DESIGN OF DOUBLE PIPE HEAT EXCHANGER FOR LABORATORY USE.

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A FINAL YEAR DESIGN PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF ENGINEERING (B.ENG.) DEGREE.

MARCH, 2000.

CERTIFICATION

This is to certify that this project on carrying out the design of double pipe heat exchanger of study and development of Bio-insecticide from neem seeds is original work of Ndagana Gimba Mohammed carried out wholly by him under supervision and submitted to the Department of Chemical Engineering, Federal University of Technology, Minna.

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Date

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Date

DEDICATION

This project is dedicated to my father Mal. Zubairu K. Mohammed, mother Mrs. Hassana Zubairu, my wife Fatima Gimba, my brothers, sisters, twins partner, and the rest members of the family.

ACKNOWLEDGEMENT

I am grateful to Allah ta'ala for sparing my life to the present day and for enabling me to complete my project work successfully.

I wish to acknowledge the effort of my father Mal. Zubairu K. Mohammed, mother Hassana, brothers, sisters, relatives for their moral and financial supports.

I am indebted to my Project Supervisor Mr. A.O.W. Akinbode and also the Project Co-ordinator Mr. Olutuye for their tireless effort, and Engineer Hussaini K. Zubairu that participated actively in ensuring the completion of the project.

Dr. J.O. Oduguri, the Head of Chemical Engineering Department, is also not left out in this regard.

I am also indebted to Mal. Ibrahim Jiya Kutiriko Staff Officer Niger State Ruwatsan for his consistently advice given to me and all other people not mentioned.

ABSTRACT

This project: The design of a double-pipe heat-exchanger for the laboratory used is aimed at carrying out the design of the exchanger using data available from experiment and literature.

Chapter one of this project deals with purposes and scope involved. The literature review talked about various classification of heat exchangers at the chapter two. Chapter three which is equipment description deals with reason for selection of double pipe-exchangers and main features. Chapter four entails the Chemical Engineering design, while chapter five is concern with the Mechanical Engineering design as pect.

Lastly, the conclusion and recommendation put the finishing touches to the project.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 GENERAL

A heat exchanger is a device used to transfer heat from a fluid flowing on one side of a barrier to another fluid (or fluids) flowing on the other side of the barrier.[3]

A double pipe heat-exchanger consists of a pair of pipes (tubes) one positioned concentrically within the other. The fluid connections are usually such that the fluid flows in counter current direction. One fluid within the inner tube and the other within the annular space. Double pipe heat exchangers are often connected in series to provide an increased in heat transfer surface. They may be connected to have a parallel flow arrangement to handle large process steam flow. The inner pipe is often finned.

The double pipe heat exchanger are adopted for low flow rate, high temperaturte and high pressure application. Because of their relatively small diameter which allow the use of small flanges. Thin wall section as compared with convectional shell and tube. Counter current flow which is a particular advantage when very close temperature approaches are required.

Many types of heat-exchanger are known to exist. In all heat is being transfered from a hot fluid into a cold fluid. If there is a phase changed in one of the flowing fluid. The device may be coiled chiller, evaporator, distillation column, reboiler, cool condenser, because in such situations there is simultaneous mass and heat transfer when the heat exchangers are freed by combustion process they become furnace, boilers, heaters and coolers. Some heat exchanger may be designed such that chemical reaction takes place in them leading to energy generation under such circumstances. They are regarded as a integral part of the reaction system such exchanger may be called catalytic reactor and so on. With the development and commercial adoption of large air-cooled heat exchanger, the example of heat exchangers will not only be tubes within which fluids flows for the purpose of cooling.

In general heat exchangers are equipment utilized in the field of heating air-conditioning and refrigerations.

1.2 Project Problem

The double pipe heat exchanger to be designed is based on the following process conditions: The two process fluids. That is hot and cold fluid are:

The flow rate of cold fluid is 10 lit/min

The flow rate of hot fluid is 10 lit/min.

	Hot fluid	Cold fluid
Inlet temperature	80°c	28°c
Out temperature	60°c	41°c
	2 inch-size IPS pipe	1.25 inch-size IPS pipe

Outside diameter	0.0605m	0.0422m
Inside diameter	0.0525m	0.0351m.

Assume dirt factor for water is $1.0 \times 10^{-4} m^2 s°C/J$

1.3 Scope of Work

(i) Provide brief literature review on heat exchangers and highlighting their uses and application.

(ii) Provide chemical and Mechanical Engineering of the double pipe heat exchanger using data provided and available from the literature.

(iii) Selection of suitable design of a double pipe heat exchanger capable of operating on above parameter.

(iv) To construct the designed heat exchanger using locally available materials.

CHAPTER TWO

2.0 Literature Review

Heat exchangers are devices that utilized the three main method of heat transfers as their basis, namely heat transfer by conduction, connection and radiation.

2.1 Classification of Heat Exchangers

Different type of heat exchangers are been used in processing industries which are classified into three categories based on their operations, such as:-

(i) Regeneration

(ii) Open type exchanger

(iii) Closed type exchanger

2.1.1 Regenerators

Regenerators are exchangers in which the hot and cold fluids flow alternatively through the same space with as little physical mixing between the two streams as possible. The amount of energy transfered is dependent upon the fluid and flow properties of the fluid streams as well as the geometry and thermal properties of the surface.[2]

2.1.2 Open-type Exchangers

Open-type heat exchangers are devices where physical mixing of the two fluid streams actually occurs. Hot and cold fluids enter, open-type exchanger and leave as a single stream. The nature of the exit stream is predicted by continuity and first low thermos necessary for the analysis of this type of heat exchangers.[2]

2.1.3 Closed type Exchanger

The closed-type exchanger or recuperator is the one that is of primary importance to us, thus, requiring most attention. In the recuperators the hot and cold fluid streams do not come into direct contact with each other but are separated by a tube wall or a surface which may be flat or curved in same manner. An additional descriptive term identifies the relative direction of flow of the two streams. The terms used being parallel or concurrent flow if the fluid flow in the same direction and counter-current, if the fluids flow is in opposite directions and cross-flow if the two fluids flow at right angles to one another.[2]

2.2 Classification of a Close-Type Heat Exchangers

A close-type heat exchanger or recuperator may be classified according to its configuration and the number of passes made by each fluid stream as it traverses the heat-exchanger.

A single-pass is one in which each fluid flows through the exchanger only once. A typical example of which is the double pipe or concentric pipe heat exchanger. The other one is multipass heat exchanger.

2.2.1 Double or Concentric Pipe Heat Exchanger

Double-pipe heat exchanger have been used for many years for low flow rates and high temperature ranges. These double pipe sections are well adopted for high pressures and temperature applications because of their relatively small diameter which allow the use of small flanges and thin wall sections for installation compared to conventional shell and tube types.

Commercial available double-pipe sectiosn range from 0.0508m through 0.102m pipe size shells with inner tube varying from 0.0195m to 0.0635m pipe size. About 12 percent of the double-pipe sections use bare tube, and the balance havce longitudinal tins on the outside of the inner tube.

Double-pipe heat exchanger can be made by inserting one pipe within another and then welding the outer jacket to to inner pipe. A packed stuffing box which is similar to that used for the outside packed heat exchanger) may be employed to permit differential movement and removal of the inner pipe for cleaning and fitting for 0.0508m by 0.03175m and 0.076m by 0.0508m double pipe section are available. These are most commonly use in refregeration service and may be either factory or field assemble.

Several manufacturers offer standard double pipe section with removable tubes and shell and tubes.

Double-pipe section permit true counter-current flow which is of particular advantage when very close temperature approaches are required. The number of sections and the series - parallel arrangement can be varied to meet conditions - Double-pipe extended surface sections are particularly useful when one fluid has a relatively low heat transfer coefficient and can be placed on the outside of the fins.

Multitude double-pipe section are available with various inner and outer pipe sections. Tubing may be of various sizes and may be either bare or with longitudinal fins. Design pressure of about 4218488 N/m^2 on the tube side have been used. The tubes are rolled into tube sheet at one and have individual u-bend connections at the other.[4]

2.2.2 Multiple Pass Heat Exchanger

This type of heat exchanger is available in various categories depending on their principle of construction as this:

(i) Bent-tube sheet heat-exchanger
(ii) Bayonet-tube heat exchanger
(iii) Teflon heat exchanger
(iv) Plate type heat exchanger
(v) Fixed tube sheet heat exchanger
(vi) U-tube heat exchanger
(vii) Float head heat exchanger

(i) Bent-Tube-Sheet heat Exchanger

In this type of heat exchanger tubes are installed with a slight bend. Differential expansion affects the amount of bend, but the need for an expansion joint or floating-tube sheet is eliminated. Evaporator section are in this manner and descalling occurs at the tube flex.[4]

(ii) Bayonet-tube Heat Exchanger

This type of exchanger is useful when there is an extreme temperature difference between shell and tube side of fluids since all parts subjected to differential expansion are freed to move independently for each other. This unique construction does not suffer failure due to freezing of steam condensale, since the steam in the inner tube melt any ice which may be formed during periods of intermittent operations. Cost are relatively high since only the outer bundle tubes transfer heat to the shell-side fluid. The inner tube are unsupported. The outer tube are supported by convectional baffles or place.[4b]

(iii) <u>Teflon heat Exchanger</u>

Teflon tube shell-and tube heat-exchanger made with tubes of chemically inert. Teflon floro-Carbon-resin are available. The tube are 2.54×10^{-3} m outer diameter by 2.032×10^{-3} m inside diameter. The longer tubes are primarily used where pressure drop limitation or particles reduces the effectiveness of 2.54×10^{-3} m tubes. These heat exchangers generally operate at higher pressure drops than convectional units are best suited for relatively clean fluids. Being chemically inert, the tubing has many applications where other materials corrode.[4b]

(iv) <u>Plate type Heat Exchanger</u>

Plate-type heat exchangers, long use in the mills industry for pasteurization and skimming, are moving in to the chemical and petroleum industries. Coiled tuber exchanger and coild plate heat exchanger are winning new assignments. Spiral-exchangers offer short cylindrical shell with flat heads, carrying inlet and outlet leading to internal spiral pages. These passages may be made with spiral plate or with spiral banks of tubes. Exchanger with mechanically scraped surfaces find favour for the use with very viscous and past like material.[5]

(v) Fixed tube sheet heat-exchanger

The fixed tube sheet-sheet is the simplest and cheapest available type of heat exchanger. Both the shell and tube are firmly together. Their limitations are high thermal stress between tubes and shell, which loosen the tube joint and impossibility of mechanic cleaning of the outside of the tubes and of the shell tubes are cleaned off, if scale deposit can be removed chemically, then a removable tube hundle is not necessary.

The principle limitation of this type is the internal hideen gasket on the floating and which may fail and cause irregularities depending on the toxicity or reactivity of the fluid.

(vi) U-tube heat exchanger

This is another type of multiple-pass heat exchanger which consist of stationary tube sheet, u-tube, baffles or supported plates and appropriate tie rod and spaces that bundle of tubes can be removed from the shell of heat exchanger, each tube is free to expand on contract irrespective of any limitation been subjected to by the other tube. The u-tube has provided the maximum clearance between the outer tube limit and the inside of the shell, because of any of the removal tube-bundle constructions.

(vii) Float Head heat-exchanger

This class of heat exchanger is used widely in petroleum refineries. The tube-bundle is removable and the floating tube-sheet moves to accommodate differential expansion between shell and tubes.

The float head cover at the floating tube sheet is hold by a split backing ring and bolt. They are located beyond the end of the shell and within large diameter shell cover split backing ring and floating head cover must be removed, before the tubes can be passed through the exchanger shell.

2.3 Type of Arrangement and Construction of Double Pipe Heat Exchanger

There are two types of arrangement in double pipe exchanger, they are as follows:

(i) Series Arrangement

(ii) Parallel Arrangement.

The series arrangement comes about when the length of the pipe to be used for certain process within a given temperature and pressure drop is too long to be accommodated in the process room, then the length of the pipe may be divided into two or more pipes for the stream to flow through the numbers of exchangers arranged in series.

Parallel arrangement comes about when the stream is too large to accommodate in several heat exchangers in series, which is then divided in half and each transverses but one exchanger through the inner piple while the flow area is constant.

In large services each parallel flow or stream may also flow through several exchangers in series in each parallel bank. The term "parallel stream" differ from "parallel flow" in that the former refers to division of the flow of one fluid, while the later refers to the direction of flow between two fluids.

2.4 Material of Construction

The selection of engineering materials for construction and design of equipment for use in the industries entails the consideration of many factors. Heat exchanger as an example, every metal seems to be a possible material in fabrication of heat exchanger. Factors to be considered when seperating heat exchanger as a pressure vessel include strength, corrosion, availability and cost, where cast steel and alloy steels are mostly used because of the strength they offer. Because of the excellent heat conductance, brass and copper find wide application in exchanger designs. Many of which are been constructed from dissimilar metals with such combinations functioning successively in a certain services. For special corrosion problems exchanger are made or design from graphite, ceramics, nickel and silver etc.

While in some segment of petroleum industries, copper alloy, stainless steel, low alloy steel and aluminium are becoming the most commonly used alloys.

2.5 General Application of heat Exchanger

Heat exchangers find wide application in the chemical process industries, including petroleum refining and petrochemical processing, in food industry. For example, for pasturization of milk and canning of processed food. In the generation of steam for production of power and electricity. In nuclear reaction system, in aircraft and space vehicles, and in the field of cryogenics for low temperature seperation of gases. Heat exchanger are the work horses of the entire field of heating, ventilating, air-conditioning and refregeration.[3]

2.6 Factors Affecting Heat Exchangers

Heat-exchanger shut downs are most often caused by:

(i) Fouling

(ii) Corrosion.

Fouling

Fouling refers to any layer or deposit of extraneous material on a heat transfer surface when heat transfer equipment has been put to use for some period of times. These materials usually have low thermal conductivity, resulting in a major resistance to heat transfer. Silling or sedimentation is the type of fouling that occur, which is due to the deposition of finely divided materials from the process stream.[4]

Corrosion:

Some of the special consideration with regard to heat exchanger corrosion are discuss below. The most common material of construction of heat exchangers is carbon steel.

therefore corrosion due to the material of construction should be known.[4]

When corrosive requirements condition do not permit the use of a single alloy for the tubes, (bimettallic for Duplex) tubes may be used. These can be made from almost any possible combination of metals.

Expanding of the tubes into the tube sheet reduces, the tube wall thickness and work-harden the metal. The included stress can lead to stress corrosion.[4]. Different expansions between tubes and shell in fixed tube-sheet exchanger can develop stress which leads to stresses corrosion. When austenitic stainless-steel tubes are used for corrosion resistance, a close fit between the tube hole is recommended in order to minimize work-hardening, and the resulting loss due to corrosion resistance.[4]

2.7 Stages Involved in heat Exchanger Designing

Where a new heat exchanger has to be design the following stages are involved:

i) Thermal analysis

ii) Preliminary Mechanical Design

iii) Design for manufacture

2.7.1 Thermal Analysis

Thermal analysis is concerned with the determination of heat transfer area that will achieve a given heat duty for given flow rates and inlet temperature of the fluid involved. Since the rate of heat transfer is specified, the exist temperature of both the "hot and cold" fluid can be computed from a knowledge of their properties, although heat-transfer area will be left unknown in the analysis.

2.7.2 <u>Preliminary Mechanical Design</u>

Preliminary Mechanical Design involve consideration pertaining to desired operating temperature and pressure corrosive characteristics of the fluids, relative thermal expansions and accompanying thermal stress, and the relation of the heat exchanger to other items of equipment in the process.

2.7.3 <u>Design for Manufacture</u>

Design for manufacturing requires the translation of physical characteristics and dimensions resulting from stage 1 and 2 into a unit which can be built at low cost and the process deals with the selection of materials, seals, enclosures and the most fitting mechanical arrangement.

The focus of which is mainly on thermal analysis, and it includes the analysis of existing exchanger, where the heating transfer area is known and the objective it to determine what the available area that can be used in term of duty, degree of heating or cooling.

CHAPTER THREE

3.0 Equiptment Description

3.1 Reasons for Choice of Double-Pipe Heat Exchanger

The double-pipe heat exchanger is prefered to other heat-exchangers when required to operates under the following conditions:

i) Low flow rates

ii) High temperature ranges which is due to their relatively small diameter that allow the use of small flanges and thin wall section.

iii) High pressure application, as a result of relatively small diametter.

iv) It can easily be constructed and costless

v) Where small total heat transfer surface is required these make its design and construction worthwhile.

3.2 Main Features of a Double-Pipe Heat Exchanger

The principal parts of a double pipe heat exchanger are two set of concentric pipes two connection tees, and a return head and return bend. The inner pipe is supported within the outer pipe by packing glands, (improvise) and the fluid enters the inner through connection located outside the exchanger section fitted with valve properly. The tees have screwed connection attached to them to permit the entry and exit of the annulus fluid, which crosses from one leg to the the other through the return head. The two lengths of the inner pipe are connected by a return bends, which are usually exposed and do not provide effective heat transfer surface, when arranged in two leg, that is called a hairpin.[2]

The double pipe heat exchanger is extremely useful because it can be assemble in any pipe-fitting shop from standard

standard parts, and provides inexpensive heat-transfer surface. The standard sizes of pipes, tees and returns head are given below:

Double pipe Heat Exchanger Fitting

Inner pipes IPS	Outer pipes IPS
1.25 (31.75mm)	2(50.8mm)
1.25 (31.75mm)	2.5 (63.5mm)
2 (508mm)	3(76.2mm)
3 (76.2mm)	4(101.6mm).

Double pipe heat exchanger are usually assembled in 3.7, 4.6 inches or 6.1m effective lengths for double pipe heat exchanger constructed (2 inch) and (1.25 inch) outer and inner pipes are used. 4 numbers of 2 inch Tees. 4 numbers of 1.25 and 1.5 inch reduces and 4 number of 1.25 inch union, 2 pieces of 1.25 inches nipples were also used. The effective length being the distance in each leg over which heat transfer occurs and excludes the inner pipe protruding beyond the exchanger section. When hair pin are employed in excess of 6.1m in length corresponding to 12.2m effective inner length or more of double pipe. The inner pipe tend to sag, and touch the outer pipe, thereby causing a poor flow distribution in the annulus.

The principal disadvantage to the use of a double pipe heat exchanger lies in the small amount of heat transfer surface contained in a single harpin. When used with distillation equipment on an industrial process, a very large number of hairpins are required. These require considerable space and each double pipe exchanger introduces no fewer than 14 point at which leakage might occur. The time and expense required for dismantling and periodically cleaning are prohibitive compare with other equipment for such purpose. However, the double pipe heat exchanger is of greatest use where the total required heat transfer is small.[2]

Since the temperature differences between the two fluid, that is hot and cold fluid is relatively small, the equipment can be used for both counter flow and parallel flow.

3.3 Lagging of the heat exchanger

Unless precaution are taken, heat losses in any thermal system can be considereable to cut these losses to a minimum, the system can be heat insulated. To accomplish this the system is lagged. Lagging mean the application to such things as pipes, wells, engines etc. of some form of heat insulating materials.

A heat insulating material will be a material which has a low thermal conductivity. Apart from its heat resisting properties it must also be able to withstand high or low temperature. It must be relatively easy to apply. It should have long span, be able to stand up to a moderate degree of handling and it cost should not be excessive. A further point that there should be no fire risk.

3.3.1 The four general type of insulation been used for holding cryogenic application are:

i) Use in vacuum

ii) Multiple layer

iii) Power

iv) Rigid foam

However, the explanation will only be counted to type of lagging done with regard to this project, i.e. rigid foam.

3.3.2 Rigid Foam: Rigid Foam are not as efficient as other cryogenic insulations but they have the advantage of not requiring an evacuated atmosphere, this permitting single shell construction of vessels and piping.

CHAPTER FOUR

4.0 Chemical Engineering Design of Double Pipe heat Exchanger

Data Utilised is as follows

	Hot fluid	Cold fluid
Flowrate	-	10 lit/min
Inlet temperature	80°c	28°c
Outlet temperature	60°c	41°c
Fluid employed	water	water

Norminal pipe Size IPS (in)	Outside Diameter (cm)	Inside Diameter (cm)	Surface (outside) m²/ft
1.25	0.0422	0.0351	0.0404
2	0.0605	0.0525	0.0578

4.1 Fluid Properties

The fluid properties are evaluated at the calorific value whcih is the same as the average temperature of the inlet and outlet temperature of the fluid.

For hot fluid:

$$T \text{ average} = \frac{(80 + 60)}{2} = 70°c$$

For cold fluid:

$$Tav = \frac{(28 + 41)}{2} = 34.5°c$$

The data above are obtained at the average temperature of the hot and cold fluid.

Hot fluid		Cold fluid	
CPH	4185.4J/kg°c	Cpc	= 4174J/kg°c
U	4.068×10^{-4}	U	= 7.31×10^{-4}
H	977.9kg/m³	c	= 994.12kg/m³
KH	0.664	Kc	= 0626

4.2 Fluid Flow Rates

Cold water flow rate = (10 lit/min) x (1min/60sec) x (10^{-3}m³)1lit) x (977.9kg)m³)

= 0.166kg/s

Assuming counter current flow.

T. = 80°c ——→—— T_2 = 60°c

t_2 = 41°c ——←—— t_1 = 28°c

Then from heat transfer balance.

Qc = Qh

Wc x Cpc x Ct_2 - t_1) = WH x CP_H x (T_2 - T_1).

$$WH = \frac{(0.16 \times 4174 \times 13)}{4185.4 \times 20)} = 0.107kg/s$$

To calculate the log mean temperature difference

(L.M.T.D)

L.M.T.D = (Dt_2 - Dt_1)/(Ln xDt_2/Dt_1)

= (T_1-t_2) - (T_2-t_1)/In x (T_1-t_2)/(T_2-t_1).

= (80-41) - (60-28)/Ln (80-41)/(60-28)

= 35.38°c

4.3 Calculation for annulus (Cold fluid

The flow area = Aa

If D_2 = 0.0525, Di = 0.0422

Therefore, flow area (Aa) = $(D_2\text{-}D.)^2/4$

= $[(0.0525)^2 - (0.0422)^2]/4$

$= (Aa) = 7.661 \times 10^{-4} m^2$

Equivalent diameter (De) $= (D_2^2 - D_\bullet^2)/Dc.$

$= De = 0.0231m$

Mass velocity (Ga) = Wc/Aa.

$= 0.166/7.661 \times 10^{-4}$

$= 216.68 kg/m^2$

Reynoid's Number (NRs) = DeGa/U

$$= \frac{(216.68 \times 0.0232)}{(7.31 \times 10^{-4})} = 6847.21$$

$N_{Re} > 2100$

Therefore,

the flow is not laminar but turbulent.

Prandth number (Pr) = Cpu/k

$$= \frac{4174 \times 7.31 \times 10^{-4}}{0.626} = 4.874$$

Nusset number (Nu) = 0.023 (DeGa)/u Cpu/k u/uw

But (u/uw) = 0 = 1.0 as fluid is water

therefore $\therefore$ Nu = 0.023 x Re x Pr

= 0.023 x (6847.21)(4.874)

= 45.41

but Nu = hoDe/k

$\therefore$ ho = Nu x k/De = (45.41 x 0.626)/0.231

= 1230.59

4.4 Calculation for Hot fluid (inner pipe)

The inside diameter of the inner pipe D = 0.0351m from

area $(A_p) = D_\circ^2/4$

$= (0.0351)^2/4$

$A_p = 9.676 \times 10^{-4} m^2$

Mass velocity (Gp) = WH/Ap

$= 0.107/9.676 \times 10^{-4}$

$Gp = 110.533 kg/m^2$

Reynolds number (Nre) = DGp/U = $(0.0351 \times 110.583)/4.068 \times 10^{-4}$

= Nre = 9541.44

$\therefore$ Nre > 2100

Prandth number (Pr) = Cpu/k

$= 4185.4 \times 4.068 \times 10^{-4}/0.664$

Pr = 2.564

Nusset number, Nu = 0.023 (Re)(Pr) (U/uw)

but (U/uw) is also assumed to be 1.0 for water.

Therefore,

Nu = 0.023 (9541.44)(2.564)

=47.903

Nu = hiD/k; hi = Nuk/D = $47.903 \times 0.664/0.0231$

= 1376.95

hio = hi x ID/OD

$= \frac{1376.95 \times 0.0351}{0.0422ii0}$

= 1145.28

4.5 Overall Heat transfer Coefficient

Clean overall coefficient (Uc)

Uc = (hio x ho)/(hio + ho)

$= \frac{1145.28 \times 1230.56)}{1145.28 + 1230.56}$

= 593.196J/sm°c.

Design overal coefficient U_D as required.

$1/U_D = 1/Uc + Rd.$ where Rd = 0.001

Therefore, $1/U_D = \frac{1}{593.196} + 0.0011 = 0.00269$

UD = 371.75J/sm°c

Required surface area,

$Q = UD_A \ DIwm$

$A = \emptyset/UD \ DTum$

But $\emptyset$ = WH x CPU X $(T_1 - T_2)$

= 4185.4 x 0.107 x 20 = 8956.756

therefore,

A = 8956.756/(371.75 x 35.38)

$= 0.681m^2$

Hence required length = 0.681/0.0404

= 16.86ft

L ——— 16ft

length 5.14m

——— 5.0meters

4.6 Pressure Drop

4.6.1 Calculation for Pressure Drop for inner pipe

D = 0.0351/m

NRe DGp/U

$$= \frac{(0.0351 \times 110.583)}{(4.068 \times 10^{-4})}$$

Re = 9541.45

$F = 0.0035 + 0.264 \ Re^{-0.42}$

$= 0.0035 + (0.264/(9541.45)^{0.42})$

F = 0.00913

$Dp = nGp^2/pg[C2LF/D) + 1/4]$

$= 2 \times (110.583)^2/(977.9 \times 9.81)((2x5.14x0.00913/0.0351) + 0.25)$

$= 2.549 \times 2.923$

$= 7.449 kg/m^2$

$\Rightarrow 7.45 kg/m^2 = 7.45 \times 10^{-4} kg/cm^2$

4.6.2 Pressure Drop: Annulus

De for pressure drop from De for heat transfer

$De = D_2 - D_1$

$=(0.0525 - 0.0422)$

$= 0.0103m$

$Nre = DeGa/u$

$= 0.0103 \times 216.68/7.31 \times 10^{-4} = 3053.083$

$F = 0.0035 + 0.264\ Re^{-0.42}$

$= 0.0035 + (0.264)/3053.083^{0.43}$

$F = 0.01258$

$Dp = nGa^2/pg\ (2LF/De + 1/4)$

$= 2 \times 216.68^2/9081 \times 994.12 \times (2x5.41 \times 0.01258/0.0103) + 0.25)$

$= 9.6285 \times 13.464$

$= 129.63 kg/m^2$

$Dp = 0.01296 kg/cm^2$

CHAPTER FIVE

5.0 Mechanical Engineering Design of A Double Pipe Heat Exchanger

5.1 Material of Construction

2 by 1.25 inch IPS galvanise steel

Outside diameter of the inner pipe is 0.0422m

Inside diameter of the inner pipe is 0.0351m

Outside diameter of the outside pipe is 0.0605m

Inside diameter of the outside pipe is 0.0525m

Pressure drop in the inner pipe is $7.451 \times 10^{-4} kg/cm^2$

Pressure drop in the annulus is $1.296 \times 10^{-4} kg/cm^2$

5.2 Material needed for the construction one Hairpin

Linear effective length of 2 inch bigger pipe is 13ft 2 inch.

Linear effective length of 1.25 smaller pipe is 16fts

4 pieces of 2 inch Tees Junctions

4 pieces of 1.25 inch elbow

4 pieces of 1.25 inch union

4 pieces of 2 by 1.25 and 1.5 by 1.25 reducers

4 pieces of 1.25 values

6 pieces of -10-10-110°^{c} range thermometers

1 gallon of aluminium paint.

5.3 Mechanical Fabrication/Design

The two pipes, bigger and smaller pipes were cut to required lengths and threaded.

The (4) four Tee Junctions were screwed. The two smaller pipes that is longer than bigger pipes was at a pair end screwed to two (2) elbows. The two elbow ends were joined using smaller pipes of specified length and a union at the centre. The free end of smaller pipe was inserted into two bigger pipes in such a way that it came out in other end of bigger pipes. The elbow ends were positioned in such a way that it has some measured distance away from the same bigger pipes ends.

The bigger pipes were join ed using reducers, pipes and union at the centre by welding and tighting of union.

The constructed double pipe heat exchanger was concentrically fitted, covered, and welded at the four ends to avoid sagging and for free circulation of fluid in the annulus. The free end that serves as inlet and outlet of the two flowing streams of fluid was constructed in such a way that inlet of Tee junction of bigger pipes serving to as inlet or outlet was fitted with reducers, smaller pipes elbow and 1.25 valve. The straight end smaller pipes was fitted with 1.25 valves and pipes.

The constructed heat exchanger was test runned, by pouring water into one side of two pipes protrusion, using cup. The annulus and inner pipe was fitted with water, area of leakages was noticed which was blocked using aradet and re-tightening of union. The test running was repeated and no more leakage. The heat exchanger was painted using aluminium paint. Thermometer were fixed into designed space. The heat exchanger was lagged using foam and aluminium fold for final mounting into stand.

5.5 Safety:

The following safety precaution must be properly ensured in the operation of the equipment:

1. Proper maintenance of the equipment and house keeping should be constantly carried out.

2. There should be flowing in and out of water constant to avoid cracking of the equipment.

3. The bulking pressure of the heat exchanger is lower than operating pressure, i.e. it is safe to operate the heat exchanger, the exchanger should be operated below the bulking pressure to avoid explosion.

CHAPTER SIX

6.0 Conclusion and Recommendation

6.1 Conclusion

Heat exchanger are units of equipment having various uses, found in most of the chemical industries. They are used for heating, cooling and condensing a fluid by another fluid without mixing with each other.

A project of this type play a great role in the course of learning as an Engineering student, for it helps the student in:

Carrying out chemical and mechanical design of a unit or a whole process units using available data and literature from books.

It exposed the students to problems that he/she may likely encountered in course of carrying out actual design.

6.2 Recommendation

I recommend that this project should be put in to construction by students with the data provided in the context.

This project work should be maintained properly by dismantling it at least once in two months for cleaning of annulus and inner pipe after the construction.

Care should always be taken to avoid the breakage of thermometers, and in case of breakage it should be replaced immediately.

NOMENCLATURE

A	-	Heat-transfer surface, m^2
Aa	-	Flow area in annulus, m^2
Ap	-	Flow area in pipe, m^2
Cpc	-	Specific heat of cold fluid in derivation
Cp_H	-	Specific heat of hot fluid in derivation
D	-	Internal diameter of the inner pipe, m
D	-	Outside diameter of the inner pipe, m
De, De'	-	Equipment diameter for heat transfer and pressure drop
F	-	Friction factor, dimensionless
Ga	-	Mass velocity in Annulus
Gp	-	Mass velocity in pipe
g	-	Acceleration to gravity, m/s^2
h,hi,ho	-	Heat transfer coefficient in general for inside fluid and for outside fluid respectively.
hio	-	Valve of hi when referred to the pipe out diameter
Kc	-	Thermal conductivity, of cold fluid
KH	-	Thermal conductivity, of hot fluid
n	-	Number of legs of hair pins
P	-	Pressure drop
Øc	-	Heat flow in cold fluid
Øh	-	Heat flow in hot fluid
Rd	-	Combined dirt factor
NRe,NRe'	-	Reynolds' number for heat transfer and pressure drop dimensionless
T_1, T_2	-	Inlet and outlet temperature of hot fluid
Tav	-	Average temperature of cold fluid
t_2, t_1	-	Temperature drop in hot fluid, temperature drop in cold

t - True or effective temperature difference in $\emptyset = U_D\ ADT$

Uc, U_D - Clean overall coeff, design coefficient

U - Viscosity at the calorific temperature

Wc - Mass flow rate of cold fluid

WH - Mass flow rate of hot fluid

SH - Density of hot fluid

Sc - Density of cold fluid

Pr - Prandth number dimensionless

Nu - Nusset number dimensionless

REFERENCES

1. D.Q Kern, Process Heat Transfer International Student - Edition (1959) pp.102-120

2. J.R. Witty, R.E. Wilson, C.E. Wicks Fundamental of Momentum Heat and Mass Transfer 2nd Edition, John Wiley and Son New York (1969)

3. Mac Graw - Hill Encyclopedia of Science and Technology Vol.6. pp.415-416

4. Perry and Clutton. Chemical Engineering Hand book MC - Graw-Hill Book Company 5th Edition (1995 - 1953) pp.10-25

5. Pitts R. Donald, Leighton E. Sissom Heat Transfer Mc-Graw-Hill Book Company pp.239-248