Sudan University of science &Technology

College of graduate studies

Design of the heat exchanger using MATLAB Programme

(Case study Khartoum Refinery Company Ltd)

تصميم المبادل الحراري بإستخدام برنامج الماتلاب

(دراسة حالة شركة مصفاة الخرطوم)

Research proposal for submitted in partial fulfillment of the degree of M.Sc. in Mechatronics Engineering

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(وَقُلِ اعْمَلُواْ فَسَيَرَى اللّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ)

صدق الله العظيم

سورة التوبة الآية 105

الإهداء

إلي من كلله الله بالهيبة والوقار.. إلي من علمني العطاء بدون انتظار.. إلي من احمل اسمه بكل افتخار ارجو من الله أن يمد في عمرك لترى ثماراً قد حان قطافها بعد طول انتظار وستبقي كلماتك نجوم اهتدي بها اليوم وفي الغد وإلي الابد

والدي العزيز

إلي ملاكي في الحياه إلي معني الحب.. وإلي معني الحنان والتفاني.. إلي بسمة الحياة وسر الوجود...إلي من كان دعائها سر نجاحي وحنانها بلسم جراحي

أمي الحبيبه الغاليه

إلى القلوب الطاهرة الرقيقة والنفوس البريئة إلى رياحين حياتي

إخوتي

إلى من جعلهم الله إخوتي بالله ... و من أحببتهم بالله

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ABSTRACT

A heat exchanger is a medium that transfers heat energy from a high temperature fluid to another low-temperature fluid without mixing the fluid together. Thermal exchange is one of the most important applications in many fields, such as food processing engineering, especially in the manufacture of materials that are highly sensitive to high temperatures, as well as difficult to heat or raise their temperature by direct methods and other materials. Heat exchangers are used in many engineering processes, including cooling, evaporation, sterilization, pasteurization, condensation and other thermal processes.

Heat exchangers are the most important component of some machines, making them an important part of scientific studies and research. This research includes a study of the design of a heat exchanger with a casing and a tube in the company of Khartoum efficiency of diesel cooling by heating the crude in the unit DCU, through Matlab in arithmetic operations and drawing diagrams between variables in design, and I found results similar to the fact with different design method but achieved the objectives of the research with the performance of the same results.

المستخلص

المبادل الحراري هوعبارة عن وسيط يقوم بنقل الطاقة الحرارية من مائع ذو درجة حرارة مرتفعة إلى مائع آخر ذو درجة حرارة منخفضة دون اختلاط المائعين ببعضهما و يعتبر التبادل الحراري من العمليات التطبيقية الهامة في العديد من المجالات مثل مجال هندسة التصنيع الغذائي خاصة في تصنيع المواد التي لها حساسية عالية لدرجات الحرارة المرتفعة، كذلك التي يصعب تسخينها أو رفع درجة حرارتها بالطرق المباشرة وغيرها من المواد وتستخدم المبادلات الحرارية في عمليات هندسية عديدة نذكر منها عمليات التبريد،التبخير،التعقيم، البسترة، التكثيف وغيرها من العمليات الحرارية المختلفة.

تشكل المبادلات الحراريه العنصر الاهم في مكونات بعض الالات مما جعلها تاخذ حيزاً مهماً من الدراسات والابحاث العلميه .يتضمن هذا البحث دراسه عمليه تصميم مبادل حراري ذو الغلاف والانبوب في شركه مصفاءة الخرطوم لتبريد الديزل عن طريق تسخين الخام في وحدة DCUعن طريق الماتلاب في العمليات الحسابيه ورسم المخططات البيانيه بين المتغيرات في التصميم ،فتوصلت الي نتائج اشبه بالحقيقه مع اختلاف في طريقه التصميم ولكن حققت اهداف البحث مع اداء نفس النتائج.

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1.1 Introduction

A heat exchanger is a medium that transfers heat energy from a high temperature fluid to another low temperature fluid. Thermal exchange is one of the most important applications in many fields, such as food processing engineering, especially in the manufacture of materials that are highly sensitive to high temperatures, as well as difficult to heat or raise their temperature by direct methods and other materials.

Heat exchangers are used in many engineering processes, including cooling, evaporation, sterilization, pasteurization, condensation and other thermal processes.

The heat exchanger is a tool for transferring heat energy from a fluid of high temperature to a fluid of low temperature when the fluid flows through it, the domestic heater, and radiator car.

Heat exchangers are widely used in the chemical and power generation industries. The shape of the heat exchanger is determined by the use of a specific temperature limit, the fluid flow (fluid or gas), the amount of heat to be transported and the pressure loss allowed for both hot and cold fluid, and in the working life, often involves design and selection using the try and error method.

The performance of the heat exchanger is affected beyond which the flow of the mass in which the specific heat and temperatures of entry and exit of fluid hot and cold and the surface area available for heat transfer and thermal conductivity of a substance tube rate and degree variables are sediments and crusts inside the tubes and the coefficients of heat transfer pregnancy from the surfaces of internal and external pipeline.

MATLAB very useful tool in the analysis and design of computer based electronic systems has become a large presence in the engineering curriculum it is also used industrially in the design of systems.

1.2 Problem Statement

The research problem in the design of a heat exchanger (shell and tube) for the purpose of heating the crude temperature of 182 C° to 213 C°and cooled diesel temperature of 232 C° to 209 C°.

1.3 Proposed Solution

The purpose of heat exchanger analysis is that we can express the total temperature of the transferred mass from hot liquid to cold fluid. In terms of the total coefficient of heat transfer, the surface area of the heat exchanger and its temperature of entry and exit of hot and cold fluids.

The thermometer is given to the fluid:

Energy lost from hot liquid = energy obtained for cold fluid

1.4 Methodology

The process of heat exchanger design is actually a process of selecting the optimal values of variable transactions such as pressure loss, pumping capacity, surface heat exchanger surface, initial cost and cleaning cost … etc.

1.5 Research Outlines

- Information gathering and analysis
- Consider considerations for the heat exchanger to be designed.
- Design of heat exchanger using mathematical equations and MATLAB.
- Explanation of design.
- Compare design with real design results.
- Discuss design results.

Chapter Two

Background

2.1 Background

Transfer of heat from one fluid to another is an important operation for most of the chemical industries. The most common application of heat transfer is in designing of heat transfer equipment for exchanging heat from one fluid to another fluid. Such devices for efficient transfer of heat are generally called Heat Exchanger. Heat exchangers are normally classified depending on the transfer process occurring in them.

A heat exchanger can be defined as any device that transfers heat from one fluid to another or from or to a fluid and the environment. Whereas in direct contact heat exchangers, there is no intervening surface between fluids, in indirect contact heat exchangers, the customary definition pertains to a device that is employed in the transfer of heat between two fluids or between a surface and a fluid.

2.1.1 Types of Heat Exchangers

Classified divided exchangers based on many considerations, including what is classified according to the mode of communication, such as the number of fluids used in the exchange, including by way of construction and the surface of the exchange, such as the heat exchange mechanism, and generally there are four heat exchangers Classified as entry into the fluid hot and cold during which method on:-

- Heat exchanger with a single fluid and constant temperature.
- Heat exchanger parallel.
- Heat exchanger with reverse flow.

- The heat exchanger with a flow perpendicular.

2.1.1.1 Double Pipe Heat Exchanger

The most famous and oldest species ever called (Double pipe) where walking the first fluid inside the tube and the second inside the space between the first tube and the second (tube within a tube) and the movement of fluids may be in the same direction (concurrent) or in the opposite direction (counter current).

2.1.1.2 Scalloped Heat Exchanger

It is the most commonly used in industries where large capacity to heat or cool large quantities of fluid. Where it consists of a large shell within which a large group of pipes matrix in parallel, there may be more than a group of tubes passing the fluid inside the shell on it more than once pass paths are called single pass or 1-1 exchanger the coincidence contains two passage ways called 1-2 exchanger.

A few times we might have more of a coincidence (shell) is the best known type of component from coincidences and four lanes 2-4 exchanger tubes. And increase the aisles are usually used to give a greater opportunity to meet between fluids and therefore a greater amount of heat transfer and species in the months exchanger psoriasis is 1-2 and 2-4 and are widely used in the industry.

2.1.1.3 Shell and tube Heat Exchanger

It is one of the most used exchanges in the field of chemical industries and other types of industrial fields and for the following reasons:

1. The overall shape of the swap gives it a large surface area of relatively small size.

2. The general shape is easy to use in many different applications.
3. It is possible to use many kinds of minerals in the production of such kind of exchanges.
4. Easy to perform inspection, maintenance and cleaning.
5. Easy design and manufacturing procedures.

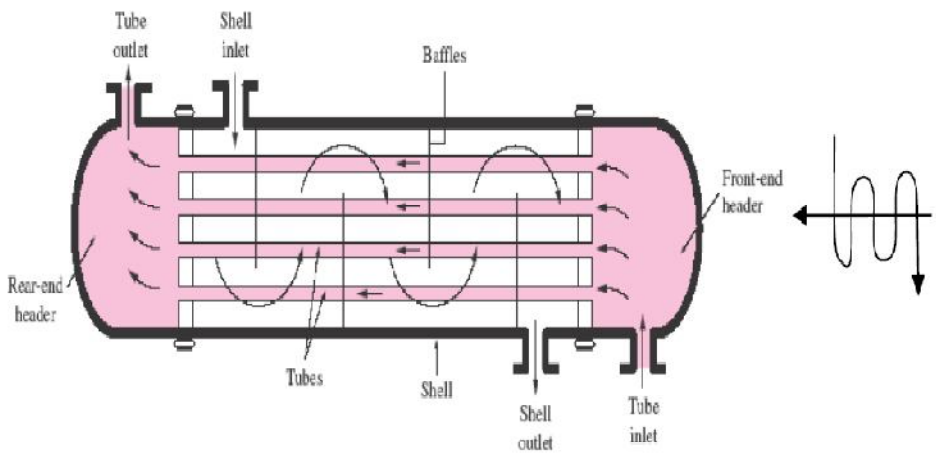

Figure (2-1) shows 1 pass of shell and 1 pass of tube heat exchanger

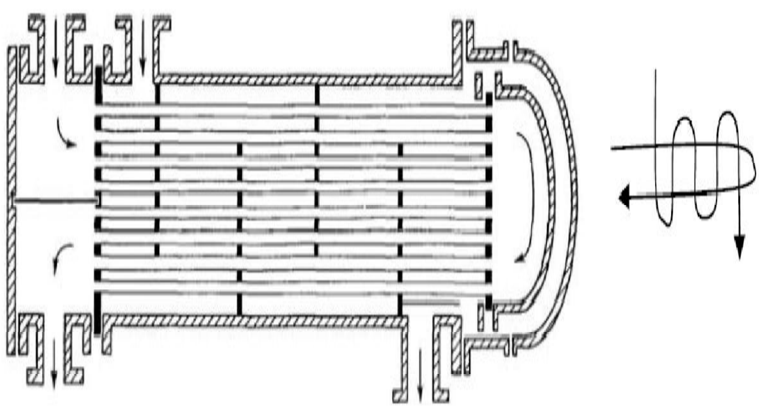

Figure (2-2) shows 1 pass of shell and 2 pass of tube heat exchanger.

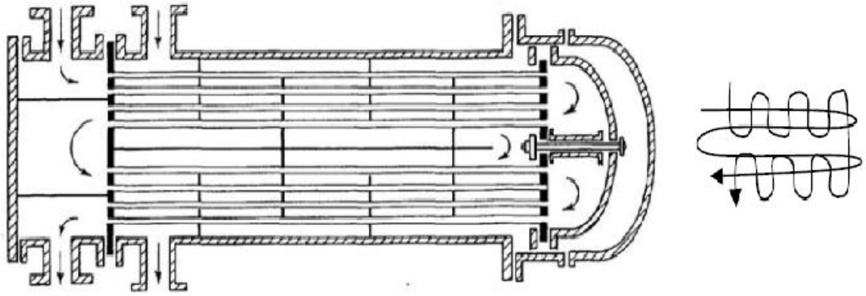

Figure (2-3) shows 2 pass of shell and 4 pass of tube heat exchanger.

Shell and tube heat exchangers represent the most widely used vehicle for the transfer of heat in industrial process applications. They are frequently selected for such duties as:

- Process liquid or gas cooling.
- Process or refrigerant vapor or steam condensing.
- Process liquid, steam or refrigerant evaporation.
- Process heat removal and preheating of feed water.
- Thermal energy conservation efforts, heat recovery.
- Compressor, turbine and engine cooling, oil and jacket water.
- Hydraulic and lube oil cooling.
- Many other industrial applications.

Shell and tube heat exchangers have the ability to transfer large amounts of heat in relatively low cost, serviceable designs. They can provide large amounts of effective tube surface while minimizing the requirements of floor space, liquid volume and weight. Shell and tube exchangers are available in a wide range of sizes. They have been used in industry for over 150 years, so the thermal technologies and manufacturing methods are well defined and applied by modern competitive manufacturers. Tube surfaces from standard to exotic metals with plain or enhanced surface characteristics are widely available. They can help provide the least costly mechanical design for the flows, liquids and temperatures involved.

2.1.1.3.1 The advantages of shell and tube exchangers

1. The configuration gives surface in a small volume.
2. Good mechanical lay out and a good shape for pressure operation.
3. Use well – established fabrication techniques.
4. Can be constructed from a wide range.
5. Easily cleaned.
6. Well – established design procedures.

For all above mentioned advantage select the shell and tube exchangers, this heat exchanger is characterized by other exchangers:

1. Easy and quick cleaning.
2. Give a large surface area in a small size.
3. Technical, uncomplicated and easy to manufacture.
4. Multiple manufacturing materials are available.

2.1.1.3.2 Tube arrangements

The tubes in exchangers are usually arranged in triangular, square, or rotated square pattern. I choose a triangular pitch because it gives higher heat transfer rates.

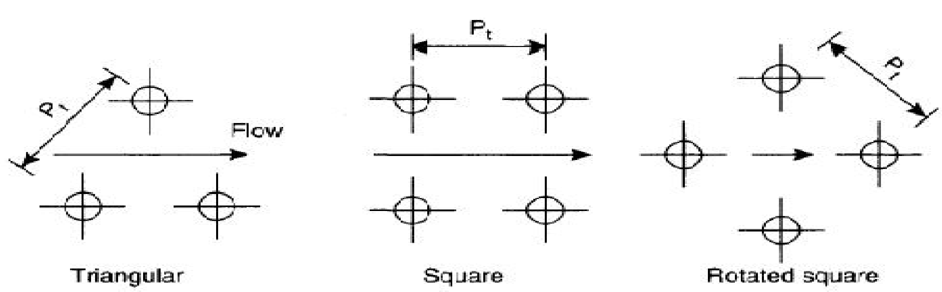

Figure 2-4 Tube patterns.

2.1.1.3.3 Tube side passes

Fluid in the tube is usually directed to flow and forth in number of passes through gropes passes of tubes arranged parallel to increase the length of flow path, the number of passes is selected to give the required tube –side design velocity.

2.1.1.3.4 Shell types (passes)

The single shell pass type is the most commonly used, tow shell passes are actually used where the shell and tube side temperature differences will be unfavorable in a single pass, thought the same flow arrangement can be obtained by using tow more exchangers shell in series .

2.1.1.3.5 Baffles

Baffles are used in the shell to direct the fluid stream across the tubes to increase the fluid velocity and so improve the rate of transfer.

The magnitude of the individual coefficients will depend on the nature of the heat transfer process (conduction, convection, condensation, boiling or radiation), on the physical properties of the fluids, on the fluid flow rates, and on the physical arrangement of the heat-transfer surface.

As the physical layout of the exchanger cannot be determined until the area is known the design of an exchanger is of necessity a trial and error procedure.

The steps in a typical design procedure are given below:

1. Define the duty: heat transfer rate, fluid flow rates temperature.

2. Collect together the fluid physical properties required: density, viscosity, temperature and conductivity.
3. Select the type of exchanger to be used.
4. Select trial value for the overall coefficient of heat transfer (U).
5. Calculate the mean temperature difference Δ Tm.
6. Calculate the area required from the equation: $Q = UA\Delta T_m$
7. Select the exchanger layout.
8. Calculate the individual heat transfer coefficients.
9. Calculate the overall heat transfer coefficient and compare it with the trial value. If the calculated value differs significantly from the estimated value, substitute the calculated for the estimated value and return to step 6.
10. Calculate the exchanger pressure drop.

2.1.1.4 Plate Heat Exchanger

It is called a plate exchanger, which consists of a set of very close panels so that the hot liquid is in a corridor followed by the cold in the other corridor.

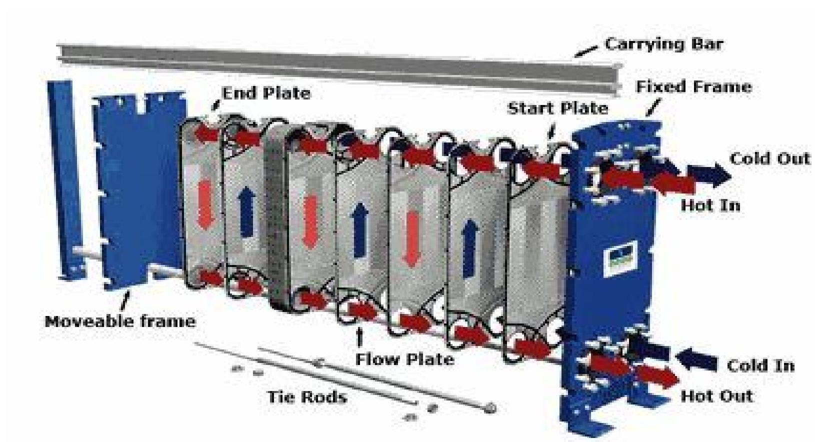

Figure (2-5) shows the plate heat exchanger.

2.1.2 Cases of fluid flow in heat exchangers

There are two cases to the direction of fluid flow in heat exchangers:

2.1.2.1 Parallel Flow

The direction of fluid flow in this case is similar.That is the fluids moves in the same direction. As in Figure:

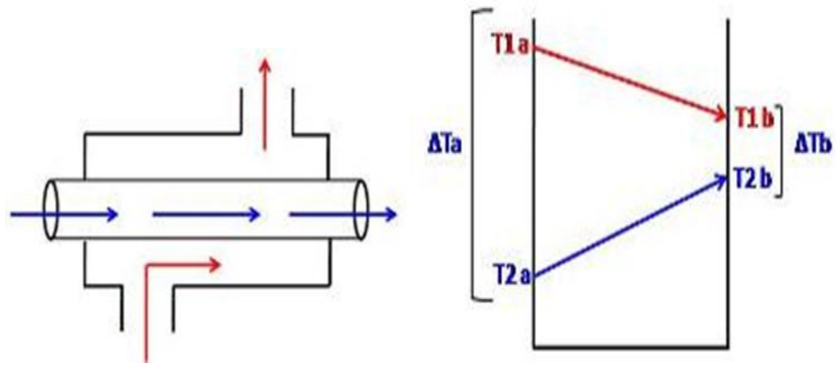

Figure (2-6) shows the parallel flow.

2.1.2.2 Counter Flow

The direction of the fluid flow is reversed. That is the fluid goes in opposite directions and as in the figure:

The direction of flow fluids contrasted that any fluids go in opposite directions as in the figure:

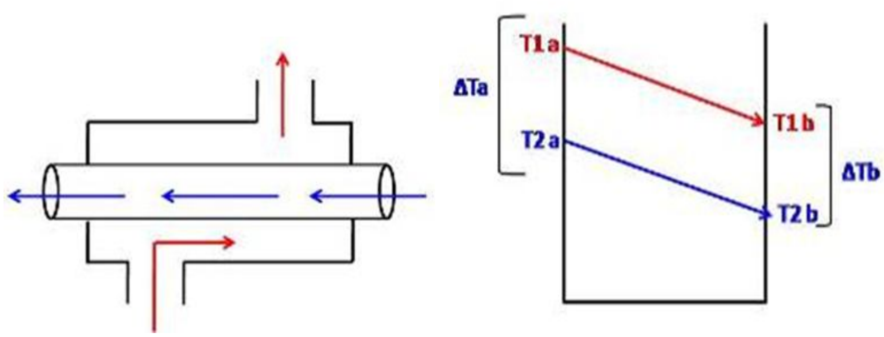

Figure (2-7) shows the counter flow.

The X-Axis horizontal axis in the two figures above represents the length of the exchanger. The notes are in counter flow temperature bands are proven almost along the heat exchanger .While in parallel flow it is noted that the difference is very large in the entry of the exchanger and decreases along its length.

Practical applications have shown that the counter flow is more efficient than the parallel flow.

The heat exchanger is used usually for the following purposes:

- Liquid or gas heating.
- Cooling liquid or gas.
- Steam intensifies.
- Steaming liquid.

2.1.2.3 Cross Flow

Usually it used for gases (often to cool), where you pass on the interceptor pipe set containing a liquid (to be heated), which is mixed where the fluid passes into the pipe group and all heats.

For gas may be mixed or may separates its parts, insulating panels and is called Mixed Among the most famous applications use of exhaust gases from certain industries in the water and heating and also be used in air-conditioners are widely.

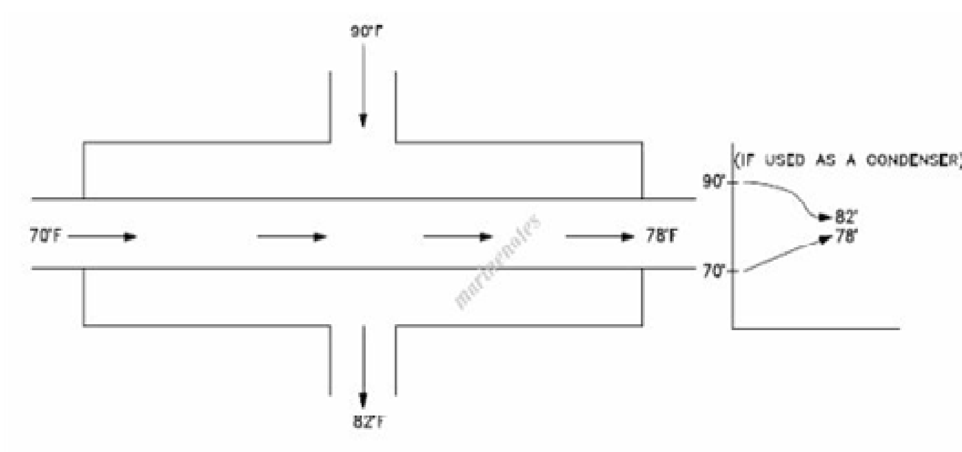

Figure (2-8) shows the cross flow.

2.1.3 Classification of heat exchangers according to the nature of the work

1. Heaters: the exchangers that are used to heat the hot liquid fluid.
2. Coolers: Heat exchangers used to cool the fluids by another liquid, usually water is used for this purpose is called the cooling water in the case of the use of air called the air chillers.
3. Condensate: Heat exchanger which is used to intensify the steam and its main objective is to remove or latent heat of vaporization and absorption of water is used for this purpose usually.
4. Evaporators: Commonly used to concentrate lotions by evaporation of water (aqueous lotions of these).
5. Boilers: Heat exchangers typically used to heat distillation towers to separate derivatives or retail towers (to separate gases from liquids). Water vapor is widely used in the petroleum industry.

2.1.4 Types of heat exchangers based on its design

2.1.4.1 Fixed-head exchangers

In these heat exchangers the pipe plate is fixed to the shell at each end of the heat exchanger.

2.1.4.2 Floating Head Exchangers

In this type of heat exchanger install one of the two tube liners from one end and leave loose from the other end. In order to allow the expansion of the pipe package as a result of thermal expansion, especially if the thermal differences between the large fluid

This type is used very widely in the oil industry and is easy to clean when doing maintenance work.

2.1.4.3 U-Type Exchangers

In this type of heat exchanger, the pipe is U-shaped and the pipe is installed on one sheet of pipe .In this type the pipes are extended freely and are usually used in boilers, especially those that are heated by steam and used for temperatures and high pressures, but it is difficult to clean them by normal means compared to other types.

It is used to clean modern mechanical means such as the use of high pressure water or fine brushes and flexible hoses. This type is commonly used in the oil industry.

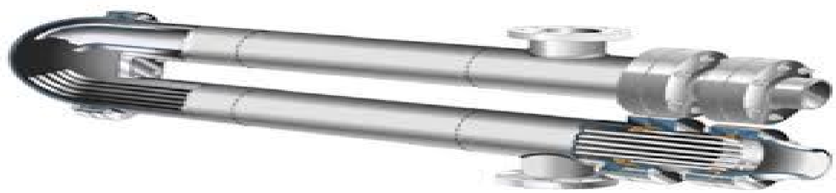

Figure (2-9) shows the U-type heat exchanger.

2.1.4.4 Double Pipe heat Exchanger

It is an external tube and another internal tube shorter and pass the material through the outer tube and other material to be cooled or heated through the internal tube and the advantage of cheaper prices.

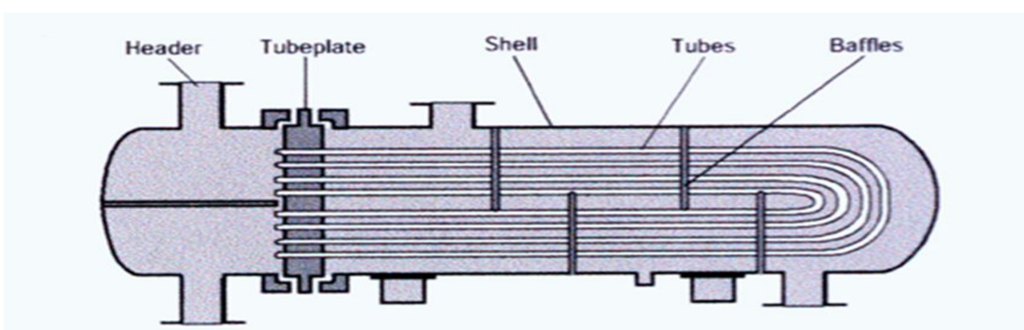

Figure (2-10) shows the double pipe heat exchanger.

2.1.5Parameters affecting thermal performance of heat exchangers

There are several factors that have a significant impact and direct impact on the thermal performance of heat exchangers which must be taken into account in the design and operation of these exchanges include the following: -

- Mass flow rate of the fluid.
- The surface of the heat exchange area.
- Coefficient of thermal conductivity.
- Heat transfer coefficient pregnancy.
- Temperatures of entry and exit of hot and cold fluid.
- Specific heat of the fluid.

2.2 Analysis of A heat exchanger

The aim of the heat exchanger analysis is an expression of the total amount of heat transferred Q of hot fluid to cold fluid in terms of the overall coefficient of heat transfer (U). The surface area of the heat exchanger (A). The temperatures of the entry and exit of hot and cold fluids and gives the thermal balance of hot and cold fluids.

Missing from the hot fluid energy equal to the energy gained cold fluid

$$\dot{m}_h \times c_{ph} \times (T_{hi} - T_{ho}) = \dot{m}_c \times c_{pc} \times (T_{co} - T_{ci}) \quad (2\text{-}1)$$

Where:

$\dot{m}_h$ = mass flow rate of the hot fluid (kg/sec).

c_{ph} = specific heat certified the pressure of the hot fluid (J/kg.k).

T_{hi} = temperature of hot water entry(C^o).

T_{ho} = temperature of hot water out(C^o).

$\dot{m}_c$ = mass flow rate of cold fluid (kg/sec).

c_{pc} = specific heat certified the pressure of cold fluid (J/kg.k).

T_{co} = temperature of the water out of the cold(C^o).

T_{ci}= the temperature of the cold water entering(C^o).

2.3 Basic Design Procedure and Theory

The general equation for transfer is:

$$Q = U A \Delta T_m \tag{2-2}$$

Where:

Q = heat transferred by unit time (W).

U = the overall heat transfer coefficient ($W/m^2.C^o$)

A = heat transfer area(m^2).

ΔT_m = the mean temperature difference (C^o)

Overall heat transfer coefficient:

$$\frac{1}{U_0} = \frac{1}{h_0} + \frac{1}{h_{od}} + \frac{d_0 \times \ln\left(\frac{d_0}{d_i}\right)}{2k_w} + \frac{d_0}{d_i} \times \frac{1}{h_{id}} + \frac{d_0}{d_i} \times \frac{1}{h_i} \tag{2-3}$$

Where:

U_0 = the overal coefficent based on the out side area of the tube

($W/m^2\ C^o$)

h_0 = outside fluid film coefficient ($W/m^2\ C^o$)

h_i = inside fluid film coefficient ($W/m^2\ C^o$)

h_{od} = outside direct coefficient ($W/m^2\ C^o$)

h_{id} = inside direct coefficient ($W/m^2\ C^o$)

k_w = thermal conductivity of the tube wall material ($W/m\ C^o$)

d_i = tube inside diameter(m)

d_0 = tube outside diameter (m)

Q = from energy balance (kw)

$$Q = m * cp * \Delta t \qquad (2\text{-}4)$$

Cp = heat capacity.

m=flow rate. kg/hr

$$\Delta Tm = \frac{[(Thi - Tco) - (Tho - Tci)]}{Ln\frac{(Thi - Tco)}{(Tho - Tci)}} \qquad (2\text{-}5)$$

$$\Delta T_m = \Delta T_m \times F_t \qquad (2\text{-}6)$$

ΔT_m = true temperature difference

F_t = the temperature correction factor.

$$R = \frac{Thi - Tho}{Tco - Tci} \quad , \quad S = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} \qquad (2\text{-}7)$$

From fig (4-1) at appendix for Temperature correction factor, split flow: two shell passes, four tube passes.

assume U from Table (A-1) at appendix.

$$A = \frac{Q}{U\Delta T_m}$$

Where:

A = heat transfer area (m^2).

Provisional area:

Chose the tube dimensions from volume 6: d_0, d_i, L [1]

Area of one tube: $a = d_0 \times L \times \pi$ (2-8)

2.3.1 Number of tubes

$$Nt = \frac{\text{total area}}{\text{area of one tube}} \quad (2\text{-}9)$$

Bundle diameter (D_b):

$$D_b = d_0 \left(\frac{N_t}{k}\right)^{\frac{1}{n}} \quad (2\text{-}10)$$

Where:

d_0 = tube outside diameter (mm)

D_b = bundle diameter (mm)

N_t = number of tubes (tubes)

k, n = constants chose by the number of passed table (A-2) at appendix there are two passes

Shell diameter (Ds): $D_s = D_b + C$ (2-11)

Where:

Use a split-ring floating head type.

C = shell bundle clearance from fig (A-2) at appendix

Tube side coefficient:

Tube cross-section area = $\frac{\pi}{4} \times (d_i)^2$ (2-12)

Tubes per pass = Number of tubes / number of passes (2-13)

Total flow area = tube per pass × tube cross sectional area (2-14)

$$\text{Diesel linear velocity } (U_t) = \frac{\text{diesel mass velocity}}{\text{desnity of diesel}} \quad (2\text{-}15)$$

2.3.2 Calculate the tube side coefficient using equation

$$N_u = J_h . R_e . p_r^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14} \quad (2\text{-}16)$$

Where:

N_u = nusselt number = $\frac{h_i d_i}{K_f}$ (2-17)

Re = Reynolds number = πvd/ μ = Gd_i/ μ (2-18)

when $\frac{L}{di}$

J_h = heat transfer factor = constant from fig (A-3) at appendix

assume : $\left(\frac{\mu}{\mu_w}\right)^{0.14} = 1$

$$P_r = \frac{C_p \times \mu}{K} \quad (2\text{-}19)$$

2.3.3 Shell side coefficient

Chose baffle spacing = $\frac{D_s}{5} = l_B$ (2-20)

The area for cross flow as for the hypothetical row of tubes at the shell equator

$$A_s = \frac{(P_t - d_o) D_s l_B}{P_t} \quad (2\text{-}21)$$

Where: l_B = baffle spacing (m).

P_t = tubes pitch = $1.25 \times d_0$ (2-22)

$$G_s = \frac{W_s}{A_s} \quad (2\text{-}23)$$

G_s: the shell side mass velocity ($kg/m^2.s$).

W_s: Fluid flow rate in the shell side (kg/s).

2.3.4 Equivalent or (hydraulic) diameter, m

$$d_e = \frac{1.1}{d_0}\left(p_t^2 - 0.917 \times d_0^2\right) \qquad (2\text{-}24)$$

$$R_e = \frac{G_s \times d_e}{\mu}$$

N_u = nusselt number.

Re = Reynolds number.

Pr = Prandtl number. (2-25)

$$p_r = \frac{C_p \times \mu}{k_f} \qquad (2\text{-}26)$$

$$N_u = \frac{h_o \times d_e}{k_f} \qquad (2\text{-}27)$$

$$N_u = c.R_e^{0.8}.p_r^{0.33}\left(\frac{\mu}{\mu_w}\right)^{0.14} \qquad (2\text{-}28)$$

c = 0.027 for viscous liquids. From volume 6 [1]

2.3.5 Overall coefficient

$$\frac{1}{U_0} = \frac{1}{h_0} + \frac{1}{h_{od}} + \frac{d_0 \times \ln\left(\frac{d_0}{d_i}\right)}{2k_w} + \frac{d_0}{d_i} \times \frac{1}{h_{id}} + \frac{d_0}{d_i} \times \frac{1}{h_i}$$

Assume:

The fouling factor (coefficient) {heavy hydrocarbons}

$h_{id} = h_{od}$ From table (A-3) at appendix

Thermal conductivity for stainless steel from table (A-4) at appendix

2.3.6 Tube side pressure drop

$$\Delta P_t = N_P \left[8 J_F \left(\frac{L}{d_i}\right)\left(\frac{\mu}{\mu_w}\right)^{-m} + 2.5\right]\frac{\rho * U_t^2}{2} \qquad (2\text{-}29)$$

Where:

ΔP_t : Tube side pressure drop (pa)

N_P : Number of tube side passes

U_t : Tube side velocity (m/s)

m : constant = 0.25 for laminar flow, Re < 2100,

= 0.14 for turbulent flow, Re > 2100.

L : length of one tube (m)

J_f : Friction factor

$$U_t : \text{Fluid mass } \frac{\text{velocity}}{\text{density}} \qquad (2\text{-}30)$$

When: Re from fig (A-4) at appendix J_f

2.3.7 Shell side pressure drop

$$\Delta P_s = 8\, J_t \times \left(\frac{D_s}{d_e}\right) \times \left(\frac{L}{L_B}\right) \rho \times \frac{U_s^2}{2} \times \left(\frac{\mu}{\mu_w}\right)^{-0.14} \qquad (2\text{-}31)$$

$$\text{Where: } U_s = \frac{G_s}{\rho} \qquad (2\text{-}32)$$

Linear velocity:

G_s = shell fluid mass velocity (kg/m^2.s)

When: Re from fig (A-5) at appendix. J_t.

2.4 Literature review

[1] **The study of Sudan University of Science and Technology Students (June 2002).**

The study entitled "increase the effectiveness of a double tube heat exchanger" The study addressed the thermal design for heat exchangers where fluid being at temperatures Different temperatures in the corridors separated by a wall, and heat is exchanged from pregnancy to it and connect them to bring Wall .

Such tradeoffs sometimes called Recovered formerly commonly used are the most important Devices and thermal transport industrially.

[2] **The study of Sudan University of Science and Technology Students (September 2006).**

The study, entitled "Study and calculate the effectiveness of heat exchangers in Khartoum refinery unit atmospheric distillation" The study dealt with in detail Heat exchanger and its impact on the distillation process so that the process is in Unit CDU's basically a distillation is a physical process so that the crude oil to a certain temperature heats up It will be separated physically by the degree of evaporation and boiling.

[3] **SIMULINK MODEL FOR A HEAT-EXCHANGER**

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The purpose of the dynamic analysis is to study the behavior of the thermal systems, but also the behavior of each part of this system, at different constraints. This dynamic analysis can lead to results with direct action on manufacturing costs, exploitation and maintenance costs, environmental protection and also, on the operating safety, on the reliability, the functioning and the maintenance of the system. The major advantage brought by this dynamic approach is that it makes possible the designing and the analysis of a thermal system before its physical existence and a constructive and functional optimization can be made with lower costs. More than, the dynamic regime functioning model gives the opportunity to make a better choice of the automatization elements for the system, to diagnose possible malfunctions of the system under certain conditions, and to develop new constructive models of the system with improved thermodynamic and economic features.

Chapter Three

Design

3.1 Heat Exchanger Design

3.1.1 Assumptions

1. The pipes are clean and free of crusts.
2. There is no thermal loss.
3. Total heat transfer coefficient constant value over the length of heat exchanger.
4. The quality temperature of the fluid keeps constant on the temperature used.

3.1.2 Design Considerations

1. The type of flow is opposite (Counter).
2. Arranging the pipes inside the casing arranging the triangular shape.
3. The high pressure fluid is in the tubes.
4. Low flow fluid shall be in tubes.
5. The high temperature fluid is in the tubes.
6. Corrosion fluids are inside the tubes.

3.2 Design calculation

1. Cold fluid in shell side (crude) : -

   Inlet temperature = $182^{o}C$

   Outlet temperature = $213^{0}C$
2. Hot fluid in tube side (diesel): -

Inlet temperature = 232^0C

Outlet temperature = 209^0C

Mean temperature of tube side fluid (diesel):

$$\frac{[T_{hi} + T_{ho}]}{2} = \left[\frac{232 + 209}{2}\right] = 220.5℃$$

The physical properties of diesel at a given temperature 220.5℃ from refinery manual as follows:

ρ = 820 kg/m^3, μ = 0.805 kg/m.s , C_p = 2.723 kJ/kg.℃ ,

K_f= 0.135 w/m. ℃

Mean temperature of shell side fluid (crude):-

$$\frac{[T_{ci} + T_{co}]}{2} = \left[\frac{182 + 213}{2}\right] = 197.5℃$$

The physical properties of the crude at temperature197.5℃ from refinery manual as follows:-

ρ = 933.8 kg/m^3 , μ = 0.815 kg/m.s, C_p = 2.532 kJ/kg.k

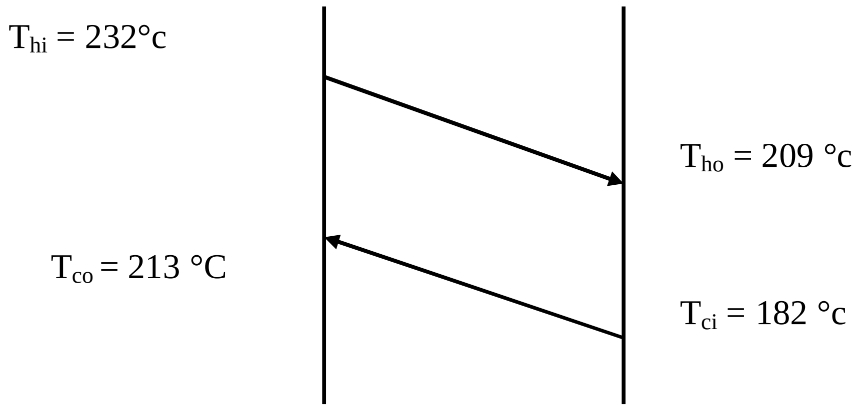
K_f = 0.130 w/m.℃

The energy balance (Q) is given by equation number (2-4)

m=123100 kg/hr

$$Q = \frac{123100}{3600} * 2.532 * (213 - 182)$$

$$Q = 2684\ kw$$



The mean temperature difference is given by equation number (2-5).

$$\Delta T_m = \frac{[(232-213)-(209-182)]}{\ln\frac{(232-213)}{(209-182)}} = 22.766^0C$$

The true temperature difference is given by equation number (2-6).

The variable (R, S) is given by equation number (2-7).

$$R = \frac{232-209}{213-182} = 0.742$$

$$S = \frac{213-182}{232-182} = 0.62$$

From fig (A-1) at appendix for Temperature correction factor, split flow: two shell passes, four tube passes.

$F_t = 0.96$

$\Delta T_m = 22.766 \times 0.96 = 21.86℃$

assume $U = 400\ w/m^2℃$ Table (A-1) at appendix.

The heat transfer area (A) is given by equation number (2-2).

Provisional area:

$$A = \frac{2684}{400*21.86} = 307m^2$$

Chose the tube dimensions from volume 6:

$d_0 = 30mm$, $d_i = 25mm$, $L = 6.10m$

The area of one tube is given by equation number (2-8).

$a = 0.030 \times 6.10 \times \pi = 0.575m^2$

Number of tubes

The Number of tubes is given by equation number (2-9).

$$Nt = \frac{307}{0.575} = 534 \text{ tubes}$$

The bundle diameter (D_b) is given by equation number (2-10).

k, n = constants chose by the number of passed table (A-2) at appendix there are two passes

So k = 0.249 n = 2.207

$$D_b = 0.030\left(\frac{534}{0.249}\right)^{\frac{1}{2.207}} = 969.5mm$$

The shell diameter (Ds) is given by equation number (2-11).

Use a split-ring floating head type.

C = shell bundle clearance = 69mm [From fig (A-2) at appendix]

$D_s = 969.5 + 69 = 1038.5$ mm

The tube side coefficient is given by equation number (2-12).

Tube cross-section area $= \frac{\pi}{4} \times (0.025)^2 = 0.0005m^2$

The tubes per pass are given by equation number (2-13).

$$\text{Tubes per pass} = \frac{534}{4} = 134 \text{ tubes}$$

The total flow area is given by equation number (2-14).

$$\text{Total flow area} = 134 \times 0.0005 = 0.067 \text{ m}^2$$

$$\text{Diesel mass velocity} = \frac{154277}{3600 \times 0.067} = 639.6 \text{ kg/m}^2.\text{s}$$

The diesel linear velocity (U_t) is given by equation number (2-15).

$$= \frac{639.6}{820} = 0.78 \text{ m/s}$$

Calculate the tube side coefficient using equation

The Prandtl number is given by equation number (2-19).

$$P_r = \frac{2.723 \times 0.805}{0.135} = 16.24$$

The Reynolds number is given by equation number (2-18).

$$R_e = \frac{639.6 \times 25 \times 10^{-3}}{0.805} = 19863.4$$

when $\frac{L}{di} = \frac{6.10}{0.025} = 244$

J_h = heat transfer factor = constant from fig (A-3) at appendix

$J_h = 2.5 \times 10^{-3}$

assume : $\left(\frac{\mu}{\mu_w}\right)^{0.14} = 1$

The Nusselt number is given by equation number (2-16).

$$N_u = 2.5 \times 10^{-3} \times 19863.4 \times (16.24)^{0.33} \times 1 = 124.6$$

The inside coefficient is given by equation number (2-17).

$$h_i = \frac{0.135 \times 124.6}{0.025} = 672.84\ w/m^2c^o$$

Shell side coefficient

They chose baffle spacing is given by equation number (2-20).

$$l_B = \frac{1038.5}{5} = 207.7mm$$

The area for cross flow as for the hypothetical row of tubes at the shell equator is given by equation number (2-21).

The tubes pitch is given by equation number (2-22).

$$P_t = 1.25 \times 30 = 37.5mm$$

$$A_s = \frac{(0.0375 - 0.030) \times 1.0384 \times 0.2077}{0.0375} = 0.043m^2$$

The shell side mass velocity is given by equation number (2-23).

$$G_s = \frac{123100}{3600 \times 0.043} = 795.22kg/m^2.s$$

Equivalent or (hydraulic) diameter, m

The equivalent (hydraulic) diameter is given by equation number (2-24).

$$d_e = \frac{1.1}{30}[((37.5)^2 - 0.917 \times (30)^2)] = 0.0213m = 21.3mm$$

The Reynolds number is given by equation number (2-25).

$$R_e = \frac{795.22 \times 21.3 \times 10^{-3}}{0.815} = 20783$$

The Prandtl number is given by equation number (2-26).

$$p_r = \frac{2.532 \times 0.815}{0.130} = 15.87$$

$N_u = \frac{h_o \times d_e}{k_f}$

c = 0.027 for viscous liquids. From volume 6 [1]

The Nusselt number is given by equation number (2-28).

$N_u = 0.027 \times (20783)^{0.8} \times (15.87)^{0.33} \times (l) = 191.3$

The outside coefficient is given by equation number (2-27).

$h_o = \frac{191.3 \times 0.130}{21.3 \times 10-3} = 1167.56 w/m^2 °C$

Overall coefficient

Th overal coefficent based on the out side area of the tube is given by equation number (2-3).

Assume:

The fouling factor (coefficient) {heavy hydrocarbons}

$h_{id} = h_{od} = 5000 w/m^2$ °C From table (A-3) at appendix

Thermal conductivity for stainless steel = 45 w/m °C from table (A-4) at appendix

$$\frac{1}{U_0} = \frac{1}{5000} + \frac{1}{1167.56} + \frac{[0.030 \times ln(1.2)]}{2 \times 45} + \frac{0.030}{0.025} \times \frac{1}{5000} + \frac{0.030}{0.025} \times \frac{1}{672.84}$$

$U_0 = 318.4 w/m^2.°C$

Tube side pressure drop

The tube side pressure drop is given by equation number (2-29).

m : constant = 0.25 for laminar flow, Re < 2100,

= 0.14 for turbulent flow, Re > 2100.

The Fluid mass is given by equation number (2-30).

$$= \frac{0.805}{820} = 9.81 * 10^{-4} m/s$$

When:

Re: 19863.4from fig (A-4) at appendix

$$J_f = 3 \times 10^{-3}$$

$$\Delta P_t = 4\left[8 \times 3 \times 10^{-3}\left(\frac{6.10}{0.030}\right) + 2.5\right] \times \frac{820 \times (0.001)^2}{2}$$

$$= 0.0121 N/m^2$$

Low could consider increasing the number of tube passes.

Shell side pressure drop

The shell side pressure drop is given by equation number (2-31).

The shell fluid mass velocity is given by equation number (2-32).

$$U_s = \frac{795.22}{933.8} = 0.85\ m/s$$

When:

Re = 20783 from fig (A-5) at appendix.

$$J_t = 9.5 \times 10^{-3}$$

$$\Delta P_s = 8 \times 9.5 \times 10^{-3}\left(\frac{1038.5}{21.3}\right) \times \left(\frac{6.1}{0.2077}\right) \times 933.8 \times \frac{(0.85)^2}{2}$$

$$= 36711 N/m^2$$

3.3 flow chart

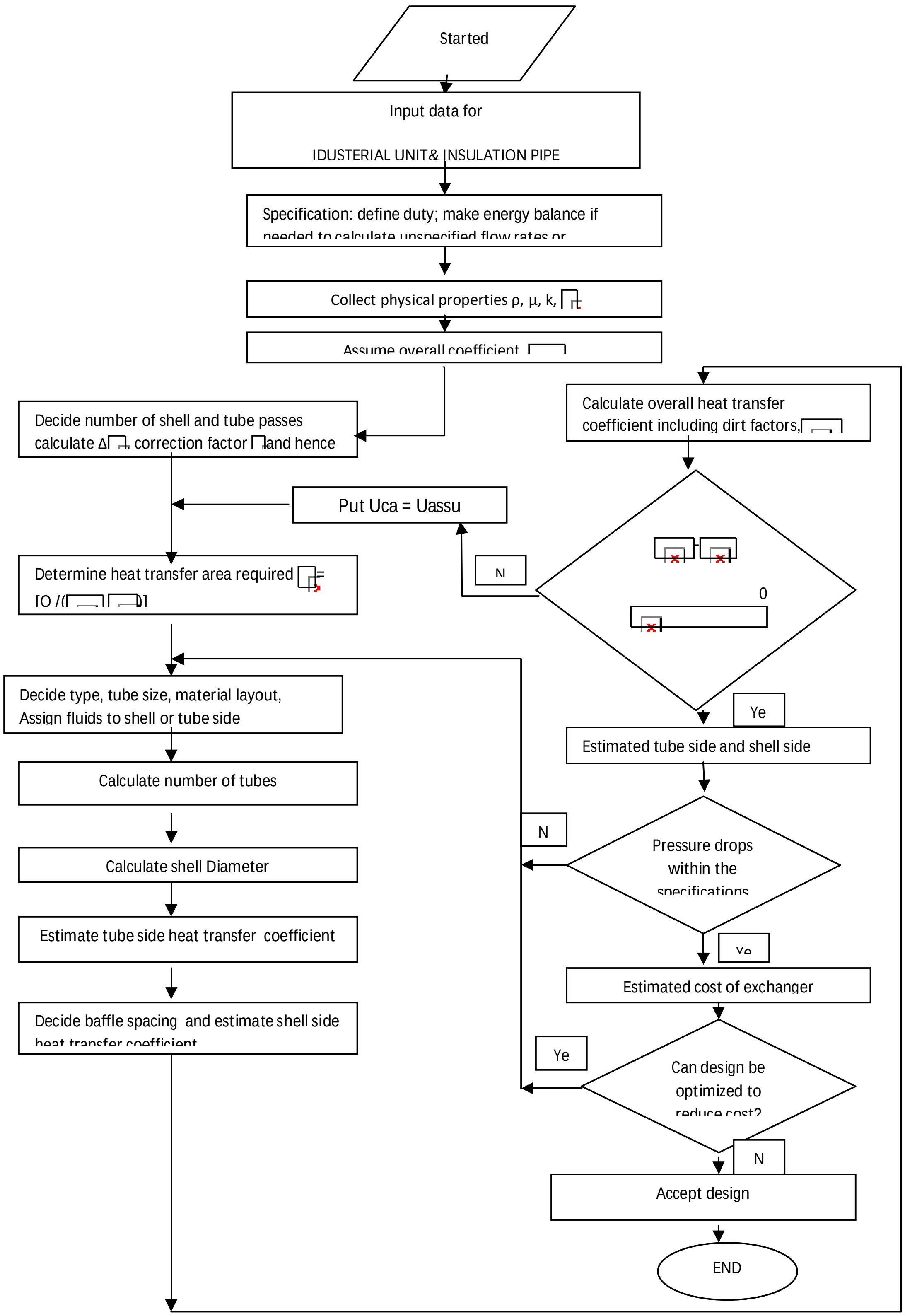


Fig (3.1) Computer program flow chart

3.4 Simulation Matlab of Heat Exchanger Design

Using background from previous courses (and a few additional assumptions), I have been able to obtain the following model equations:

1. $Q = UA(Tco - Tho)$
2. $wCp\frac{dTho}{dt} = m^{\cdot}Cp(Tho - Thi) + Q$

   $= m^{\cdot}Cp(Tho - Thi) + UA(Tco - Tho)$

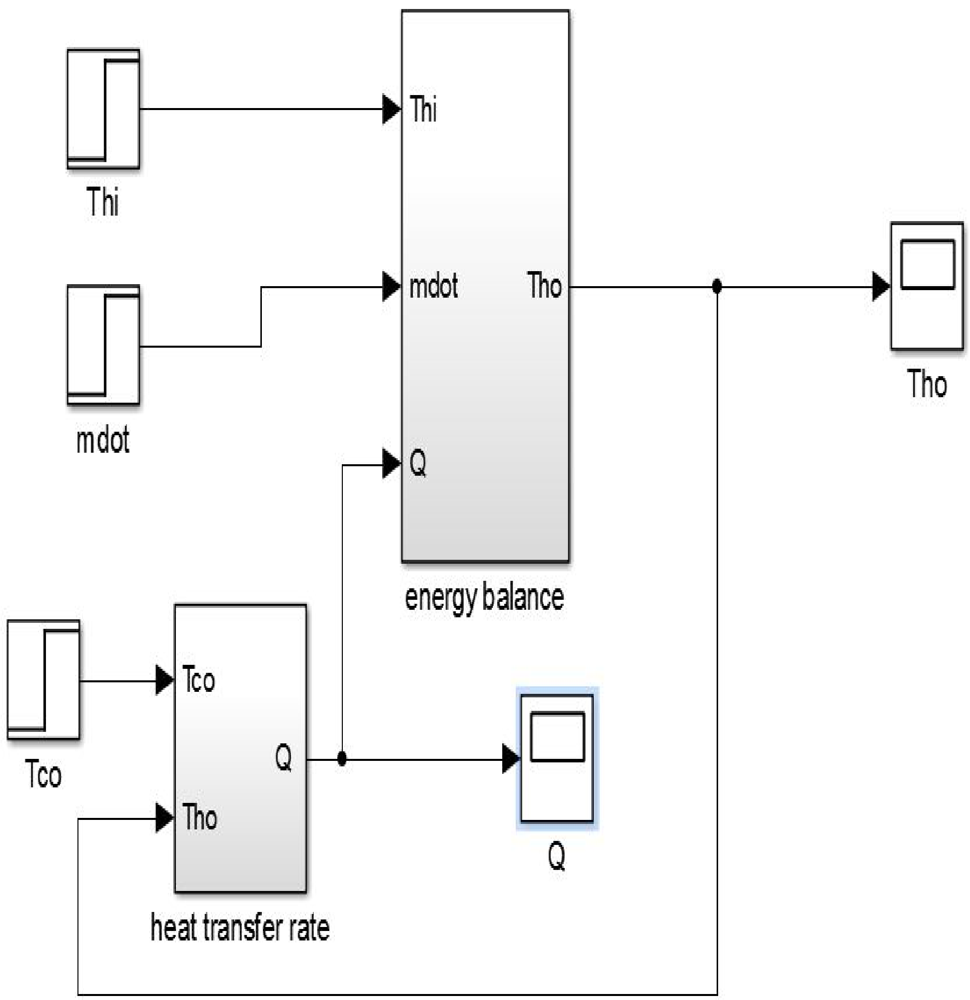


Figure (3-1) simulation of equation.

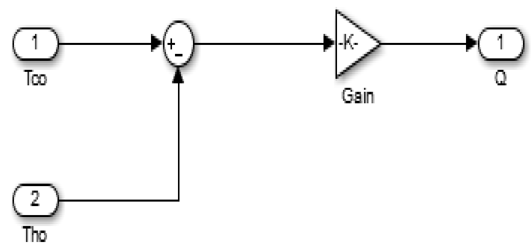


Figure (3-2) heat transfer rate.

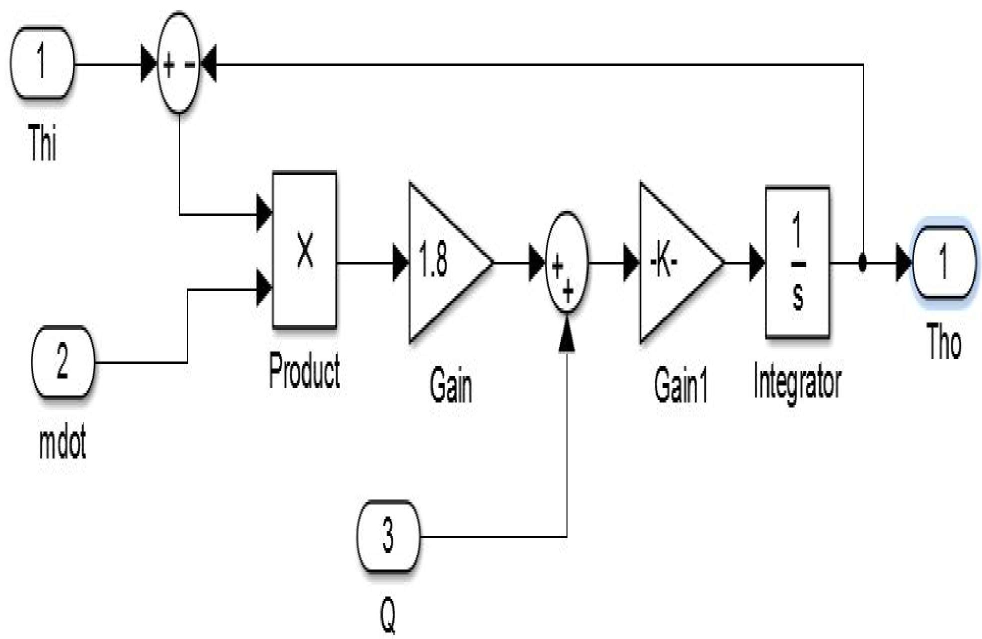


Figure (3-3) energy balance.

Chapter Four

Analysis and Discussion

4.1 Analysis of Design

The heat exchanger to be designed contains diesel and crude, each of which has a flow rate and temperature of entry and exit as is known in the design, as well as the physical properties of each.

It is known that the internal surfaces of heat exchanger tubes do not remain clean after several months of operation, where the crusts and oil deposits on these surfaces, in fact, crusts and sediments on the interior surfaces are only a gradual accumulation of layers of excuses. Due to impurities in the oil fluid, or as a result of the chemical reaction of rust between oil and metal (rust).

These sediments strongly affect the heat transfer equations and the effluent plant expresses the sediment effect quantitatively.

After carrying out the calculations, we reached the nearest real value in the basic design of the real exchanger by equating the thermal equilibrium, where the Q value was closer to the real with a slight difference in ΔT_m by the correction factor.

ΔT_m Through the opposite flow From Table (4-1), choose u = 400 $w/m^2.°C$, and choose a triangular pitch because it gives higher heat transfer rates.

The area of the heat exchanger was 307 m^2 despite the real heat exchanger area of 695m^2, but the difference is due to the quality of the exchanger chosen in the design is a heat exchanger with four paths for the tube and the two tracks of the plane to enlarge the area of the surface separating the fluid through which the heat.

And then chose from the reference the inner and outer diameter and the length of the pipe where the area of the pipe was 0.575m^2. Then the number of pipes was 534 tubes and after the diameter of the beam by the number of pipes and constants of the equation and the value of 969.5 mm and the addition of the value shell clearance we get the value of Shell diameter.

Calculates the number of lines in a single path , Divided the number of pipes on the number of tracks for the pipe and then hit the output in the diameter of the tube to get the total area of the tubes is 0.067m^2 and then calculated the value of Re and then Nu.

To get the value of Tube-side coefficient and also to calculate the Shell side coefficient values were baffle spacing, Equivalent to approximately half the real value in the real design, because of the difference in the number of tracks by shell and tube

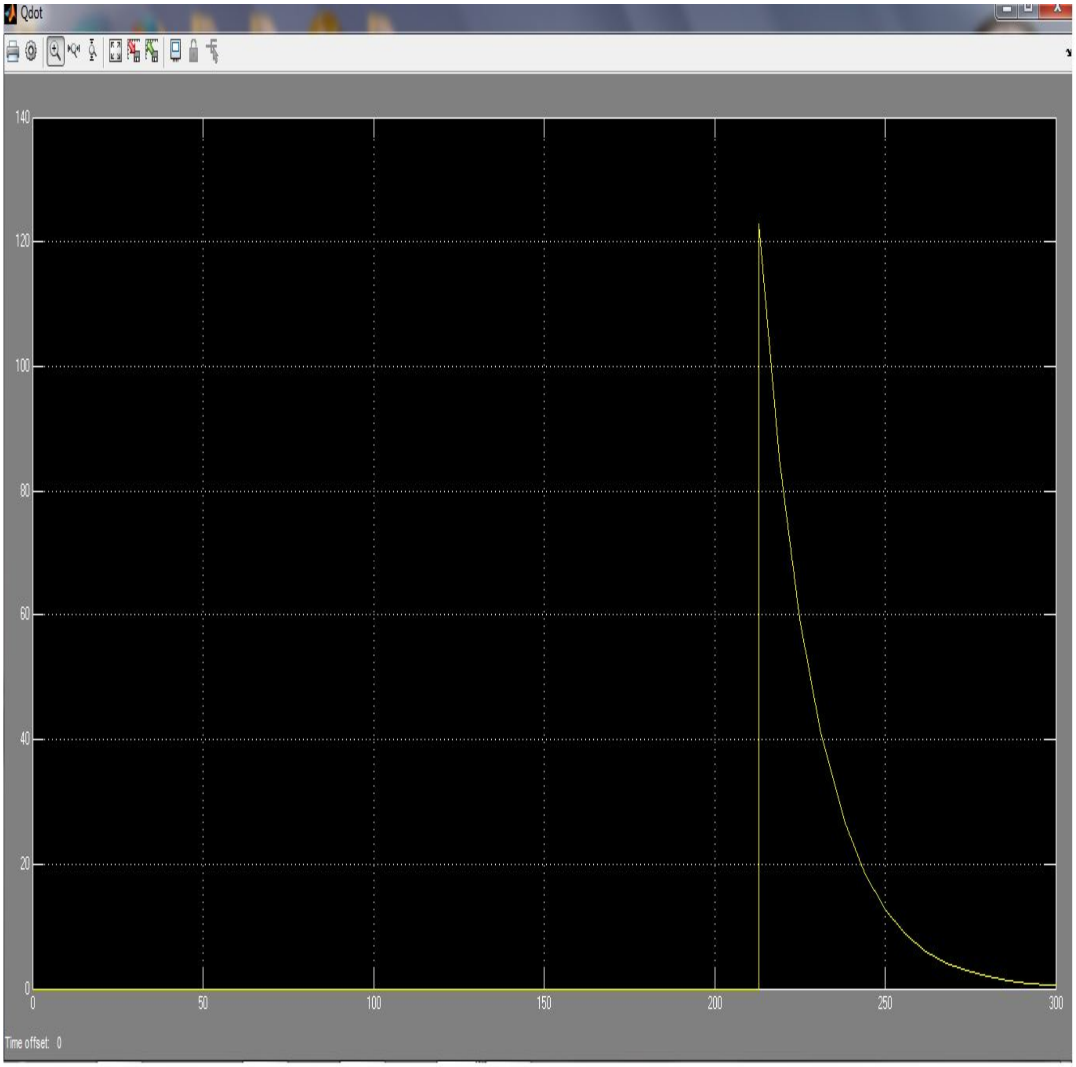
As for the value of u real design was 318.4 w/m^2. °Cless than the value imposed in the first design.

The heat exchanger performance is affected by several variables, namely the mass flow rate during the exchanger, its quality temperature, Temperature, hot and cold discharge, surface area available for heat transfer, thermal conductivity of pipe material, the degree of sediments or crusts inside the tubes of the heat exchanger and transient heat transfer coefficients from internal and external surfaces of pipes. The pressure loss through the heat exchanger is directly related to the required pumping capacity and is indirectly associated with the heat transfer coefficient.

The losses in the pressure were as follows

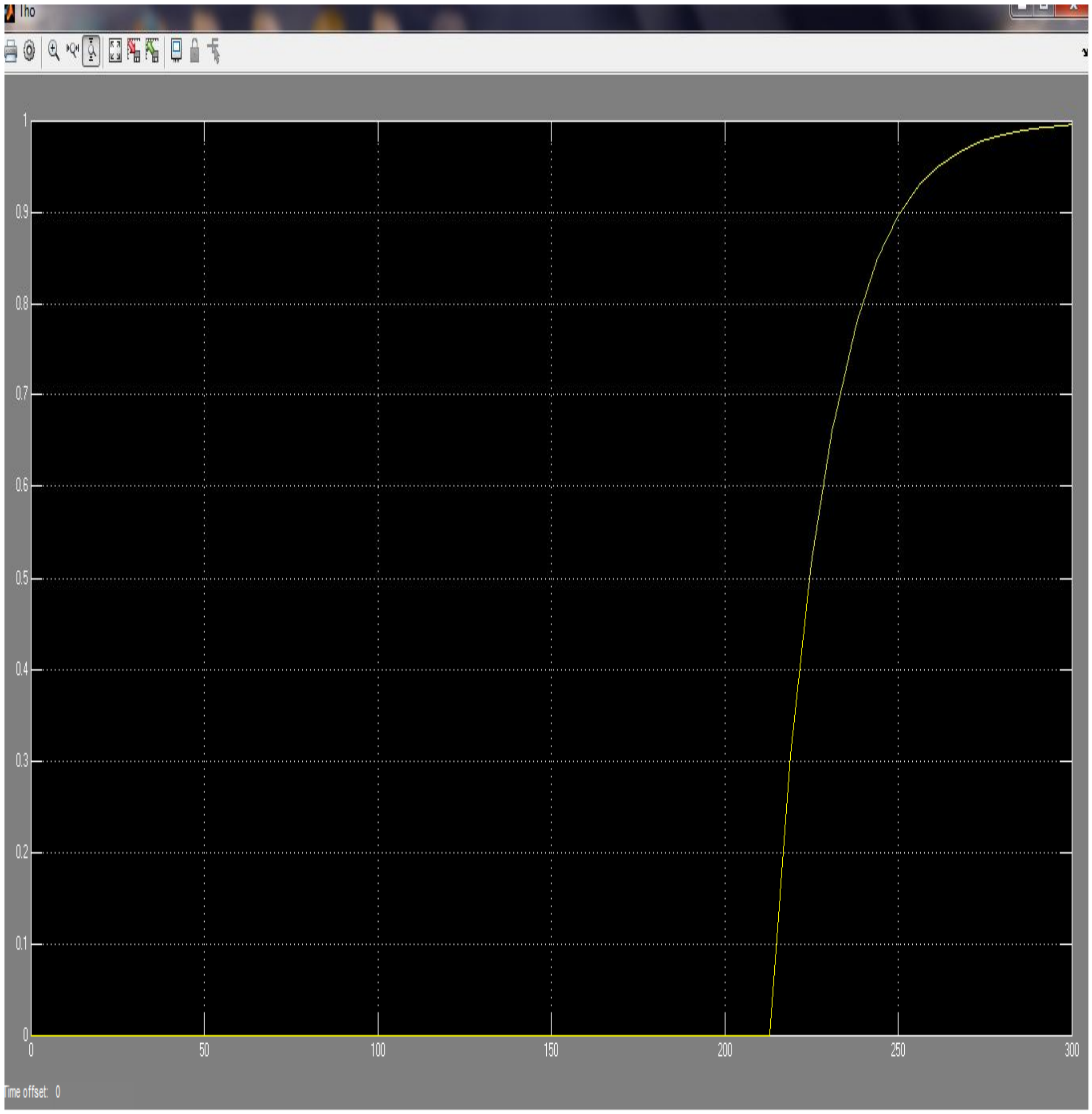
- Tube side pressure drop 0.0121N / m2.
- Shell side pressure drop 36711N / m2.

4.2 Diagrams



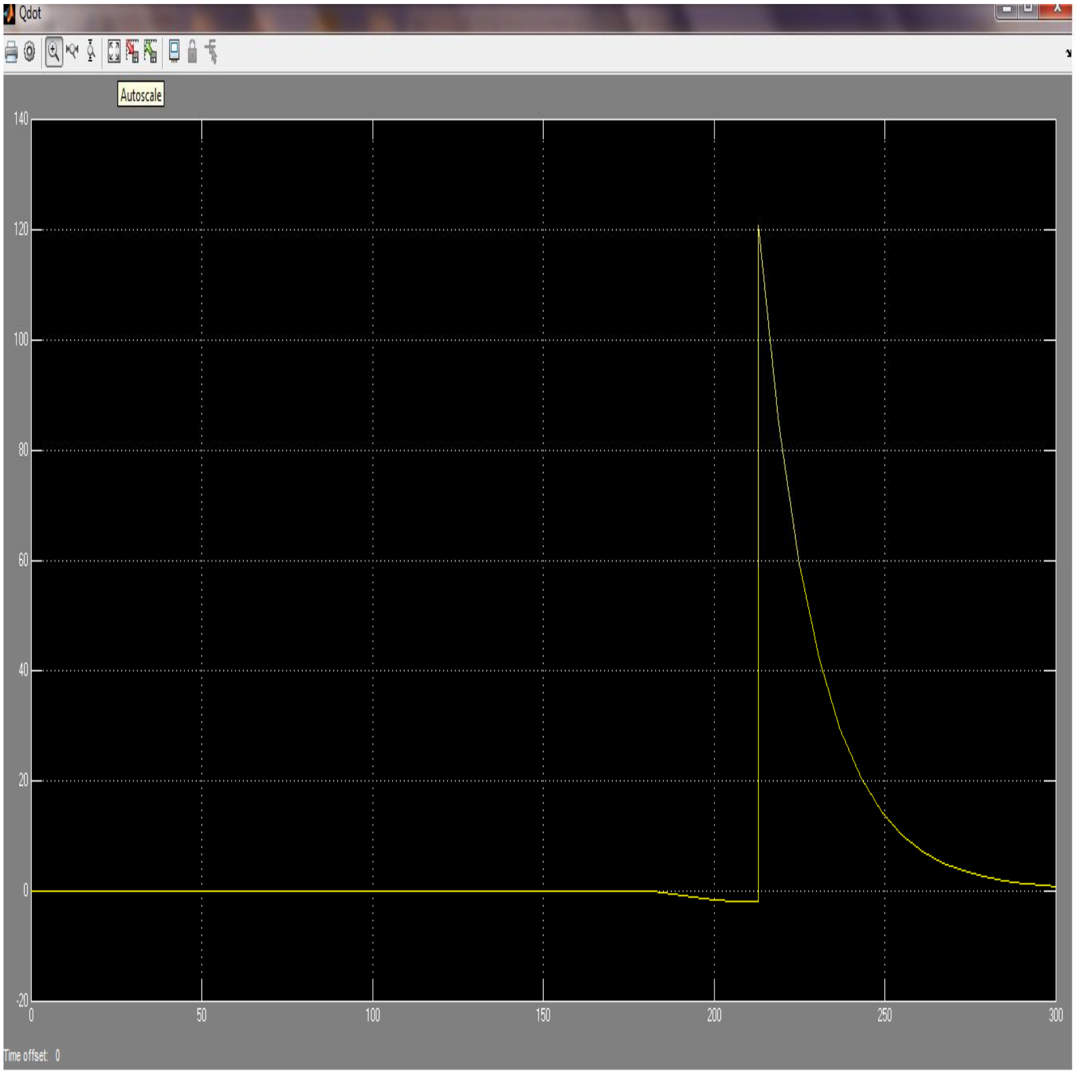
The diagram (4-1) shows the relationship between temperature and the amount of heat transferred to diesel.

The above diagram shows the relationship between the external temperatures of the fluids and the amount of heat transported, and that when the flow of liquid at the rate of diesel flow .Where the (x) axis represents the temperature and the (y) axis represents the amount of heat transferred.



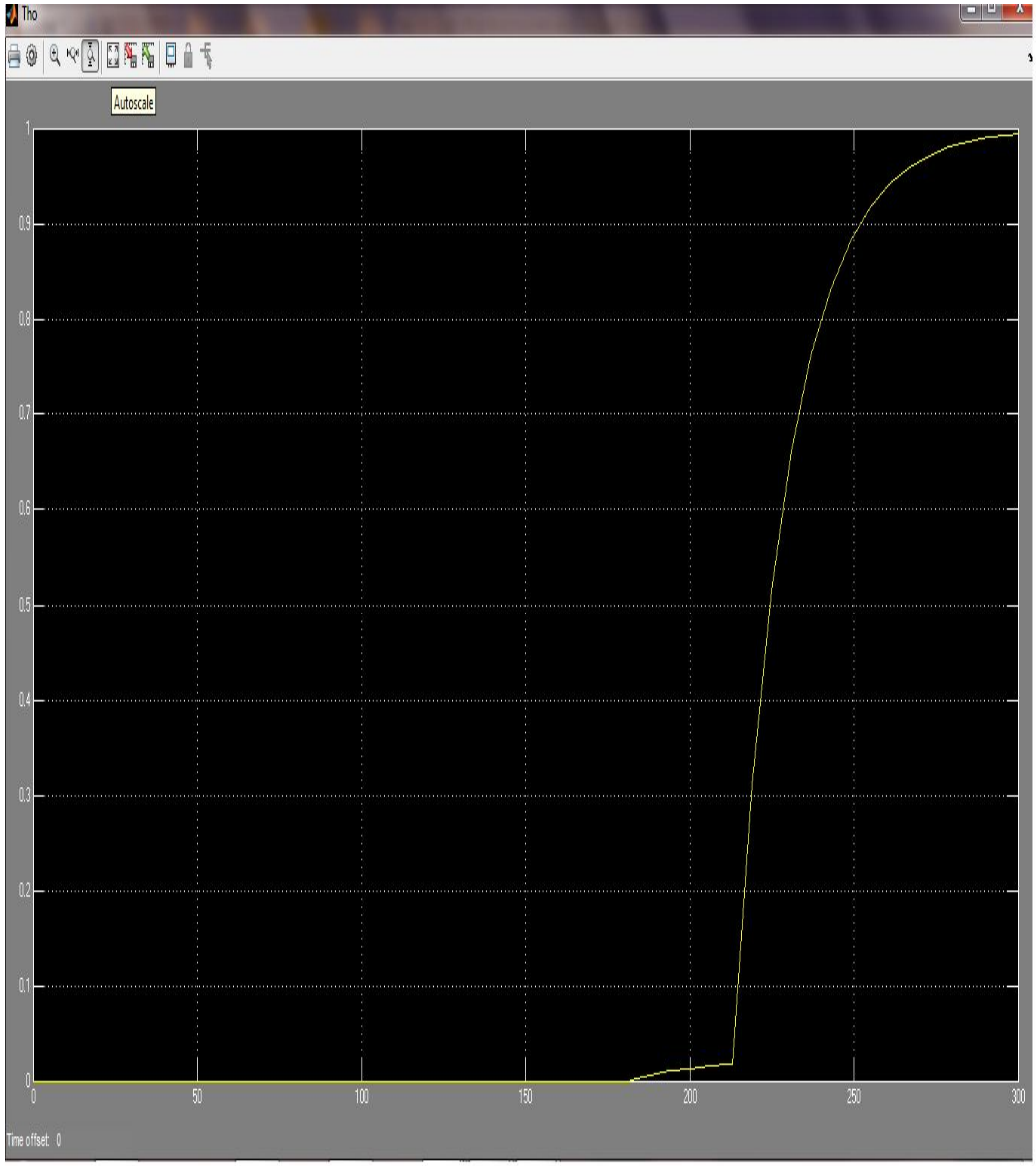
The diagram (4-2) shows the relationship between the temperature of entry and exit of diesel.

The diagram above shows the relationship between the exit temperature of diesel and the time where the axis (x) represents the temperature of the exit of the diesel and the axis (y) represents the time, and that when the flow of fluid at the rate of the flow of diesel flow as it rises with time to get stability in the temperature



The diagram (4-3) shows the relationship between temperature and the amount of heat transferred to crude.

The diagram above shows the relationship between the external temperatures of the fluids and the amount of heat transferred. This is when the flow of the two reactors at the rate of the flow of crude where the axis (x) represents the temperature and the axis (y) represents the amount of heat transferred.



The diagram (4-4) shows the relationship between the temperature of entry and exit of crude.

The diagram above shows the relationship between the exit temperature of diesel and time. The (x) axis represents the exit temperature of the diesel and the (y) axis represents the time. This is when the flow of liquid flows at the flow rate of the crude.

4.3 Design results

Table 4.1 Summary of Heat Exchanger Design

Type of heat exchanger:	Date of preparing data sheet:
Number of Item:	Name of designer: Mohammed
Quantity required: one	
Exchanger operation: heating crude	
Heat load: 2684 kW	Area of heat transfer:307 m^2
TUBE SIDE	SHELL SIDE
The fluid : diesel	The fluid : crude
Fluid velocity: m/s	Fluid velocity: m/s
Mass flow rate: kg/hr	Mass flow rate: 123100kg/hr
Material of tube: Stainless steal	Material of pipe: Stainless steal
Number of pass: 4	Number of pass: 2
Number of tubes: 534tubes	Number of baffles: 30 baffles
Tube outer diameter:30mm	Shell diameter :1038.5mm
Tube inner diameter: 25mm	Length of shell: 6.1m
Tube pitch: 37.5 mm	Baffles spacing :207.7 mm
Tube distribution: triangular pitch	Type of head :Constant
The mean temperature of fluid:220.5°C	The mean temperature of fluid:197.5°C
The pressure drop:0.0121 N/m^2	The pressure drop:36711N/m^2
Heat transfer coefficient:672.8W/ m^2.°C	Heat transfer coefficient:1167 W/ m^2.°C

Chapter Five

5.1 Conclusion

- The prime objective in the design of an exchanger is to determine the surface area required for the specified duty (rate of heat transfer) using the temperature differences available.
- The magnitude of the individual coefficients will depend on the nature of the heat transfer process (conduction, convection, condensation, boiling or radiation), on the physical properties of the fluids, on the fluid flow rates, and on the physical arrangement of the heat transfer surface.
- The tubes in exchangers are usually arranged in an equilateral, triangular, square, or rotated square pattern. I choose a triangular pitch because it gives higher heat transfer rates.
- I found different results in some design but the main variables are the same values and the variation of the shape of the heat exchanger.

5.2 Recommendations

- The Matlab programs is very useful in design processes and recommend designing experiments on other programs for ease of use and accurate calculations in a short time.
- The periodic cleaning of the heat exchanger should be carried out in schedules and the best methods of cleaning should be chosen.
- The heat exchanger design and operating conditions shall be according to the type of fluid in which it operates and its characteristics.
- The Matlab software should be used in designs on a larger scale to improve the efficiency of the exchanger and the efficiency of operation.
- When cooling oil products with very high temperature must be passed through heat exchanger tubes and must be very slow speed.
- Plates shall be selected from corrosion resistant materials.
- Researchers should take into account modern methods in protecting heat exchanger corrosion and corrosion

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Appendix

Table (A-1) typical overall coefficients.

Shell and tube exchangers		
Hot fluid	Cold fluid	U (W/m^2°C)
Heat exchangers		
Water	Water	800–1500
Organic solvents	Organic solvents	100–300
Light oils	Light oils	100–400
Heavy oils	Heavy oils	50–300
Gases	Gases	10–50
Coolers		
Organic solvents	Water	250–750
Light oils	Water	350–900
Heavy oils	Water	60–300
Gases	Water	20–300
Organic solvents	Brine	150–500
.Water	Brine	600–1200
Gases	Brine	15–250
Heaters		
Steam	Water	1500–4000
Steam	Organic solvents	500–1000
Steam	Light oils	300–900
Steam	Heavy oils	60–450
Steam	Gases	30–300
Dowtherm	Heavy oils	50–300
Dowtherm	Gases	20–200
Flue gases	Steam	30–100
Flue	Hydrocarbon vapours	30–100
Condensers		
Aqueous vapours	Water	1000–1500
Organic vapours	Water	700–1000
Organics (some non-condensables)	Water	500–700
Vacuum condensers	Water	200–500
Vaporisers		
Steam	Aqueous solutions	1000–1500
Steam	Light organics	900–1200
Steam	Heavy organics	600–900

Table (A-2) Constants for use in equation of bundle diameter

Triangular pitch, $p_t = 1.25d_o$					
No. passes	1	2	4	6	8
K_1	0.319	0.249	0.175	0.0743	0.0365
n_1	2.142	2.207	2.285	2.499	2.675

Table (A-3) Fouling factors (coefficients), typical values.

Fluid	Coefficient (W/m^2°C)	Factor (resistance) (m^2°C/W)
River water	3000–12,000	0.0003–0.0001
Sea water	1000–3000	0.001–0.0003
Cooling water (towers)	3000–6000	0.0003–0.00017
Towns water (soft)	3000–5000	0.0003–0.0002
Towns water (hard)	1000–2000	0.001–0.0005
Steam condensate	1500–5000	0.00067–0.0002
Steam (oil free)	4000–10,000	0.0025–0.0001
Steam (oil traces)	2000–5000	0.0005–0.0002
Refrigerated brine	3000–5000	0.0003–0.0002
Air and industrial gases	5000–10,000	0.0002–0.0001
Flue gases	2000–5000	0.0005–0.0002
Organic vapours	5000	0.0002
Organic liquids	5000	0.0002
Light hydrocarbons	5000	0.0002
Heavy hydrocarbons	2000	0.0005
Boiling organics	2500	0.0004
Condensing organics	5000	0.0002
Heat transfer fluids	5000	0.0002
Aqueous salt solutions	3000–5000	0.0003–0.0002

Table (A- 4) Conductivity of metals.

Metal	Temperature (°C)	k_w (W/m°C)
Aluminium	0	202
	100	206
Brass	0	97
(70 Cu, 30 Zn)	100	104
	400	116
Copper	0	388
	100	378
Nickel	0	62
	212	59
Cupro-nickel (10 per cent Ni)	0–100	45
Monel	0–100	30
Stainless steel (18/8)	0–100	16
Steel	0	45
	100	45
	600	36
Titanium	0–100	16

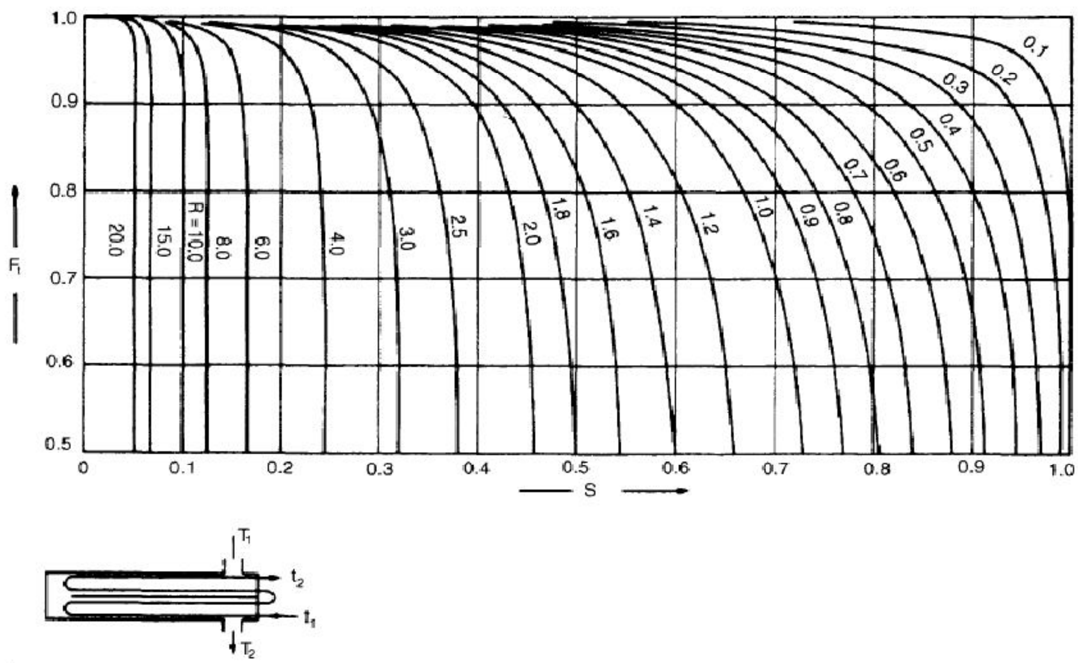

Figure (A-1) Temperature correction factor: two shell passes, four tube passes.

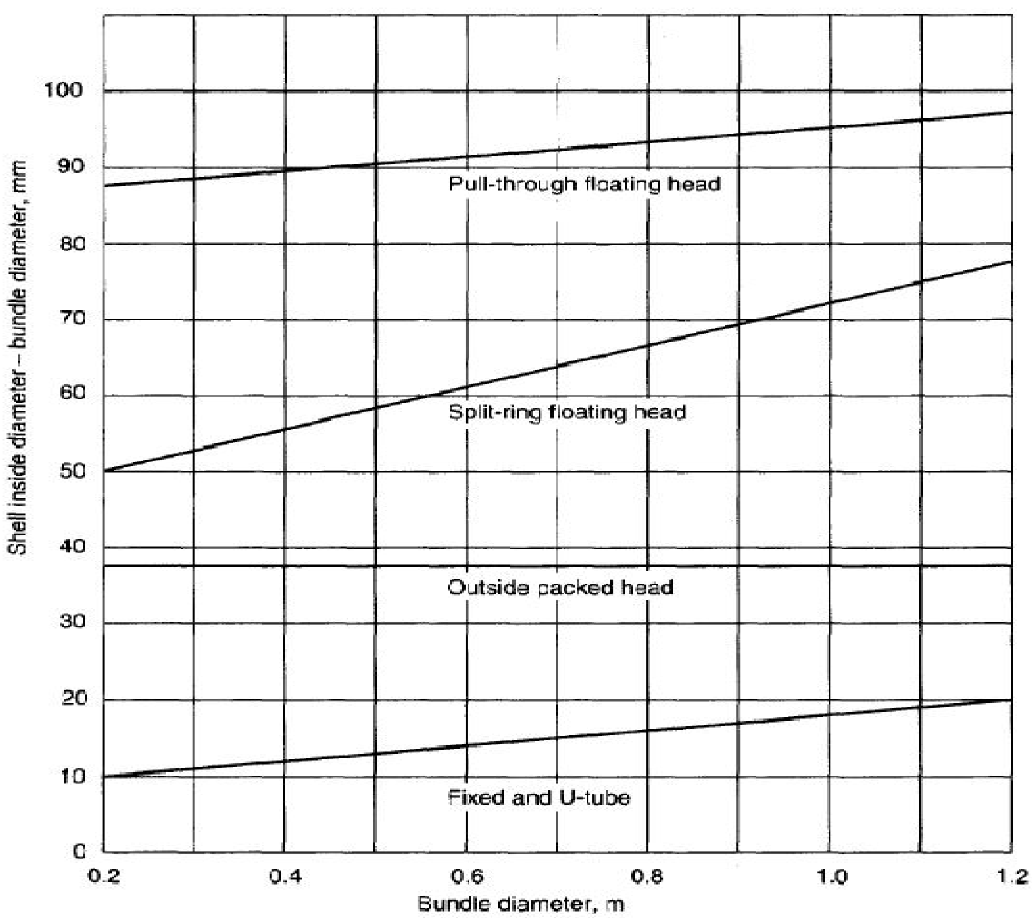

Figure (A-2) Shell-bundle clearance.

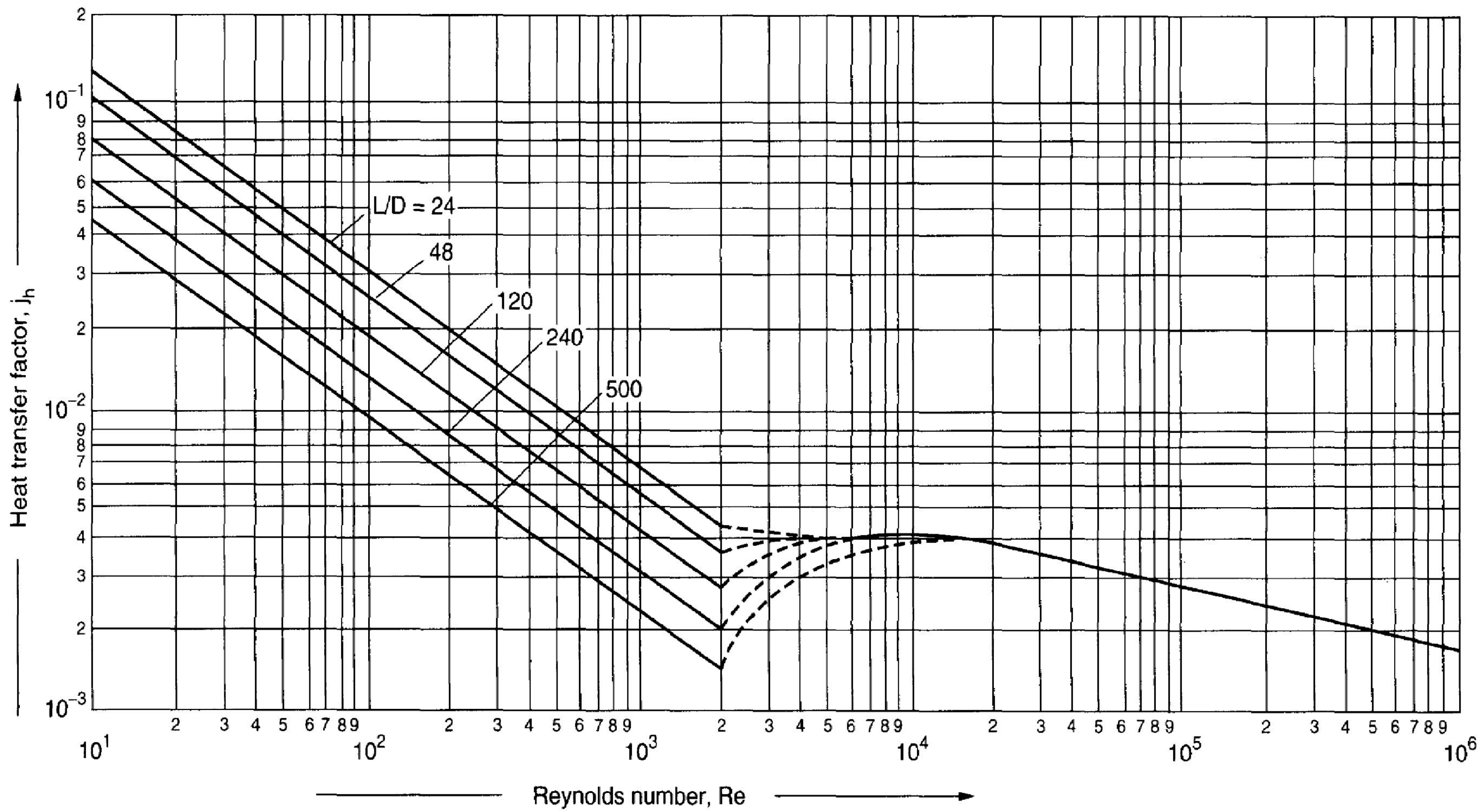

Figure (4-3) Tube-side heat-transfer factor.

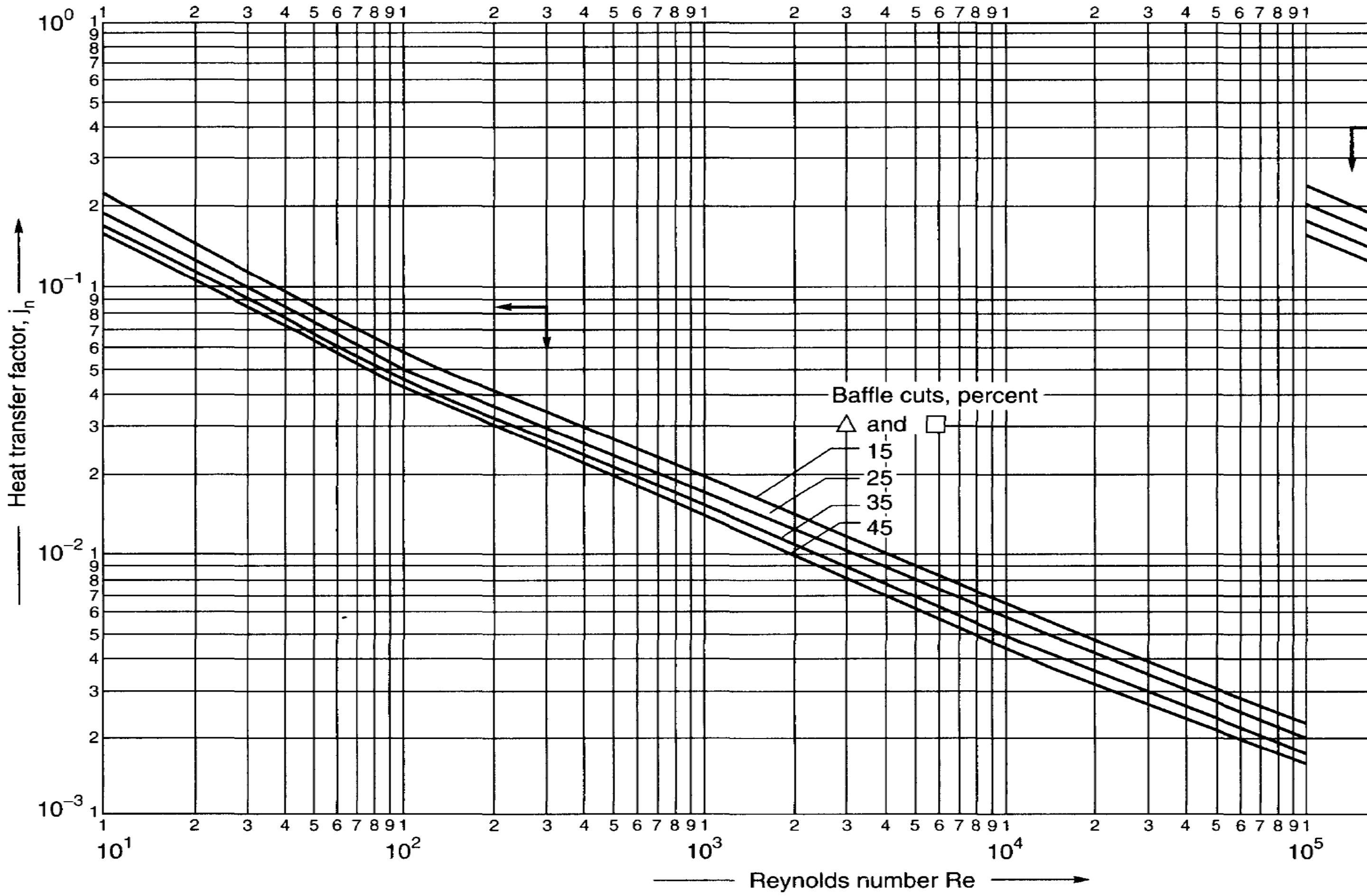

Figure (4-4) Shell-side heat-transfer factors, segmental baffles.

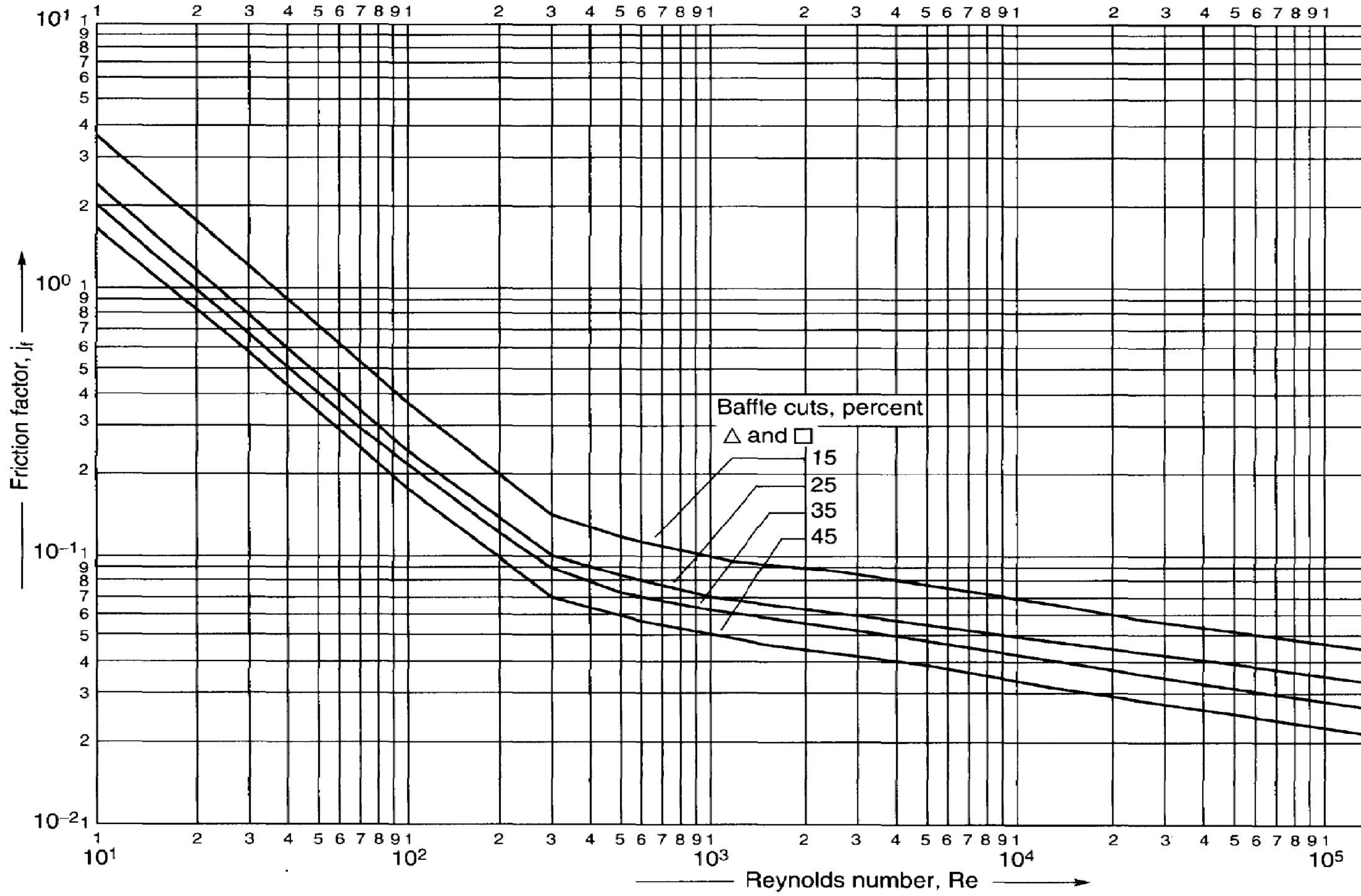

Figure (4-5) Shell-side friction factors, segmental baffles.

Matlab Program

```
Clc
Clear
%Heat Exchanger Design
% Basic design procedure and theory
%Design calculation
%Cold fluid in shell side (crude)
Tci=182;
Tco=213;
Tcm=197.5;
Rc= 933.8;
mc =0.815;
Cpc=2.532;
Kfc=0.130;
Mc=123100;
%Hot fluid in tube side (diesel)
Thi=232;
Tho=209;
Thm=220.5;
Cph=2.723;
mh=0.805;
Rh=820;
Kfh= 0.131;
Mh=154277;
%The general equation for transfer is
R= (Thi-Tho)/ (Tco-Tci)
S= (Tco-Tci)/ (Thi-Tci)
%From fig (4.1) at appendix
```

```
%Ft= the temperature correction factor.
Ft=0.96;
%Q = from energy balance
dtc =Tco-Tci;
Q=Mc*Cpc*dtc*10^3/3600
dTm =((Thi -Tco)-(Tho-Tci))/log((Thi-Tco)/(Tho-Tci))
DTm=dTm*Ft
U=400;%assume from table (4.2)at appendix
%Where: A heat transfer area, m2
%Provisional area:
A= (Q)/ (U*DTm)
%Chose the tube dimensions from volume 6:
d0=0.03;
di=0.025;
L=6.10;
%Area of one tube:
a=3.14*d0*L
%Number of tubes:
N= A/a
%Bundle diameter (Db):
%k, n = constants chose by the number of passed table (4.2) at appendix
there are two passes
k = 0.249;
n = 2.207;
Db=d0*(N/k)^(1/n)
%Shell diameter (Ds):
%Use a split-ring floating head type.
%C = shell bundle clearance
%From fig (4.2) at appendix
```

```
C=0.069;
Ds= Db+C
%Tube side coefficient:
%at=Tube cross-section area
at= 0.7854*(di)^2
%Nt=Tubes per pass=Number of tubes / number of passes
Nt =N/4
%af=Total flow area = tube per pass × tube cross sectional area
af=Nt*at
%dv=Diesel mass velocity
G=Mh/(3600*af)
%Calculate the tube side coefficient using equation:
%Nu = nusselt number
%Re = Reynolds number
Re=G*di*10^3/mh
Pr=(Cph*mh)/Kfh
%when
L/di   ;
%Jh = heat transfer factor = constant from fig (4-3) at appendix
Jh=2.5*10^(-3) ;
Nu=Jh*Re*Pr^0.33
hi= Nu*Kfh/di
%Shell side coefficient:
%Chose baffle spacing =lB
lB=Ds/5
%The area for cross flow as for the hypothetical row of tubes at the shell
equator
%Pt= tubes pitch
Pt= 1.25*d0
```

```
As=((Pt-d0)*Ds*lB)/Pt
Gs= Mc/(As*3600)
%Gs: the shell side mass velocity
%Ws: Fluid flow rate in the shell side kg/s
% Equivalent or (hydraulic) diameter, m:
de= 1.1/d0*(Pt^2-0.917*d0^2)
Re=(Gs*de)*10^3/mc
pr=(Cpc*mc)/Kfc
c = 0.027 ;%for viscous liquids. From volume 6
Nu=c*Re^0.8*pr^0.33
ho= (Nu*Kfc)/de
%Overall coefficient
%Assume: The fouling factor (coefficient) {heavy hydrocarbons}
hid =5000;
hod =5000;  %From table (4.3) at appendix
%Thermal conductivity for stainless steel
kw=45   ;%from table (4.4) at appendix
U0 =1/(1/ho + 1/hod +(d0*log(d0/di ))/(2*kw )+ d0/di*(1/hid)
+d0/di*(1/hi))
    %Tube side pressure drop
%Where:
%NP : Number of tube side passes
NP=4;
%dPt : Tube side pressure drop, pa
%Jf  : Friction factor
Ut=mh/Rh
%When:
Re: 19863.4;%from fig (4.4) at appendix
Jf=3*10^(-3);
```

```
dPt= NP*(8*Jf*(L/di)+2.5)*Rh*Ut^2/2
%Low could consider increasing the number of tube passes.
    %Shell side pressure drop:
%Where:
Us=Gs/Rc  %Linear velocity
%When:
Re = 20783;
Jt=9.5*10^(-3);
dPs=8*Jt*(Ds/de)*(L/lB)*Rc*Us^2/2
```

Real Design of Heat Exchanger

表 LC55-05

China Petroleum EastChina Design Institute, CNPC	**Directions**	File: 2003D03AB-3 /T05
	Collection of Heat Exchangers **$200x10^4$t/a Delayed Coking Unit (Phase I)** **Extension Engineering of Sudan Khartoum Refinery Co., Ltd.** （**coking section**）	Period: As-built DWG; Rev.
		Date: 20070128
		Sheet: 36 of 114

Item	Unit								
Tag No.		E-70105A～D		E-70106A～D		E-70107A.B		E-70108A,B	
Service of unit		Crude-diesel(I) exchanger		Crude-wax pumparound exchanger		Crude-wax(I) exchanger		Deaerated water-wax exchanger	
Specification		LBES1000-4.0-275-6/25-2I		BES1100-4.0-325-6/25-4I		BES800-4.0-145-6/25-4I		BES600-4.0-85-6/25-4I-CF	
Qty.	(set)	4		4		2		2	
Unit heat transfer areas	m^2								
Actual total heat transfer areas	m^2	1100		1300		290		170	
Qty. in series	set	4		4		2		2	
Qty. in parallel	set								
Parameter and medium		Shell	Tube	Shell	Tube	Shell	Tube	Shell	Tube
Medium		Crude	Diesel (I)	Crude	Wax	Crude	Wax(I)	Wax	Deaerated water
Medium total flow rate	kg/h	123100	154277	123100	58394	123100	23650	18025	9650
Inlet conditions Temp.	℃	182	232	213	345	270	335	231	104
Pres.	MPa(g)								
Outlet conditions Temp.	℃	213	209	270	230	278	278	160	180
Pres.	MPa(g)								
Calc. thermal load	kW	2684		5404		1113		1123	
Aver. temp. diff.	˚C	22		37		24		39	
Cal. heat transfer coefficient	W/(m²K)	243		206		262		228	
Act. heat transfer coefficient	W/(m²K)	174		148		176		210	
Calc. total heat transfer areas	m^2	695		975		262		137	
Actual. heat transfer areas	m^2	1100		1300		290		170	
Specification (inner dia.×length)	mm	20x6000		20x6000		20x6000		20x6000	
Pipe type		Higher level cold-drawn tube		Higher level cold-drawn tube		Higher level cold-drawn tube		Higher level cold-drawn tube	
Baffle type		Baffle spacing		Baffle spacing		Baffle spacing		Baffle spacing	
Baffle space	mm	450		300		300		200	
Medium corrosivity									
Service of unit of corrosive medium		naphthenic acid		naphthenic acid		naphthenic acid		naphthenic acid	
Amount of corrosive medium	m %								
Remarks									

Prepared:	Checked:	Approved:		