COMPUTER AIDED DESIGN OF SHELL AND TUBE HEAT EXCHANGER

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A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POST GRADUATE DIPLOMA IN COMPUTER SCIENCE DEPARTMENT OF MATHEMATICS AND COMPUTER SCIENCE

FEDERAL UNIVERSITY OF TECHNOLOGY
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DEDICATION

This project work is heartily dedicated to Almighty God, the Author and finisher of my faith.

AND

To my son, JESUMUYIWA AJAKAYE FAVOURSON

AND

TO SUPEREME NURSERY AND PRIMARY SCHOOL CHANCHAGA MINNA

CERTIFICATION

This project has been certified as having met the requirements of the Department of Mathematics and Computer Science, Federal University of Technology, Minna for the Award of Post Graduate Diploma in Computer Science.

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MAL. Y.U. ABUBAKAR DATE

SUPERVISOR.

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HEAD OF DEPARTMENT DATE

MR. L.N. EZEAKO.

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EXTERNAL EXAMINER DATE

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The completion of this project is not the sole work of the writer. The materials in this book are as a result of contribution from many people of high educational intelligence.

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Almighty is to be praised.

ABSTRACT

The computer aided design (CAD) is a utility that enables the speedy processing of design procedure and calculations. This eliminates the rigour encountered and associated with manual calculation. CAD, is such that, it is programmed to evaluate on the physical properties needed, which would have taken manual design a significant time in interpolating, extraplating and interpreting data from curves, monographs or tables.

For this particular project, the design of a shell and tube heat exchanger was carried out with the aim to develop a program that can perform the rigorous and tedious calculation needed in the design, simulation and optimization of a shell and tube exchanger.

For the design, a problem was taken from a certified literature (Richardson and Coulson Vol. 6), so to acertain the accuracy of the design. An assumed overall heat transfer coefficient was taken along side the other variables. At the end of the process, the values that were got by the computer process were similar to those calculated for in the literature.

NOMENCLATURE

A Heat transfer area. .... m^2
C_p Heat capacity at constant pressure.
D_b Bundle diameter. .... m
D_S Shell diameter. .... m
de Equivalent diameter. .... m
di Tube inside diameter .... m
do Tube outside diameter.
Gp Mass flow-rate per unit cross-sectional between plates .... Kg/s
Gs Shell-side mass flow rate per unjt area.Kg/s
hc Heat-transfer coefficient in condensation.. $W/m^2{}^oC$
(hc)1 Mean condensation heat-transfer coefficient for a single tube...................... $W/m^2{}^oC$
(hc)b Heat-transfer coefficient for condensation on a horizontal tube bundle.
(hc)v Heat-transfer coefficient for condensation on a vertical tube........................ $W/m^2{}^oC$
(hc)bk Condensation coefficient from Boko-Kruzhilin correlation........................ $W/m^2{}^oC$
hi' Inside film coefficient in Boyko-Kruzhilin correlation .... $W/m^2{}^oC$
hid Fouling coefficient on inside of tube. .... $W/m^2{}^oC$
ho Heat-transfer coefficient outside a tube. .... $W/m^2{}^oC$
hod Fouling coefficient on outside of tube. .... $W/m^2{}^oC$
hs Shell-side heat-transfer coefficient.. $W/m^2{}^oC$
kf Thermal conductivity of fluid. .... W/m^oC
kl Thermal conductivity of liquid. .... W/m^oC
kv Thermal conductivity of vapor. .... W/m^oC
Nr Number of tube in a vertical row. -
Nt Number of tubes in a tube bundle. -

ΔP_s shell-sidepressure drop .... N/m^2

ΔP_t .... Tu
be-side pressure drop. N/m^2

Pt Tube pitch. .... m
-
Q Heat transferred in unit time.. W
R$ S Dimensionless temperature ratios.
Ts Shell-side temperature.. ^oC
Tsat Saturation temperature.
Tt Tube surface temperature .... ^oC
Tv Vapor (gas) temperature. .... ^oC
Tw Wall (surface) temperature.
ΔTlm Logarithmic mean temperature difference .... ^oC
ΔTm Mean temperature difference .... ^oC
tc Local coolant temperature.. ^oC

t1	Tube-side inlet temperature	^{o}C
t2	Overall heat-transfer coefficient	$W/m^{2o}C$
Uo	Overall heat-transfer coefficient based on tube outside area	$W/m^{2o}C$
Us	Shell-side fluid velocity	m/s
Wc	Total condensate mass flow-rate	kg/s
μ_l	Liquid viscosity	mNs/m^2
μ_v	Vapor viscosity	mNs/m^2
ρ	Fluid density kg/m^3	
ρ_l	Liquid density kg/m^3	
ρ_v	Vapor density kg/m^3	
τ_h	Condensate loading on horizontal tube kg/ms	
τ_v	Condensate loading on a vertical tube kg/ms	
Nu	Nusselt number	-
Re	Reynolds number	-

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CHAPTER ONE

GENERAL INTRODUCTION

1.1. INTRODUCTION

This operation is employed in almost all chemical processing industries, such as petroleum, petrochemical, plastic, refrigeration e.t.c. In order to carry out this operation, large variety of heat exchangers and condensers are used on distillation columns. Cooling water from a river, ocean or cooling tower is the most frequently used as coolant, but refrigeration is used in some columns operating at low temperature and some column overhead condensers are used to generate steam for use elsewhere in the plant. The overhead vapor from high-temperature column can be used to provide heat in the reboiler of a lower temperature column.

Tube- in-shell heat exchangers are frequently used. The coolant can be on either shell side or the tube side. The condensing process vapors are usually put on the tube side if the pressure in the system is high, since only the tubes have to withstand the high pressure or if the material is corrosive or tends to plug the tubes, since it is much easier to clean the inside of tubes than to clean the shell side.

Air cooled heat exchangers are used in some columns. They have advantage of not requiring make-up water that would be needed in a cooling system.

However, not quite as temperatures can be obtained in the reflux drum with air as with water (130oF Vs 120oF respectively). This causes column pressure to be some what higher, which can increase energy consumption in some chemical systems, since relative volatilities end to decrease as pressure increase.

Spray condensers are used in high-vacuum columns to eliminate undesirable pressure drop through the overhead vapour piping and condenser. Liquid is circulated around, through a cooler at high flow rate and is sprayed into the vapour space in the condenser, spray condensers are usually used in situation where the overhead temperature is fairly high, so that large amounts of sub cooling required in the cooled liquid can be achieved.

Most condensers are mounted in or above the top of the column so that the reflux can flow back into the column without using pumps. The gravity flow systems are useful when very corrosive, toxic or hazardous material is being handled and pumping is to be avoided because of possible leaks or explosions.

1.2 COMPUTER AIDED DESIGN

Computer aided design (CAD) is a utility that enables the Speedy processing of design procedure and calculations. This eliminates the rigour encountered and associated with manual calculation. CAD, is such that, it is programmed to evaluate all the physical properties needed, which would have taken manual design a significant time in interpolating, extrapolating and interpreting data from curve's, monographs or tables. However all these time consuming operations are systematically avoided when computer is used in the design. Hence, time wastage is also avoided and conversely high design efficiency of the equipment can be achieved.

Following the development in computer technology, chemical processing equipment cannot be left aside, if efficiency and economical design is to be obtained. Thus advanced computer languages that are user friendly, easy to operate and interpret results have to be used in designing these equipment.

1.3 INTRODUCTION TO VISUAL BASIC (VB)

Graphical user interfaces, or GUIS (Pronounced "gooise"), have revolutionized the micro-computer industry. Instead of the cryptic C:> prompt that DOS users have long seen, you are presented with a desktop filled with icons and with programs that use mice and menus. Windows applications generally have a consistent user interface. This means that users can spend more time mastering the application and less time worrying about which keystrokes do what within menus and dialog boxes.

In particular, visual basic lets you add menus, text boxes, command buttons, option button, check boxes, scroll bars and file and directory boxes to blank windows. You can use grid to handle tabular data. You can communicate with other windows applications, and perhaps most importantly, you will have an easy method to let users control and access.

1.4 AIM AND OBJECTIVE

The aim of this wok is to develop a program that can perform the rigorous and tedious calculations needed in the design, simulation and optimization of a shell and Tube Heat Exchanger.

The objective is to use a programming language that is user friendly, in addition to the modeling of equations that eliminate the dependency on graphs and table for basic data.

1.5. JUSTIFICATION OF RESEARCH

The advantage of computer analysis over analytical method cannot be over emphasize viz the following: -

(a) Rapid and accurate Calculations:- computer can carry out complicated calculations like the logarithmic mean temperature difference (LMTD), overall Heat Transfer Coefficient and heat exchanger area accurately quickly and unlike human counterpart they hardly make mistakes through over tiredness, it does not require rest break and care carry out in seconds what may take days to do by manual methods.

(b) Relief from tedious of Calculation

There is no justification for manually carrying out routine and repetitive design calculations in the design office as the computer can perform these task so much better, thus relieving Engineers from the tedious of routine calculators and allowing them to spend more time on the more creative and possibly more cost – effective aspects of their work.

(c) Replacement with code requirements

The modern code of practice and standards are complex documents with many design requirements often cross – referenced in different sections of the design standard for the design of, say optimized, economic heat exchanger all the requirements for ultimate limit stage and serviceability design, together with detailing rules, can be incorporated into one program or into a number of sub-programs, hence making it possible for all relevant requirements taking into considerations.

(d) Replacement of Design Charts, data Sheets E.T.C.

Large number of traditional design aids, including design charts, is replaced by computer programs, which are not subject to graphical interpretation errors. Tables of design data are built into computerized databanks, accessed rapidly and accurately and, as design standards change amended easily.

(e) Consideration of Multiple design options

At the feasibility design stage the engineer will wish to consider various design options and to make rapid but approximate estimates of section sizes and material quantities. These calculations will enable the final economic area of heat exchanger to be chosen but, because of the need for rapid estimates, such calculations will often be based on approximations, which if examined in detail, will prove to be far from accurate.

(f) Using a computer, various alternative Heat exchanger area configurations may be quickly examined in detail before a final choice is made.

CHAPTER TWO

2.0. LITERATURE REVIEW

In the mid – 1950s major changes began to occur in engineering and science with the introduction of a new tool called a digital computer.

Although computer had been in limited use since shortly after World War II, It was only at this time that it become easily accessible to engineers outside of a laboratory environment. Several of the first commercial computers which were readily available to Engineering design and analysis were the Bendix G15 and IBM 650 (John F. Faning 1891). By present day standard these computers were very slow and the programming language which were available were difficult to learn and tedious to apply.

Even with these deficiencies many for sighted individuals saw the potentials on computers to relief the Engineers of the time – consuming and error prone calculations required in many types of analysis and design. Programs began to appear, which performed many of these engineering computations from input supplied by engineer.

One of the pioneer areas of engineering in which computer were utilized was the field of civil engineering and particularly the area of structural analysis and design. As early as 1958 the Structural Division of the American society of Civil engineers held a conference in Keinsas city Missouri on the use of digital computers in structural engineering. The proceeding of this conference contain a number of papers which show early attempts by structural engineers to apply the computer to problems in structural field.

2.1 ORIGIN OF COMPUTER AIDED DESIGN

Computer aided design (CAD) is barely thirty years old, yet by the 1980's it was transforming the working practices of designers in many industries and has become a huge worldwide industry itself Onifade, (2000). Lyan Sutherland at Massachusetts institute of Technology {MIT} can trace the origin of CAD back to the revolutionary SKETCH systems developed in 1962 (Sutherland, 1965). Computers have been used before then for making analytical calculation in engineering design. SKETCH PAD afforded the designers to interact with the computer graphically. The first version was limited to drawings in two dimensions, which was later upgraded to cater for objects to be modeled in three dimensions and gives a perspective view of the design from different view points. During 1980s, CAD has spread widely into various application areas such as graphics and textile design, television and film animation, topography and engineering, with software such as SPICE, CHEMCAD, AUTOCAD MATHCAD e.t.c.

2.2 HEAT EXCHANGER DESIGN

For the design of multi-component heat exchanger in which liquid passing through the shell and tube exchange heat, an estimate of the mean condensing co-efficient can be made using the single component correlation with the liquid physical properties evaluated at the average condensate composition. It is important to cater for a safety factor for heat and mass transfer a factor of 0.65 and increasing the area of thee condenser were suggested (Frank, 1978; kern, 1950). But where a more exact estimate of the co-efficient is required and justified by the data, the rigorous methods developed for partial condensation can be used. However the methods developed for partial condensation for a non-condensable gas can be divided into classes, viz:

(a) **EMPIRICAL METHOD:** approximate methods, in which the resistance to heat transfer is considered to control the rate of condensation and the mass transfer resistance is neglected (Bell and Ghadly, 1973:, Silver, 1947 and Ward, 1960).

(b) **ANALYTICAL METHOD:** More exact procedures which are based on some model of heat and mass transfer process and which take into account the diffusional resistance to mass transfer. The classic method is developed in different period of time (Colburn and Drew, 1937: Colburn and Hougen, 1934: porter and Jeffreys, 1963). The analytical methods are complex requiring step-by-step, trial and error calculations or graphical methods. An assessment of the methods available for the design of condenser where the condensation is from non-condensable gas is recently developed. (McNaught, 1983).

It is important to note that in the approximate method, the local co-efficient of heat transfer can be expressed in terms of the local condensate film co-efficient and the local co-efficient for sensible heat transfer for vapor. Silver (1947), proposed the relationship described above.

For total condensation, horizontal shell-side and vertical tube-side are the most commonly used. A horizontal exchanger with condensation in the tube is rarely used as a process condenser, but it is the usual arrangement for heaters and vaporizers using condensing steam as the heating medium (Adeniyi, 1998).

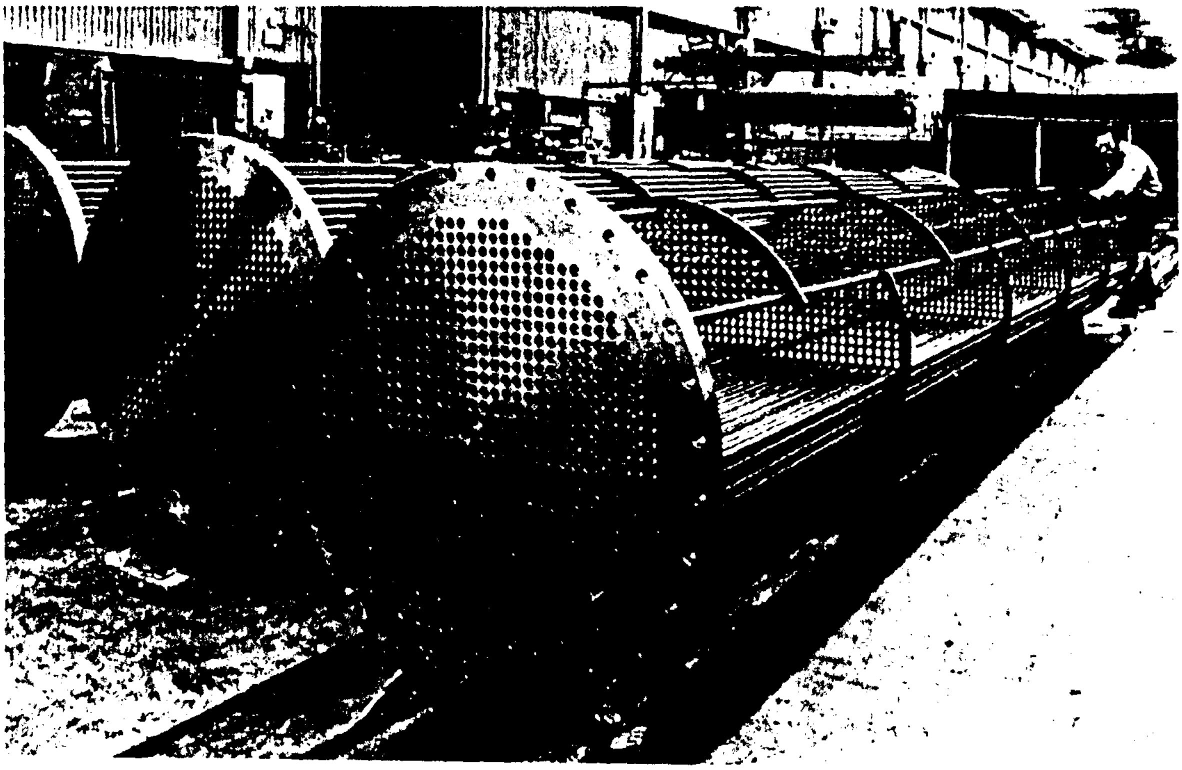


Fig 2.2: - Shell and Tube Heat Exchanger

2.3.0. DESIGN SPECIFICATION

There are various types of heat exchanger as pointed out in the previous chapter. This program (design) is specifically for shell and tube heat exchanger with the following features:

1. Indirect contact condensers , with the following configurations:
   - (a) Horizontal type
   - (b) Condensation is in the shell.
   - (c) Cooling medium is in the tube.
2. One shell pass and two or more even passes.

3. Wide baffle spacing.

4. Mixture of light hydrocarbons and various organic compounds.

5. Small condensation range, so that corrected logarithmic mean temperature difference (LMTD) can be used

2.4. GENERAL ASSUMPTION

To cater for the deviation that may arise from the temperature correction factor, F_t, the following assumptions were made (Sinnot, 1993).

(a) There are no leakages of fluids between shell passes.

(b) Equal heat transfer area in each pass.

(c) A constant overall heat transfer coefficient in each pass.

(d) The temperature of the shell-side fluid in any pass is constant across any cross section.

CHAPTER THREE

3.1. A REVIEW OF THE OLD SYSTEM

Preliminary investigation was conducted on the old system to determine whether the solution to the problem is feasible. This study is very necessary in developing a new system, this is to prevent washing of capital and human effort in trying to carry out a project that is very large or too difficult to carry out.

3.1.2. BASIC EQUATIONS FOR HEAT EXCHANGER DESIGN

For an open system under steady state conditions, with negligible potential and kinetic energy changes and from the first law of dynamics the enthalpy change of one of the fluid streams is given by:

$$\delta Q := m \times di \quad \ldots\ldots\ldots\ldots\ldots (3.1)$$

Integrating equation 2.1 we have.

$$Q = m \times (i_2 - i_1) \quad \ldots\ldots\ldots\ldots (3.2)$$

I_1 and I_2 are the initial and final enthalpies of the fluid stream. Where there is an adiabatic process, that is, when the heat transfer between the condenser and the surrounding is negligible, integrating equation 2.2 for hot and cold fluids gives:

$$Q = mh \times (i_{h1} - i_{h2}) \quad \ldots\ldots\ldots\ldots (3.3)$$

$$Q = (i_{c2} - i_{c2}) \quad \ldots\ldots\ldots (3.4)$$

Where the subscripts h and c refers to the hot and cold fluids and 1 and 2 implies the fluid inlet and outlet conditions. If there is no change in phase of the fluids and that the fluids have constant specific heats with $d_i = C_p \Delta T$, then equations 3.3 and 3.4 can be written as:

$$Q = (m \times Cp)_h \times (T_{h1} - T_{h2}) \quad \ldots\ldots\ldots (3.5)$$

$$Q = (m \times Cp)_c \times (T_{c1} - T_{c2}) \quad \ldots\ldots(3.6)$$

It is important to note that the temperature difference between the hot and cold fluid varies with position in the condenser. It is therefore appropriate to establish a mean value of the temperature difference, so that the total heat transfer rate, Q between the fluids can be obtained from the relationship given by:

$$Q = U \times A \times \Delta T_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Where U is the overall heat transfer co-efficient based on the area and A is the total heat transfer area. DTm can be obtained from Th_1, Th_2, and Tc1 and T_{c2}.

3.1.2. OVERALL HEAT TRANSFER CO-EFFICIENT

The walls of a condenser are normally made up of a single material, though the way sometimes be bimetallic (steel with Aluminium cladding) or coated with a plastic as a protection against corrosion.

For condensers or heat exchangers in general, the surface tends to acquire an additional heat transfer resistance that increases with time, this may either be a very thin surface oxidation layer, or at the other extreme, it may be a thick crush deposits such as that which result from a salt-water coolant in stream condensers. The above-mentioned effects can be taken into consideration by introducing an additional thermal resistance, known as fouling resistance Rs. The value of the fouling resistance is depended on temperature of the fluid, type of surface, fluid velocity and the length of the condenser (Heat exchanger).

In addition, fins are often added to the surface exposed to either or both fluids, and, by increasing the surface area they reduce the resistance to convection heat transfer. The overall heat transfer co-efficient for a single smooth and clean plain wall is given by:

$$U_A = \frac{1}{R_t} = \frac{1}{\left(\frac{1}{h_{iA.i}} + \frac{t}{K \times A} + \frac{1}{h_0 \times A_0}\right)} \qquad \text{................(3.8)}$$

Where t is the thickness of the wall, R_t is the overall thermal resistance to heat across the surface between the inside and outside flow, while h_i and h_o are heat transfer co-efficient for inside and outside flow respectively.

However, if the exchanger is tubular, unfinned and clean, the overall heat transfer co-efficient is given by:

$$U_{0A.o} = U_i \times A_i = \frac{1}{R_t} = \frac{1}{\left(\frac{1}{h_i \times A_i} + \frac{\ln\left(\frac{r_0}{r_i}\right)}{2 \times \pi \times K \times L} + \frac{1}{h_0 \times A_0}\right)} \qquad \text{....................(3.9)}$$

If the heat transfer surface is fouled with the accumulation of deposits, this in turn introduces an additional thermal resistance in the path of the heat flow, then we have for the unfinned tubular heats exchanger, the overall heat transfer co-efficient as:

$$U_o = \frac{1}{\frac{r_o}{r_i} \square \times \frac{1}{h_i} + \frac{r_o}{r_i} R_{fi} + \frac{r_o \ln\left(\frac{r_o}{r_i}\right)}{K} + Rfo + \frac{1}{h_o}} \qquad \text{.......... (3.10)}$$

Where R_{fi} and R_{fo} are the fouling factors for inner and outer walls respectively. The overall heat transfer co- efficient can be determined from the knowledge of the inside and outside heat transfer co-efficient, fouling factors and the appropriate geometrical parameters.

Typical values of the overall heat-transfer co-efficient for condensers are given in the table below.

Table 3.1: Typical Values of Overall Coefficient for Heat Exchanger (Perry and Green,1984)

HOT FLUID	COLD FLUID	U ($W/m^{2o}C$)
Aqueous vapors	Water	1000 – 1500
Organic vapours	Water	700 – 1000
Organics (non Condensable)	Water	500 – 900
Vacuum Condensers	Water	200 – 500

For heat exchange across a typical heat exchanger tube, the relationships between the overall co-efficient and the individual co-efficient are given by the relationship below:

$$\frac{1}{U_0} = \frac{1}{h_0} + \frac{1}{h_{od}} + \frac{d_0 \times \ln\left(\frac{d_0}{d_i}\right)}{2 \times Kw} + \left(\frac{d_0}{d_i} \times \frac{1}{h_{id}}\right) + \left(\frac{d_0}{d_i} \times \frac{1}{hi}\right) \quad \text{..........(3.11)}$$

3.1.3. THE LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD)

If we consider a simple counterflow or parallel flow heat exchanger, from equation 2.7 Dim may be determined by applying an energy balance to a differential area element dA in the hot and cold fluids. The temperature of the hot fluid will drop by dTh. The temperature of the hot fluid cold fluid will also drip by dTc over the element dA for counterflow, but it will increase by dTc for parallel flow if the hot – fluid direction is taken as positive. Consequently, from the differential forms of equations 2.5 and 2.6 or from 2.1 for adiabatic, steady state flow, the energy balance gives.

$$\delta Q = -(m \times Cp)_h \times dT_h = -(m \times Cp)_C \times dT_C \quad \text{............(3.12a)}$$

$$\delta Q = -C_h \times dT_h = C_C \times dT_C \quad \text{.........................(3.12b)}$$

Where Ch and Cc are the hot and cold fluid heat capacity rates respectively. The positive sign (+) refers to parallel flow. The rate of heat transfer δQ from the hot to the cold fluid across the heat transfer area dA may also be expressed as

$$\delta Q = U \times \left(T_h - T_C\right) \times dA \qquad \text{.............. (3.13)}$$

From equation 2.12 fro counterflow, we obtain.

$$d\left(T_h - T_C\right) = dT_h - dT_C = \delta Q\left(\frac{1}{C_c} - \frac{1}{C_h}\right) \qquad \text{............. (3.14)}$$

Substituting the value of δQ from equation 2.13 into equation 2.14 we Obtain

$$\frac{d\left(T_h - T_C\right)}{\left(T_h - T_C\right)} = U\left(\frac{1}{C_c} - \frac{1}{C_h}\right) \times dA \qquad \text{........... (3.15)}$$

If equation 2.15 is integrated with constants U, Ch and Cc over the entire length of the condenser gives:

$$\ln\left[\frac{\left(\left(T_{h2} - T_{c1}\right)\right)}{T_{h1} - T_{c2}}\right] = UA\left(\frac{1}{C_c} - \frac{1}{C_h}\right) \qquad \text{......................... (3.16a)}$$

Or

$$T_{h2} - T_{c1} = \left(T_{h1} - T_{c2}\right)e^{\left(UA\left(\frac{1}{C_c} - \frac{1}{C_h}\right)\right)} \qquad \text{................ (3.16b)}$$

From the above expression, it can be seen that the temperature distribution is exponential. Therefore, in a counterflow condenser, the temperature difference ($T_h - T_c$) decreases in the direction of flow if $C_h < C_c$, but increases if $C_h > C_c$. The expression for C_c and C_h can then be obtained from equations 2.5 and 2.6 and substituted in equation (2.16a). Solving for Q and rearranging, we obtain:

$$Q = \frac{UA\left(T_{h1} - T_{h2}\right) - T_{h2} - T_{c2}}{\ln\left(\frac{T_{h1} - T_{c2}}{T_{h2} - T_{c1}}\right)} \qquad \text{.............................. (3.17a)}$$

Or

$$Q = UA \times \frac{\left(\Delta T_1 - \Delta T2\right)}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \qquad \text{.................................... (3.17b)}$$

Where ΔT_1, is the temperature difference between the two fluids at one end of the condenser and ΔT_2 is the temperature of the fluids at the other end of the condenser.

The overage temperature of the hot and cold fluids over the entire lengths of the condenser is given by:

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \quad \text{............................ (3.18)}$$

To estimate the "true temperature difference" from the logarithmic mean temperature, a correction factor is employed to cater for the departure from true counter – current flow. Thus, we have.

$$\Delta Tm = \Delta Tlm \times F_t \quad \text{................. (3.19)}$$

The correction factor is dependent on the shell and tube fluid temperatures and the number of tube and shell passes. It is normally correlated as a function of two dimensionless temperature ratios.

$$R = \frac{(T_1 - T_2)}{(t_1 - t_2)} \quad \text{.................... (3.20)}$$

$$S = \left(\frac{t_2 - t_1}{T_1 - t_1}\right) \quad \text{...................... (3.21)}$$

R is the shell – side fluid flow rate times the fluid mean specific heat divided by the tube – side fluid flow- rate times the tube- side fluid specific heat. S is a measure of the temperature efficiency of the exchanger.

For a single shell; two tube pass exchanger, the correction factor is proposed by Kern(1950) as:

$$F_t = \frac{\sqrt{(R^2 + 1)} \times \ln\left[\frac{(1 - S)}{(1 - R \times S)}\right]}{(R - 1) \times \ln\left(\frac{2 - S\left(R + 1 - \sqrt{R^2 + 1}\right)}{2 - S\left(R + 1 + \sqrt{R^2 + 1}\right)}\right)} \qquad (3.22)$$

The equation can also be used for any exchanger with an even number of tube passes.

3.1.4. PHYSICAL PROPERTIES

The physical properties of the condensate used in this project research are evaluated at the average condensate film temperature which is the mean of the condensing temperature and the tube wall temperature. Equations were modeled and used for density and viscosity while data base is incorporated, which is used in calculating the values of thermal conductivity at various temperatures.

3.1.5. MEAN TEMPERATURE DEFFERENCE OF CONDENSATE

At constant pressure and fixed temperature a pure vapour will condense. Since this process is isothermal, the simple logarithmic mean temperature difference can be obtained from equation 2.7, no correction factor for multiple passes in needed. The logarithmic mean temperature difference is given by;

$$\Delta T_{ln} = \frac{(t_2 - t_1)}{\ln\left(\frac{T_{sat} - t_1}{T_{sat} - t_2}\right)} \qquad (3.23)$$

When the condensation process is not completely isothermal but the change in temperature is small, such as where there is significant change in pressure, or where a narrow boiling range multi-component mixture is being condensed, the logarithmic mean temperature difference can still be used, but the temperature correction factor will be needed for multi-pass condensers.

3.1.6. FOULING FACTORS (DIRT FACTORS)

Fouling refers to any change in the solid bounary separating two heat transfer fluids, whether by dirt accumulation or other means, which result in a decrease in the rate of heat, transfer occurring across that boundry. Fouling may be classified by mechanism into six, these are, corrosion fouling, biofouling, particulate fouling, chemical reaction fouling, precipitation fouling and freezing fouling. The deposited material will normally have relatively low thermal conductivity and will reduce the overall co-efficient. It is therefore necessary to oversize the condenser to allow for the reduction in performance during operation. Fouling factors are usually quoted as heat transfer resistance rather than co-efficient they are difficult to predict and are usually based on past experience.

Typical values for the fouling factors of common process and service fluids are given in Table 3.2.

Table 3.2: Typical Values of Fouling Factors. (TEMA standards (1998) and Ludwig (1965))

	Coefficient (W/m$_2$^{0}C)
Organic vapors	5000
Organic liquids	5000
Light hydrocarbons	5000
Heavy hydrocarbons	2000
Boring organics	2500
Condensing organics	5000
Heat transfer fluids	5000
A aqueous salt solutions	3000 – 5000

The selection of the design-fouling factor will often be an economic decision. The optimum design will be obtained by balancing the extra capital cost of a larger exchanger against the savings in operating cost obtained from the longer operating time between cleanings that the large area will give.

3.1.7. DESIGN PARAMETER FOR SHELL AND TUBE CONDENSERS.

3.1.8. SHELL-SIDE PARAMETERS

For pressure applications, the shell thickness will be sized according to the pressure vessel design standards. The minimum allowance for shell thickness is given in BS3274 and the TEMA Standards. The value converted to SI units is given below:

Table 3.3: Minimum Shell Thickness, (mm)

NOMINAL SHELL DIAMETER (mm)	CARBON STEEL		ALLOY STEEL
	PIPE	PLATE	
152	7.1	-	3.2
203 – 305	9.3	-	3.2
3330 – 737	9.5	9.5	4.8
762 – 991	-	11.1	6.4
1016 - 1524	-	12.7	7.9

The shell diameter must be selected to give as close a fit to the tube bundle as practicable. The clearance required between outermost tubes in the bundle and the shell inside diameter will depend on the type of exchanger and manufacturing tolerances, typical values are obtained in standard graphs and tables but for the purpose of the design work, computer modules have been created for the clearance required based on shell diameter.(see section 2.9)

3.1.9 TUBE-SIDE PARAMETERS

The bundle diameter will depend not only on the number of tubes but also on the number of tube passes, as spaces must often be left in the pattern of tubes on the tube sheet to accommodate the pass partition plates. An estimate of the bundle diameter, Db can be obtained from equation 2.24, which is an empirical equation based on standard tube layouts. The constants for use in this equation, for triangular and square patterns, are given in Table 3.4

$$N_t = K_1 \times \left(\frac{D_b}{D_0}\right)^n \qquad \text{.........................} (3.24a)$$

$$D_b = d_0 \times \left(\frac{N_t}{K_1}\right)^{\frac{1}{n}} \qquad \text{......................} (3.24b)$$

Table 3.4: Constants for use in Equation 3.24

TRIANGULAR PITCH, P_t = 1.25 D_0

Passes→	1	1	4	6	8
K1 →	0.319	0.249	0.175	0.0743	0.0365
Ni →	2.142	2.207	2.285	2.499	2.675

SQUARE PITCH, P_t = 25 DO

Passes→	1	1	4	6	8
K1 →	0.215	0.156	0.158	0.0402	0.0331
Ni →	2.207	2.291	2.263	2.617	2.643

3.2.0. FLUID ALLOCATION: SHELL OR TUBES

The allocation of fluid streams to the shell or tube in the absence of phase change depends on the following factors.

(1) **CORROSION:** The more corrosive fluid is allocated to the tube side in order reduce the cost of expensive alloys or clad components.

(2) **FOULING:** The fluid that has greater tendency to foul the heat transfer surface should be placed in the tubes. This will give better control over the designed fluid velocity, and the higher allowable velocity in the tubes will reduce fouling. Also, tubes will be easier to clean.

(3) **FLUID TEMPERATURES:** If the temperatures are high enough to require the use of special alloys, placing the higher temperature fluid in the tubes will reduce the overall cost. At moderate temperatures, placing the hotter fluid in tubes will

reduce the shell surface temperature and hence the need for lagging to reduce heat loss, or for safety reasons.

(4) **OPERATING PRESSURES:** The higher-pressure stream should be allocated of the tube-side. High-pressure tubes will be cheaper than a high-pressure shell.

(5) **PRESSURE DROP:** For the same pressure drop, higher heat – transfer coefficient will be obtained on tube side than the shell side and fluid with the lowest allowable pressure drop should be allocated to the tube-side.

(6) **VISCOSITY:** Generally, a high heat-transfer co-efficient will be obtained by allocating the more viscous material to the shell side, provided the flow is turbulent. The critical Reynolds numbers from turbulent flow in the shell is in region of 200. If turbulent flow cannot be achieved in the shell, it is better to place the fluid in the tubes, as the tube-side heat-transfer coefficients can be predicted with more ceterainly.

(7) **STEAM FLOW –RATES:** Allocating the fluid with the lowest flow rate to the shell side will normally give the most economical design.

3.2.1. PRESSURE DROP

3.2.2. TUBE – SIDE PRESSURE DROP

There are two major sources of pressure loss on he tube-side of a shell and tube exchanger. These are namely the friction loss in the tubes and the losses due to the sudden contraction and expansion and flow reversal that the fluid experiences in flow through the tube arrangement.

The basic equation for isothermal flow in pipes (Constant temp) Is:

.... (3.25)

The flow in a heat exchanger will clearly not be isothermal, and this is allowed for, by including an empirical correction factor accounting for the change in physical properties with temperature. Normally only the change in viscosity is considered:

$$\Delta P = 8 \times j_f \times \left(\frac{L}{d_i}\right) \times \frac{\rho \times \mu_t^2}{2} \times \left(\frac{\mu}{\mu_w}\right)^{-m} \qquad \text{.......................... (3.26)}$$

m = 0.25 for laminar flow, $Re < 2100$

m = 0.14 for turbulent flow, $Re > 2100$

There is no entirely satisfactory method for estimating these losses.
Kern (1950) suggest adding four velocity heads per pass. Frank (1978) considers this to be too high, and recommends 2.5 velocity heads. From this, it appears that frank's recommended value of 2.5 velocity heads per pass is the most realistic value to use. Combining these factors with equation 2.26 gives:

$$\Delta P = N_p \times \left[8 \times j_f \times \left(\frac{L}{d_i} \right) \times \frac{\rho \times \mu_t^{\,2}}{2} \times \left(\frac{\mu}{\mu_w} \right)^{-m} + 2.5 \right] \times \frac{\rho \times \mu_t}{2} \qquad \text{............ (3.27)}$$

3.2.3. SHELL – SIDE PRESSUE DROP

This method was based on experimental work on commercial heat exchangers with standard tolerance and will give a reasonable satisfactory prediction of heat transfer coefficient for standard designs. The prediction of pressure drop is less satisfactory, as pressure drop is more affected by leakage and by passing than heat transfer. Shell-side jf factor for use in this method are given in standard graphs for various baffle cuts and tube arrangements. Computer modules have been developed for these graphs and it takes care of the necessary options without the designer referring to the graphs.

The procedure for calculating the shell-side heat transfers coefficient and a pressure drop for a single shell pass exchanger as given below.

(1) Calculate the area for cross- flow as for the hypothetical row of tubes at the shell using equation given by;

The term (Pt – do) / pt is the ratio of the clearance between tubes and the total distance between tube centers.

$$A_s = \frac{(P_t - d_0) \times D_s \times L_B}{P_t} \qquad \text{................................ (3.28)}$$

(2) Calculate the shell – side mass velocity Gs and the linear velocity Us:.

$$G_s = \frac{W_s}{A_s} \qquad \text{..................... (3.29a)}$$

$$U_s = \frac{G_s}{\rho} \qquad \text{........................... (3.29b)}$$

(3)Calculate the shell -- side equivalent diameter (Hydraulic diameter).For a square pitch arrangement

$$d_e = \frac{1.27}{d_0} \times \left(P_t^2 - 0.785 \times d_0^2\right) \qquad \text{:..(3.30)}$$

$$d_e = \frac{A \times \left(P_t - \frac{\pi \times d_0}{A}\right)}{\pi \times d_0}$$

For an equilateral triangular pitch arrangement.

$$d_e = \frac{A \times \left[\left(\frac{P_t}{2}\right) \times 0.87 \times P_t - \frac{1}{2} \times \pi \times \frac{d_0^2}{A}\right]}{\pi \times \frac{d_0}{2}} \qquad \text{............................. (3.31)}$$

$$d_e = \frac{1.10}{d_0} \times \left(P_t^2 - 0.917 \times d_0^2\right)$$

(4) Calculate the shell – side Reynolds number, given by:

$$Re = \frac{G_s \times d_e}{\mu_v} \qquad \text{................................... (3.32)}$$

(5) For the calculated shell-side Reynolds number, read the friction factor from kern's graph and calculate the shell-side pressure drop from:

$$\Delta P_S = 8 \times j_f \times \left(\frac{D_S}{d_e}\right) \times \left(\frac{L}{L_B}\right) \times \rho \times \frac{U_S^2}{2} \times \left(\frac{\mu}{\mu_w}\right)^{-0.14}$$

The term (L/L_B) is the number of times the flow crosses the tube bundle (Nb +1) where Nb is the number of baffles.

3.2.4. CONDENSATION HEAT TRANSFER

3.2.5. HEAT TRANSFER COEFFICIENT

$$h_{C_b} = 0.95 \times K_L \times \left[\frac{\rho_L \times (\rho_L - \rho_V) \times g}{\mu_L \times \tau_h}\right]^{\frac{1}{3}} \times N_r^{\frac{-1}{6}} \quad \text{.............. (3.34)}$$

The above equation is governing condensation outside horizontal tube.

In a bank of tubes, the condensate from the upper rows of tubes will add to that condensing on the lower tubes. If there are Nn tubes in a vertical row and the condensate is assumed to flow smoothly from row to row, and if the flow remains laminar, the mean coefficient predicted by the Nusselt model is related to that for the top tube by.

$$h_{c_{NT}} = (h_c) \times N_r^{\frac{-1}{4}} \quad \text{........................... (3.35)}$$

In practice, the condensate will not flow smoothly from tube to tube, and the factor of (Nr) – ¼ applied to the single tube co-efficient in equation 2.35 is considered to be too conservative. Based on result from commercial exchangers, kern (1950), suggests using an index of 1/6. Frank (1978) suggests multiplying single tube coefficient by a factor 0.75. Using kern's method, the mean coefficient for a tube bundle is given by;

$$h_{C_b} = 0.95 \times K_L \times \left[\frac{\rho_L \times (\rho_L - \rho_V) \times g}{\mu_L \times \tau_h}\right]^{\frac{1}{3}} \times N_r^{\frac{-1}{6}} \qquad \text{(3.36)}$$

$$\tau_h = \frac{W_C}{L \times N_t} \qquad \text{(3.37)}$$

3.2.6. SHELL HEAT TRANSFER COEEFICIENT

When condensation occurs in a horizontal tube, the heat transfer coefficient at any point along the tube will depend on the flow pattern at that point. The various patterns that can exist in two phases flow.

The flow models are used to estimate the mean condensation co-efficient in horizontal tubes. These can be stratified flow and annular flow. For stratified flow model, the condensate film coefficient can be estimated from the nusselt equation, the coefficient for stratified flow can be estimated from.

$$h_{C_S} = 0.76 \times K_L \times \left[\frac{\rho_L \times (\rho_L - \rho_V) \times g}{\mu_L \times \tau_h}\right]^{\frac{1}{3}} \qquad \text{(3.38)}$$

The Boyko – kruzhilin equation can be used to estimate the co-efficient for annular flow. It is given by:

$$h_i = 0.02 k \left(\frac{K_L}{d_i}\right) \times Re^{0.8} \times Pr^{0.43} \qquad \text{(3.39)}$$

3.2.7. DESIGN EQUATIONS

The equations used in this program are modeled from graphs using a powerful computer package called MATHCAD 2000 professional. Mathcad has the capacity to predict co-efficient and constants of both linear and non-linear equations with random values taken at various points. Most importantly the variations are always negligible, in addition to the plotting capability of the package. Thus the equations developed are:

(1) BUNDLE CLEARANCE

(a) For pull-trough floating head

$C = 85.976364 + 9.636364Db.$

(b) For split – ring floating head

$C = 44.793939 + 27.393939\ Db$

(c) For outside packed head

$C = 38$

(d) for fixed and U-tube head

$C = 8.192857 + 10.071429\ Db$

(2) FRICTION FACTOR

(a) Shell-side friction factor

For 100 < Re < 1000

$$Jf_1 = 0.253467 - 0.000097324401Re + 0.00000151655\ Re^2 - 0.0000000752918Re^3$$

For 1000 < Re < 10000

$$Jf_1 = 0.052667 - 0.000003972727Re + 1.96967 \times 10^{-10}\ Re^2$$

For 1000 < Re < 10000

$$Jf_1 = 0.003967 - 0.0000001498485Re + 2.272731 \times 10^{-13}\ Re^2$$

For 1000 < Re < 10000

$Jf_1 = 0.022247 - 0.0000001282424Rc + 5.757922 \times 10^{-15} Rc^2$

(b) Tube-side friction factor

For 10 < Rc < 100

$Jf_2 = 16.363334 - 1.160773\ Rc + 0.037895\ Rc^2 - 0.0006170979\ Rc^3 +$ $0/000004873543\ Rc^4 - 0.00000001487179Rc^5$

For 1000 < Rc < 100000

$Jf_2 = 0.00501 - 0.0000000444697\ Rc + 2.1967 \times 10^{-13}\ Rc^2$

3.2.9. SAMPLE PROBLEM

Design a shell and tube for the following heat duty. 10000kg/h of methanol leaves the base of a methanol side stripping column at 95 °C and is to be cooled to 40 °C by exchanging with 20, 000 kg/hr water coming from storage at 25 °C. The methanol enters the exchanger at a pressure of 5 bar and the water at 6.5 bar. A pressure drop of 0.8 bar is permissible on both streams. Allowance should be made for fouling by including a fouling factor of 0.00035 ($W/m^2\ ^oC$) on the water stream and 0.0002 ($W/m^2\ ^oC$) on the methanol stream.

3.3.0. MANUAL CALCULATION

Only the thermal design will be considered
This example & illustrates Kern's method
Coolant is corrosive, so assign to tube – side
Heat capacity methanol = 2. 84KJ/Kg°C.

$$\text{Heat load} = \frac{100{,}00}{360} \times 2.84\,(95 - 40) = 4340\text{Kw}$$

Heat capacity water = 4.2KJ/Kg°C

$$\text{Cooling water flow} = \frac{4340}{4.2(40 - 25)} = 68.9\text{kg/s}$$

$$(3.4)\quad AT_{lm} = \frac{(95 - 40) - (40 - 25)}{\ln \frac{(95 - 40)}{(40 - 25)}} = 31^oC$$

Use one shell pass and two tube passes

3.6 $$R = \frac{95 - 40}{40 - 25} = 3.67$$

3.7 $$S = \frac{40 - 25}{95 - 25} = 0.21$$

From fig 12.19 $F_t = 0.85$

$\Delta T_m = 0.85 \times 31 = 26^{0}C$

From fig 12.1 $U = 600 w/m^{2 0}C$

Provisional area

3.1 $$A = \frac{4340 \times 10^3}{26 \times 600} = 278m^2$$

Choose 20mm o.d, 16mm.id, 4.88m – long tube (¾in x 16ft)
Cropro – nickel Allowing for tube – sheet thickness take

$L = 4.83m$

Area of one tube = $4.83 \times 20 \times 10^{-3} \pi = 0.303m^2$

Number of tubes = $\frac{278}{0.303} = 918$

As the shell – side fluid is relatively clean use 1.25 triangular pitch.

(2.3b) Bundle diameter $D_b = 20 \left(\frac{918}{0.249}\right)^{1/2.207} = 826mm$

Use a spit – ring floating heat type
From fig. 12.10, bundle diameter clearance = 68mm

Shell diameter, $D_s = 826 + 68 = 894mm$

(Note nearest standard pipe sizes are 863.6 or 914.4mm.
Shell size could be read from standard tube count tables.

Tube side coefficient

Mean water temperature =40 + 25 = 33°C

Tube Cross – sectional area = $\pi \times 16^2 = 201mm^2$

Tube per pass = $\frac{918}{2} = 459$

Total flow area = $459 \times 201 \times 10^{-6} = 0.092m^2$

Water mass velocity = 68.9 = 749Kg/sm²

Density water = $995 kg/m^3$

Water linear velocity = 749/995 = 0.75m/s

(3.17) hi = 4200 (1.35 + 0.02 x 33) $0.75^{0.3}/m^{2 0}C$

The coefficient can also be calculated using equation 12.15, this is done to illustrate use of this method

$$\frac{Hidi}{kf} = jl\ Re\ Pr^{0.33} \left(\frac{\mu}{\mu}\right) 0.14$$

Viscosity of water = $0.8 mNS/M^2$

Thermal conductivity = $0.59\ w/m^oC$

$$Re = \frac{Pudi}{\mu} = \frac{995 \times 0.75 \times 16 \times 10^{-3}}{0.8 \times 10^{-3}} = 14,925$$

$$pr = \frac{Cp\mu}{kf} = \frac{4.2 \times 10^3 \times 0.8 \times 10^{-3}}{0.59} = 5.7$$

Neglect (μ/uw)

$$L/di = \frac{4.83}{16} \times 10^3$$

from fig 12.23 jh = 3.9×10^{-3}

$$hi = \frac{0.59}{16 \times 10^{-3}} \times 3.9 \times 10^{-3}\ 14,925 \times 15.7^{0.33} = 3812 w/m^2C$$

Cheeks rean sunably well with value calculated from equation 12.17, use lower figure

Shell – side coefficient

Choose baffle spacing = $Ds/5 = \frac{894}{5} = 178mm$

Tube pitch = 1.25 x 20 = 25mm

Cross – flow area

3.21 As = (25 – 20) 894 x 178 x 10^{-6} = $0.032m^2$

mass Velocity Gs = $\frac{100,000}{3600} \times \frac{1}{0.032} = 868 kg/5m^2$

Equivalent diameter

3.23 de = 1.1 (25^2 – 0.917 x 20^2) = 14.4mm

Mean shell side temperature = $\frac{95 + 40}{2} = 68^oC$

Methanol density = $750 kg/m^3$

Viscosity = $0.34m\ Ns/m^2$

Heat Capacity = 2. $84 kg/kg^oC$

Thermal Conductivity = $0.19 w/m^oC$

3.24 $Re = \frac{Gsde}{\mu} = \frac{868 \times 14.4 \times 10^{-3}}{0.34 \times 10^{-3}} = 36{,}762$

$Pr = \frac{Cp\mu}{Kf} = \frac{2.84 \times 10^{3} \times 0.34 \times 10^{-3}}{0.19} = 5.1$

Choose 25 percent baffle cut, from fig 12.29

$jh = 3.3 \times 10^{-3}$

without the Viscosity correction term

3.25 $hs = \frac{0.19}{14.4 \times 10^{-3}} \times 3.3 \times 10^{-3} \times 36,762 \times 5.1^{1/3} = 2740 w/m^{2 0}C$

estimate wall temperature

mean temperature difference = 68 – 33 = 35°C

across all resistance

across methanol film = $\mu \times \Delta T = \frac{600}{2740} \times 35 = 8^{0}C$

mean wall temperature = 68 – 8 = 60°C

$\mu w = 0.37m\ Ms/m^2$

$\left(\frac{\mu}{\mu w}\right)^{0.14} = 0.99$

which shows that the correlation for a low – viscosity fluid is not significant

Overall coefficient

Thermal conducting of cupro – nichel alloys = 50w/m°C.

Take the following coefficients as 6000w/m^{20}C.

3.11 $\frac{1}{\mu} = \frac{1}{2740} + \frac{1}{6000} + \frac{20 \times 10^{-3} \ln (20/16)}{2 \times 50} + \frac{20}{16} \times \frac{1}{6000} + \frac{20}{11} \times \frac{1}{3812}$

$\mu_0 = 899 w/m^{2\ 0}C$

pressure drop

tube – side

from fig 12.24, for re = 14,925

$jf = 4.3 \times 10^{-3}$

Neglecting the Viscosity correction term

(3.20) Pt $= 2(8 \times 4.3 \times 10^{-3} \frac{(4.83 \times 10^{3})}{16} + 2.5) \frac{995 \times 0.75^2}{2}$

Shell side

Linear Velocity $\frac{Gs}{P} = \frac{868}{750} = 1.16m/s$

From Fig. 12.30 at Re = 36, 762
$Jf = 4 \times 10^{-2}$

Neglect Viscosity Correction

3.26 $ds = 8 \times 4 \times 10^{-2} \frac{(894)}{14.4} \frac{(4.83 \times 10^{3})}{178} \quad \frac{75. \times 1.16^2}{}$

$= 272, 019N/m^2$

272KP,a

3.4. ELEMENT OF SYSTEM DESIGN

3.4.1. SYSTEM DESIGN

After analysis of the current system, the next step in the system processes, is the designing of the new system. This is achieved only after the system analysis by the analyst approved the proposal of a new system.

3.4..2. NEW SYSTEM DESIGN CRITERIA

(a) Volume: - the proposed system is designed to handle large amount of data for evaluation.

(b) Simplicity: - The system through designed to handle complete operations of computation or evaluation should be simple to use.

(c) Flexibility: - the system can operate in a dynamic rather than static environment

(d) Security: - The security of the system should be taken into consideration, such that the output report are provided only for the authorized user to have access.

(e) Efficiency: - The system should be desired of the desire evaluation.

(f) User or friendly: - It system should be designed in such a way that it simply gives the operations a choice of different transaction for implementation.

3.4.3. INPUT DESIGN

Input design is one of the items of elements of design. In designing a system, the type of input media, Data collection method, volume of input documents and design of input layouts are to be put into consideration. The purpose of input design is to make sure that all input data are correctly identified and accurately recorded and also that the processing of all data is accomplished without addition or omission.

3.4.4. INPUT SPECIFICATION

In the design a new system, the following specification are required:-

(1) Total heat load

(2) Fluid quantities entering and leaving the exchanger

(3) Inlet and outlet temperature of the fluid in use.

(4) Fouling factors of the fluid in use.

(5) Heat exchanger type

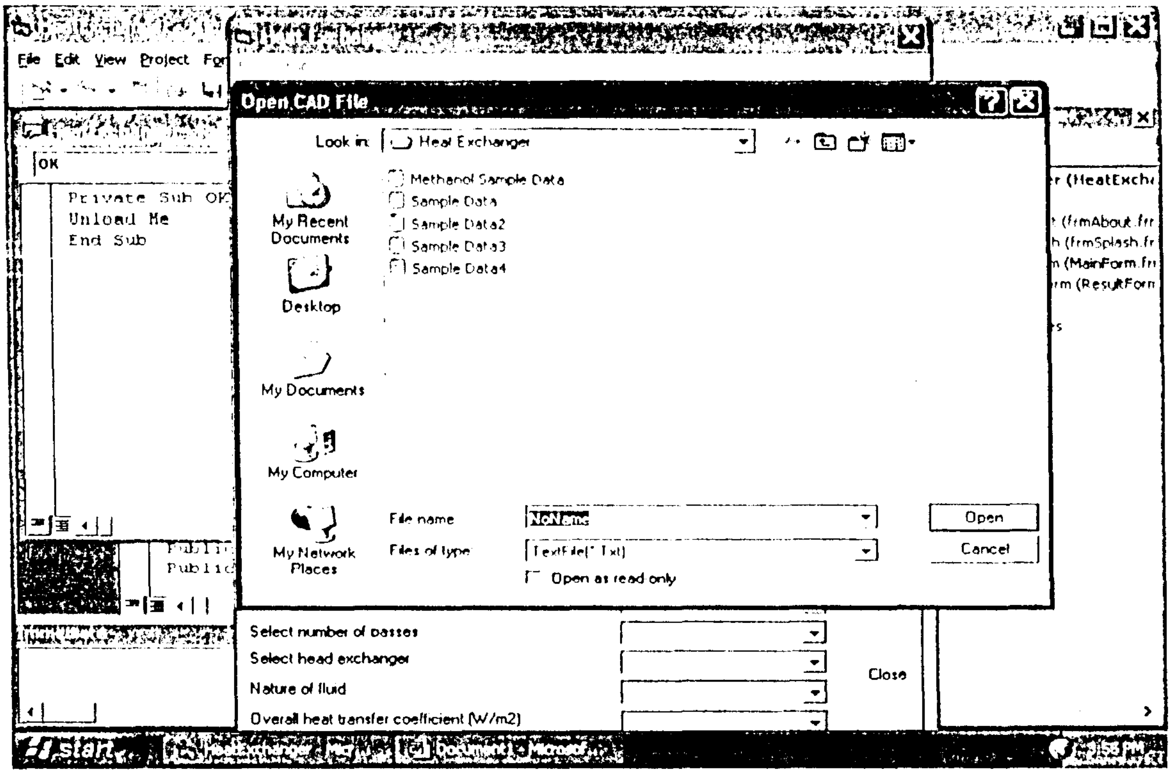
(6) Allowable pressure drop

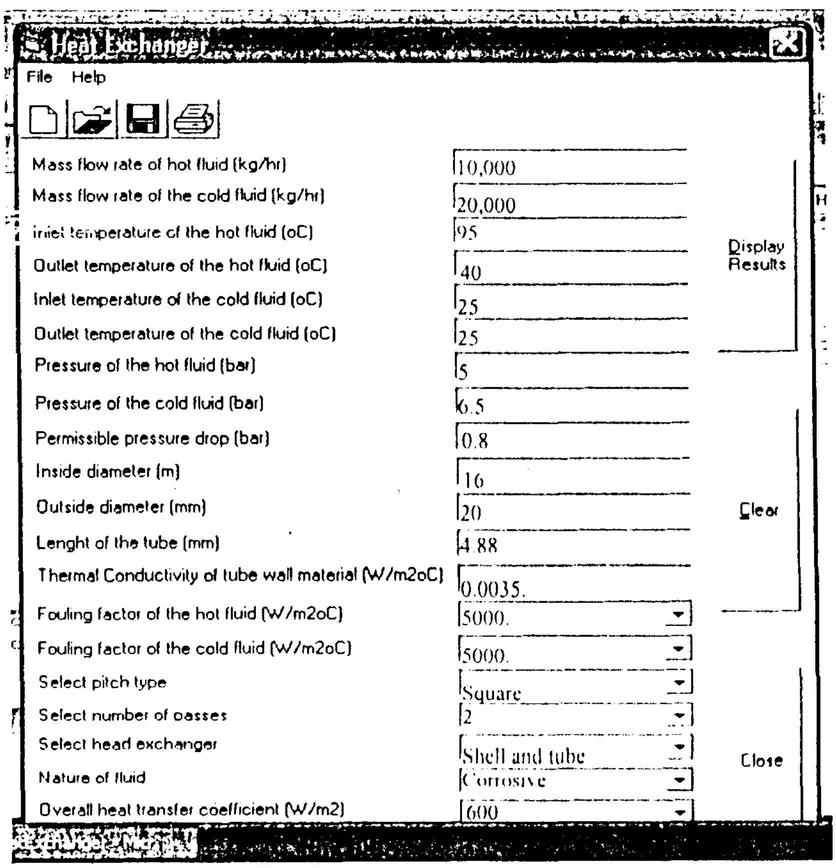
(7) Design pressure

(8) Take wall thickness for corrosion consideration

(9) Size or space limitation

(10) Horizontal or vertical installation limit


Open CAD File
Look in: Heat Exchanger
Methanol Sample Data
Sample Data
Sample Data2
Sample Data3
Sample Data4
My Recent Documents
Desktop
My Documents
My Computer
My Network Places
File name
Files of type
Open as read only
Open
Cancel
Private Sub OK
Unload Me
End Sub
Select number of passes
Select head exchanger
Nature of fluid
Overall heat transfer coefficient (W/m2)
Close


Heat Exchanger
File Help
Mass flow rate of hot fluid (kg/hr)
10,000
Mass flow rate of the cold fluid (kg/hr)
20,000
inlet temperature of the hot fluid (oC)
95
Outlet temperature of the hot fluid (oC)
40
Inlet temperature of the cold fluid (oC)
25
Outlet temperature of the cold fluid (oC)
25
Pressure of the hot fluid (bar)
5
Pressure of the cold fluid (bar)
6.5
Permissible pressure drop (bar)
0.8
Inside diameter (m)
16
Outside diameter (mm)
20
Lenght of the tube (mm)
4.88
Thermal Conductivity of tube wall material (W/m2oC)
0.0035.
Fouling factor of the hot fluid (W/m2oC)
5000.
Fouling factor of the cold fluid (W/m2oC)
5000.
Select pitch type
Square
Select number of passes
2
Select head exchanger
Shell and tube
Nature of fluid
Corrosive
Overall heat transfer coefficient (W/m2)
600
Display Results
Clear
Close

3.4.5. OUTPUT DESIGN

Output design is establishable as a final check on the accuracy of the processed data. In designing an output, certain, things are to be put into consideration such as the time and how often the output result is needed, whether daily, weekly e.t.c. for this heat exchanger result is needed immediately.

3.4.6. OUTPUT SPECIFICATION

The output report that is expected from the new system are: -

(1) Calculated LMTD

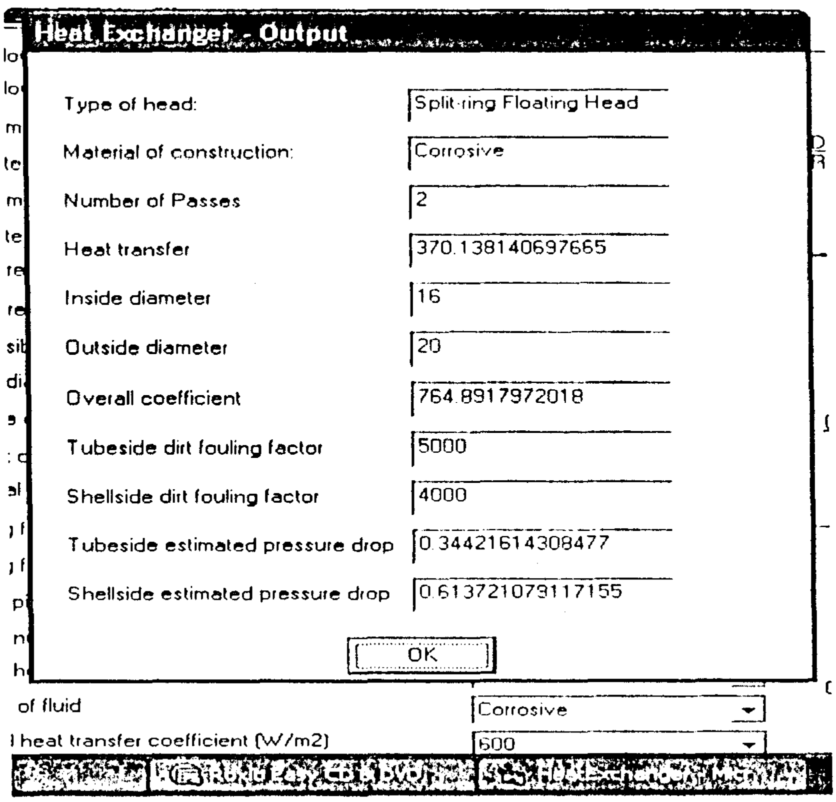
(2) Calculated Shell – Side Coefficient

(3) Calculated tube – side Coefficient

(4) Calculated overall coefficient

(5) Calculated pressure drop of tube

(6) Calculated pressure drop of side



3.4.7. COST BENEFIT ANALYSIS

The proposed system will need hardware and software and human ware to accomplish its task or purpose. The project cost of developing the system are as follows

3.5.1. COST OF DEVELOPING SYSTEM

System analysis and requirement determination (5 weeks) for

2 person	= N2000	N4000
System Design		
4 weeks		N8,000
Development and Implement		
5 diskettes		N400
A complete cost hardware with		N120,000
Pentium 4 processor		N136,000

The Consultancy fees for designing Heat exchanger is about N150, 000.Comparing the cost of design and implementing the software with the cost to charge a Chemical firm that wants Heat exchanger. Also coupled with time, speed saved in using the software. The benefit still outweighed the costs of designing the system. Hence, it is recommended.

CHAPTER FOUR

4.0. SYSTEM DEVELOPMENT AND IMPLEMENTATION

4.1. INTRODUCTION

In every system development, the emphasis is to develop a system structure into a program that will help in achieving the goals of the proposed system.

This Chapter discusses the programming language use, shows the algorithms and in addition, detail on the operation of the new system is explain.

4.2. PROGRAMMING LANGUAGE USED

Programming language selection involves determining of the best programming language for the application. Some factors to be considered includes: -

(a) The difficulty of the program

(b) The technical skill required of the computer programmer.

(c) The availability of programmers for various languages.

(d) The availability of sub routine that may be used by the program

(e) The existing hardware and software configuration.

In developing this system, visual Basic programming Language is used. The main reason of choosing is that is easy to understand and use.

Other advantage over other programmes includes:- CAS soon as the user submits a program and some data to the computer the computer executes the program, produces the result back to the users immediately, thus, it easy for the user to find out whether the program is working properly or there is a bug.

In most scientific field and Engineering field Visual basic is used to perform complex calculation on small set of data or simple calculation, which involves complicated manipulation of large set of data. Thus these are major things carried out in design of shell and to be heat exchanger.

4.3. ALGORITHMS

Algorithms can be defined as a set of well defined instructions for the solution of a problem in a finite number of steps.

Design steps

The following the steps taken in design procedure.

(a) Define the duty: heat transfer rate, fluid flow rate temperature

(b) Collect together the fluids physical properties required: - density, viscosity and thermal conductivity.

(c) Decide on the layout of the condenses to be used.

(d) Select a trial value for the over all coefficient U

(e) Calculate the mean temperature difference, DTM

(f) Calculate the required area.

(g) Calculate the tube and shell coefficient. Calculate the overall coefficient and compare with the trial value. If the calculated value differs significantly from the estimated value, substitute the value calculated for the estimated value and return to step C

(h) Calculate the exchanger pressure drop; if unsatisfactory, return to step f or d or c in order of preference.

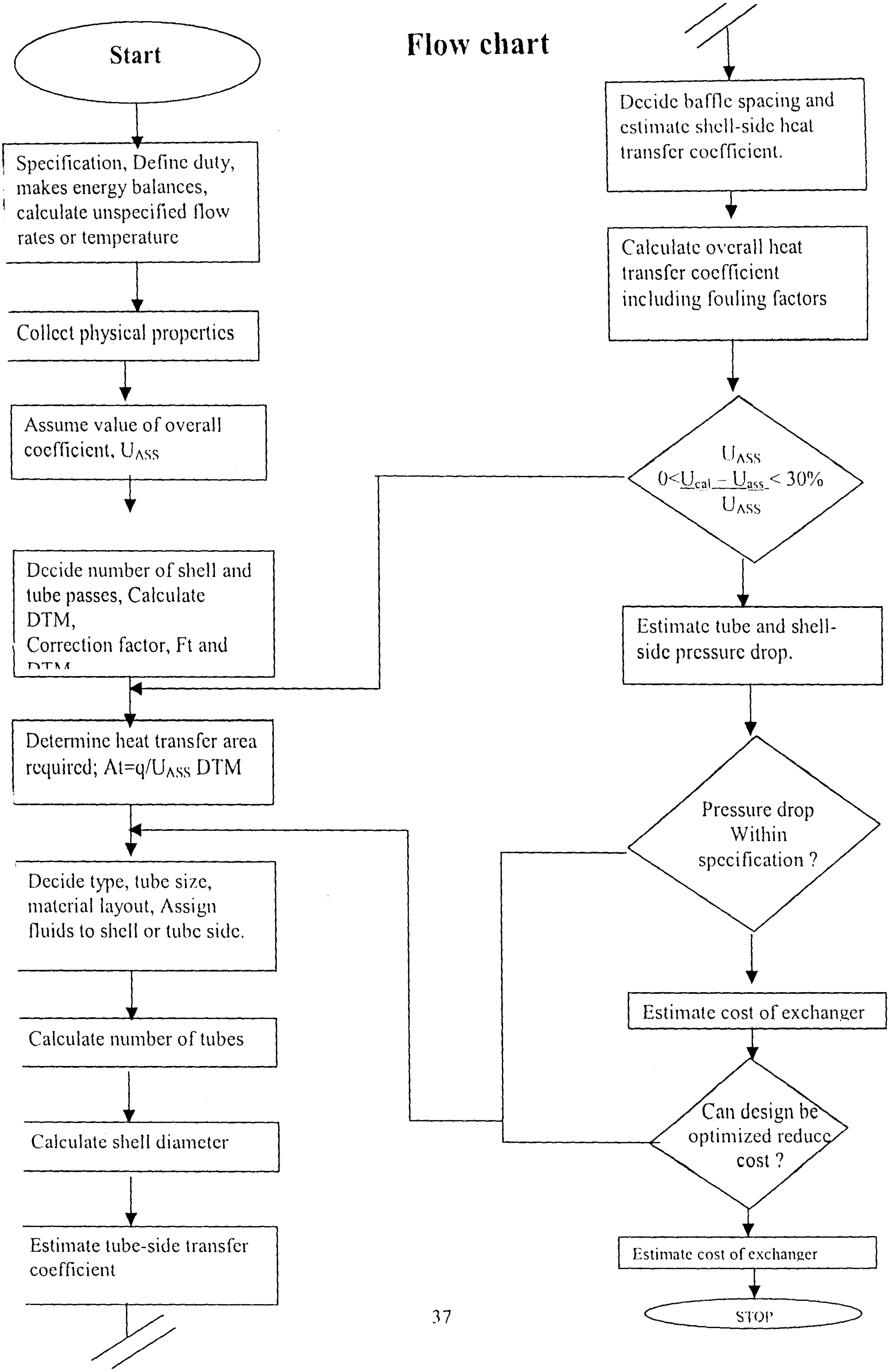
(i) Optimise the design. Repeat steps d to j, as necessary, to determine the cheapest exchanger that will satisfy the duty. Usually this will be the one with smallest area.

4.4 PROGRAM CODES

The programme is developed in visual basic environment, with a view of eliminating the rigour of going through several databanks, use of tables in determination of physical properties and various coefficients associated with in previous similar programs.

The procedure adopted in coding this program, is the use of equations for monographs, charts and graphs thereby minimizing errors encountered during data reading them. In addition, the computation is such that, it is independent of interpolations which are also source of errors when using tables Databank is incorporated, for calculating specific heat capacities and conductivities at various temperature Also, fouling factors are added into the databank, so that design for various compounds can be accommodated.

Flow chart


Start
Specification, Define duty, makes energy balances, calculate unspecified flow rates or temperature
Collect physical properties
Assume value of overall coefficient, U_{ASS}
Decide number of shell and tube passes, Calculate DTM, Correction factor, Ft and DTM
Determine heat transfer area required; $At = q/U_{ASS}$ DTM
Decide type, tube size, material layout, Assign fluids to shell or tube side.
Calculate number of tubes
Calculate shell diameter
Estimate tube-side transfer coefficient
Decide baffle spacing and estimate shell-side heat transfer coefficient.
Calculate overall heat transfer coefficient including fouling factors
$0 < \frac{U_{cal} - U_{ass}}{U_{ASS}} < 30\%$
Estimate tube and shell-side pressure drop.
Pressure drop Within specification ?
Estimate cost of exchanger
Can design be optimized reduce cost ?
Estimate cost of exchanger
STOP

4.5. PROGRAM INTERFACE /DOCUMENTATION

The program (listing in appendix) can be run in three ways viz:

(a) On Visual Basic (VB) environment.

(b) At DOS prompt.

(c) Using a set up utility [compiled form].

STEP 1: On VB environment, open the floppy disk containing the Program.

STEP 2: Click on "EXISTING" then on "CADMHEATEXCHANGER"; the flask form (fig c1) appears for few seconds, followed by the main form (fig c2) for input data.

STEP 3: Input the appropriate data under the appropriate headings. Make the required specifications, making sure of consistent units.

STEP 4: Click on "DISPLAY RESULT" Button. The evaluated results for various parameters are shown.

STEP 5: Click on "CLOSE" button, to close the result.

STEP 6: The results obtained can be saved, opened and printed.

STEP 7: A new form can be obtained by clicking on new.

The results are summarised in Table 4.1. Details of the calculations are shown in appendix B while the computer printouts for CAD module are given in appendix C.

4.6 RESULT

Table 4.1 Comparison of CAD result and Manual solutions

DESIGN PARAMETER	DESIGN SOLUTIONS	
	CAD	MANUAL
Type of Head	Split ring floating Head	Split ring floating Head
Material of construction	Carbon steel	Carbon steel
Number of passes	1 shell pass , 4 tube passes	1 shell pass , 4 tube passes
Heat transfer area m^2	370.138	278
Inside diameter mm	16	16
Outside diameter mm	20	20
Overall coefficient estimate, $W/m^2\,^oC$	797.204	899
Tubeside Dirt Fouling factor, $(W/m^2\,^oC)^{-1}$	5000	6000
Shellside Dirt fouling factor $(W/m^2\,^oC)^{-1}$	4000	4000
Tubeside estimated pressure drop bar	0.3442	0.3
Shellside estimated pressure drop bar	0.6137	0.365

4.6 1. DISCUSSION OF RESULT

The result obtained by the computer-aided design, compares favorably with the standard result computed manually, the values of parameters like the heat duty of the hot fluid, which in turn used in the determination of the tube velocity, the number of tubes, various temperatures tally accurately.

The number of tubes calculated using the CAD is a little bit higher as a result of approximations used in calculating the trial area, during manual evaluation, since the former utilizes higher decimal place in addition to the automatic iteration ability embedded in the program.

The overall – co-efficient, which is a very vital parameter in the design of all heat transfer equipment is found to be very accurate when compared with the manual result, which was obtained through a laborious "trial and error'. But such a task is achieved within seconds of running the program. This can be appreciated for the fact that, it is this value that indicates the continuation or otherwise of the design.

The shell-side pressure drop is higher in CAD. This is as a result of inaccurate accessibility of data of several mixtures of the hydrocarbons involved. Properties like viscosity and conductivity vary slightly due to variation in the physical properties of the components involved, hence the cause of the deviation.

The value of the tube-side pressure drop is within a reasonable degree of tolerance compared to the manual value. This is because water is taken as the coolant for this heat exchanger, for economic reasons.

All the computer-aided design results can be altered by changing one or two parameters, depending on the program's algorithm.

Finally, the correlation coefficient obtained is very close to 1 which shows that the two results have almost agreed.

4.7 CHANGE OVER

The change from the old system to the new system is known as conversion, it involves the conversion of the old file data into the firm required by the new system. There are four method of handling a system conversion. Each method is considered based on the opportunities, it offers and problems that it may cause or have.

(a) Parallel system: - This is the most secured method of converting from old to new system. Under the approach, users continue to operate the old and the new systems the output or result from both system are cross – checked.

For this computer aid design of heat exchanger parallel system was used.

4.8 Installation

The following tools will be needed to check the quality of the new system.

(i) Code testing and specification Test: - This test examine what program should do how it should do it, in line with the result obtained.

(ii) Verification Test: - This test involves executing the software in a simulated environment, using some assumption, testing a data for error findings

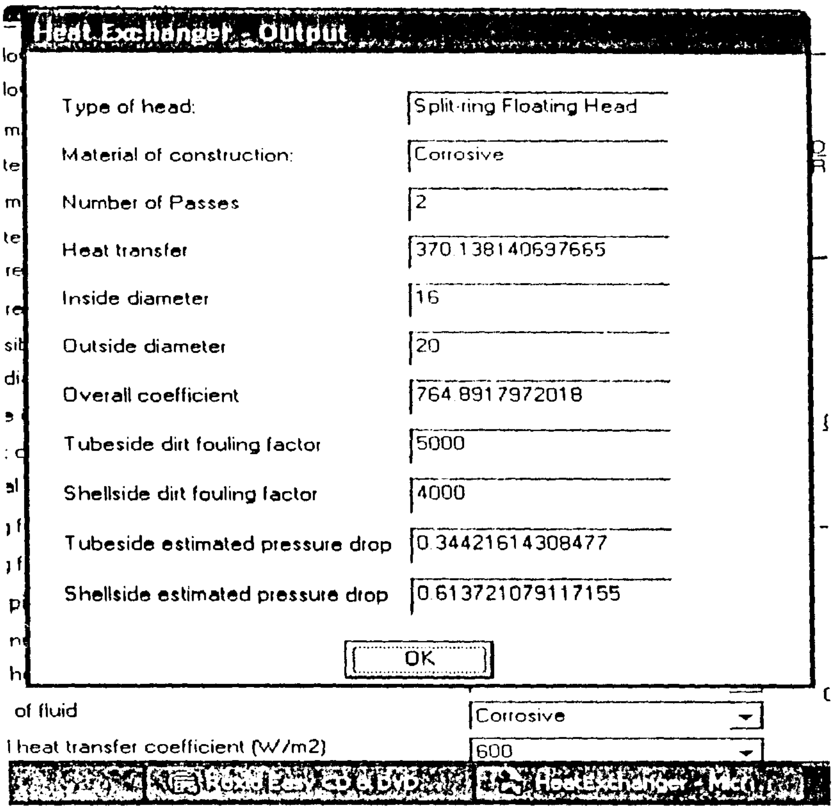
(iii) Validation test: - This test involve, the process of using soft ware in a live environment for the purpose of spotting error.

(iv) Certification test: - This test involves endorsement of software for correctness.

4.9 TRAINING PERSONNEL

Even a well designed and technical system can fail because of the way they are operated and used. Hence personnel that will use this computer aided design must be given an appropriate training once the system is implemented to enable him or her have the basic knowledge on how to operate the computer and its peripheral device

Output of the Program



CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. SUMMARY

This piece of work has been carried out with the aim to develop program that can perform the rigorous and tedious calculations needed in the design simulation and optimization of a shell and tube heat exchanger.

Before the designing of the new system a though study of the manual design system used in a certified literature (Richardson and Coulson Vol 6) was taken. During the study of the design, it was discovered that the manual system was characterized by limitations such as

(1) Rigorous and tedious calculations

(2) Dependency on graphs and table for basic data

(3) Simulation and optimization of a shell and tube exchanger.

(4) Delay in the result of design

The (program) computerized system was designed in order to reduce all the lapses that were characterized with the manual system the program was developed in Visual basic environment.

The result obtained by the computer aided design, compares favourably with the standard result computed manually, the values of parameters like the heat duty of the hot fluid, which in turn used in the determination of the tube velocity, the number of tubes, various temperature tally accurately.

The overall -- coefficient, which is a very vital parameter in the design of all heat transfer equipment is found to be very accurate when compared with the manual result, which was obtained through a laborious "trial and error" But such a task is achieved within seconds of running the program.

5.2. CONCLUSION

From the result obtained and discussed, it is obvious that computer aided design saves time, energy, cost and minimizes errors. Thus, for optimization of any parameter at any given condition, the result can be used, since it is easily accessed within short period of time.

The module is easy to run, therefore a lot of value can be tried and the best optimal value would be obtained. The versatility of this program and in effect its result makes it possible for easy economic analysis and easy equipment construction.

Finally, the program gives a designer the opportunity to shift emphasis on calculations during the conceptual stage and during the design stage to the final design stage.

5.3 RECOMMENDATION

Although work has been done in computer-aided design of a heat exchanger, there is still the need to:

1. Extend this work to cover mechanical design such as evaluating length, diameter e.t.c
2. Design other configurations and types of heat exchanger for a specific Operation.
3. Expand the database to include large numbers of components.
4. Lastly, in terms of accuracy, the new system provides accurate evaluation and generates a comprehensive result, it is therefore recommended.

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APPENDIX A

PROGRAM SOURCE CODE

STANDARD MODULE(MODULE1.BAS) DECLARATIONS(global variable declarations i.e variables visible to all form modules in the project.)

```
Dim ResultLabel As String
Dim MenuItem As Integer
Dim MenuItem2 As Integer
Dim ResultString As String
Public ResultArray() As String
Public ResultCounter As Integer

'declarations

Public Factor As ClassFoulingFactor
Public FactorCollection As Collection

Public i As Integer
Public CountMolecular As Integer
Public HV As Single
Public hc As Single
Public T As Double 'Reference Temperature
Public QV As Single
Public Wc As Single
Public CW As Single
Public Tc As Single
Public Tc1 As Single 'tc
Public R As Single
Public Tv As Double
Public Tv1 As Double 'tv
Public S As Single
Public Tlm As Double
Public Ft As Single
Public Tm As Double
Public UASS As Single
Public At As Single
Public SA As Double
Public D0 As Double
Public D1 As Double
Public L As Double
Public Nt As Double
Public OldNt As Single
Public Pt As Single
```

```
Public BundleDiameter As Double
Public BundleClearance As Double
Public C As Double
Public Nr As Single
Public Tss As Double
Public Tts As Double
Public Uc As Double
Public Tw As Double
Public Tmc As Double
Public rhoc As Double
Public Vis As Double
Public Kl As Single
Public MolecularWeight As Double
Public CPc As Double
Public TR As Double
Public AMW As Double
Public rhov As Double
Public Th As Double
Public No As Double

Public ShellCoefficient As Single
Public Atc As Double
Public rhow As Double
Public Vt As Double
Public hi As Double
Public Kw As Double
Public hod As Single

Public Ucal As Double
Public sid As Double
Public As1 As Double
Public Gs As Double
Public de As Double
Public Re As Double

Public Re1 As Double
Public jf1 As Double
Public jf2 As Double
Public Us As Double
Public Ps As Double
Public Visw As Double
Public Ut As Double

Public db As Database
Public rs As Recordset
Public qr As QueryDef
```

```
Public db1 As Database
Public rs1 As Recordset
Public qr1 As QueryDef

Public k1 As Double
Public n1 As Double

Public NameOfFile As String
Public FileHandle As Long


Sub main()
frmSplash.Show

End Sub
```

CLASS MODULE(CLASSFOULINGFACTOR.CLS)

DECLARATIONS(Associates a compound with its Fouling Factor)

```
Public CompoundName As String
Public FoulingFactor As Long
```

MAINFORM CODE(The main user interface where program execution starts from)

```
Dim myArray(1 To 6) As Long

Public Function PrintResultToFile(Counter As Integer) As String
Dim ResultString2 As String

Select Case Counter
Case 1: ResultString2 = "Cooling Water Flow(Kg/s)=" & " " & Str(CW)

 Case 2: ResultString2 = "Trial Area(m2)=" & " " & Str(At)


 Case 3: ResultString2 = "Surface Area One Tube(m2)=" & " " & Str(SA)
```

```
Case 4: ResultString2 = "Number Of Tubes=" & " " & Str(Nt)

Case 5: ResultString2 = "Number Of Tubes In Centre Row=" & " " & Str(Nr)

Case 6: ResultString2 = "Shell-side temperature(oC)=" & " " & Str(Tss)

Case 7: ResultString2 = "Tube-side temperature(oC)=" & " " & Str(Tts)

Case 8: ResultString2 = "Wall temperature(oC)=" & " " & Str(Tw)

Case 9: ResultString2 = "Mean temperature condensate(oC)=" & " " & Str(Tmc)

Case 10: ResultString2 = "Shell-side Coefficient(W/m2oC)=" & " " &
Str(ShellCoefficient)

Case 11: ResultString2 = "Tube Cross-sectional Area(m2)=" & " " & Str(Atc)

Case 12: ResultString2 = "Tube Velocity(m/s)=" & " " & Str(Vt)

Case 13: ResultString2 = "Tube-side coefficient(W/m2oC)=" & " " & Str(hi)

Case 14: ResultString2 = "Overall Coefficient(W/m2oC)=" & " " & Str(Ucal)

Case 15: ResultString2 = "Shell Internal Diameter(m)=" & " " & Str(sid)

Case 16: ResultString2 = "Cross-flow Area(m2)=" & " " & Str(As1)

Case 17: ResultString2 = "Equivalent Diameter(m)=" & " " & Str(de)

Case 18: ResultString2 = "Shell-side Pressure Drop(N/m2)=" & " " & Str(Ps)

Case 19: ResultString2 = "Tube-side Pressure Drop(N/m2)=" & " " & Str(Pt)

End Select
 PrintResultToFile = ResultString2

End Function

Private Sub Close_Click()
End

End Sub
```

```
Private Sub EnthalpyOfCondensateText1_Change()

End Sub

Private Sub EnthalpyOfCondensateText1_KeyPress(KeyAscii As Integer)

End Sub

Private Sub DisplayResult_Click()


'Print Results on the form


ResultForm.Show
ResultForm.DisplayResults_Click

End Sub

Private Sub EnthalpyOfCondensateText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(EnthalpyOfCondensateText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
      KeyAscii = 0
      Beep
      MsgBox "Invalid Character input"

 End Select


 End Sub

Private Sub EnthalpyOfVapourText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
```

```
 Case Asc("."):
 If InStr(EnthalpyOfVapourText, ".") <> 0 Then
 KeyAscii = 0
 Beep
 MsgBox "Only Integer or Decimal Number is allowed"


 End If

 Case 8:
 Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

End Select



End Sub

Private Sub FlowRateOfVapourText_KeyPress(KeyAscii As Integer)

Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(FlowRateOfVapourText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
      KeyAscii = 0
      Beep
      MsgBox "Invalid Character input"

 End Select



End Sub
```

```
Private Sub FlowRateOfWaterTextText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(FlowRateOfWaterTextText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

 End Select


End Sub

Private Sub Form_Click()
Debug.Print App.Path & "\Chemical Substances.mdb"

End Sub

Private Sub Form_Load()
i = 1
UASS = 900
Uc = 1500
ResultCounter = 1
ReDim ResultArray(ResultCounter)

CountMolecular = 0

myArray(1) = Uc
myArray(2) = 1400
myArray(3) = 1300
myArray(4) = 1200
myArray(5) = 1100
myArray(6) = 1000

Set Factor = New ClassFoulingFactor
```

```
Set FactorCollection = New Collection

Factor.CompoundName = " Cooling Water"
Factor.FoulingFactor = 4000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName

Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Stream Condensate"
Factor.FoulingFactor = 3000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName


Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Organic vapours"
Factor.FoulingFactor = 5000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName


Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Organic liquids"
Factor.FoulingFactor = 5000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName


Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Light hydrocarbons"
Factor.FoulingFactor = 5000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName


Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Heavy hydrocarbons"
Factor.FoulingFactor = 2000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName


Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Boiling organics"
```

```
Factor.FoulingFactor = 2500
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName



Set Factor = New ClassFoulingFactor
Factor.CompoundName = "Acqueous solutions"
Factor.FoulingFactor = 4000
FactorCollection.Add Factor
FoulingFactorCombo.AddItem Factor.CompoundName


'Populating PitchCombo
PitchCombo.AddItem "Triangular Pitch"
PitchCombo.AddItem "Square Pitch"

'Populating NumberOfPassesCombo
NumberOfPassesCombo.AddItem "1"
NumberOfPassesCombo.AddItem "2"
NumberOfPassesCombo.AddItem "4"
NumberOfPassesCombo.AddItem "6"
NumberOfPassesCombo.AddItem "8"

'Populate HeadCombo

HeadCombo.AddItem "Pull-through Floating Head"
HeadCombo.AddItem "Split-ring Floating Head"
HeadCombo.AddItem "Outside packed Head"
HeadCombo.AddItem "Fixed and U-tube Head"



Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from HeatCapacityOfLiquid")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
rs1.MoveFirst
Do While Not rs1.EOF
  LiquidCompoundCombo.AddItem rs1("CompoundName")

  rs1.MoveNext

Loop

End Sub
```

```
Sub CollectParameters()
On Error GoTo L1

Tv = Val(InletTempOfVapoutText)

HV = Val(EnthalpyOfVapourText)
hc = Val(EnthalpyOfCondensateText)

Tc = Val(InletTempOfCoolantText)
Wc = Val(FlowRateOfVapourText)
Tc1 = Val(OutletTempOfCoolantText)
D0 = Val(OutsideDiameterText)
D1 = Val(InsideDiameterText)
L = Val(TubeLenghtText)
Tv1 = Val(OutletTempOfWaterText)
QV = Wc / 3600 * (HV - hc)
CW = QV / ((Tc1 - Tc) * 4.18)
Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Private Sub FoulingFactorCombo_Click()
Dim FObj As ClassFoulingFactor

Set FObj = New ClassFoulingFactor

For Each FObj In FactorCollection
  If FoulingFactorCombo.Text = FObj.CompoundName Then
      hod = FObj.FoulingFactor

      Exit For

  End If
Next


End Sub

Private Sub InletTempOfCoolantText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(InletTempOfCoolantText, ".") <> 0 Then
  KeyAscii = 0
```

```
Beep
MsgBox "Only Integer or Decimal Number is allowed"


End If

Case 8:
Case Else
    KeyAscii = 0
    Beep
    MsgBox "Invalid Character input"

End Select


End Sub

Private Sub InletTempOfVapoutText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(InletTempOfVapoutText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
      KeyAscii = 0
      Beep
      MsgBox "Invalid Character input"

End Select


End Sub

Private Sub InsideDiameterText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(InsideDiameterText, ".") <> 0 Then
  KeyAscii = 0
```

```
 Beep
 MsgBox "Only Integer or Decimal Number is allowed"


 End If

 Case 8:
 Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

End Select


End Sub

Public Sub mnOverallCoefficient_Click()

Dim PitchType$
Dim NPasses As Integer
Dim CPc As Double
Dim Kl As Double
Dim AMW2 As Double
Dim hc As Double
On Error GoTo L1
Kw = 50
'Collect Input parameters by calling a procedure
CollectParameters
Pt = 1.25 * D0
'Call At,Ft,Others
 Call FTAT

'Surface Area Of one tube
SA = D0 * 3.142 * L

'Number Of Tubes
Nt = At / SA
PitchType = PitchCombo
NPasses = Val(NumberOfPassesCombo)

 Call CheckPitchTypeAndPasses(PitchType, NPasses)

BundleDiameter = D0 * (Nt / k1) ^ (1 / n1)
Nr = BundleDiameter / Pt
```

```
Tss = (Tv + Tv1) / 2

Tts = (Tc1 + Tc) / 2
Tw = Tss - ((Tss - Tts) * UASS) / Uc
Tmc = (Tss + Tw) / 2


Set db = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr = db.CreateQueryDef("", "Select * from HeatCapacityOfLiquid where
CompoundName='" & LiquidCompoundCombo & "'")
Set rs = qr.OpenRecordset(dbOpenSnapshot)

CPc = rs("A") + rs("B") * Tmc + rs("C") * (Tmc ^ 2)

rhoc = (0.618 * 1.22 ^ (-1 * (1 - ((Tmc + 273) / 374.14)) ^ (2 / 7))) * 1000
Kl = (3.56 * 0.000005 * CPc * rhoc) / (rs("MolecularWeight") ^ (1 / 3))

Vis = 0.190069 + (-0.0044303970) * Tmc + (0.0003653992) * Tmc ^ 2 + (-0.00001082065)
* Tmc ^ 3 + (0.0000001246762) * Tmc ^ 4 + (-4.947917E-10) * Tmc ^ 5



TR = (Tc1 - Tc)
'Do this if methane is selected

If MethaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & MethaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)

AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If


'Do this if Ethane is selected

If EthaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & EthaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1
```

```
End If


'Do this if Propane is selected

If PropaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & PropaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

'Do this if Butane is selected
If PropaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & ButaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If


'Do this if Pentane is selected
If PentaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & PentaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

'Do this if Hexane is selected
If HexaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & HexaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
```

```
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

AMW2 = AMW / CountMolecular

'Vapour Density At Mean Vapour Temperature(rhov)

rhov = ((AMW2 / 22.4) * 273) / (273 + Tss) * TR / 1
Th = Wc / (3600 * L * Nt)

No = (2 / 3) * Nr

'My new Shell

ShellCoefficient = 0.95 * (Kl * ((rhoc * (rhoc - rhov) * 9.81) / (Vis * 0.001 * Th)) ^ (1 / 3)
* (No) ^ (-1 / 6))

'-----

Atc = 3.142 / 4 * (D1 ^ 2) * Nt / 4
'Tube side Coefficient
rhoc = (0.995 * 1.003 ^ (-1 * (1 - ((Tts + 273) / 374.14)) ^ (2 / 7))) * 1000
Vt = (CW / rhoc) * 1 / Atc

hi = 4200 * (1.35 + (0.02 * Tts)) * (Vt ^ 0.8) / ((D1 * 1000) ^ 0.2)

Ucal = 1 / ((1 / ShellCoefficient) + (1 / hod) + ((D0 * Log(D0 / D1)) / (2 * Kw)) + (D0 /
D1) * (1 / hod) + (D0 / D1) * (1 / hi))

MenuItem = 14
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)



Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1


End Sub
```

```
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuEquivalentDiameter_Click()
Dim CPc As Double
Dim Kl As Double

On Error GoTo L1

Kw = 50
'Collect Input parameters by calling a procedure
CollectParameters
Pt = 1.25 * D0
'Call At,Ft,Others
 Call FTAT


'Call SA,SID
 Call SASID

As1 = ((Pt - D0) * sid * sid) / Pt
Gs = (Wc / 3600) * (1 / As1)
de = (1.27 / D0) * ((Pt ^ 2) - ((0.785) * (D0 ^ 2)))

MenuItem = 17
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub


Public Sub mnuMeanTemperatureOfCondensate_Click()
```

```
'Collect Input parameters by calling a procedure

CollectParameters
Tss = Tv + Tv1 / 2

Tts = Tc1 + Tc / 2


Tw = Tss - (Tss - Tts) * UASS / Uc
Tmc = Tss + Tw / 2

MenuItem = 9
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub

Private Sub mnuExit_Click()
End

End Sub

Public Sub mnuMeanTemperatureCondensate_Click()

'Collect Input parameters by calling a procedure

CollectParameters
Tss = (Tv + Tv1) / 2

Tts = (Tc1 + Tc) / 2

Tw = Tss - ((Tss - Tts) * UASS) / Uc
Tmc = (Tss + Tw) / 2

MenuItem = 9
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub
```

```
Private Sub mnuNew_Click()

FlowRateOfVapourText.Text = ""
EnthalpyOfVapourText.Text = ""
EnthalpyOfCondensateText.Text = ""

InletTempOfVapoutText.Text = ""
OutletTempOfWaterText.Text = ""
InletTempOfCoolantText.Text = ""
OutletTempOfCoolantText.Text = ""
OutsideDiameterText.Text = ""
InsideDiameterText.Text = ""
TubeLenghtText.Text = ""

End Sub

Public Sub mnuNumberOfTubes_Click()
On Error GoTo L1
'Collect Input parameters by calling a procedure

CollectParameters

FTAT
'Surface Area Of one tube
SA = D0 * 3.142 * L

'Check if a new Nt exists
If (UASS - Ucal) <= 10 Then
  'Calculate new area
   At = (QV * 0.001) / (Ucal * Tm)

  'Calculate new Nt
   OldNt = Nt
    Nt = At / SA
Else
'Use old Number Of Tubes
 Nt = At / SA
End If


MenuItem = 4
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)
```

```
Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuNumberOfTubesInCentreRow_Click()
On Error GoTo L1

Dim PitchType As String
Dim NPasses As Integer

'Collect Input parameters by calling a procedure

CollectParameters
Pt = 1.25 * D0

FTAT

'Surface Area Of one tube
SA = D0 * 3.142 * L

'Number Of Tubes
Nt = At / SA

PitchType = PitchCombo
NPasses = NumberOfPassesCombo

 Call CheckPitchTypeAndPasses(PitchType, NPasses)

BundleDiameter = D0 * ((Nt / k1) ^ (1 / n1))
Nr = BundleDiameter / Pt

MenuItem = 5
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub
```

```
Private Sub mnuOpen_Click()
Dim A$
Dim Wrap$
Dim AllText$
On Error GoTo L1

Wrap$ = Chr$(13) + Chr$(10)
FileViewer.Text1.FontName = "Arial"
FileViewer.Text1.FontSize = 10
With CommonDialog1
   .DefaultExt = "Txt"
   .DialogTitle = "Save CAD File"
   .filename = "NoName"
   .Filter = "TextFile(*.Txt)|*.Txt"
   .InitDir = App.Path
   .ShowOpen
End With
 FileHandle = FreeFile()
 NameOfFile = CommonDialog1.filename

 Open NameOfFile For Input As #FileHandle
 Do While Not EOF(FileHandle)
   Line Input #FileHandle, A$
   AllText$ = AllText$ + A$ + Wrap$

 Loop
  FileViewer.Text1.Text = AllText$
  FileViewer.Show

 Exit Sub
L1: MsgBox "No file selected. " & vbCrLf & "Click OK to continue.", vbOKOnly +
vbCritical + vbDefaultButton1


End Sub



Private Sub mnuPrint_Click()
On Error GoTo L1
   Printer.Print "  "; "INPUT PARAMETERS"
   Printer.Print "  "; "---------------------------------"
   Printer.Print "  "; "Liquid Compound=" & LiquidCompoundCombo
   Printer.Print "  "; "Gaseous Compound = " & GaseousCompoundCombo
   Printer.Print "  "; "Mass Flow Rate Of Vapour =" & FlowRateOfVapourText
   Printer.Print "  "; "Enthalpy Of Vapour =" & EnthalpyOfVapourText
```

```
  Printer.Print "  "; "Enthalpy Of Condensate =" & EnthalpyOfCondensateText
  Printer.Print "  "; "Condenser Operating Pressure =" & OperatingPressureText
  Printer.Print "  "; "Inlet Temperature Of The Vapour=" & InletTempOfVapoutText
  Printer.Print "  "; "Outlet Temperature Of The Vapour =" & OutletTempOfWaterText
  Printer.Print "  "; "Inlet Temperature Of The Coolant=" & InletTempOfCoolantText
  Printer.Print "  "; "Outlet Temperature Of The Coolant=" & OutletTempOfCoolantText
  Printer.Print "  "; "Condenser Tube Outside Diameter =" & OutsideDiameterText.Text
  Printer.Print "  "; "Condenser Tube Inside Diameter =" & InsideDiameterText
  Printer.Print "  "; "Lenght Of The Tube =" & TubeLenghtText
  Printer.Print "  "; " Pitch Type=" & PitchCombo
  Printer.Print "  "; "Number Of Passes =" & NumberOfPassesCombo
  Printer.Print "  "; " Head Type For Exchanger=" & HeadCombo

  Printer.Print "  "; "Fouling Factor =" & FoulingFactorCombo
  'Save Result

  Printer.Print "  "; "                                          "
  Printer.Print "  "; "                                          "
  'Print results to file

  Printer.Print "  "; "RESULTS OBTAINED"
  Printer.Print "  "; "---------------------------------"
    For ck = 1 To ResultCounter - 1

    Printer.Print "  "; ResultArray(ck)
    Next ck

 Exit Sub
L1:  MsgBox Err.Description


End Sub

Private Sub mnuSave_Click()
Dim ck As Integer
On Error GoTo L1

With CommonDialog1
   .DefaultExt = "Txt"
   .DialogTitle = "Save CAD File"
   .filename = "NoName"
   .Filter = "TextFile(*.Txt)|*.Txt"
   .InitDir = App.Path
   .ShowSave
End With
```

```
FileHandle = FreeFile()
NameOfFile = CommonDialog1.filename

 Open NameOfFile For Output As #FileHandle
 Print #FileHandle, "INPUT PARAMETERS"
 Print #FileHandle, "--------------------------------"
 Print #FileHandle, "Liquid Compound=" & LiquidCompoundCombo
 Print #FileHandle, "Gaseous Compound used = " & "Light Hydrocarbons"
 Print #FileHandle, "Mass Flow Rate Of Vapour(Kg/h) =" & FlowRateOfVapourText
 Print #FileHandle, "Enthalpy Of Vapour(KJ/Kg) =" & EnthalpyOfVapourText
 Print #FileHandle, "Enthalpy Of Condensate(KJ/Kg) =" & EnthalpyOfCondensateText
 Print #FileHandle, "Condenser Operating Pressure(bar) =" & OperatingPressureText
 Print #FileHandle, "Inlet Temperature Of The Vapour(oC)=" & InletTempOfVapoutText
 Print #FileHandle, "Outlet Temperature Of The Vapour(oC) =" &
OutletTempOfWaterText
 Print #FileHandle, "Inlet Temperature Of The Coolant(oC)=" &
InletTempOfCoolantText
 Print #FileHandle, "Outlet Temperature Of The Coolant(oC)=" &
OutletTempOfCoolantText
 Print #FileHandle, "Condenser Tube Outside Diameter(m) =" &
OutsideDiameterText.Text
 Print #FileHandle, "Condenser Tube Inside Diameter(m) =" & InsideDiameterText
 Print #FileHandle, "Lenght Of The Tube(m) =" & TubeLenghtText
 Print #FileHandle, " Pitch Type=" & PitchCombo
 Print #FileHandle, "Number Of Passes =" & NumberOfPassesCombo
 Print #FileHandle, " Head Type For Exchanger=" & HeadCombo
 Print #FileHandle, "Fouling Factor(W/m2oC) =" & FoulingFactorCombo
 'Save Result

 Print #FileHandle, "                                        "
 Print #FileHandle, "                                        "
 'Print results to file

 Print #FileHandle, "RESULTS OBTAINED"
 Print #FileHandle, "----------------------------------"
  For ck = 1 To ResultCounter - 1

  Print #FileHandle, ResultArray(ck)
  Next ck


Close #FileHandle

Exit Sub
L1: MsgBox Err.Description
```

```
End Sub

Public Sub mnuShellInternalDiameter_Click()
Dim CPc As Double
Dim Kl As Double

Kw = 50
'Collect Input parameters by calling a procedure
CollectParameters
'Call At,Ft,Others
Call FTAT

Call SASID


MenuItem = 15
'CheckMenuItem (MenuItem)

ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub
Sub SASID()
Dim PitchType$
Dim NPasses As Integer
On Error GoTo L1

SA = D0 * 3.142 * L
Pt = 1.25 * D0



'Number Of Tubes
Nt = At / SA
PitchType = PitchCombo
NPasses = Val(NumberOfPassesCombo)

Call CheckPitchTypeAndPasses(PitchType, NPasses)

BundleDiameter = D0 * (Nt / k1) ^ (1 / n1)
Nr = BundleDiameter / Pt

Tss = (Tv + Tv1) / 2
```

```
Tts = (Tc1 + Tc) / 2

Tw = Tss - ((Tss - Tts) * UASS) / Uc
Tmc = (Tss + Tw) / 2


Set db = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr = db.CreateQueryDef("", "Select * from HeatCapacityOfLiquid where
CompoundName='" & LiquidCompoundCombo & "'")
Set rs = qr.OpenRecordset(dbOpenSnapshot)

CPc = rs("A") + rs("B") * Tmc + rs("C") * (Tmc ^ 2)

rhoc = (0.618 * 1.22 ^ (-1 * (1 - ((Tmc + 273) / 374.14)) ^ (2 / 7))) * 1000
Kl = (3.56 * 0.000005 * CPc * rhoc) / (rs("MolecularWeight") ^ (1 / 3))

Vis = 0.190069 + (-0.004430397) * Tmc + (0.0003653992) * Tmc ^ 2 + (-0.00001082065)
* Tmc ^ 3 + (0.0000001246762) * Tmc ^ 4 + (-4.947917E-10) * Tmc ^ 5


TR = (Tc1 - Tc)
'Do this if methane is selected

If MethaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & MethaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)

AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If


'Do this if Ethane is selected

If EthaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & EthaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1
```

```
End If


'Do this if Propane is selected

If PropaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & PropaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

'Do this if Butane is selected
If PropaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & ButaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If


'Do this if Pentane is selected
If PentaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & PentaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

'Do this if Hexane is selected
If HexaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & HexaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
```

```
Private Sub mnuAboutCAD_Click()
AboutForm.Show

End Sub

Public Sub mnuCoolingWaterFlow_Click()

'Collect Input parameters by calling a procedure

 CollectParameters

 MenuItem = 1
 'MenuItem2 = 1

 'CheckMenuItem (MenuItem)
 ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
 ResultCounter = ResultCounter + 1
 ReDim Preserve ResultArray(ResultCounter)


 End Sub




 Public Sub mnuCrossflowArea_Click()

 Dim CPc As Double
 Dim Kl As Double

 On Error GoTo L1

 Kw = 50
 'Collect Input parameters by calling a procedure
 CollectParameters
 Pt = 1.25 * D0
 'Call At.Ft.Others
  Call FTAT

 Call SASID

 As1 = ((Pt - D0) * sid * sid) / Pt

 MenuItem = 16
 'CheckMenuItem (MenuItem)
```

```
CountMolecular = CountMolecular + 1

End If


AMW2 = AMW / CountMolecular


'Vapour Density At Mean Vapour Temperature(rhov)

rhov = ((AMW2 / 22.4) * 273) / (273 + Tss) * TR / 1
Th = Wc / (3600 * L * Nt)

No = (2 / 3) * Nr



'My new Shell

ShellCoefficient = 0.95 * (Kl * ((rhoc * (rhoc - rhov) * 9.81) / (Vis * 0.001 * Th)) ^ (1 / 3)
* (No) ^ (-1 / 6))

'-----

Atc = 3.142 / 4 * (D1 ^ 2) * Nt / 4
'Tube side Coefficient
rhoc = (0.995 * 1.003 ^ (-1 * (1 - ((Tts + 273) / 374.14)) ^ (2 / 7))) * 1000
Vt = (CW / rhoc) * 1 / Atc

hi = 4200 * (1.35 + (0.02 * Tts)) * (Vt ^ 0.8) / ((D1 * 1000) ^ 0.2)


Ucal = 1 / ((1 / ShellCoefficient) + (1 / hod) + ((D0 * Log(D0 / D1)) / (2 * Kw)) + (D0 /
D1) * (1 / hod) + (D0 / D1) * (1 / hi))


If (UASS - Ucal) <= 10 Then
 'Calculate new area
  At = (QV * 0.001) / (Ucal * Tm)

 'Calculate new Nt
  OldNt = Nt
  Nt = At / SA
```

```
'Calculate new Vt
 Vt = Vt * (OldNt / Nt)

 UASS = Ucal
End If
Select Case HeadCombo
   Case "Pull-through Floating Head":
        C = 85.976364 + (9.636364 * BundleDiameter)
   Case "Split-ring Floating Head":
        C = 44.793939 + (27.393939 * BundleDiameter)
   Case "Outside packed Head":
        C = 38
   Case "Fixed and U-tube Head":
        C = 8.192857 + (0.071429 * BundleDiameter)
   Case Else
      MsgBox "No Exchanger Head Selected"
End Select
sid = BundleDiameter + (C / 1000)


Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuShellSideCoefficient_Click()


'Collect Input parameters by calling a procedure
CollectParameters
'Call Ft,At,Others
 Call FTAT

'Surface Area Of one tube
SA = D0 * 3.142 * L

Tss = (Tv + Tv1) / 2

Tts = (Tc1 + Tc) / 2

Tw = Tss - ((Tss - Tts) * UASS) / Uc
Debug.Print Uc

Tmc = (Tss + Tw) / 2
Call PitchAndPasses
```

```
Call AMWFUNCTION

MenuItem = 10
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub
Sub AMWFUNCTION()
Dim CPc As Double
Dim Kl As Double
Dim AMW2 As Double
On Error GoTo L1

Set db = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr = db.CreateQueryDef("", "Select * from HeatCapacityOfLiquid where
CompoundName='" & LiquidCompoundCombo & "'")
Set rs = qr.OpenRecordset(dbOpenSnapshot)

CPc = rs("A") + rs("B") * Tmc + rs("C") * (Tmc ^ 2)

rhoc = (0.618 * 1.22 ^ (-1 * (1 - ((Tmc + 273) / 374.14)) ^ (2 / 7))) * 1000
Kl = (3.56 * 0.000005 * CPc * rhoc) / rs("MolecularWeight") ^ (1 / 3)

Vis = 0.190069 + (-0.0044303997) * Tmc + (0.0003653992) * Tmc ^ 2 + (-0.00001082065)
* Tmc ^ 3 + (0.0000001246762) * Tmc ^ 4 + (-4.947917E-10) * Tmc ^ 5



TR = (Tc1 - Tc)
'Do this if methane is selected

If MethaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & MethaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)

AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If
```

```
'Do this if Ethane is selected

If EthaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & EthaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If



'Do this if Propane is selected

If PropaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & PropaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

'Do this if Butane is selected
If PropaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & ButaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If


'Do this if Pentane is selected
If PentaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & PentaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
```

```
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If

'Do this if Hexane is selected
If HexaneCheck.Value Then
Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from EnthalpyOfVapour where
CompoundName='" & HexaneCheck.Caption & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
AMW = AMW + rs1("MolecularWeight")
CountMolecular = CountMolecular + 1

End If


AMW2 = AMW / CountMolecular


'Vapour Density At Mean Vapour Temperature(rhov)

rhov = ((AMW2 / 22.4) * 273) / (273 + Tss) * TR / 1
Th = Wc / (3600 * L * Nt)

No = (2 / 3) * Nr

ShellCoefficient = 0.95 * (Kl * ((rhoc * (rhoc - rhov) * 9.81) / (Vis * 0.001 * Th)) ^ (1 / 3)
* (No) ^ (-1 / 6))


If i >= 6 Then
   i = 1
End If

If (ShellCoefficient - myArray(i)) > 150 Then

     Uc = myArray(i + 1)

End If
 i = i + 1

 Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1
```

```
End Sub
Sub PitchAndPasses()
Dim PitchType$
Dim NPasses As Integer
On Error GoTo L1

D0 = Val(OutsideDiameterText)
Pt = 1.25 * D0
'Number Of Tubes
Nt = At / SA
PitchType = PitchCombo
NPasses = Val(NumberOfPassesCombo)

Call CheckPitchTypeAndPasses(PitchType, NPasses)

BundleDiameter = D0 * (Nt / k1) ^ (1 / n1)

Nr = BundleDiameter / Pt

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1


End Sub


Public Sub mnuShellSidePressureDrop_Click()
Dim CPc As Double
Dim Kl As Double
Dim Visv As Single

On Error GoTo L1

Kw = 50

'Collect Input parameters by calling a procedure
CollectParameters
Pt = 1.25 * D0
'Call At,Ft,others
 Call FTAT

'Call A,SID
 Call SASID
```

```
'Call AMW
'Call AMWFUNCTION

As1 = ((Pt - D0) * sid * sid) / Pt
Gs = (Wc / 3600) * (1 / As1)
de = (1.27 / D0) * ((Pt ^ 2) - ((0.785) * (D0 ^ 2)))
'Value of Visv
Visv = 0.000008

Re = (Gs * de) / Visv
If Re > 100 And Re < 1000 Then
   jf1 = 0.253467 - (0.0009732401 * Re) + (0.00000151655 * (Re ^ 2)) -
0.00000007529138 * (Re ^ 3)
ElseIf Re > 1000 And Re < 10000 Then
   jf1 = 0.052667 - (0.000003972727 * Re) + (1.969697E-10 * (Re ^ 2))
ElseIf Re > 10000 And Re < 100000 Then
   jf1 = 0.032967 - (0.0000001498485 * Re) + (2.272731E-13 * (Re ^ 2))
ElseIf Re > 100000 And Re < 1000000 Then
   jf1 = 0.022247 - (0.00000001282424 * Re) + (5.757922E-15 * (Re ^ 2))
End If
Us = Gs / rhov
Ps = (1 / 2) * (8 * jf1 * (sid / de) * (1. / sid) * ((rhov * (Us ^ 2)) / 2))


MenuItem = 18
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuShellSideTemperature_Click()


'Collect Input parameters by calling a procedure

CollectParameters
Tss = (Tv + Tv1) / 2

MenuItem = 6
'CheckMenuItem (MenuItem)
```

```
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub



Public Sub mnuSurfaceAreaOfTube_Click()

'Collect Input parameters by calling a procedure

CollectParameters

'Collect Ft,At,Others

FTAT

'Surface Area Of one tube
SA = D0 * 3.142 * L

MenuItem = 3
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

End Sub

Public Sub mnuTrialArea_Click()

'Collect Input parameters by calling a procedure
 Call CollectParameters

Call FTAT


MenuItem = 2
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub
```

```
Sub FTAT()
Dim Ft1 As Single
Dim Ft2 As Single
Dim At1 As Single
Dim At2 As Single
On Error GoTo L1

'Calculated R and S
R = (Tv - Tv1) / (Tc1 - Tc)
S = (Tc1 - Tc) / (Tv - Tc)


'Logarithmic mean temperature difference Tlm

Tlm = ((Tv - Tc1) - (Tv1 - Tc)) / Log((Tv - Tc1) / (Tv1 - Tc))


'Calculating Ft
Ft1 = Sqr(R ^ 2 + 1) * Log((1 - S) / (1 - R * S))
Ft2 = (R - 1) * Log((2 - S * (R + 1 - Sqr(R ^ 2 + 1))) / (2 - S * (R + 1 + Sqr(R ^ 2 + 1))))


Ft = Ft1 / Ft2

'Corrected logarithmic mean temperature difference

Tm = Tlm * Ft

'Check if a new value exists for At
If (UASS - Ucal) <= 10 Then
 'Calculate new  Trial Area
   At = (QV * 0.001) / (Ucal * Tm)
Else
' Use old Trial Area
At1 = QV * 1000
At2 = UASS * Tm

At = At1 / At2
End If

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1
```

```
End Sub

Public Sub mnuTubeCrossSectionalArea_Click()
On Error GoTo L1

'Collect Input parameters by calling a procedure

CollectParameters

'Call At,Ft,Others
 Call FTAT

'Surface Area Of one tube
SA = D0 * 3.142 * L

'Number Of Tubes
Nt = At / SA
Atc = 3.142 / 4 * (D1 ^ 2) * Nt / 4

MenuItem = 11
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuTubeSideCoefficient_Click()
Dim CPc As Double
Dim Kl As Double
Dim PitchType$
Dim NPasses As Integer

On Error GoTo L1

'Collect Input parameters by calling a procedure
CollectParameters
'Call At,Ft,Others
  Call FTAT
'Surface Area Of one tube
SA = D0 * 3.142 * L
Pt = 1.25 * D0
```

```
'Number Of Tubes
Nt = At / SA
PitchType = PitchCombo
NPasses = NumberOfPassesCombo

Call CheckPitchTypeAndPasses(PitchType, NPasses)

BundleDiameter = D0 * (Nt / k1) ^ (1 / n1)
Nr = BundleDiameter / Pt

Tss = (Tv + Tv1) / 2

Tts = (Tc1 + Tc) / 2

Tw = Tss - ((Tss - Tts) * UASS) / Uc
Tmc = (Tss + Tw) / 2


Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from HeatCapacityOfLiquid where
CompoundName='" & LiquidCompoundCombo & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
rhoc = (0.995 * 1.003 ^ (-1 * (1 - ((Tts + 273) / 374.14)) ^ (2 / 7))) * 1000

Atc = 3.142 / 4 * (D1 ^ 2) * Nt / 4
'Check if Vt has changed
If (UASS - Ucal) <= 10 Then
  'Calculate new area
   At = (QV * 0.001) / (Ucal * Tm)

  'Calculate new Nt
   OldNt = Nt
   Nt = At / SA

 'Calculate new Vt
  Vt = Vt * (OldNt / Nt)
Else
  'Use old Vt

 Vt = (CW / rhoc) * 1 / Atc
 End If

hi = 4200 * (1.35 + (0.02 * Tts)) * (Vt ^ 0.8) / ((D1 * 1000) ^ 0.2)
```

```
MenuItem = 13
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuTubeSidePressureDrop_Click()
Dim CPc As Double
Dim Kl As Double
Dim Visv As Single
On Error GoTo L1

Kw = 50
'Collect Input parameters by calling a procedure
CollectParameters
Pt = 1.25 * D0
'Call At,Ft,Others
 Call FTAT
'Call SA,SID
 Call SASID

As1 = ((Pt - D0) * sid * sid * 0.000001) / Pt
Gs = (Wc / 3600) * (1 / As1)
de = (1.27 / Pt) * ((Pt ^ 2) - ((0.785) * (D0 ^ 2)))
'Value of rhov
Visw = 0.999161 + (-0.00638205) * Tts + (-0.0004665501) * (Tts ^ 2) + (0.000011883566)
* (Tts ^ 3) + (-0.0000001118881) * (Tts ^ 4) + (3.846154E-10) * (Tts ^ 5)


rhoc = (0.995 * 1.003 ^ (-1 * (1 - ((Tts + 273) / 374.14)) ^ (2 / 7))) * 1000
Re = (Vt * rhoc * D1) / (Visw * 0.001)
If Re > 10 And Re < 100 Then
    jf2 = 16.363334 - (1.160773 * Re) + (0.037895 * (Re ^ 2)) - (0.0006170979 * (Re ^ 3))
+ (0.000004873543 * (Re ^ 4)) - (0.00000001487179 * (Re ^ 5))
ElseIf Re > 10000 And Re < 100000 Then
     jf2 = 0.00501 - (0.0000000444697 * Re) + (2.1967E-13 * (Re ^ 2))
End If
```

```
rhoc = (0.995 * 1.003 ^ (-1 * (1 - ((Tts + 273) / 374.14)) ^ (2 / 7))) * 1000

 'Calculate new area
 At = (QV * 1000) / (Ucal * Tm)

 'Calculate new Nt
  OldNt = Nt
   Nt = At / SA

 'Calculate new Vt
  Vt = Vt * (OldNt / Nt)

Pt = 4 * (8 * jf2 * (L / D1) + 2.5) * (rhoc * (Vt ^ 2)) / 2


MenuItem = 19
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub

Public Sub mnuTubeSideTemperature_Click()

'Collect Input parameters by calling a procedure

CollectParameters
Tts = (Tc1 + Tc) / 2

MenuItem = 7
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)

End Sub

Public Sub mnuTubeVelocity_Click()
Dim CPc As Double
Dim Kl As Double
On Error GoTo L1
```

```
'Collect Input parameters by calling a procedure
CollectParameters
'Call At,Ft,Others
 Call FTAT

'Surface Area Of one tube
SA = D0 * 3.142 * L

'Number Of Tubes
Nt = At / SA
Call PitchAndPasses


Tss = (Tv + Tv1) / 2

Tts = (Tc1 + Tc) / 2

Tw = Tss - ((Tss - Tts) * UASS) / Uc
Tmc = (Tss + Tw) / 2


Set db1 = Workspaces(0).OpenDatabase(App.Path & "\Chemical Substances.mdb")
Set qr1 = db1.CreateQueryDef("", "Select * from HeatCapacityOfLiquid where
CompoundName='" & LiquidCompoundCombo & "'")
Set rs1 = qr1.OpenRecordset(dbOpenSnapshot)
rhoc = (0.993 * 1.003 ^ (-1 * (1 - ((Tts + 273) / 374.14)) ^ (2 / 7))) * 1000


Atc = 3.142 / 4 * (D1 ^ 2) * Nt / 4
 Vt = (CW / rhoc) * 1 / Atc


MenuItem = 12
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


Exit Sub
L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1

End Sub
```

```
Public Sub mnuWallTemperature_Click()

'Collect Input parameters by calling a procedure

CollectParameters
Tss = (Tv + Tv1) / 2

Tts = (Tc1 + Tc) / 2

Tw = Tss - ((Tss - Tts) * UASS) / Uc



MenuItem = 8
'CheckMenuItem (MenuItem)
ResultArray(ResultCounter) = PrintResultToFile((MenuItem))
ResultCounter = ResultCounter + 1
ReDim Preserve ResultArray(ResultCounter)


End Sub

Sub CheckPitchTypeAndPasses(PitchType As String, NumberOfPasses As Integer)
'On Error GoTo L1

Select Case PitchType
  Case "Triangular Pitch":
    Select Case NumberOfPasses
      Case 1: k1 = 0.319
          n1 = 2.142
      Case 2: k1 = 0.249
          n1 = 2.207
      Case 4: k1 = 0.175
          n1 = 2.285
      Case 6: k1 = 0.0743
          n1 = 2.499
      Case 8: k1 = 0.0365
          n1 = 2.675
      Case Else
          MsgBox "Number Of Passes NOT specified For Pitch Type"
    End Select

  Case "Square Pitch":
    Select Case NumberOfPasses
      Case 1: k1 = 0.215
          n1 = 2.207
```

```
    Case 2: k1 = 0.156
          n1 = 2.291
    Case 4: k1 = 0.158
          n1 = 2.263
    Case 6: k1 = 0.0402
          n1 = 2.617
    Case 8: k1 = 0.0331
          n1 = 2.643
    Case Else
          MsgBox "Number Of Passes NOT specified For Pitch Type"
  End Select

 Case Else
      MsgBox "Pitch Type NOT selected"
End Select

'Exit Sub
'L1: MsgBox "One or more parameters missing. " & vbCrLf & "Click OK to continue.",
vbOKOnly + vbCritical + vbDefaultButton1


End Sub

Private Sub OperatingPressureText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(OperatingPressureText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

 End Select


 End Sub
```

```
Private Sub OutletTempOfCoolantText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(OutletTempOfCoolantText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

 End Select


End Sub

Private Sub OutletTempOfWaterText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(OutletTempOfWaterText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

 End Select


End Sub
```

```
Private Sub OutsideDiameterText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(OutsideDiameterText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

 End Select


End Sub

Private Sub PitchCombo_Click()
NumberOfPassesCombo.Enabled = True


End Sub

Private Sub Print_Click()
mnuPrint_Click

End Sub

Private Sub TemperatureText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(TemperatureText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If
```

```
Case 8:
Case Else
    KeyAscii = 0
    Beep
    MsgBox "Invalid Character input"

End Select


End Sub


Private Sub Toolbar1_ButtonClick(ByVal Button As ComctlLib.Button)
Select Case Button.Key
  Case "New": mnuNew_Click
  Case "Open": mnuOpen_Click
  Case "Save": mnuSave_Click
  Case "Print": mnuPrint_Click
End Select
End Sub

Private Sub TubeLenghtText_KeyPress(KeyAscii As Integer)
Select Case KeyAscii
  Case Asc("0") To Asc("9")
  Case Asc("."):
  If InStr(TubeLenghtText, ".") <> 0 Then
  KeyAscii = 0
  Beep
  MsgBox "Only Integer or Decimal Number is allowed"


  End If

  Case 8:
  Case Else
     KeyAscii = 0
     Beep
     MsgBox "Invalid Character input"

 End Select


End Sub
```

RESULTFORM CODE(Displays the output)

```
Private Sub Command1_Click()
Unload Me
End Sub

Public Sub Command2_Click()

End Sub

Public Sub DisplayResults_Click()
MainForm.mnuCoolingWaterFlow_Click

MainForm.mnuTrialArea_Click
MainForm.mnuSurfaceAreaOfTube_Click
MainForm.mnuNumberOfTubes_Click
MainForm.mnuNumberOfTubesInCentreRow_Click
MainForm.mnuShellSideTemperature_Click
MainForm.mnuTubeSideTemperature_Click
MainForm.mnuWallTemperature_Click
MainForm.mnuMeanTemperatureCondensate_Click
MainForm.mnuShellSideCoefficient_Click
MainForm.mnuTubeCrossSectionalArea_Click
MainForm.mnuTubeVelocity_Click
MainForm.mnuTubeSideCoefficient_Click
MainForm.mnOverallCoefficient_Click
MainForm.mnuShellInternalDiameter_Click
MainForm.mnuCrossflowArea_Click
MainForm.mnuEquivalentDiameter_Click
MainForm.mnuShellSidePressureDrop_Click
MainForm.mnuTubeSidePressureDrop_Click


Print "Cooling Water Flow(Kg/s)=" & " " & Str(CW)

Print " "

Print "Trial Area(m2)=" & " " & Str(At)

Print " "

Print "Surface Area One Tube(m2)=" & " " & Str(SA)
```

Adapted from Rechardson and Coulson Vol. 6

APPENDIX B

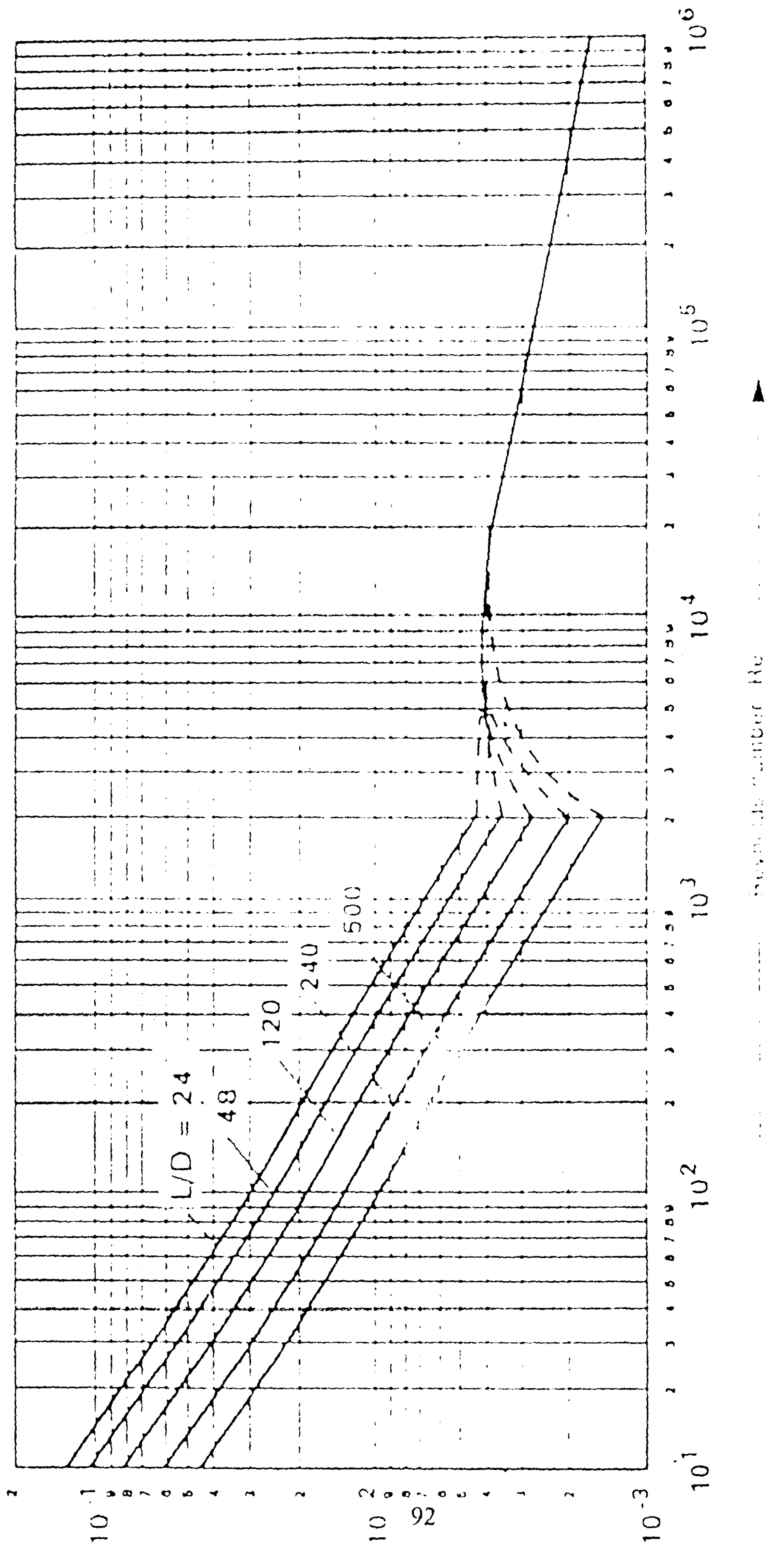

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Fig. 12.23 Tube-side heat-transfer factor

Adapted from Rechardson and Coulson Vol. 6

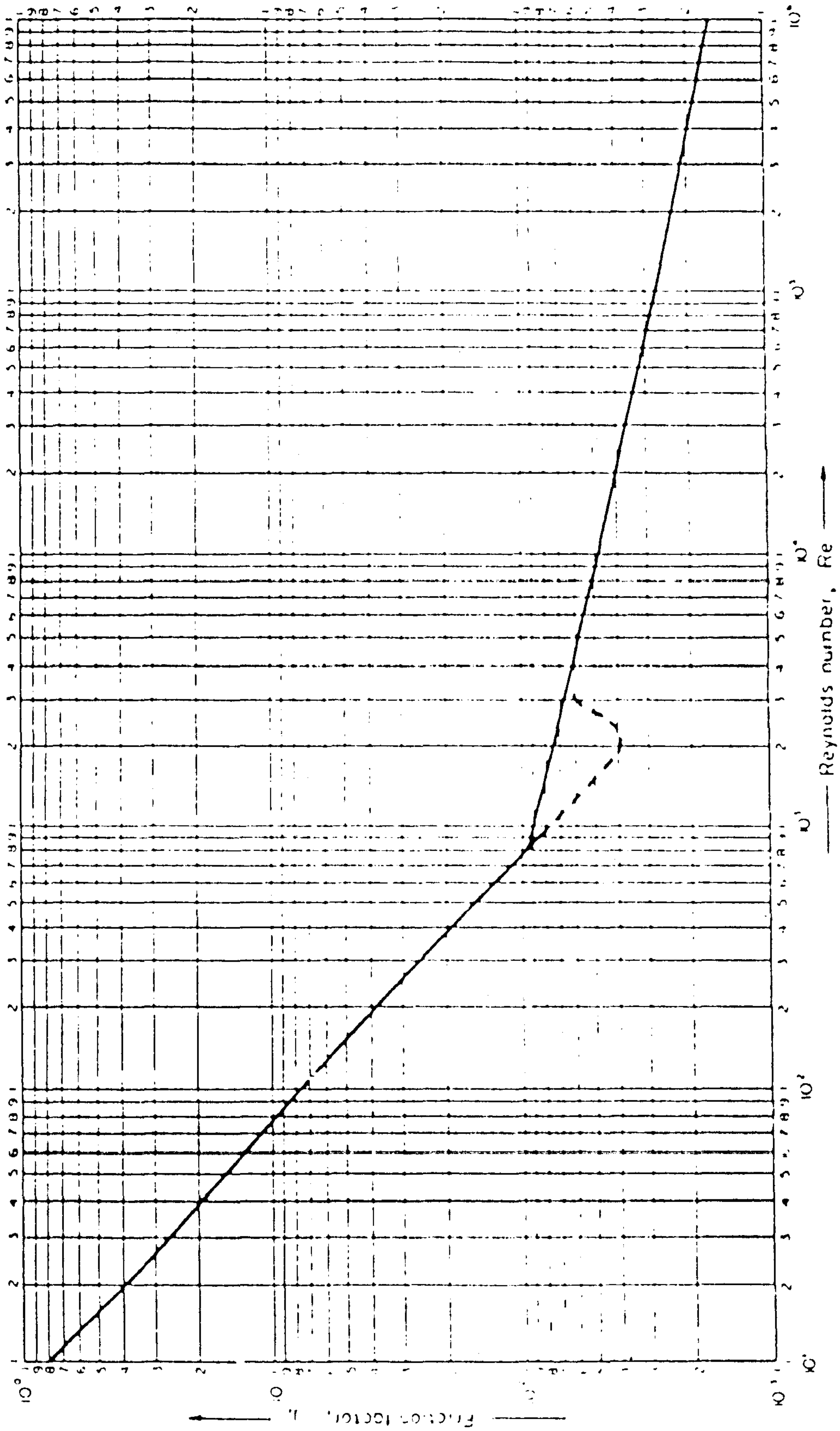

Fig. 12.24 Tube-side friction factors

Note: The friction factor j_f is the same as the friction factor for pipes $\phi\left(=\frac{R}{\rho u^2}\right)$, defined in Volume 1 Chapter 3.

Adapted from Rechardson and Coulson Vol. 6

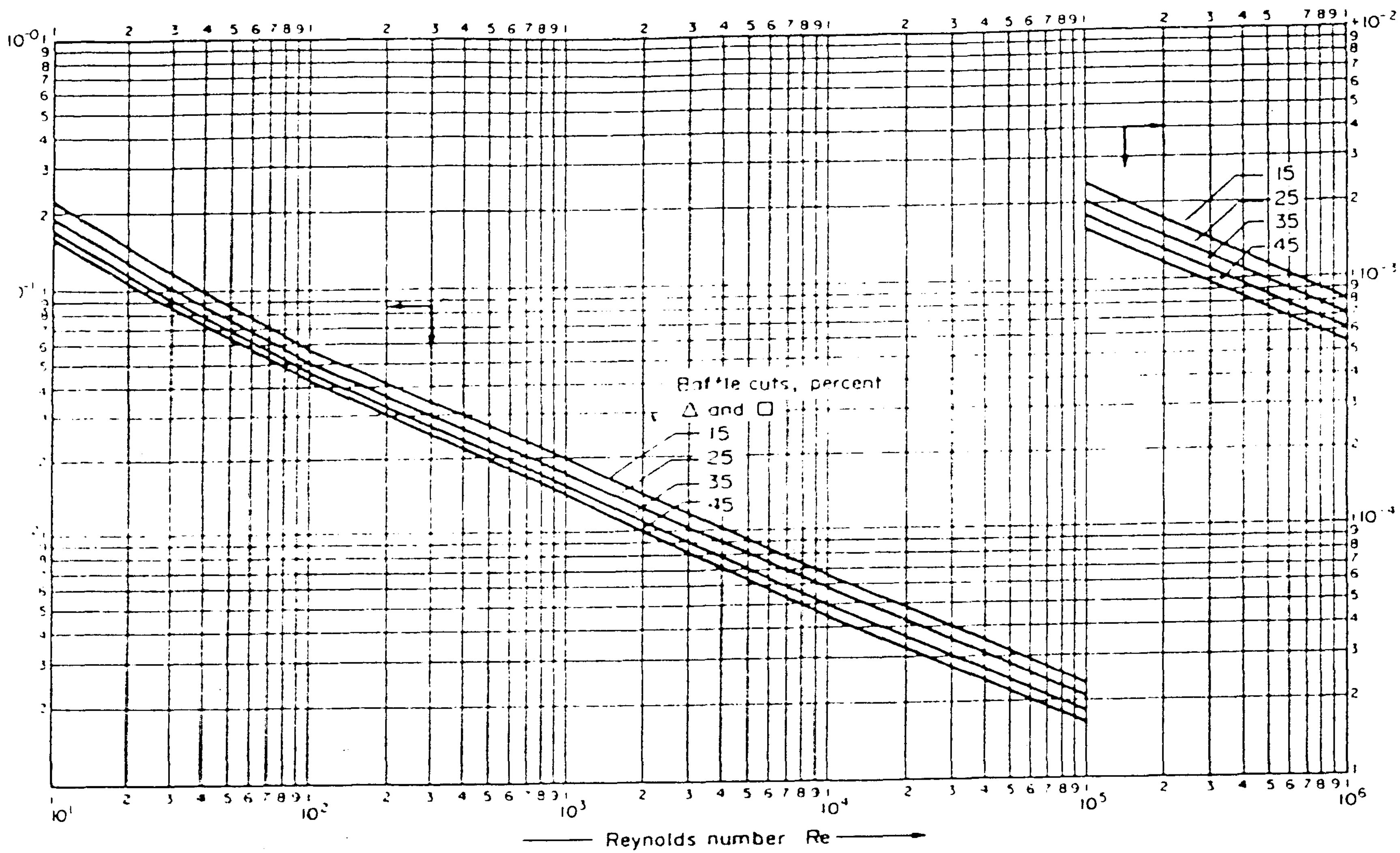

FIG. 12.29. Shell-side heat-transfer factors, segmental baffles

Adapted from Rechardson and Coulson Vol. 6

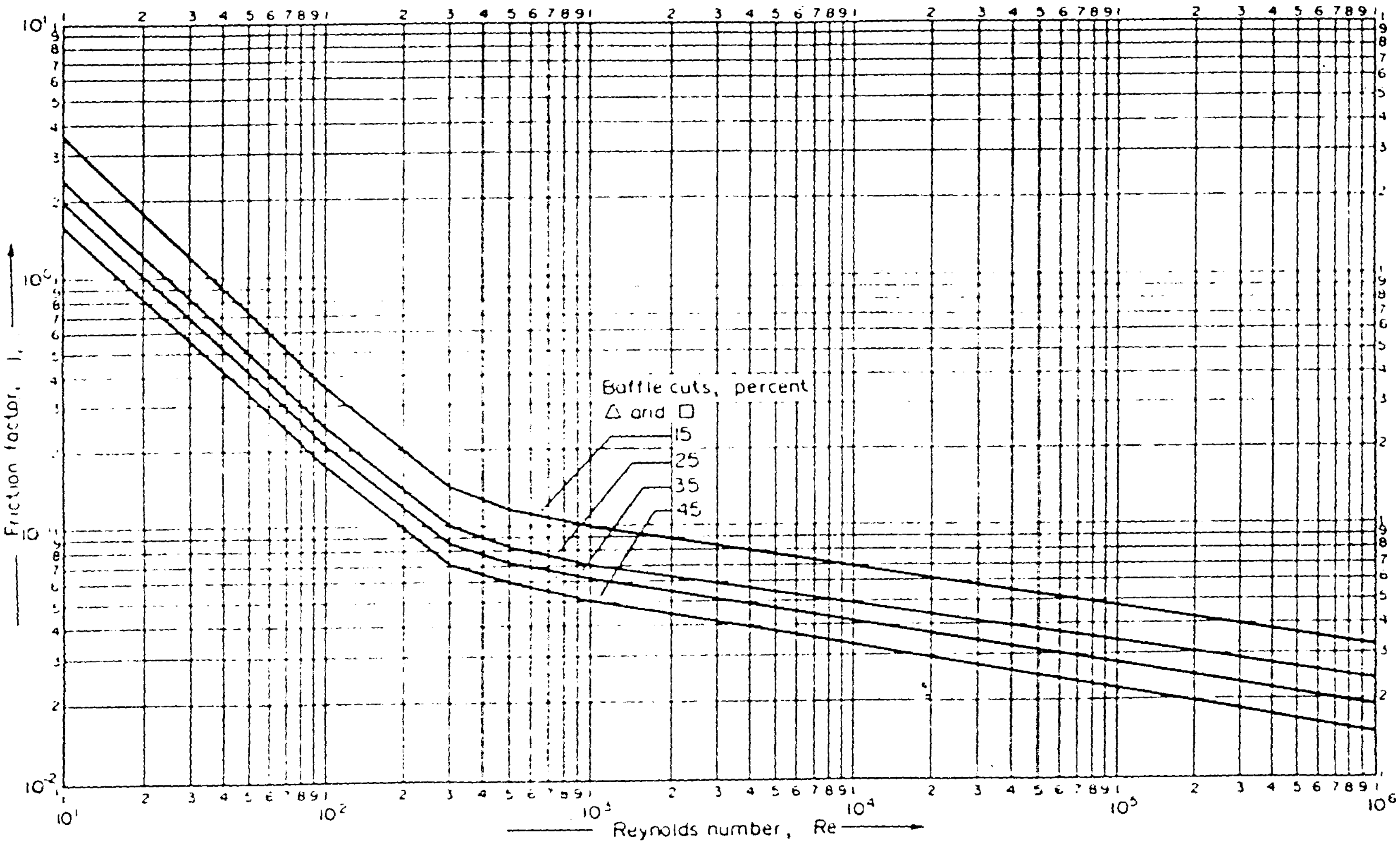

FIG. 12.30 Shell-side friction factors, segmental baffles

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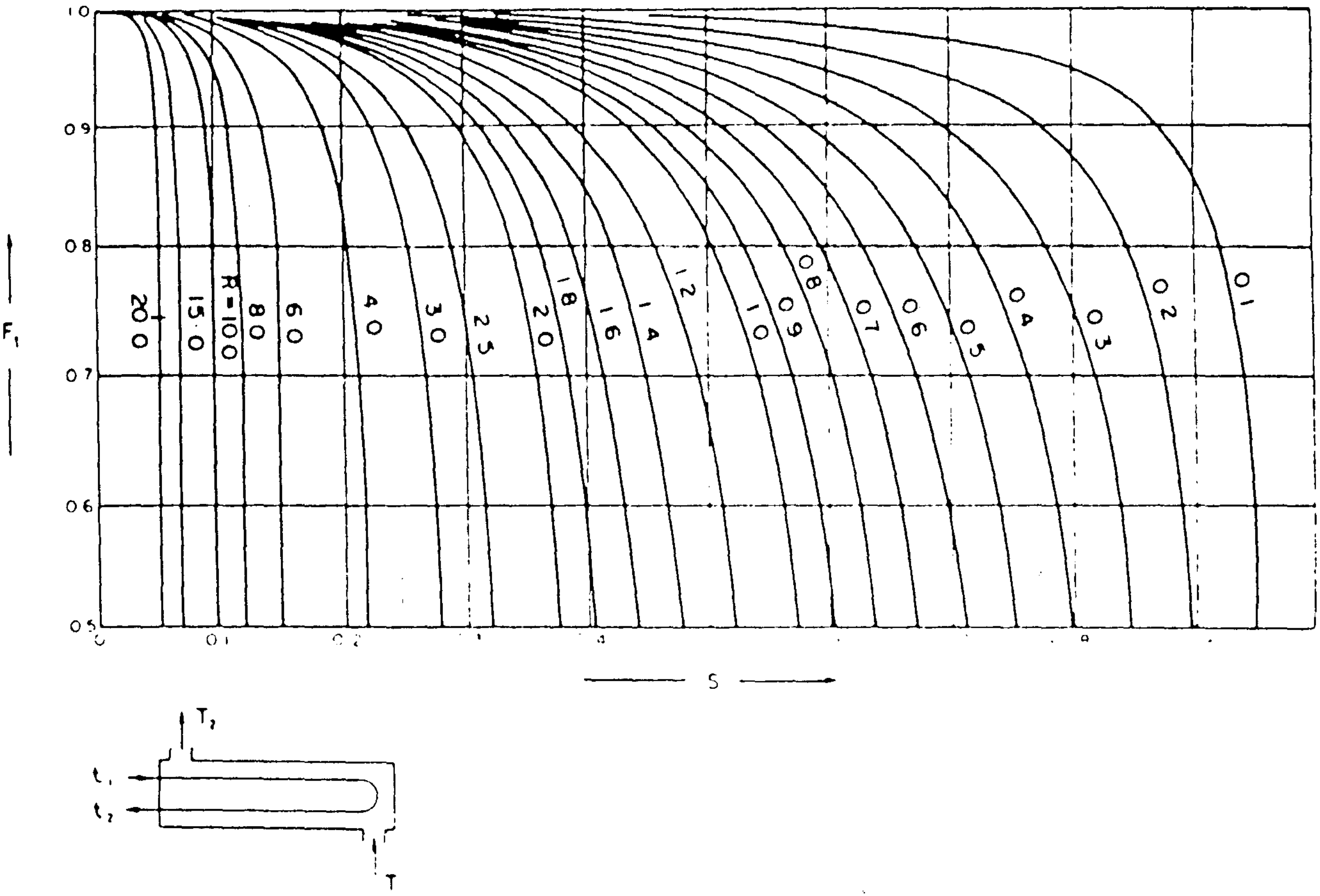
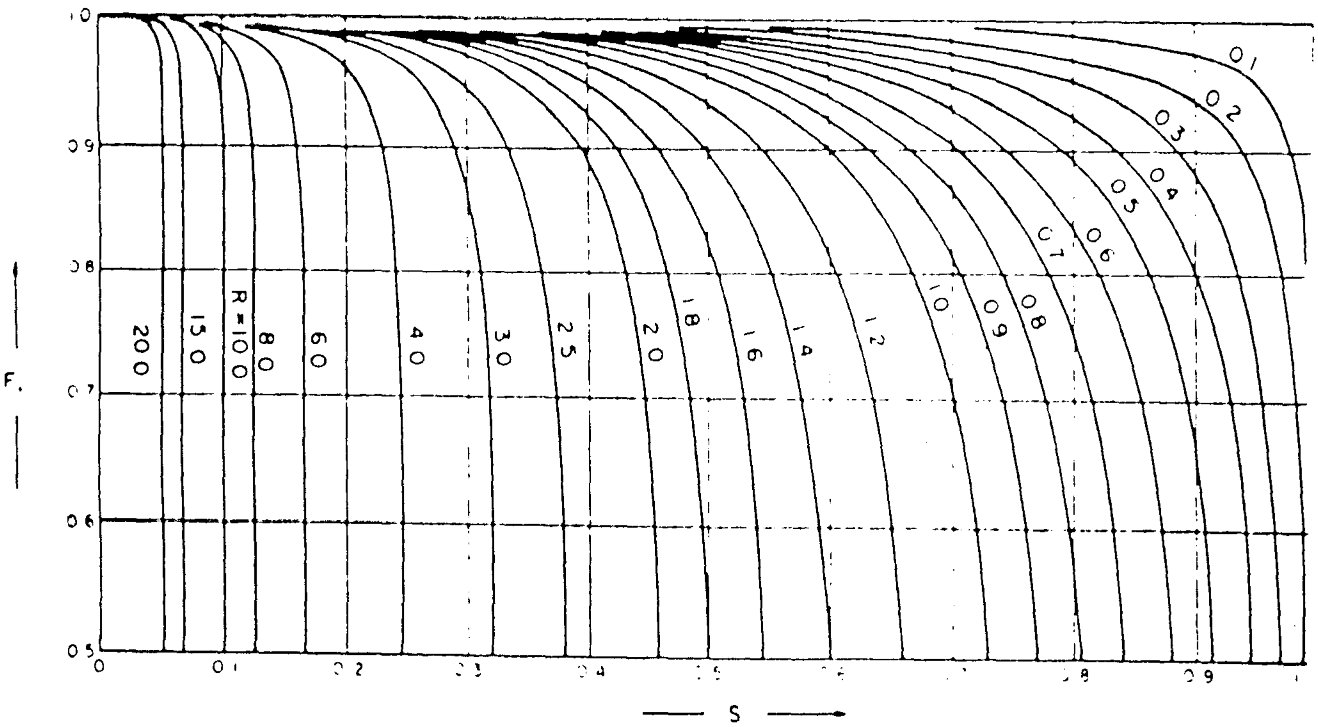


FIG. 12.19. Temperature correction factor: one shell pass; two or more even tube passes



Adapted from Rechardson and Coulson Vol. 6