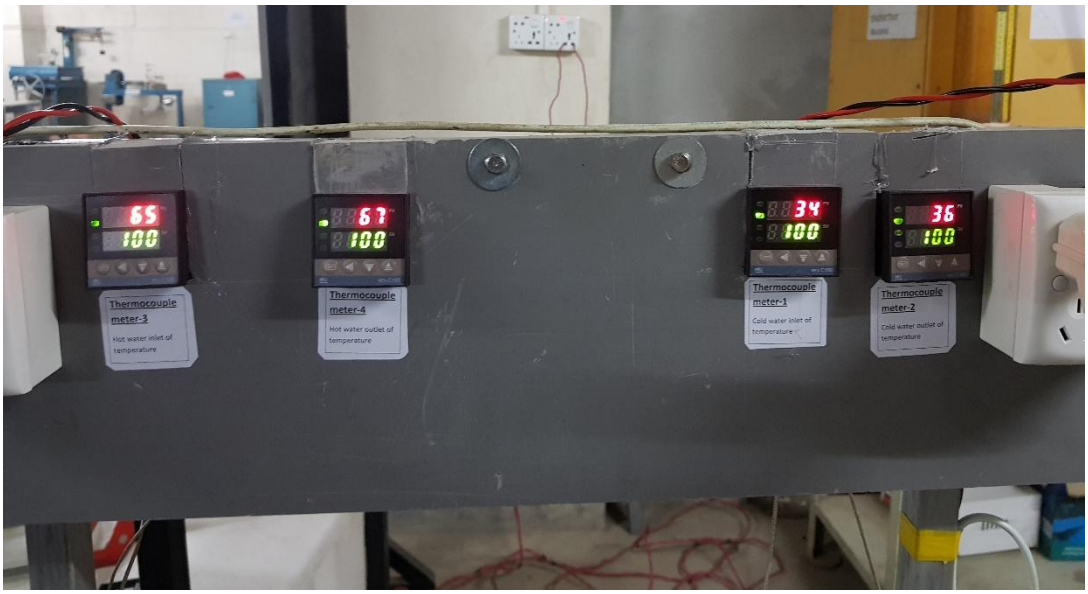


Fig: Data collection Board

Pump:



Fig: Submersible Pump

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.

4.2 Temperature Control:

Temperature control is a process in which change of temperature of a space (and objects collectively there within), or of a substance, is measured or otherwise detected, and the passage of heat energy into or out of the space or substance is adjusted to achieve a desired temperature.

Air-conditioners, space-heaters, refrigerators, water-heaters, etc. are examples of devices that perform temperature control. These are often broadly classified as Thermostatically Controlled Loads (TCLs).



Fig: Temperature Controller Display

4.3 Thermocouple Sensor:

A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

There are many types of thermocouples, each with its own unique characteristics in terms of temperature range, durability, vibration resistance, chemical resistance, and application compatibility. Type J, K, T, & E are “Base Metal” thermocouples, the most common types of thermocouples. Type R, S, and B thermocouples are “Noble Metal” thermocouples, which are used in high temperature applications (see thermocouple temperature ranges for details).

Thermocouples are used in many industrial, scientific, and OEM applications. They can be found in nearly all industrial markets: Power Generation, Oil/Gas, Pharmaceutical, Bio Tech , Cement, Paper & Pulp, etc. Thermocouples are also used in everyday appliances like stoves, furnaces, and toasters.

Thermocouples are typically selected because of their low cost, high temperature limits, wide temperature ranges, and durable nature.



Fig: Thermocouple

4.4 Water Heater:

Water heating is a heat transfer process that uses an energy source to heat water above its initial temperature. Typical domestic uses of hot water include cooking, cleaning, bathing, and space heating. In industry, hot water and water heated to steam have many uses.



Fig: Water Heater

CHAPTER 5
DATA COLLECTION AND CALCULATION

5.1 Data Collection Method

Using the following steps, the data has been collected:

- A pipe was connected from a bucket to the tube side inlet of heat exchanger and hot water has been supplied using gravity.
- Water was heated in a container using gas stove.
- Tap water as cold water was supplied through the shell side inlet of heat exchanger.
- Mass flow rate was measured using a bucket. At first the empty bucket weight was measured then bucket filled with water was measured and subtracting these two mass flow rate with respect to time was obtained.
- Using four thermometers the inlet and outlet temperature of both hot and cold water were noted down.
- Temperature reading was collected when it became steady.

5.2 Data

Inlet temperature of cold water = T_{cin} ^{o}C

Outlet temperature of cold water = T_{cout} ^{o}C

Inlet temperature of hot water = $T_{h,in}$ ^{o}C

Outlet temperature of hot water = T_{hout} ^{o}C

Mass flow rate of cold water= $m_c$kg/s

Mass flow rate of hot water= $m_h$kg/s

5.3 Data calculation for Stainless Tube with Water

Trial 1:

T_{cin}= 32^{o} C

T_{cout}= 39^{o} C

T_{hin} = 50^{o} C

T_{hout}= 41^{o} C

m_c= 0.230 kg/s

m_h= 0.179 kg/s

ΔT_1= (T_{hin} – T_{cout}) = (50-39) = 11^{o} C

ΔT_2= (T_{hout} –T_{cin}) = (41-32) = 9^{o} C

A= 2πdL= 2×3.1416×0.045×1.14=0.32 m^2

Thermal balance

$Q_c = m_c c_{pc} (T_{cout} - T_{cin})$ = 0.230×4184× (39-32) =6736.24 W

$Q_h = m_h c_{ph} (T_{hin} - T_{hout})$

=0.179×4184× (50-41) =6740.424 W

Log Mean Temperature Difference (LMTD)

$\Delta T_m = (\Delta T_1 - \Delta T_2) / \ln (\Delta T_1 / \Delta T_2)$

$= (11-9)/ \ln (11/9)$

$= 9.97^{o}$ C

Effectiveness

$Q = Q_h$

$Q_{max} = (m_h c_{ph})_{min} (T_{hin} - T_{cin}) = (0.179 \times 4184) \times (50-41) = 6740.424$ W

Overall Heat Transfer Co-efficient

$U = Q/A \Delta T_m$

$= 6748.584/ (0.0.32 \times 9.97)$

$= 2115.278$ W/m$^{2\ o}$ C

Trial 2:

$T_{cin} = 34^{o}$ C
$T_{cout} = 42^{o}$ C
$T_{hin} = 55^{o}$ C
$T_{hout} = 44^{o}$ C
$m_c = 0.229$ kg/s
$m_h = 0.167$ kg/s
$\Delta T_1 = (T_{hin} - T_{cout}) = (55-42) = 13^{o}$ C
$\Delta T_2 = (T_{hout} - T_{cin}) = (44-34) = 10^{o}$ C
$A = 2\pi dL = 2 \times 3.1416 \times 0.045 \times 1.14 = 0.32$ m^2

Thermal balance

$Q_c = m_c c_{pc} (T_{cout} - T_{cin}) = 0.229 \times 4184 \times (42-34)$
$= 7665.088$ W
$Q_h = m_h c_{ph} (T_{hin} - T_{hout})$
$= 0.167 \times 4184 \times (55-44) = 7686.008$ W

Log Mean Temperature Difference (LMTD)

$\Delta T_m = (\Delta T_1 - \Delta T_2) / \ln (\Delta T_1 / \Delta T_2)$

$= (13-10)/ \ln (13/10)$

$= 11.43^{o}$ C

Effectiveness

$Q = Q_h$

$Q_{max} = (m_h c_{ph})_{min} (T_{hin} - T_{cin}) = (0.167 \times 4184) \times (55-34) = 14673.288$ W

Overall Heat Transfer Co-efficient

$U = Q/A\ \Delta T_m$

$= 7680.96/(0.32 \times 11.43)$

$= 2100\ W/m^{2\ o}C$

Trial 3:

$T_{cin} = 34^{o}$ C
$T_{cout} = 42^{o}$ C
$T_{hin} = 55^{o}$ C
$T_{hout} = 44^{o}$ C
$m_c = 0.229$ kg/s
$m_h = 0.167$ kg/s
$\Delta T_1 = (T_{hin} - T_{cout}) = (55-42) = 13^{o}$ C
$\Delta T_2 = (T_{hout} - T_{cin}) = (44-34) = 10^{o}$ C
$A = 2\pi dL = 2 \times 3.1416 \times 0.045 \times 1.14 = 0.32\ m^2$

Thermal balance

$Q_c = m_c c_{pc} (T_{cout} - T_{cin}) = 0.229 \times 4184 \times (42-34)$
$= 7665.088$ W
$Q_h = m_h c_{ph} (T_{hin} - T_{hout})$
$= 0.167 \times 4184 \times (55-44) = 7686.008$ W

Log Mean Temperature Difference (LMTD)

$\Delta T_m = (\Delta T_1 - \Delta T_2) / \ln (\Delta T_1 / \Delta T_2)$

$= (13-10)/ \ln (13/10)$

$= 11.43^{o}$ C

Effectiveness

$Q = Q_h$

$Q_{max} = (m_h c_{ph})_{min} (T_{hin} - T_{cin}) = (0.167 \times 4184) \times (55-34) = 14673.288$ W

Overall Heat Transfer Co-efficient

$U = Q/A \, \Delta T_m$

$= 7680.96/(0.32 \times 11.43)$

$= 2175$ W/m$^{2\,o}$ C

CHAPTER 6

RESULT AND DISCUSSION

6.1 Results:

My project objective was to design and fabrication of a U-tube heat exchanger and find the log mean temperature difference, overall heat transfer coefficient, amount of heat transferred.

6.2 Discussion:

The experimental reading has been taken five times to observe and the system is in unsteady condition. We got slight variation in the results of various parameters of heat exchangers due to limitations of set up. We could get better & more authentic data to look into the performance of this constructed heat exchanger if we could decrease the mass flow rate. It was not possible due to limitations of water supply arrangements. There could be parallax error while taking data. We used different types of U-tube material as Stainless steel and Copper for compare heat transfer efficiency. Better effectiveness could be achieved if we could heat the water more effectively. We ignore the heat losses through the inlet and outlet pipes. If we would consider it & insert the thermometer making a hole into the inlet and outlet, then better LMTD could be gained as heat loss could be reduced to some extent. The inlet cold water temperature should have been same but varied depending on the surrounding temperature as we used tap water as the cold water. Loss of heat by convection and radiation has been neglected. Moreover, the size of heat exchanger was too small as compared to the actual size that is why amount of heat exchanged and temperature difference is not so much negligible. By increasing the number of tube inside the heat exchanger the performance can be enhanced.

CHAPTER 7

CONCLUSION

7.1 Conclusion

Among various types of heat exchangers, U tube heat exchanger has designed & constructed because of its significant advantages. Most important of all is cleaning which is a big problem for heat exchanger when dirty fluid is used. The structure of U tube heat exchanger provides smooth & effective cleaning of each part manually by disassembling all the parts of it. It is extremely suitable for severe performance requirements with maximum thermal expansion capability. This heat exchanger is suitable for thermal shock application because each tube can expand and contract individually. It also provides multi-pass circuit arrangement. The tube area is more because of U-bend which ensures more cooling. Apart from these advantages it has some disadvantages. The tubes can be cleaned only by chemical means because of U bend. Individual tubes are difficult to replace because of U-tube nesting. Tube wall thickness is thinner at the U-bend than the straight portion of the tubes. It is difficult to drain the fluid through the tube when the heat exchanger is mounted in the vertical position with the head side up. It is used in oil, water & chemical heating application & excellent for steam to liquid application.

REFERENCE

References:

[1] Su Thet Mon Than, Khin Aung Lin, Mi Sandar Mon, “Heat Exchanger design", World Academy of Science, Engineering and Technology 46 2008.

[2] Rajeev Mukherjee, “Effective design of shell and tube heat exchanger”, American Institute of Chemical Engineering, 1988.

[3] Yusuf Ali Kara, Ozbilen Guraras, “A computer program for designing of Shell and tube heat exchanger”, Applied Thermal Engineering 24(2004) 1797–1805.

[4] Andre L.H. Costa, Eduardo M. Queiroz, “Design optimization of shell and-tube heat exchangers”, Applied Thermal Engineering 28 (2008) 1798–1805.

[5] Md. Maruf Majid, BME 160016, “Design and performance analysis of shell and tube heat exchanger.’’

[6] Md. Sujit Mostafa, BME 170048, “has worked on the design of Shell and tube heat exchanger.’’

[7] https://en.wikipedia.org/wiki/Shell_and_tube_heat_exchanger

[8] M. Negati Ozisik “Heat Transfer- A BASIC APPROACH” Published by McGraw-Hill INTERNATIONAL EDITION 1985