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Dedications

After all, it is thanks to God that he arrived me here.

To my dear parents, the light of my life

To my lovely father Kaddour, who eagerly awaited this day, he was a very appreciable throughout my life and especially during All my student years, your words will be always the key to my success may God have mercy you.

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Dedications

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To all those who have an effect on my life and all those who my heart loved and my pen forgot them.

Habchi Safaa.

List of abbreviation and symbols:

a : Tube exchange surface[m²].

qm_h, qm_c: mass flow rate of hot and cold fluids in [kg/s].

C_{Ph}, C_{Pc}: specific heat at constant pressure of hot and cold fluids respectively [kg. k̇].

ΔT_h, ΔT_c: temperature difference of hot and cold fluids, respectively, in [K] or [°C].

T_{hi}, T_{ci}: hot and cold fluid inlet temperatures, respectively, in [K] or [°C].

T_{ho}, T_{co}: hot and cold outlet temperatures, respectively, in [K] or [°C].

E: The efficiency of the heat exchanger.

Fr: fouling resistance [m²/k.w].

U_p: coefficient in propre conditions [w /m² k].

U_s: coefficient in conditions fouling [w /m² k].

R: resistance (R= 1/U_s -1/U_p).

Q_V: Shell side fluid volume flow [m³/h].

Q'_V: Tube side fluid volume flow [m³/h].

ρ: The density of the fluid on the shell side [kg/m³].

ρ': Fluid density on the tube side [kg/m³].

T1: Inlet shell Side Temperature [C°].

T2: Outlet temperature on the shell side [C°].

t1: Tube side input temperature [C°].

t2: Tube side output temperature [C°].

e: Thickness[m].

F: the efficiency of the device with respect to the pure counter current.

a_t: Section per pass[m²].

G_t: Mass velocity[kg/h.m²].

G_{st}: mass speed side shell [kg/h. m²]

Re: Reynolds number.

D_e: equivalent diameter[m²]

F_c: Correction Factor.

A: surface[m²].

n_s: number of passes on the shell side.

n_t: number of passes on the tube side.

F_t: Friction factor inside the tubes as a function of Reynolds number.

d_i: internal diameter of the tubes[m].

d_e: external of the tubes[m].

L: = the length of the tubes[m].

ϕ_t: Corrective tube side.

N_c: number of chicanes.

N_t: number of tubes.

D_e: equivalent diameter[m²].

ϕ_s: Patch on the front shell.

C_p: The specific heat.

T_i, T_o: Inlet and outlet temperatures of stabilized crude oil (shell side).

t_i, t_o: Inlet and outlet temperatures of stabilized crude oil (shell side).

T_p: wall temperature[°c].

ΔP: pressure drops[bar].

Φ: Surface density of heat flux [w/m²].

ϕ: Heat flux [W].

λ: Thermal conductivity [W/m. K].

ρ: Density[kg/m³].

μ: Dynamic viscosity [Kg/ms]

v: cinematic viscosity [m²/s]

ε: Effectiveness

Clues

o: outlet, I: Inlet , S: shell , t: tube.

Symbols

NUT: Transfer unit Numbers.

ΔT_{LM} : Average logarithmic temperature difference between the two fluids.

TEMA: Tubular Exchanger Manufactures Association.

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*General
introduction*

Introduction:

Development and research on thermal transfer in compact heat exchangers became significant during the last years. Although the number of compact heat exchangers applied to the industrial plants increases, such as the tube and shell exchangers, there is always a lack of information about the heat exchange phenomenon along the heat-transferring surface. The manufacturers reserve increasingly significant budgets in the search of a maximum capacity exchange and a high compactness [1].

One of the major problems with which the heat exchangers are confronted, intended for the chemical, oil, food industries is accumulation, on the heat-transferring surfaces of substance organics or of dissolved matters or present in suspension in the food fluid [2]

This phenomenon, called fouling, with correct operation of industrial plants and, in particular, of heat exchangers. It constitutes, so a major problem in the design and the operation of this equipment and that, since the beginning of century.

As an example, the Algiers Refinery always suffers from problem of stopping tubes of heat exchanger.

The major technological concern of heat exchangers is the improvement of the heat exchange between the two fluids while generating the least pressure drops or reducing them to their lowest possible level, in our case the cause of this reduction is fouling which is a preponderant phenomenon in the reduction of the performance of these installations where its degree is assessed by measuring the overall transfer exchange coefficient and also the fouling resistance as a function of time.

The objective of this work is to study the dynamic and thermal behavior of two flows in a heat exchanger in the current case of a tube and shell exchanger and the design case in the fluid flow.

This study is divided into three chapters.

After a general introduction about the fouling phenomenon, thesis is organized as follows:

Chapter one summarizes the heat transfer phenomenon, heat exchangers types and applications. The P30-GA-21-01 A/B pre-heater technology (case study) in the UTBS south crude processing unit and a presentation of the major problem (tube side fouling) influencing the performance of this exchanger also these remedies. Are presented in Chapter two. The third chapter illustrates the thermal and dynamic study of the flow of fluids in the shell and the tubes. This chapter will be ended with a comparison of the performance of the design case and the current case after revision.

Finally, the dissertation includes overall conclusions and recommendations for future research.

Chapter I:
Heat Exchange's overview

Chapter I: Heat Exchange's overview

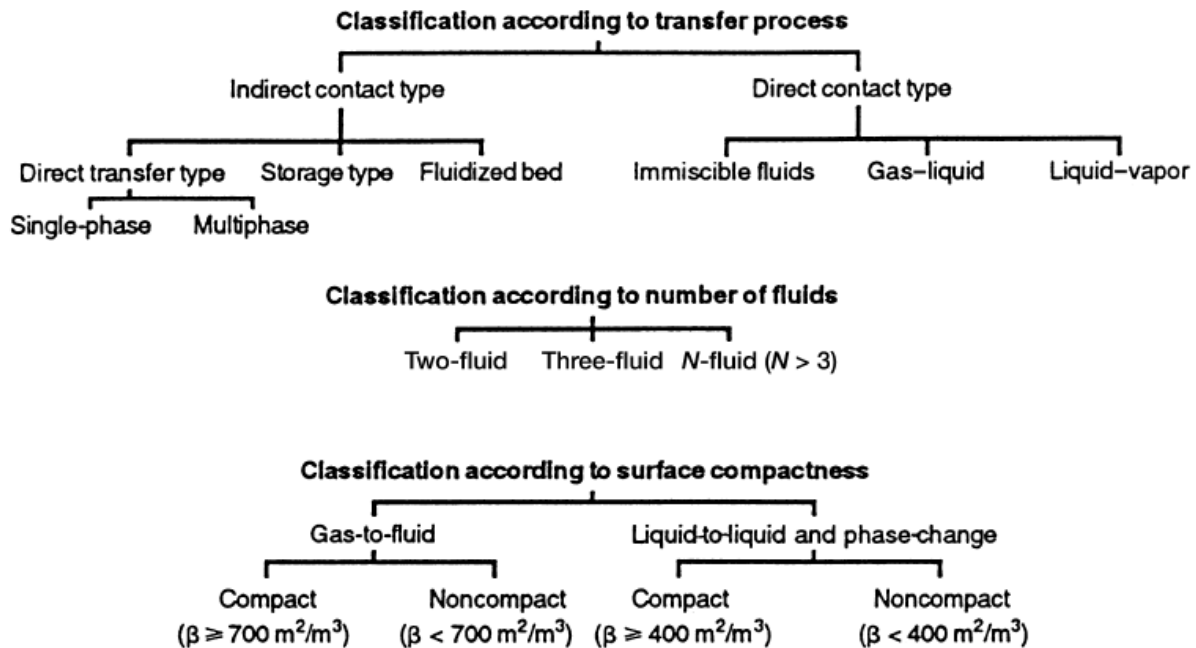
I-1) Definitions, Classifications, and applications:

The term "heat exchanger" is used to refer to any device that exclusively allows the transfer of heat from one fluid to another through a wall.

A heat exchanger has the function of allowing a transfer of thermal energy from one fluid to another without these two fluids mixing. This definition, which is very general, actually covers very different uses. The application of different heat transfer modes in the design of industrial heat exchange equipment is of great importance. The cost of heat in an industrial unit is enormous and it is essential to recover this energy to make the best use of it in the production chain. Thus, the economy plays an important role in the development of devices that can carry out heat transfers between phases.

There are many applications for heat exchangers, whether it is heating or cooling water, oil, oil or any other liquid or gas.

The choice of an exchanger depends on many parameters: temperature, pressure range, fluids, physical and chemical properties. [3]



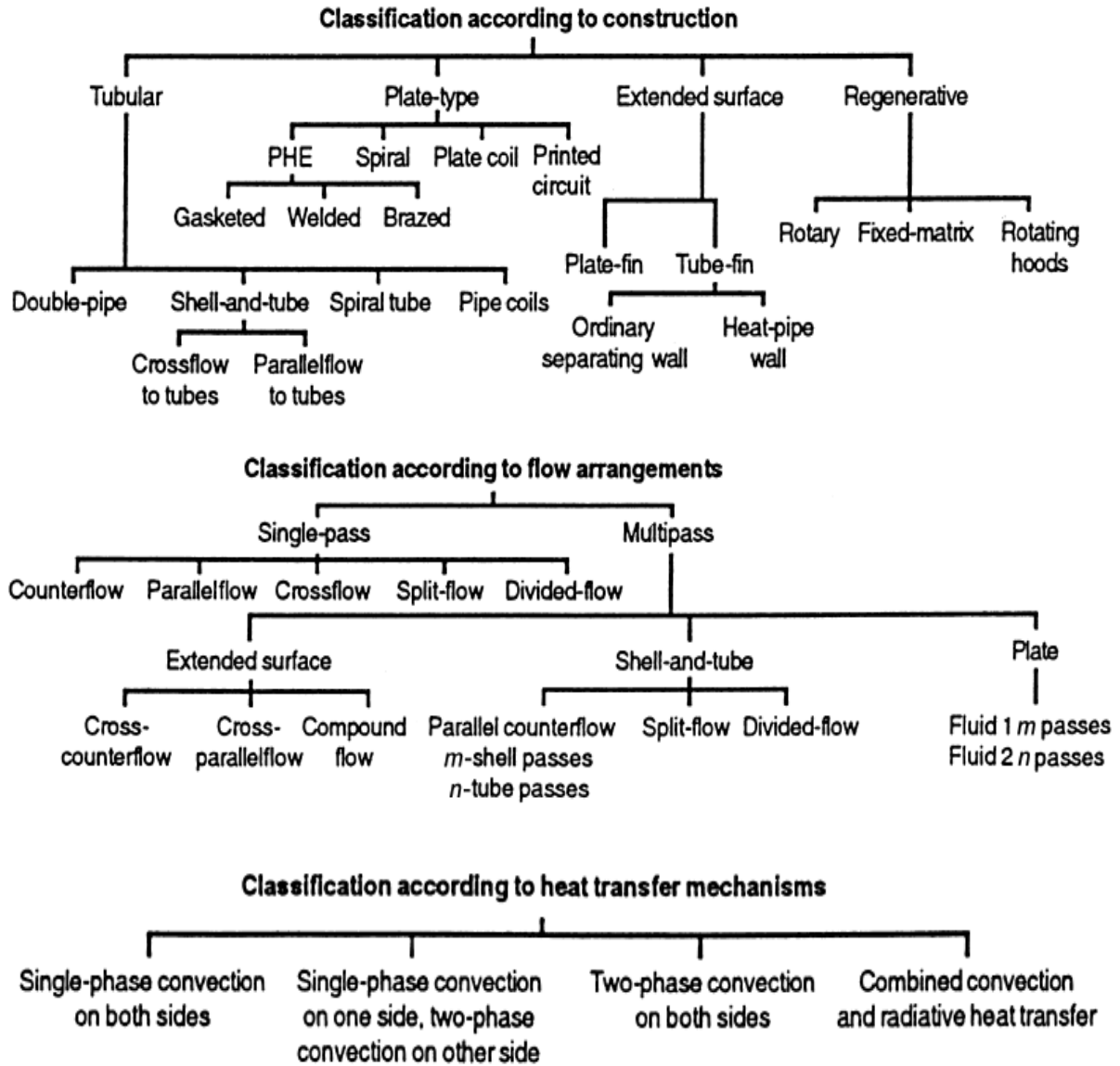


Figure I .1. a): Classification of heat exchangers [3].

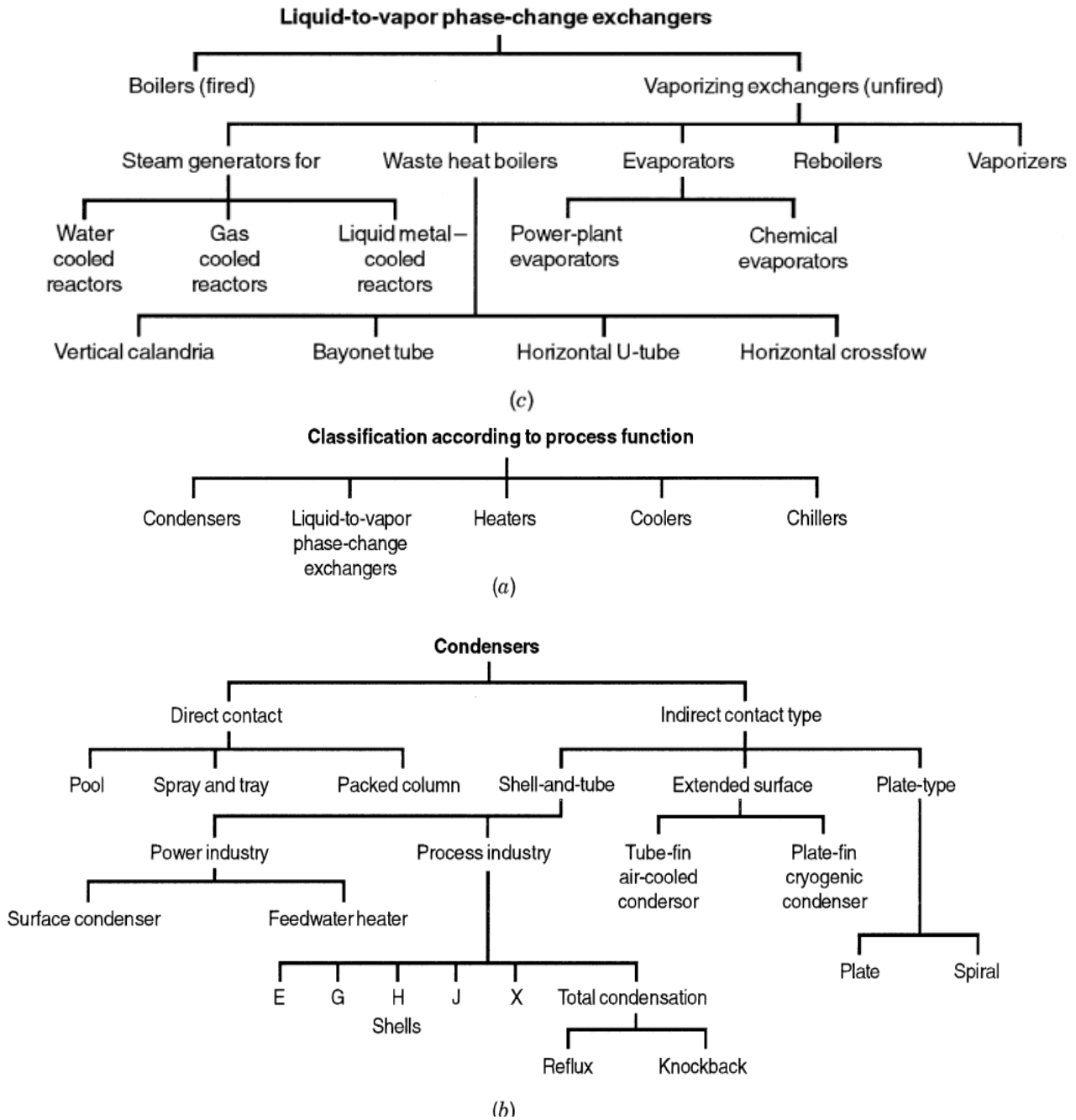
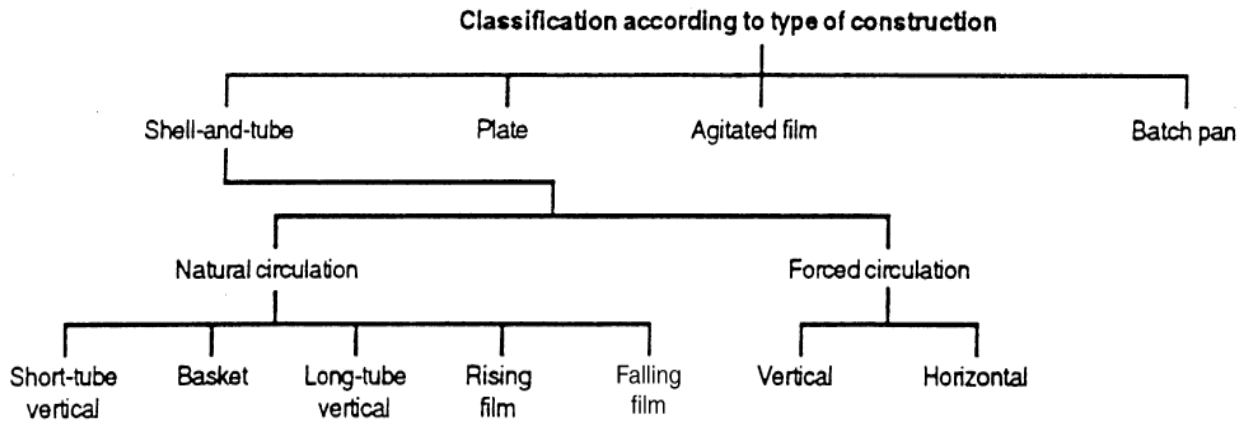
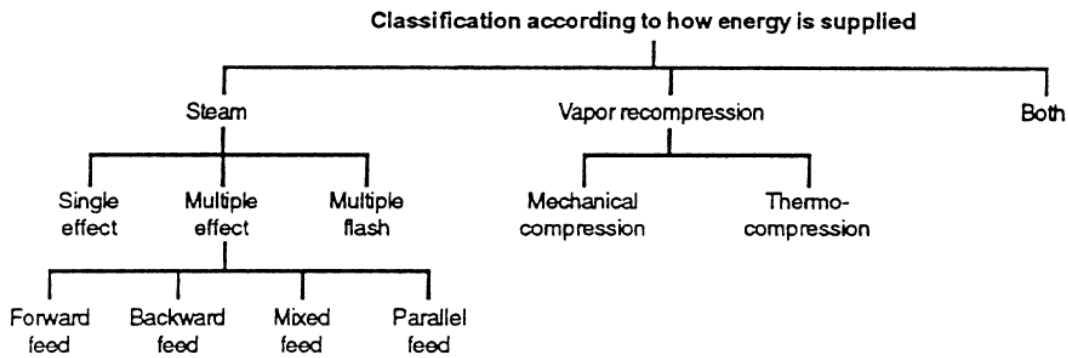


Figure I .1. b): (a) Classification according to process function; (b) classification of condensers;(c) classification of liquid-to-vapor phase-change exchangers.[3]



(d) (i)



(d) (ii)

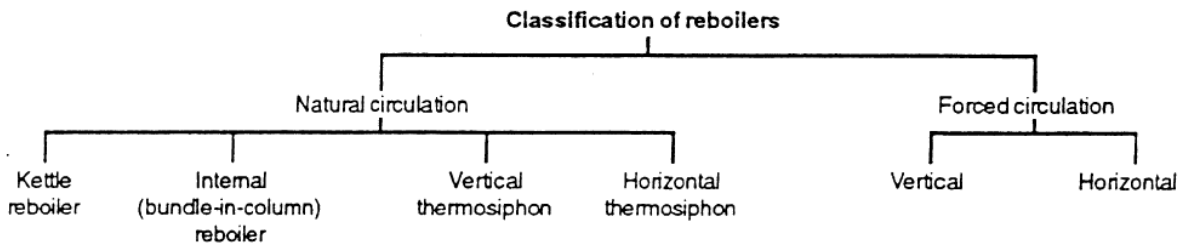


Figure I.1.c): (d) classification of chemical evaporators according to (i) the type of construction, and (ii) how energy is supplied (Shah and Mueller, 1988); (e) classification of reboilers. [3]

For many years, heat exchangers have been used in industries, they have many applications. For information, 30% of equipment of petrochemical units are made up of heat exchanger.

In the oil industry, heat exchangers are an essential component, especially for the treatment of crude oil and the atmospheric distillation of the latter constitute the base unit of an oil refinery.

I-2- Fouling phenomenon:

The phenomenon of fouling in heat exchangers is a subject, The main problems encountered by heat exchanger users are related to the phenomena of fouling.

Knowledge of the laws of heat transmission for all engineers and technicians who have to deal with thermal problems: refrigeration engineers. Thermal engineers, process engineering specialists, ... when two bodies, or two circles. are not at the same temperature. they are not in thermal equilibrium. we can then observe a passage of calorific heat energy. from the body or middle, warmer towards the coldest .it is known that spontaneous heat transfer is impossible from a cold medium to a hot medium.[4]

There are 2 methods for calculation:

- ✓ Transfer unit number (NUT)method.
- ✓ Average logarithmic temperature difference between the two fluids (DTLM).

To transmit heat uses three basic mechanisms:

- Conduction
- Convection
- The radiation

I-3- exchanger calculation methods:

I-3-1-Transfer unit number (NUT)method:

Purpose: dimensioning of a tubular exchanger by the method of the Number of Transfer Units (NUT). Concrete example of this dimensioning.

The Transfer Unit Number (NUT) method is based on the calculation of the performance of a heat exchanger. Indeed, this method allows:

- ✓ estimate the number of transfer units.
- ✓ calculate the efficiency of the exchanger from the numerical equations or from the abacus.
- ✓ determine fluid outlet temperatures where efficiency is known.

The efficiency of an exchanger is defined as the ratio of the heat output actually exchanged P real to the maximum power that it is theoretically possible to exchange P_{max} if the exchanger is perfect.[5]

$$E = \frac{P_{real}}{P_{max}}$$

The actual heat output of an exchanger P_{real} [w].

or:

q_{mh} , q_{mc} : mass flow rate of hot and cold fluids in [kg/s].

C_{Ph} , C_{pc} : specific heat at constant pressure of hot and cold fluids respectively/kg.k.

ΔTh , ΔTc : temperature difference of hot and cold fluids, respectively, in K or °C.

$$\Delta Th = T_{hi} - T_{ho}$$

$$\Delta Tc = T_{ci} - T_{co}$$

T_{hi} , T_{ci} : hot and cold fluid inlet temperatures, respectively, in K or °C.

T_{ho} , T_{co} : hot and cold outlet temperatures, respectively, in K or °C.

The theoretically possible maximum exchange power P_{max} is the product of the lowest heat capacity flow rate of a fluid C_{min} [W/K] and the temperature equal to the maximum deviation in the heat exchanger either ($T_{hi}-T_{ci}$)

$$P_{max}=C_{min} (T_{hi}-T_{ci})$$

The minimum mass heat capacity flow rate C_{min} is the product of mass flow (q_m) by the specific heat (c_p) of the fluid:

$$C_{min}=\min (q_{mh}\cdot c_{ph} ; q_{mc}\cdot c_{pc}) =\min (C_h ; C_c)$$

The efficiency of the heat exchanger is:

if the hot side has the minimum (q_m , c_p) product:

$$E = \left(\frac{P_{real}}{P_{max}} \right) = C_h \cdot \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}} = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}} = \Delta T_h / \Delta T_{max}$$

Or: if the cold side has the minimum product (q_m , c_p):

$$E = \left(\frac{P_{real}}{P_{max}} \right) = C_c \cdot \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} = \Delta T_c / \Delta T_{max}$$

When the fluid outlet temperatures are unknown (which is often the case in a simulation), the efficiency of an exchanger is determined by the following equations:

For flow of counter-current fluids:

$$E = \frac{1 - e^{-NUT \cdot (1-C)}}{1 - C \cdot e^{-NUT \cdot (1-C)}}$$

For co-current fluid circulation:

$$E = \frac{1 - e^{-NUT \cdot (1+C)}}{1 + C}$$

By deducting NUT from the above equations, we can have the following relationships:

For flow of countercurrent fluids:

$$NUT = \frac{1}{C - 1} \cdot \ln \left(\frac{E - 1}{C \cdot E - 1} \right)$$

For co-current fluid circulation:

$$NUT = \frac{-\ln[1 - (1 + C) \cdot E]}{1 + C}$$

With:

NUT: number of transfer units that is representative of the exchanger's trading power:

$$NUT = \frac{U \cdot S}{C_{min}}$$

U: global heat exchange coefficient that depends on flow and fluid characteristics, in W/(m².K).

S: Swap surface, in(m²).

C: ratio of thermal capacity flows.

$$C = \frac{C_{min}}{C_{max}}$$

Particular cases:

For all types of exchangers: if C=1

$$E = 1 - e^{-NUT}$$

For counter current heat exchanger: if C=1.

$$E = \frac{NUT}{NUT + 1}$$

In case the output temperatures are known, the calculation of an exchanger by the Transfer Unit Number (NUT) method consists of:

Calculate heat exchanger efficiency E and ratio of heat capacity flows:

$$C = C_{min} - C_{max}$$

Determine the number of NUT transfer units by using formulas or charts.

Determine the exchange area S by the following equation:

$$NUT = \frac{U \cdot S}{C_{min}}$$

I-3-2-Average logarithmic temperature difference between the two fluids (ΔTLM):

Purpose: Calculation of the difference in average logarithmic temperature between the two fluids (DTLM) as a function of their flow mode for a heat exchanger. Example of concrete use of this calculation.

A heat exchanger (or heat exchanger) is a system intended to transfer thermal energy from one fluid to another.

The heat exchanger occupies an indispensable place in all thermal systems (industrial, automotive, aeronautical, residential or tertiary building).[5]

The main roles of heat exchangers are:

- lowering or increasing the temperature of a fluid.
- make one or more state changes.

There are three different flow modes:

- co-flow: parallel flow of fluids in the same direction.
- counter-current flow: parallel flows of fluids but in opposite directions.
- and cross-current flow: perpendicular flows between the two fluids.

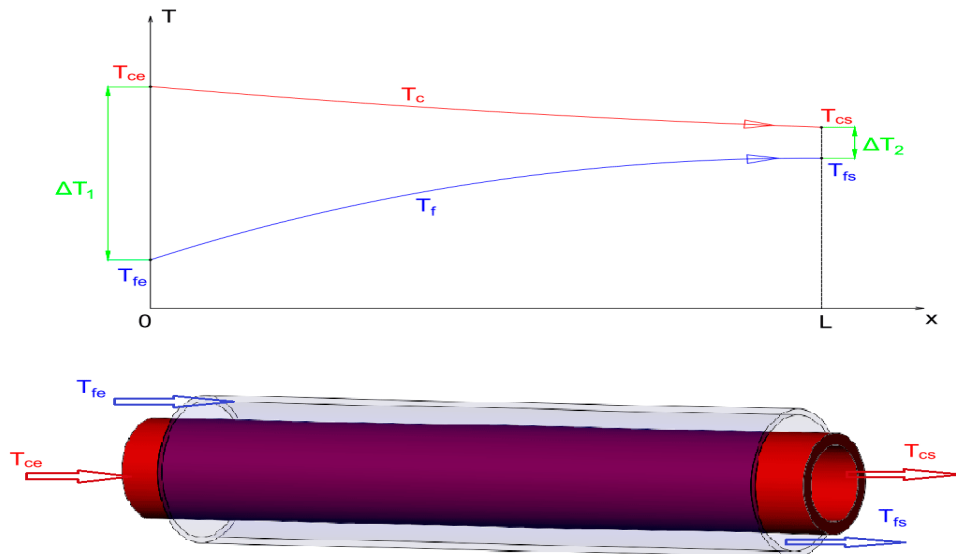
Exchanger operating on co-current:

Figure I.2): Temperature evolution of hot and cold fluid along a co-current heat exchanger.

The mean logarithmic temperature difference ΔTLM (DTLM) is defined as follows:

$$\Delta TLM = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

With:

$$\Delta T = T_{hi} - T_{ci}$$

$$\Delta T = T_{ho} - T_{co}$$

T_{hi} , T_{ci} : hot and cold fluid inlet temperatures, respectively.

T_{ho} , T_{co} : Temperature output of hot and cold fluids respectively.

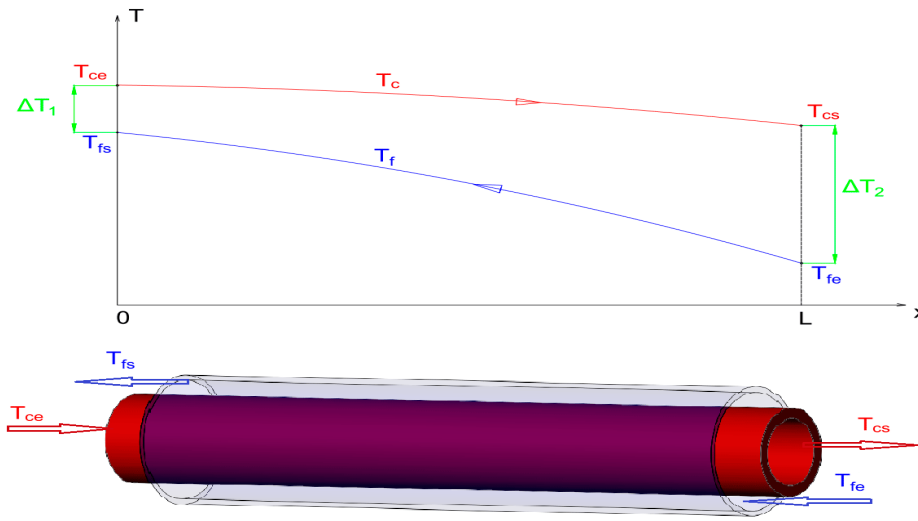
Counter current heat exchanger:

Figure I.3): Temperature evolution of hot and cold fluid along counter current heat exchanger.

A similar approach to that adopted in the case of co-current then leads to:

$$\Delta TLM = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

With:

$$\Delta T_1: T_{hi} - T_{co}$$

$$\Delta T_2 = T_{ho} - T_{ci}$$

T_{hi} , T_{ci} : hot and cold fluid inlet temperatures, respectively.

T_{ho} , T_{co} : hot and cold fluid outlet temperatures, respectively.

a) Quantity of heat(Q):

It is a quantity of calorific energy brought into play (absorbed, produced or transferred).it is expressed in the international system of unit (SI), in joules (J)or in (1cal=4.1855J).

b) Temperature(T):

It is expressing the thermal state of a medium, a state linked to the level of thermal agitation of the molecules that constitute it .it can be located in a conventional scale, such as the Celsius scale (°C), or it is measured in absolute scale defined by relying on the law of thermodynamics.

Like the kelvin(K)scale.

c) Phenomenon of thermal conduction:

Thermal convection mainly occurs during heat exchange between a solid wall and a fluid in contact with the wall.

This convection can be natural when the variation of the density of the fluid, result from the variations of its temperature, as it can be forced if the movement of the fluid is carried out by an external mechanical work (ventilation, agitation, pumping).

As a result of natural or forced convection phenomena, the convector fluid can simply heat up or cool down without changing its physical state, it is then convection without changing of state, but it can also, in contact with the wall which it exchanges heat, undergo a modification in its physical state, it is then a question of convection with change of state (boiling, condensation, ...)

- **Law of Fourier:**

Based on the fundamental Fourier hypothesis governing one-dimensional heat transfer by conduction the law stated by Fourier is written:

$$Q = -\lambda * A \left(\frac{dt}{dx} \right)$$

Q: amount of heat exchanged [KW]

A : surface d'échange de chaleur [m²]

dt/dx : gradient de température le long de X

λ : coefficient of proportionality of the furnace law (or thermal conductivity) [KW/m.K]

the sign (-) that appears in this expression means that the heat propagates in the direction of decreasing temperatures.

d) phenomenal thermal convection:

- **Definition:**

Thermal convection occurs mainly during thermal exchanges between a wall.

This convection can be natural when variations in the fluid's volume mass result from variations in its temperature, as it can be forced if the movement of the fluid is achieved by external mechanical work (ventilation, agitation, pumping).

then natural or forced convective phenomena. the convector fluid can simply warm up or cool down without changing its physical state. it then becomes convection without change of state. but it can also, on contact with the wall with which it exchanges heat, undergo a change in its physical state. convection with change of state (boiling, condensation...)

- **Newton's law:**

It is the fundamental law of thermal convection given by Newton's law:

$$Q = hA(T_s - T_\infty)$$

Q: amount of heat exchanged [KW]

A : surface d'échange de chaleur [m²]

T_s: temperature of the surface of the solid in contact with the fluid.

T_∞: fluid temperature.

h: Newton's law coefficient (thermal convection coefficient).

this characteristic coefficient the efficiency of the convection it depends:

a- characteristics of the wall in contact with the fluid: shape, size and surface condition.

b-the way in which the fluid circulates in relation to the wall the direction and magnitude of the velocity.

c- physical characteristics of the fluid: thermal conductivity, mass heat, volume mass and viscosity.

e) **Phenomenal radiation:**

• **Definition:**

When a body is raised to any temperature, it emits electromagnetic radiation comparable to light or radio waves, which carry energy and can propagate in absolute vacuum. at light speed ($C=3*10^8\text{m/s}$). another body receiving this radiation, can absorb a more or less fraction of it is then transformed into heat.

It is thus possible to transmit heat from one body to another at a lower temperature, thanks to the scratch, even in the absence of any material support.

• **Law of Boltzmann:**

It concerns the total emission of a surface of a black or grey body, the Boltzmann law expresses the heat flux emitted by the surface:

$$Q = \varepsilon\sigma T^4$$

Q: heat flux emitted [KW/m²].

ε : emissivity of the surface.

$\sigma=5.669*10^{-8}\text{W/m}^2\text{K}^4$: constant from Stephan -Boltzmann.

$$Q = FGF\varepsilon\sigma(T_i^4 - T_o^4)$$

FG: geometric factor ($FG =1$, if all body energy (1) is received by the body (2), and vice versa).

F ε : Function factor of body emissivity's.

In reality, all heat exchange takes place simultaneously and possibly under three modes of transfer which compete, the exchange is then the sum of the three effects. However, when one mode is predominant, the effect of the other two modes will be ignored.

The processes used in industry often require that the treated fluids be heated or cooled with or without phase change during the various operations to which they are submitted. The heat applied represents a significant expenditure of energy of which it is necessary to recover as much as possible. Therefore, heat exchangers are important equipment.[6]

I.4. Operating principle:

A heat exchanger is a device for energy recovery heat from one fluid to another. The heat flux passes through the separation wall of the different fluids.

Heat can be characterized as a transfer of energy from one system to another due to a difference in temperature. According to the second law of thermodynamics (heat in the universe flows continuously from hot bodies to cold bodies), this transfer of energy takes place from the most important temperature to the lowest. It therefore stops when the two fluids are of identical temperatures [7][8].

I.5. Principle of technological implementation and mode of circulation:

Fluid circulation on each side of the wall forming the surface exchange corresponds to different basic modes [9].

I.5.1 Co-current circulation:

These are so-called co-current exchangers where the temperature of the cold fluid cannot be higher than the temperature of the hot fluid outlet. The temperature of the fluid's changes during their longitudinal crossing of the exchanger, unless one of the fluids undergoes a phase change.

Figure I (4) give the qualitative evolution of these temperatures along a very simple co-current tube exchanger; the length of the exchanger has been. abscissa, the temperatures are marked with indices (e) meaning input and (s) output, 1 designing the hot fluid and 2 the cold fluid.

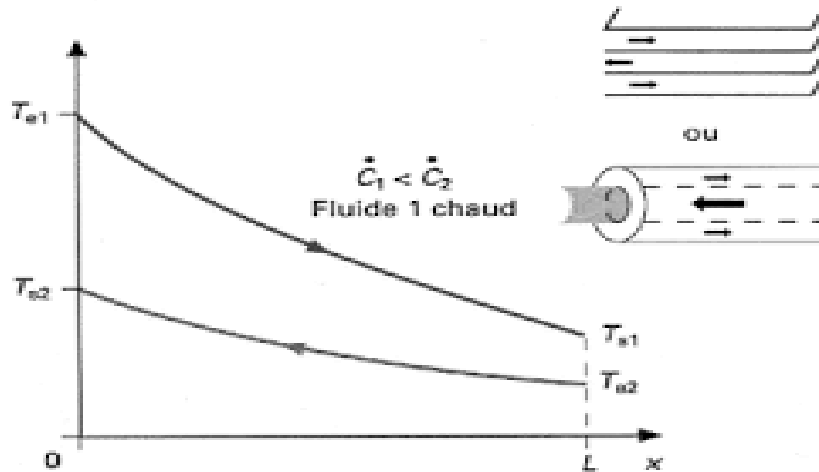


Figure I .4): Qualitative temperature evolution in a common tubular heat exchanger.

I.5.2 Counter-current circulation:

These are counter-current exchangers where the temperature of the cold fluid may exceed the temperature of the hot fluid outlet. This arrangement is one of the most favorable for the heat exchanger.

The advantage of the counter current heat exchanger over the co-current heat exchanger is that, for the same heat flow, lower exchange surfaces are required.

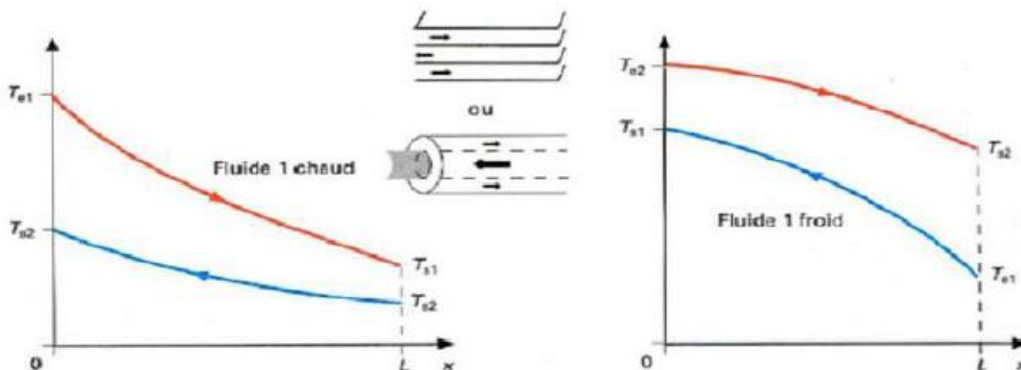


Figure I .5): Qualitative temperature changes in a tubular or co-current plate heat exchanger.

I.5.3 Cross current circulation:

The two fluids flow perpendicular to each other figure I (6), the unfiltered fluid is channeled: it is the one whose vein is divided between several Separate parallel channels with low cross-section. The other fluid circulates freely between the veins and can be considered partially stirred due to the vortices generated by the tubes. Mixing has the effect of homogenizing temperatures in the straight sections of the fluid vein. Without this, temperatures vary not only with the direction of flow, but also in the vein section. A schematic representation of the cross current exchanger is given in Figure I (6).

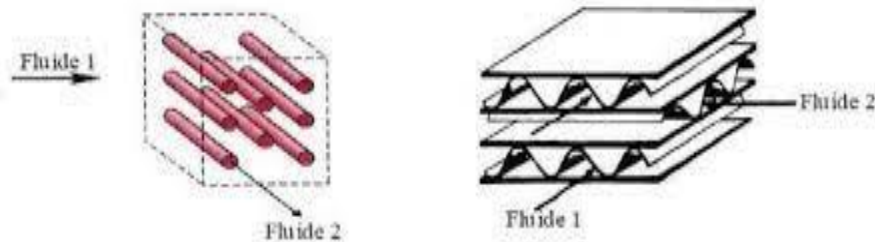


Figure I .6): examples of cross current exchangers.

I.6 Interchange Classification Criteria:

There are several criteria for classifying the different types of exchangers, the main ones being [9]:

I.6.1 Technological classification:

The main types of exchangers encountered are:

- Single-tube, coaxial or multi-tubular tubes.
- With primary or secondary surface plates.
- Other types: direct contact or fluidized bed.

I.6.2 Classification according to heat transfer method:

The three heat transfer modes (conduction, convection, radiation) are coupled in most applications (combustion chamber, fume recovery, etc.), there is often a predominant transfer mode. For any heat exchanger with heat transfer through a wall, conduction occurs.

I.6.3 Classification according to heat transfer process:

A heat recovery or regenerative operation is defined:

Transfer without storage, therefore in recuperator, with 2 or n passages and a flow in general continuous.

I.6.4 Functional classification:

The passage of fluids in the heat exchanger can be done with or without phase change, depending on the case, it is said that one has a single-phase or two-phase flow.

We then encounter the following different cases:

- Both fluids have monophasic flow.
- Only one fluid has a flow with phase change, case of evaporators or condensers.
- Both fluids have a flow with phase change, case of evaluators.

I.6.5 Classification according to the compactness of the heat exchanger:

Compactness is defined by the ratio of the area of the exchange surface to the volume of the exchanger.

I.6.6 Classification according to the type of heat exchange:

wall material Two types of walls are used:

- Metal exchangers of steel, copper, aluminum or special materials: superalloys, metals or refractory alloys.
- Non-metallic plastic, ceramic, graphite, glass, etc.

I.7. Different types of heat exchangers:**I.7.1 Tubular exchangers:**

For historical and economic reasons, exchangers using tubes as the main component of the exchange wall are the most common [9].

Three categories can be distinguished according to the number of tubes and their arrangements always made to have the best possible efficiency for a given use:

a. Monotube exchanger: in which the tube is placed inside a tank and generally has the shape of a coil. (Figure I .7). a)

b. Coaxial exchanger: in which the tubes are most often bent. In general, hot or high-pressure fluid flows into the inner tube. (Figure I .7). b)

c. Multitubular exchanger: existing in four forms:

Separate tube exchanger: inside a tube of sufficient diameter is placed several small diameter tubes held apart by spacers.

The heat exchanger can be either straight or rolled. (Figure .7).c)

- Close-fitting tube exchanger: to hold the tubes and to obtain a sufficient passage for the external fluid to the tube, a spiral-wound tape is placed around some of them. (Figure I .7). d).
- Fin tube exchanger: these tubes improve the heat exchange coefficient (Figure I .7). e).
- Tube and shell exchanger: it is currently the most common exchanger.

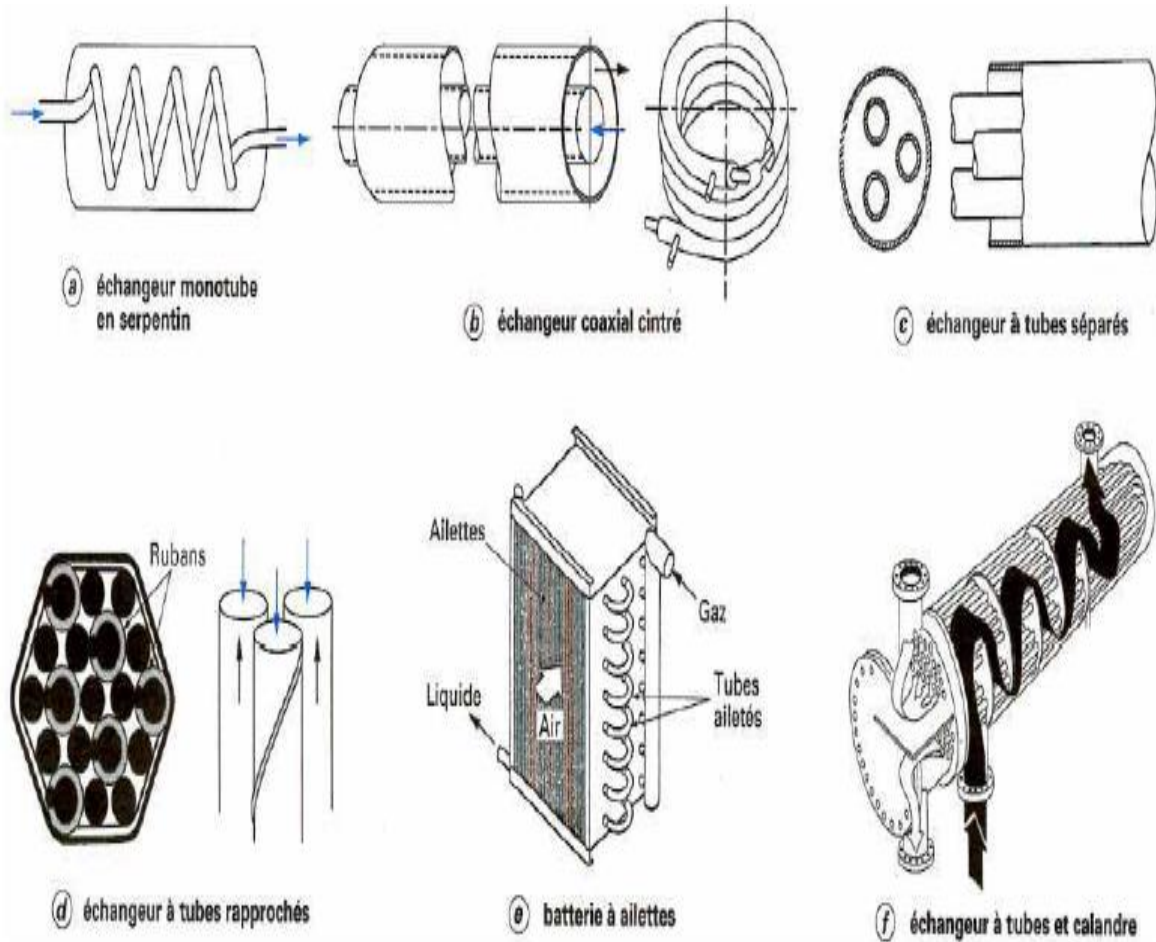


Figure I.7): the different types of tubular exchangers.

I.7.2 Plate exchangers:

These heat exchangers were originally designed to meet the needs of the dairy industry and subsequently used in various branches of the industry (chemical, nuclear, etc.) [10].

Depending on the channel geometry used, the surface heat exchangers are distinguished primary and secondary surface heat exchangers.

a. Primary surface exchanger: these exchangers can be:

- Plate and joint exchanger: they are used for heat transfer between single phase fluid or double-phase condensation or vaporization.
- Heat exchanger with soldered or brazed plate: they are used for the recovery of heat, in the fields of chemistry, petrochemical, agri-food etc. These exchangers can be: lamellar exchangers, spiral exchangers or brazed exchangers.

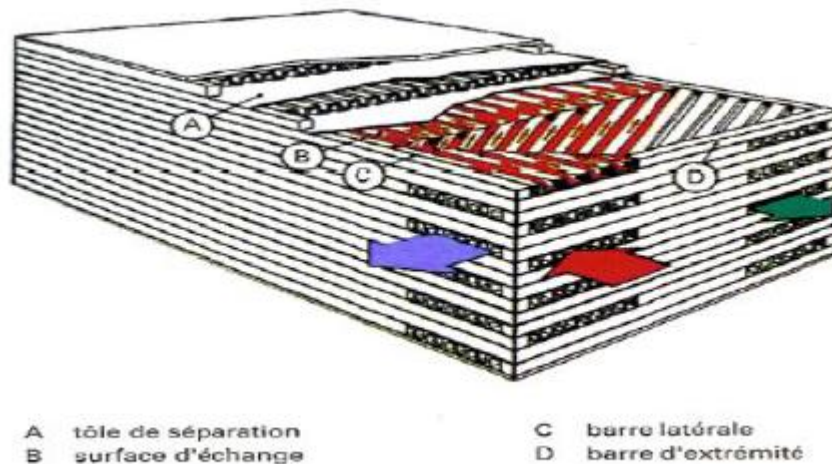


Figure I .8): Exchanger with brazed plates: assembly of plates.

b. Secondary surface exchangers made of aluminum or steel stainless.

I.8. Tube and shell Tubular Exchangers:

This type of device is most common in refineries. It consists of a bundle of tubes mounted on two tubular plates and carrying a number of baffles.

At each end are attached the distribution boxes that ensure the circulation of fluid inside the tubes in several passes. The tubes is housed in a shell with inlet and outlet tubing. For the second fluid that circulates outside the tubes following the path imposed by the baffles [11].

The most commonly applied designation for this type of heat exchanger and the American standard TEMA (Tubular Exchanger Manufactures Association).

✓ Tube-shell Assembly:

The main tube and shell exchanger technologies are:

- a. Fixed tubular plate exchanger: this plate can be welded directly on the shell. These devices can accommodate the maximum number of tubes inside the casing, but they can only be used if the temperature difference between hot and cold fluids is sufficiently small that expansion or beam concentration is acceptable. Cleaning of the outside of the tubes can only be done by chemical means.
- b. Floating head exchanger: one of the tubular plates is fixed, the second plate of a lower diameter, carries the return box and can slide freely inside the hood that closes the shell. These devices allow the thermal expansion of the beam as well as its mechanical cleaning.

c. U-tube exchanger: The use of angled tubes removes a tubular plate, while designing the expansion properties of the floating head. The cleaning Mechanical inside the tubes is impossible these beams are usually used in steam reboilers.

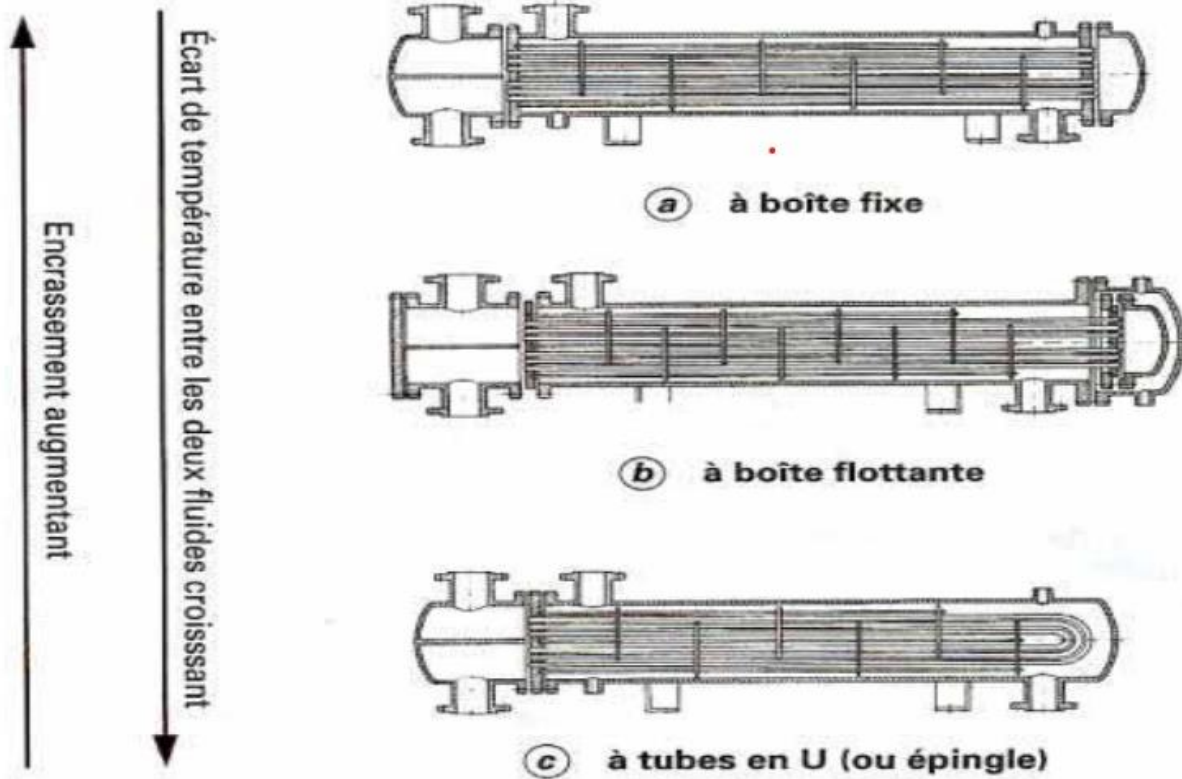


Figure I .9): tube and shell exchanger: main technology with fixed box, floating box and U tube.

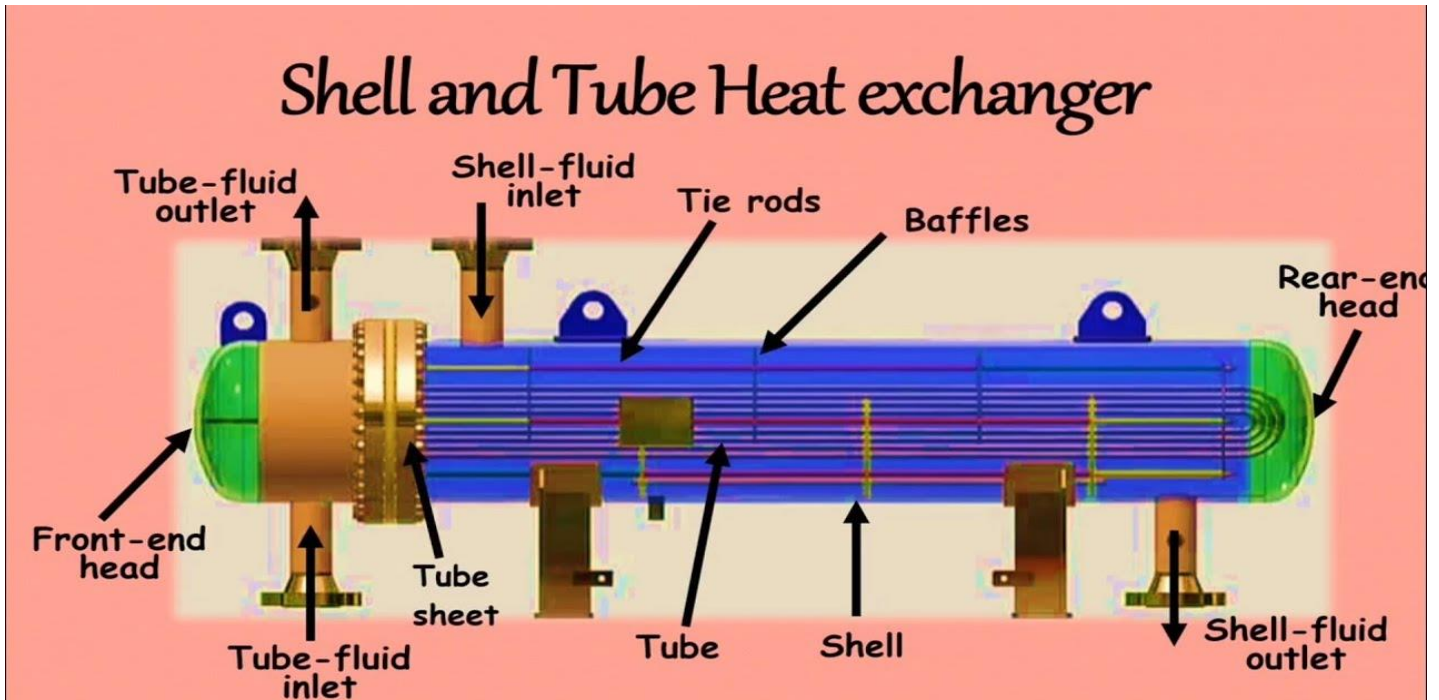


Figure I .10): Various components of a tube and shell heat exchanger.

Conclusion:

The existence of a wide variety of heat exchangers, used in many applications and different industrial fields and because of their importance in production units. It is necessary and important to ensure a good profitability of these units and to improve the efficiency, which often depends on the surface condition of the exchangers and their operation. The study of these devices can be analytical or numerical. The methods of calculation of heat exchangers will be the subject of the chapter number three.[12]

***Chapter II:
Fouling phenomenon.***

Chapter II: Fouling phenomenon.

Industrial use of heat exchangers is not a problem if the walls of the exchange surfaces remain clean for the duration of operation of the appliance. But in many applications, this is not so. The circulation of one of the fluids is often accompanied by deposition formation and usually the thickness of the latter increases with time. The presence of these deposits reduces the heat flow and prevents the desired operation from being fully realized. It is therefore essential to perform a periodic cleaning of such an exchanger.

Fouling remains one of the least understood phenomena of the industry. The significant increase in the cost of energy and raw materials in recent years and the need for industries to become more competitive have necessitated a more thorough approach to these mechanisms.

Fouling of heat transfer equipment is a phenomenon leading in the reduction of performance: such as the decrease in heat transfer coefficients, increasing the temperature of hot fluid and therefore energy consumption.

II.1. Definition of Fouling:

It is the accumulation of undesirable solid elements by deposition on surfaces exchange which will increase the thermal resistance and thus make the passage of heat more difficult.

This deposition, which evolves over time, can consist of crystals, sediments, biological residues, products of a chemical reaction or be the combination of several of these elements.

Fouling plays a key role in the performance of heat exchangers. Heat, it occurs with or without temperature gradient in a large number of natural processes, it is extremely important to choose the type of heat exchanger suitable for particular applications and to adopt realistic values of the dirt resistance.[13],[14]

II.2 Classification of different types of fouling:

It is possible to classify fouling according to the mechanism that controls the deposition speed, according to the conditions of use of the exchanger or according to the dominant mechanism, even if it does not control the deposition speed: for this we distinguish according to [15],[16],[17]:

- Particulate fouling.
- Fouling by scaling.
- Fouling by corrosion.
- Organic fouling.
- Fouling by chemical reaction.
- Fouling by solidification.

But most real deposits are the result of the combination of at least two types cited, one type can predominate and accelerate to the contribution of others.

Considering that only one category of this phenomenon several researches have been made to predict effective methods that highlight different means to minimize fouling; most of the work was based only on the type of particulate fouling (deposition and re-training phenomenon).[18]

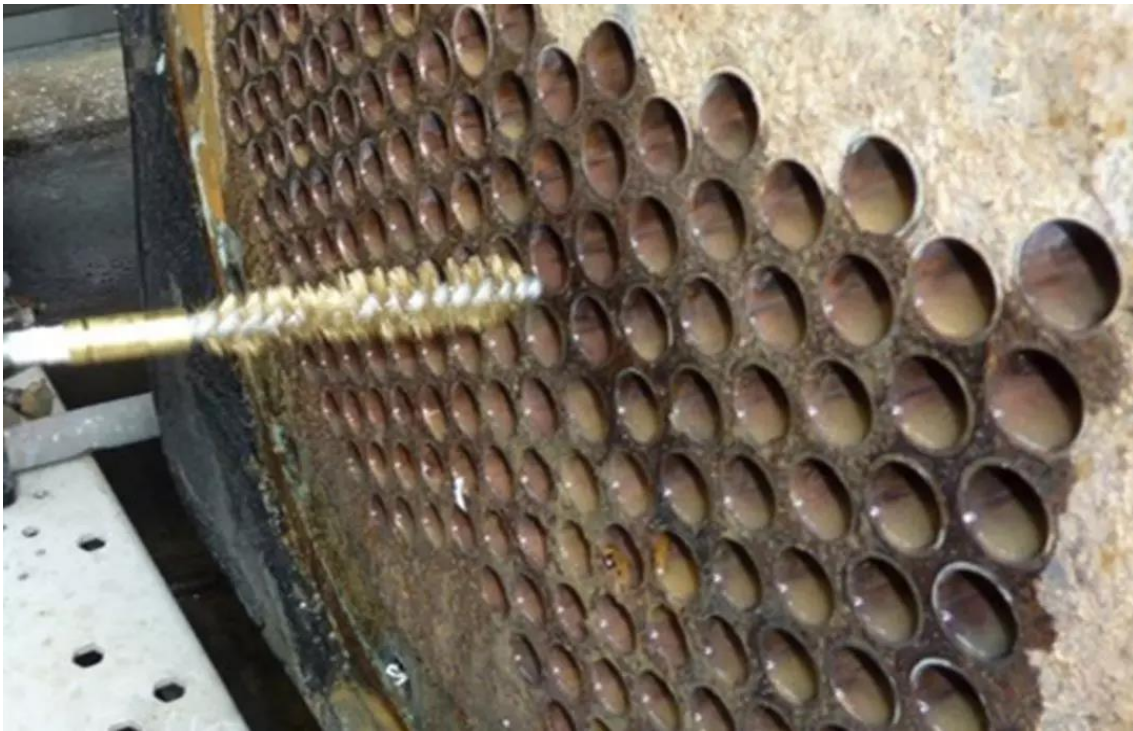


Figure II .1): fouling in a tubular exchanger.

II.2.1 Particulate Fouling:

Most flows, industrial fluids (liquid or gaseous) carry suspended particles ranging in size from a fraction of μm to a few tens of μm ; the deposition is inevitable of some of these particles on the exchange surface [19].

- Boiler water containing corrosion products, cooling towers, airborne particles and corrosion products (iron oxides and hydroxides).
- Gas flows which can be heavily charged with dust particles.
- Industrial fumes from solid combustion residues.

II.2.2 Fouling by scaling:

It is generally associated with the production of a crystalline solid from a liquid solution [20]. It is therefore highly dependent on the composition of industrial waters.

Scaling is materialized by a formation of sticky and hard inlays on the surfaces of exchanges generally metallic. For scaling to occur, two conditions must be met:

- The solubility limit must be exceeded, that is, saturation: this is the thermodynamic aspect.
- Deposition speed must be fast enough: this is the kinetic aspect.[21],[21]

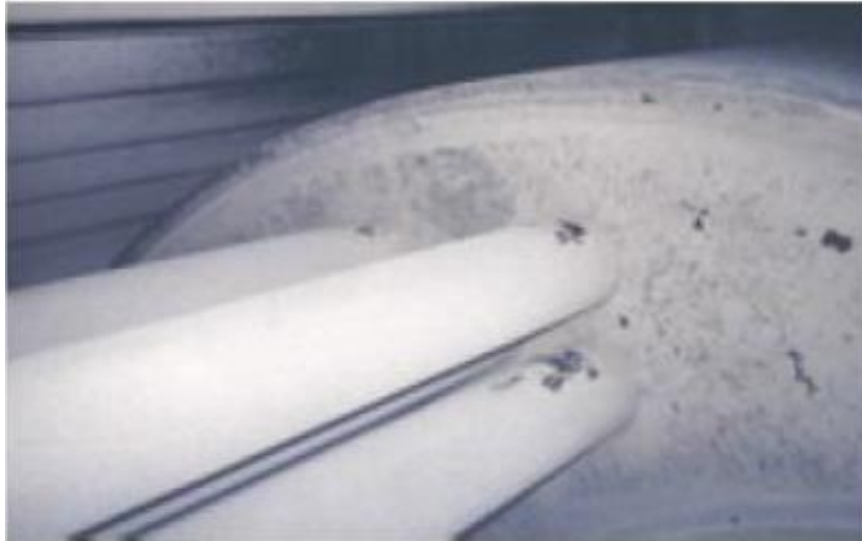


Figure II .2): scaling of a smoke tube boiler.

II.2.3 Corrosion Fouling:

It is the result of a chemical or electrochemical reaction between the heat transfer surface and the flowing fluid, we distinguish Uniform corrosion characterized by a steady loss of thickness but whose speed is not necessarily proportional to time.

- Pitting or etching corrosion is limited to very small areas ($\sim 1\text{mm}^2$).
- Corrosion cracking at the intergranular or trans granular microscopic scale.

Selective corrosion or only one element of an alloy undergoes a selective attack.[22]



Figure II .3): significant corrosion.

Corrosion fouling is a potential promoter for all other types of fouling, corrosion products can serve as nucleation germs for supersaturated solutions, trap suspended particles, serve as a shelter for micro-development organisms and even catalyze certain reactions [22].

The reaction products that form and remain on the exchange surface create the deposition, which is a corrosion mechanism, in situ, when the fouling is of a particulate type.

II.2.4 Biofouling:

It is due to the development of micro-organisms that create a film on contact with the exchange surface, it can be caused by three main types of micro-organisms: bacteria, algae and fungi [23].

Bacterial development is due to a nutrient supply (hydrocarbons, ammonia), The development of algae is due to the presence of solar energy with photosynthesis.

Fungi develop with the addition of nutrients but mainly due to changes in physical conditions (pH, humidity, temperature).



Figure II .4): deposit of bacterial slime, hydrocarbons and metal oxides in a heat exchanger water hydrocarbon (petroleum refinery).

II.2.5 Fouling by chemical reaction:

It is due to a chemical reaction that occurs near an exchange surface of heat and that the solid products of the reaction settle there, this reaction is often a polymerization and the result is the formation of a high molecular weight substance deposition [24],[25].

The parameters affecting this type of fouling are:

- ❖ The temperature of the surface.
- ❖ The average temperature of the fluid.
- ❖ The increase in pressure.

- ❖ The speed of the fluid.
- ❖ Composition alongside the main constituent, secondary constituents even at trace levels, in particular olefins, molecular oxygen and air, dissolved organometallic complex compounds and corrosion products may affect deposition.
- ❖ The surface condition of the metal and deposition as well as the flow geometry that affects the velocity, temperature and concentration distributions near the surface.

II.2.6 Fouling by solidification:

The solidification of a pure liquid in contact with an exchange surface under-cooled (formation of a layer of ice within the forced lines or frost) or the deposition of a high melting point component of a liquid on contact with a cold heat transfer surface (paraffinic hydrocarbon deposition).

A vapor can also be deposited in a solid form without going through liquid state (ice formation).[26]

II.3. Causes of fouling:

The causes of fouling are varied according to the origins, we can distinguish essentially:

-Soiling due to suspension materials in insoluble, sandy or Clay brought by the water before introduction into the circuit. They can be deposited by any or traffic speed is reduced.

-Fouling due to organisms: especially in the cooling circuit recycling, the conditions (aeration, light, temperature, etc.) are very favorable to development of living organisms (algae, fungi, etc.).

- Fouling due to precipitation of mineral salts deposited on the walls of exchangers.[27]

II.4 Prevention of Fouling:

Mechanical or chemical methods to prevent fouling during the operation of the heat exchanger can significantly improve the performance of the heat exchangers but also extend the time between stops.[28]

II.4.1 Mechanical Processes for Liquids:

The techniques used for liquids are well suited when the deposits are soft and friable, with low resistance of re-training.

Various techniques are available on the market for the continuous cleaning of the internal surface of tubular exchangers: ball or spring. These processes refiltration upstream of the heat exchanger.[28]

II.4.2 Mechanical processes for gases:

For exchangers operating with dusty gases, there are several mechanical cleaning or acoustic blowing processes, etc. The process to be retained depends on the type of deposit and the nature of the exchange surface.[28]

II.4.3 Chemical Water Treatment Processes:

There is a significant amount of information on the effectiveness of the various chemical treatment of water, which can be used to reduce fouling. To avoid or minimize scaling deposits, different chemical treatments for the efficient use of lime, resin or acid, softening, seeding, scaling inhibitors. Actions to prevent biological fouling require either. Destroy microorganisms or prevent their development. The corresponding treatments use biocides.[28]

II.5 Consequences of Fouling:

Fouling of the exchanger results in:

- The reduction in the efficiency of the device that causes the load losses.
- Decrease in its performance (decrease in heat exchange, decrease in cross-sections, decrease in flow rates if there is maintained pressure and transfer power drop... etc.).
- Capping of the tubes following the formation of a film of fouling around the walls of the tubes.
- Degradation of the equipment and therefore malfunctioning of the uses with repairs and production losses.[29]

II.6 Impact of fouling on the design of the exchangers:

From a thermal point of view, the fouling of an exchanger results in a decrease in its performance. In fact, the various deposits located on the exchange surface generate additional thermal resistance which prevents the transfer of heat through the wall and consequently a decrease in the overall exchange coefficient. And for this There are mechanical and chemical methods for preventing fouling during the operation of the exchanger. The aim of these processes is not only a significant improvement in performance, but also an increase in service life between scheduled shutdowns (for maintenance).[30]

II.7 Effects of fouling on performance heat exchanger:

Phenomenologically, fouling is a transient heat problem and mass which requires the simultaneous action of several complex processes [31].

Epstein broke down the fouling mechanisms into 4 events sequential:

- Initiation as the time required before the deposit is formed on clean surface.
- It should be noted that in the vast majority of studies experiments dealing with particle fouling on tubes of exchangers, the initiation phase of the fouling process is not detected.

-The adhesion of particles under the influence of Van der Waals forces, forces electrostatic or capillary; Re-drive of deposited particles due to shear forces acting on the deposit, erosion or chipping.

-The aging of the deposit characterized by a change of texture and a wear and tear of said depot.[32][33]

Conclusion:

The industrial use of heat exchangers does not pose particular problems in the case where the walls of the exchange surfaces remain clean throughout the operation of the apparatus. But in many applications, this is not so. The circulation of one of the fluids is often accompanied by deposition formation and usually the thickness of the latter increases over time. The presence of these deposits reduces the heat flow and prevents the desired operation from being fully realized. It is therefore essential to perform a periodic cleaning of such an exchanger.[34]

Chapter III:
***Thermal and dynamic
calculation***

Chapter III: Thermal and dynamic calculation

III.1. Experimental study of fouling:

The study of a heat exchanger makes it possible to size a device providing a given thermal service with an optimum exchange surface and geometry. In fact, it is a question of providing the user with an exchanger that is as economical as possible. Faced with technological (size, standardization, etc.) and economic constraints, a compromise has to be made between the pumping power and the cost of an exchanger.

Purpose of calculation:

The aim of our calculation concerns primarily the verification of the performance of the P30-GA-21-01 A/B exchanger after cleaning and changing the tubes (retubing), by calculating the fouling resistance, its pressure drops and its efficiency. And in the second part we are interested in monitoring the performance of the exchanger over time before maintenance.

In the case of our study the pre-heater is composed of two exchangers placed in series, can be considered as a single exchanger having the following characteristics:

- The same flow of crude crosses the tube side of each exchanger.
- The same flow of crude crosses the shell side of each exchanger.
- The total number of tubes is the sum of the tubes of each exchanger.
- The total number of passes on the tube side is equal to twice the number of passes on the tube side of each exchanger.
- The inlet and outlet temperatures of the fluids are taken at the ends of the coil.
- The volume flow of the crude remains constant along the preheating circuit.

Simplifying assumptions:

We limit ourselves in our study to the thermal aspect of the problem, by posing certain assumptions for this, namely:

- the regime is permanent,
- the thermo-physical properties of the fluids are constant (in the considered temperature interval),
- the exchanger is adiabatic,
- heat transfer takes place by convection and conduction,
- the only exchange surface is the separation surface of the two fluids (no phase change).

The characteristics of these exchangers are presented in the following table:

III.2. Interchange Data:

Table III.1: Design characteristics of preheaters (A and B) for heat and fluids

	Shell side	Tube side
Circulating fluid	Stabilized Crude	Unstabilized crude
Incoming flow (Kg/h)	M=539 081,1	m=454452,2
Inlet temperature (°C)	Ti=160	ti=68 =68 ,1
Outlet temperature (°C)	To =119,8	to=114,1
Number of passes	02	04
Pressure drops (bar)	0.7	0.6
Density at 15°	0.79	0.78
Specific heat at constant pressure (Kj/Kg°C)	2.466	2.198
Fouling factor (m² k° / w)	0.00035	0.00035
Tubes Outer diameter (m)	25,4 10 ⁻³	
Shell Inner diameter (m)	1.2	
Tubes number	1830	
Pitch: squirt (m)	31,75 10 ⁻³	
Tube thickness(m)	2,77 10 ⁻³	
Tube length (m)	6.096	

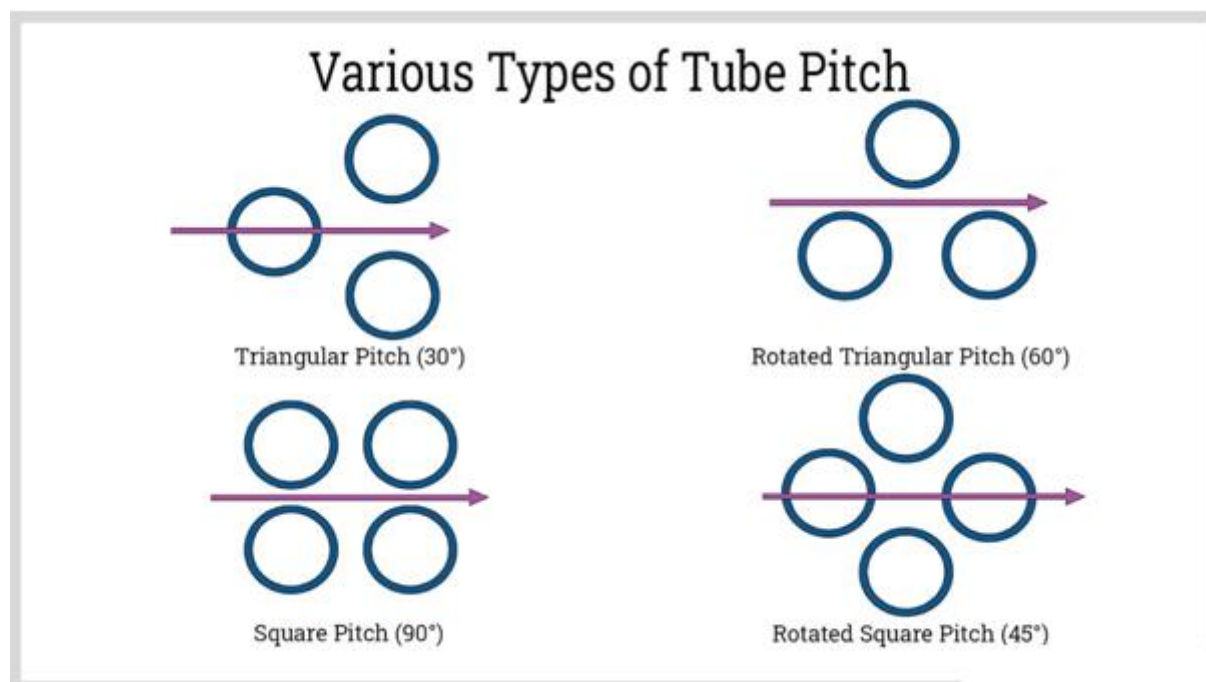


Figure III .1): The figure shows different types of pitch (Pas des tubes) (just to inform you).

III .3 Calculation of fouling resistance

To access the fouling resistance Fr [34], it is necessary to determine:

- At start-up of the installation, the exchange coefficient in propre conditions Up
- Periodically, the global exchange coefficient in conditions fouling US
- The fouling resistance is given by $Fr= 1/Us -1/Up$

If the conditions at the terminals of the exchanger (flow rates, inlet temperatures) are not stationary, it is necessary to re-evaluate the overall exchange coefficient in proper conditions corresponding to the new operating conditions.

For the calculation of a shell and tube exchanger, this method is semi-empirical, based on experimental work on commercial exchangers.

III.3.1 physical properties of the two fluids

The correlations used for the calculation of the physical properties of the two fluids are represented in the following table:

Table III .2: correlations used for the calculation of the physical properties of the two fluids

Physical properties	Correlations	Terms of use
Density	$d_4^T = d_4^{15} - \alpha * (T_m - 15)$	$T(c^\circ)$ $\alpha = 0,00075$ $d_4^{15}: 0,765 - 0,770$ $\alpha = 0,00075$ $d_4^{15}: 0,785 - 0,795$ $\alpha = 0,00075$ $d_4^{15}: 0,795 - 0,800$
Specific heat [9] (KJ/Kg°C)	Relationship of Gragoe: $C_p = (0,388 + 0,00045 * T_m * 4,187 / (spgr60/60)) 0,5$	$32F^\circ < T < 400F^\circ$ $0,96$ $< spgr60/60 < 0,96$
Dynamic viscosity [9] (kg/ms)	$\mu = A * e^{B/T_m}$	$T (K)$ for the Brut $A = 1,06 \cdot 10^{-3}$ $B = 15,003$
Thermal conductivity [10] (W/m2 K)	$\lambda = 0,17 - (1,418 \cdot 10^{-4} T_m)$	$T(K)$

III.3.2 Heat balance:

Sum of incoming energies = sum of outgoing energies

$$Q = M \cdot C_p \cdot (T_1 - T_2) = m \cdot C_p' \cdot (t_1 - t_2)$$

$$Q = Q_v \cdot \rho \cdot C_p \cdot (T_1 - T_2) = Q'v \cdot \rho' \cdot C_p' \cdot (t_1 - t_2)$$

QV: Shell side fluid volume flow (m³/h)

Q'V: Tube side fluid volume flow (m³/h)

ρ: The density of the fluid on the shell side (kg/m³)

ρ': Fluid density on the beam side (kg/m³)

Cp: Average heat (kJ/kg C)

T₁: Inlet shell Side Temperature (C°)

T₂: Outlet temperature on the shell side (C°)

t₁: Tube side input temperature (C°)

t₂: Tube side output temperature (C°)

III.3.3 Calculation of the mean temperature difference (ΔTLM) The temperature difference is given by:

The temperature difference is given by:

$$\Delta TLM = \frac{(\Delta T_{max} - \Delta T_{min})}{\log(\Delta T_{max} / \Delta T_{min})}$$

Such as:

T₁: inlet shell temperature.

T₂: radiator shell outlet temperature.

t₁: Tube inlet temperature.

t₂: Tube output temperature.

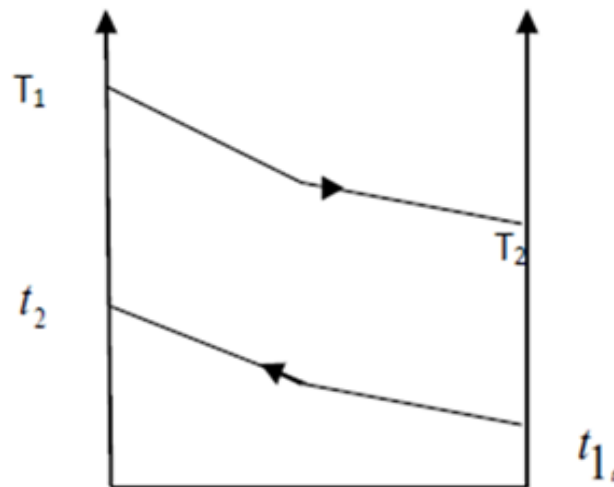


Figure III .2): Counter-current exchange

Calculation of the corrected mean temperature:

$$\Delta TLM \text{ corrected} = \Delta TLM \cdot F$$

Where: F is determined from graph $F=f(R, E)$ (see Appendix A figure 1).

$$R = (T_1 - T_2) / (t_2 - t_1)$$

And:

$$E = (t_2 - t_1) / (T_1 - t_1)$$

Remarks

- the term E characterizes the efficiency of the heat exchange
- the term F measures the efficiency of the device with respect to the pure counter current
- $0.8 < F < 1$ for shell and tube heat exchangers with four passes on the tube side and two passes on the shell side

III.3.4 Determination of caloric temperature T_c .tc:

$$T_c = T_2 + F_c (T_1 - T_2)$$

$$t_c = t_1 + F_c (t_2 - t_1)$$

With: $F_s = f(k_c, R)$, $k_c = f(\Delta t, d)$ and $R = t_2 - t_1 / T_1 - T_2$ are determined according to the graph see Appendix A figure N°2).

III.3.5 Calculation of fouling resistance by the KERN method:

The determination of local transfer coefficient U_p requires the estimation of film coefficients h_i and h_o , the following we will present the steps for determining the coefficient of proper transfer

A. Tube side:

- Section per pass:

$$at = \frac{Nt}{nt} * \frac{\pi d_i^2}{4}$$

- Mass velocity G_t :

$$G_t = \frac{m}{at}$$

Fluid characteristics a T_c and t_c : C_p , d , λ

- Calculation of Reynolds number:

$$Re = \frac{(d_i * G_t)}{\mu}$$

- Determination j_h according to the Reynolds number and the graph (see appendix A, graph N°3) we find the coefficients j_h and F :

$$j_h = \left(h_i * \frac{d_i}{\lambda} \right) * \left(c_p * \frac{\mu}{\lambda} \right)^{1/3} * \Phi_t^{-1}$$

$$\left(\frac{h_i}{\Phi_t} \right) = j_h \left(\frac{\lambda}{d_i} \right) * \left(c_p * \frac{\mu}{\lambda} \right)^{1/3}$$

$$\left(\frac{h_{io}}{\Phi_t} \right) = \left(\frac{h_i}{\Phi_t} \right) \left(\frac{d_i}{d_o} \right)$$

Shell side:

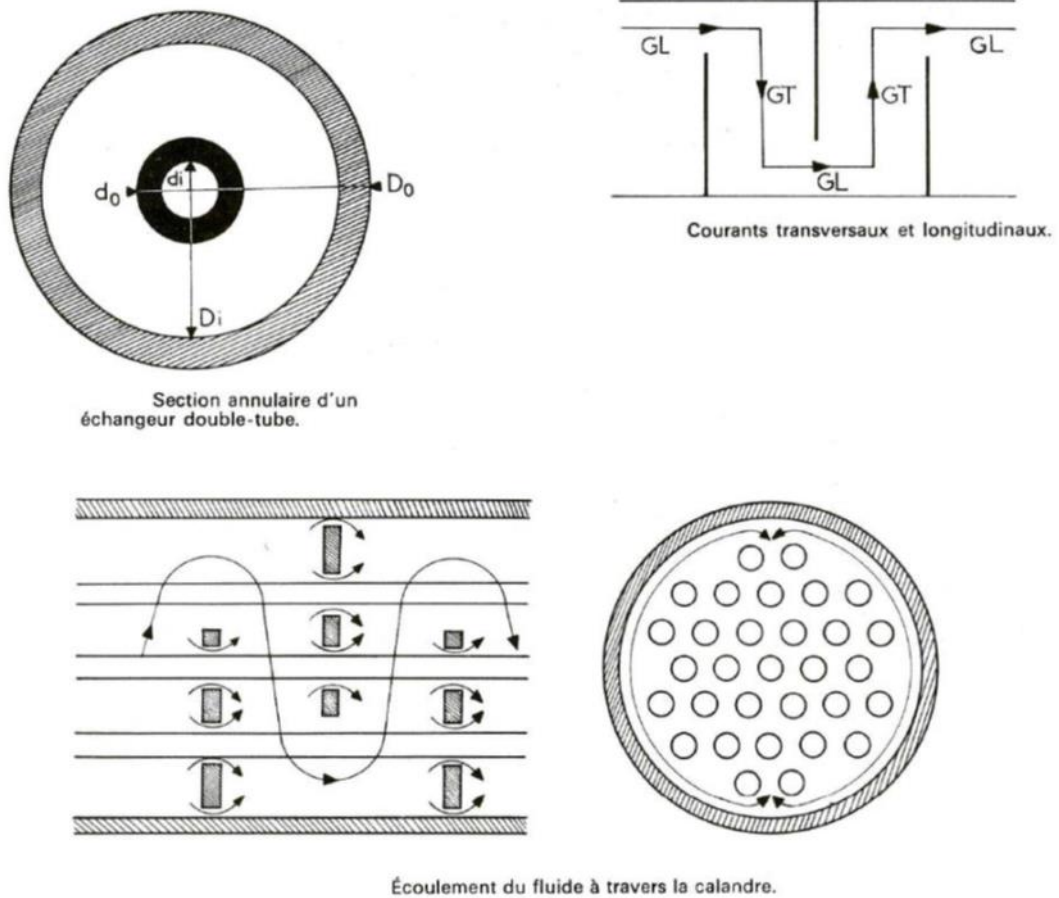


Figure III .3): Fluid flow through the shell.

B. Section by shell:

$$a_{ct} = \left(\frac{Dc}{p}\right) * \left(\frac{p}{d_o}\right) * B$$

- Mass speed Gt' :

To fluid characteristics: Cp' , d' , d , λ'

$$G'_t = \left(\frac{M}{a_{ct}}\right)$$

- Calculation of the Reynolds number:

$$Re' = \left(\frac{De}{Gt'/\mu}\right)$$

- Calculation of equivalent diameter (De):

$$De = \left(\frac{4 \cdot p^2}{\pi \cdot d_o} \right) - d_o$$

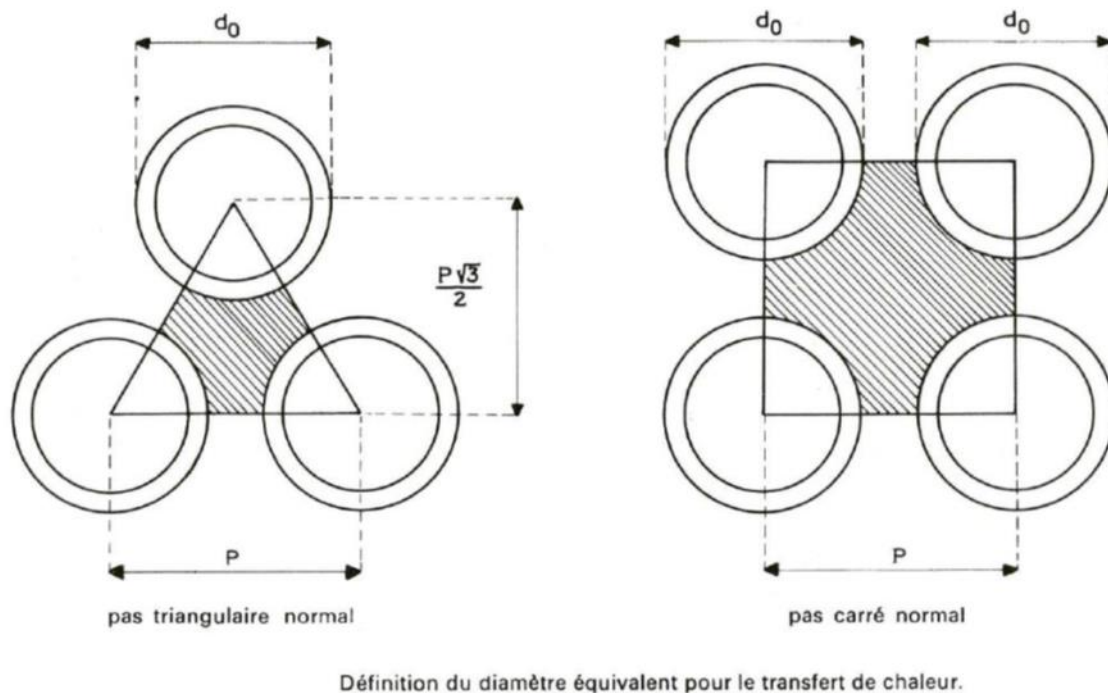


Figure III .4): Definition of equivalent diameter

Determination j_h According to the Reynolds number and the graph (see Appendix A, graph N°4), the coefficients j_h' and F' are drawn:

$$j_h' = \left(\frac{h_o \cdot De}{\lambda_l} \right) \left(\frac{c p_l \cdot \mu_l}{\lambda_l} \right)^{1/3} \cdot \Phi_s^{-1}$$

So:

$$\left(\frac{h_o}{\Phi_s} \right) = j_h' \cdot \left(\frac{\lambda_l}{De} \right) \cdot \left(\frac{c p_l \cdot \mu_l}{\lambda_l} \right)^{1/3}$$

Calculation of wall temperature:

Viscosity μ_p depends on temperature T_p :

$$T_p = t_c - \frac{\frac{h_o}{\Phi_s}}{\frac{h_o}{\Phi_s} + \frac{h_{io}}{\Phi_s}} (T_c - t_c)$$

➤ Determination from μ_t to t :

$$\Phi_t = \left(\frac{\mu}{\mu_p}\right)^{0.14}$$

$$h_{io} = \left(\frac{h_{io}}{\Phi_t}\right) * \Phi_t$$

➤ Determination from μ_t to t :

$$\Phi_s = \left(\frac{\mu'}{\mu_p}\right)^{0.14}$$

$$h_o = \left(\frac{h_o}{\Phi_s}\right) * \Phi_s$$

Calculation of own transfer coefficient:

$$U_p = \left(\frac{h_{io} * h_o}{h_{io} + h_o}\right)$$

Coefficient of fouling resistance:

$$F_r = \frac{U_p - U_s}{U_p U_s}$$

III.3.6 Calculation example:

For this example, the date of (01/08/2016) is taken, which corresponds to the few days train 30 was put back into service after the 2016 triennial revision, the procedure for calculating the fouling resistance is organized as below.

➤ Caloric temperatures T_c , t_c :

$$T_c = T_2 + F_c(T_1 - T_2)$$

$$t_c = t_2 + F_c(t_1 - t_2)$$

$$T_1 = 143.22^\circ\text{C}$$

$$T_2 = 121.36^\circ\text{C}$$

$$d_4^{15} = 0.8019$$

$$t_1 = 67.8^\circ\text{C}$$

$$t_2 = 92.88^\circ\text{C}$$

$$d_4^{15} = 0.7993$$

According to (graph No. 2 of Annex A), we have $F_s = 0.52$, and consequently

$$T_s = 131.83^\circ\text{C} \text{ and } t_s = 80.86^\circ\text{C}$$

Physical properties of both fluids T_c and t_c :

Table .3: Physical properties of both fluids

Stabilized crude			Unstabilized crude				
ρ_h (kg/m ³)	C_{ph} (KJ/Kg°C)	μ_h (kg/ms)	λ_h (W/m K)	$\rho_{h'}$ (kg/m ³)	$C_{pc'}$ (KJ/Kg°C)	$\mu_{c'}$ (kg/ms)	$\lambda_{h'}$ (W/m K)
719,797	2,093	0,0010996	0,113	752,90	1,9864	0,0011059	1,20

Using the previously calculated heat temperatures and the correlation in Table (2), and the appendices, the physical properties of the two fluids:

➤ Calculation of ΔTLM :

$$\Delta TLM = \frac{(T1-t2)-(T2-t1)}{\ln \frac{(T1-t2)}{(T2-t1)}}$$

Correction Factor Fc:

$$R = \frac{(T1-T2)}{(t2-t1)} = 0.87$$

$$E = \frac{(t2-t1)}{(T1-t1)} = 0.33$$

According to the graph (see Appendix 01, Graph 1) $F_c = 0.98$.

$$\Delta TLM_c = \Delta TLM * F_c$$

$$\Delta TLM_c = 50.89^\circ C$$

➤ US Dirty Transfer thermic Coefficient:

$$A = 851 m^2$$

$$A = \frac{q}{(US * DTLM_c)} \text{ et } Us = \frac{q}{A * DTLM_c}$$

$$Us = 251.99 w/m^2 . k$$

Table. 4: Calculated values of parameters relating to the geometry of the exchangers

	Symbols	Expression	Value
Passage section on the tube side (m ²)	at	$at = \left(\frac{Nt}{nt}\right) * (\pi * d^2 i / 4)$ $di = d_o - 2e$	0,142
Air passage side shell (m ²)	act	$act = (Dc/p) * (p - d_o) * B$	0,17
Relative hydraulic diameter external flow of the tube bundles (m ²)	De	$De = (4 * p^2 / \pi * d_o) - d_o$	0,025

Calculation of the own transfer coefficient Up:

A. Tube side:

➤ Section per pass:

$$a_t = \left(\frac{Nt}{nt}\right) * \left(\frac{\pi d_i^2}{4}\right) \quad a_t = 0.142 \text{m}^2$$

➤ Mass speed G_t:

$$G_t = \left(\frac{m}{a_t}\right) \quad G_t = 826.06 \text{kg.m}^2\text{h}$$

➤ Calculation of the Reynolds number:

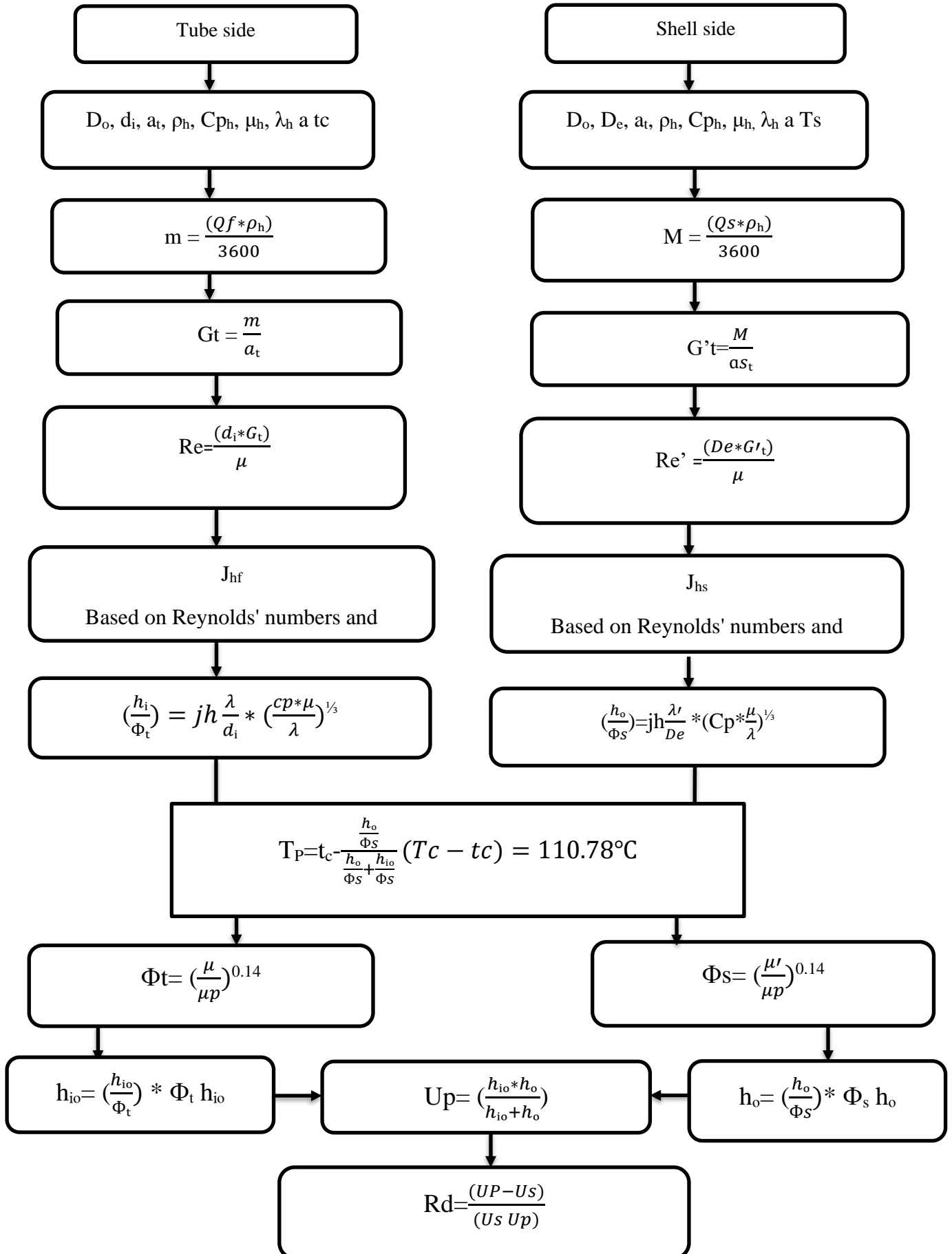
$$Re = \left(\frac{d_i * G_t}{\mu}\right) \quad Re = 14938.4378$$

According to the number of Reynolds and (see Appendix 01, Graph No. 3) the coefficients and F are drawn:

$$J_h = \left(\frac{h_i * d_i}{\lambda}\right) * \left(cp * \frac{\mu}{\lambda}\right)^{1/3} * \Phi_t - 1 j_h \quad j_h = 50 \quad \text{and} \quad F = 0.05$$

$$\text{So: } \left(\frac{h_i}{\Phi_t}\right) = j_h \left(\frac{\lambda}{d_i}\right) * \left(cp * \frac{\mu}{\lambda}\right)^{1/3} = 790.125 \text{ w/m}^2\text{k}$$

$$\left(\frac{h_{io}}{\Phi_t}\right) = \left(\frac{h_i}{\Phi_t}\right) * \left(\frac{d_i}{d_o}\right) = 632.099 \text{ w/m}^2\text{k}$$



III.3.7 Calculation algorithm using the KERN method:

The calculation of the fouling resistance by the KERN method is carried out by following the flowchart illustrated in the following figure.

III.4. Results and interpretation:

A Before revision 2016:

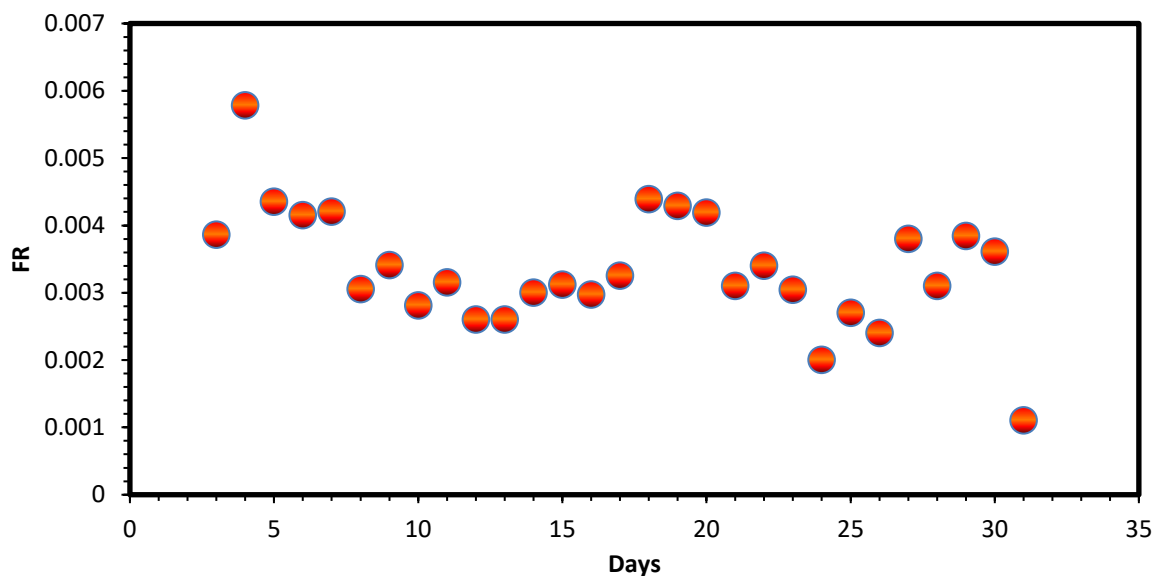


Figure III .5): The evolution of fouling resistance during the month of January

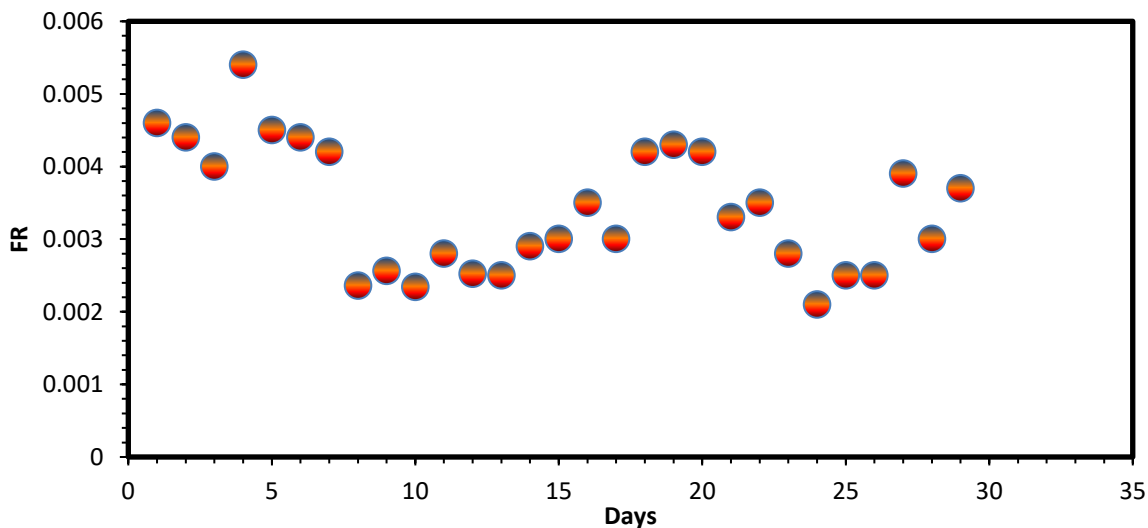


Figure III .6): The evolution of fouling resistance during the month of February

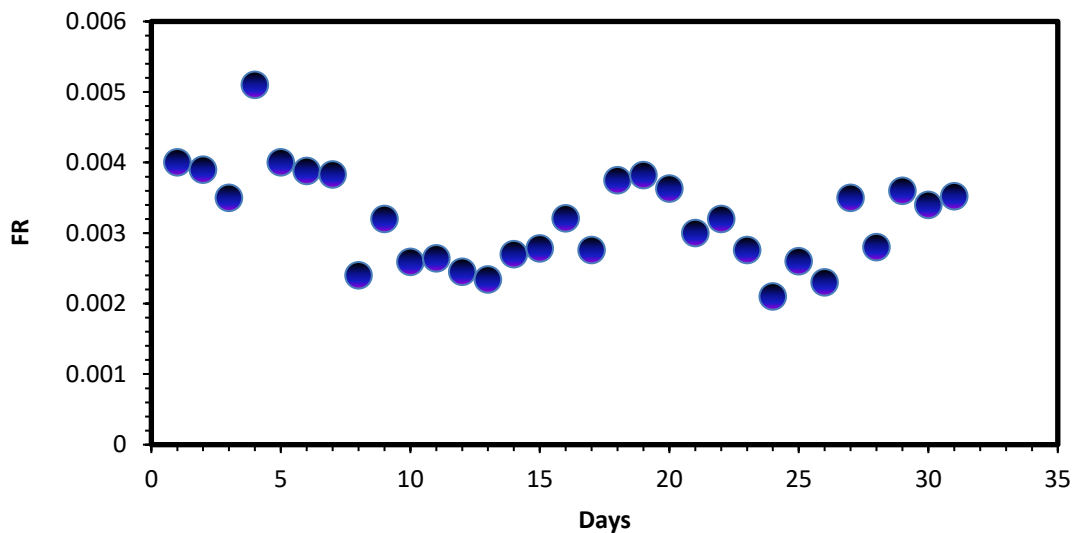


Figure III .7): The evolution of fouling resistance during the month of March

B. After revision 2016

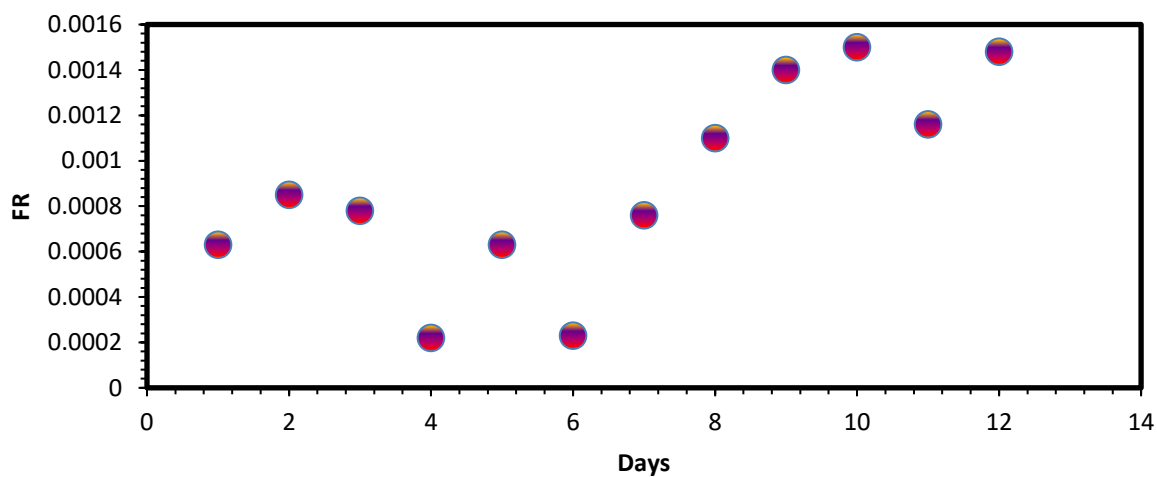


Figure III .8): The evolution of fouling resistance during the month of July

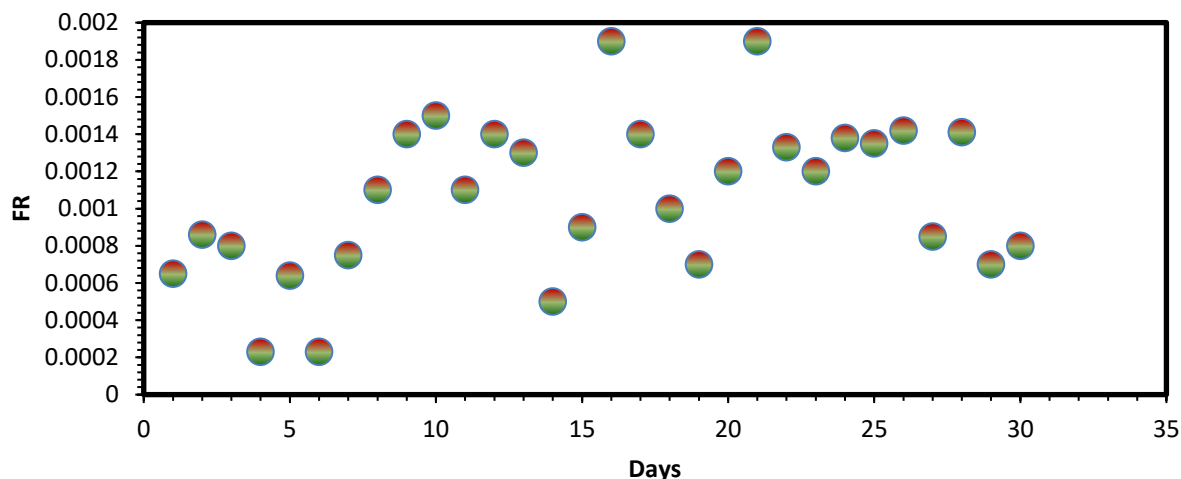


Figure III .9): The evolution of fouling resistance during the month of August

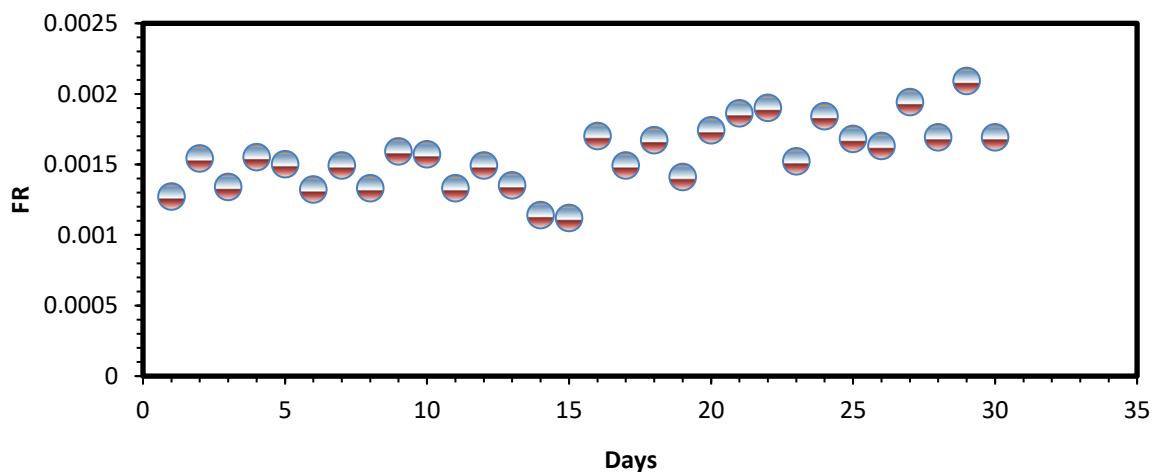


Figure III .10): The evolution of fouling resistance during the month of September

The value of the fouling resistance FR oscillates between 0.003 and 0.006 m²k/w (figure III .6), III .7), and III .8)).

The increase in the value of the resistance for the three months before the revision is explained by the significant presence of deposits on the exchange surfaces on the tube side up to a practically stable value, the fluctuation of FR is due to the variation process parameters between other flow rate and temperature at the level of the pre-heater battery.

The evolution of the fouling resistance as a function of time follows a linear pattern, the value of the fouling resistance FR after the revision oscillates between 0.001 and 0.0025 m² k° /w (figure III .9), III .10), and III .11)).

The decrease in Rd is due to the cleaning of the preheater coil tubes.

From the figures (III .6) III .7), III .8), III .9), III .10), and III .11), we notice that the fouling resistance as a function of time is not constant, it is higher than that of design, knowing that the flow rate is low compared to the design.

In the light of the figures (III .6), III .7), III .8), III .9), III .10), and III .11)) it can be said that the fouling resistance of the pre-heater, calculated during the six months of monitoring, is high compared to that tolerated value in the design, this constitutes a means of evaluating the importance of the deposit formed on the exchange surface on the tube side.

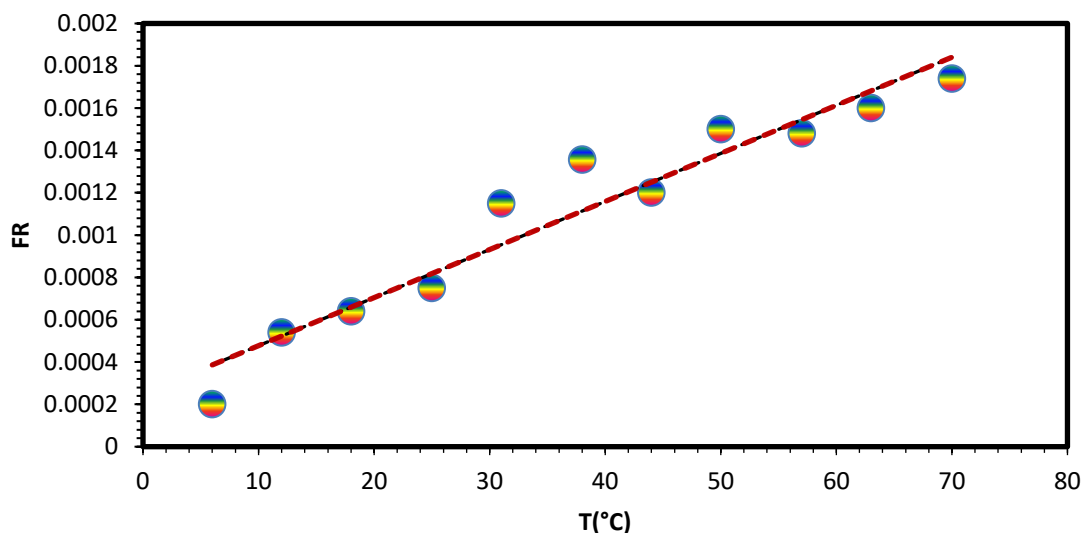


Figure III .11): The evolution of the fouling resistance as a function of the temperature on the tube side

Figure III .11), represents the evolution of the fouling resistance as a function of the temperature of the unstabilized crude on the tube side which is a linear curve which increases so we conclude that the increase in the temperature of the fluid above 68°C (the design value), promotes the increase in fouling resistance and therefore the formation of the deposit on the walls of the tubes.

The evolution of the speed of circulation

$$\text{Circulation Velocity} = \text{Mass Flow Density} = G/\rho$$

After revision 2016:

The circulation speed value fluctuates between 0.8 and 1.2 m/s and is closer to the design value (1.8 m/s).

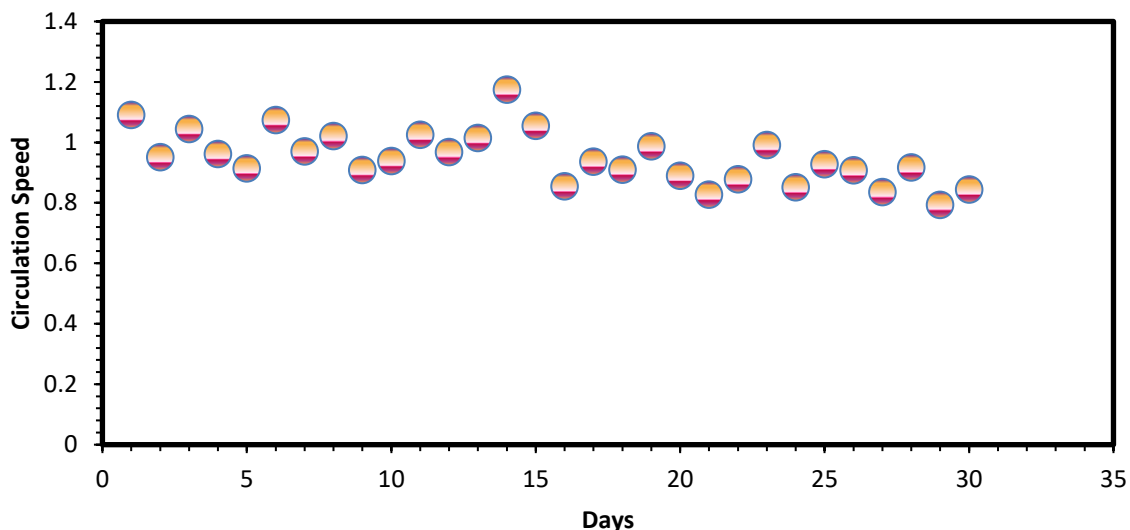


Figure III .12): The evolution of the speed of circulation as a function of time during the month of August.

Figure III .12), represents the evolution of the cold fluid circulation speed on the tube side as a function of time during the month of August, when the tubes are clean.

B. Before revision 2016:

The following figure shows the evolution of the circulation speed as a function of time during the month of March before the revision (the tubes are dirty).

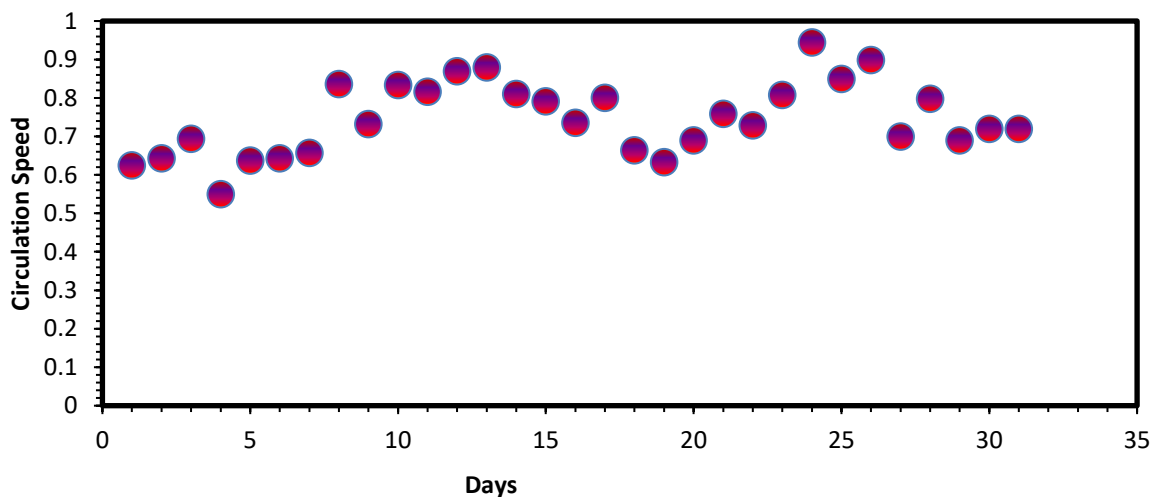


Figure III .13): The evolution of the speed of circulation as a function of time during the month of March.

The value of the circulation speed oscillates between 0.5 and 0.9 m/s.

According to figure III .14), the flow rate of unstabilized crude on the tube side is not constant, it is lower than that of design (1.8m s) due to fouling and the low flow of unstabilized crude. stabilized. (By-pass open on tube side).

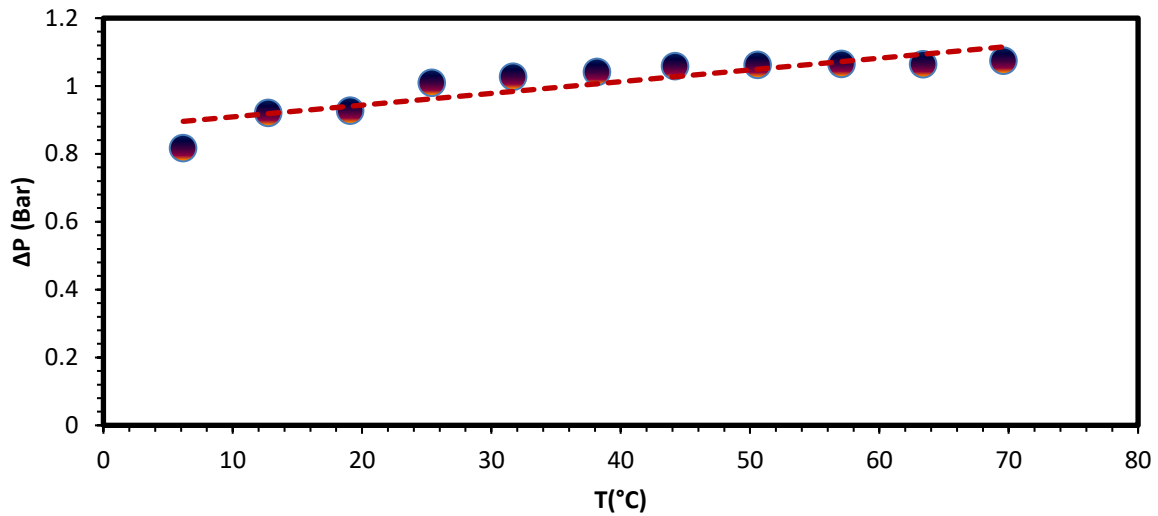


Figure III .14): Pressure drops as a function of the pre-heater inlet temperature

According to the graph, there is a slight increase in pressure drops between 68°C and 70°C preheater inlet, then from 70°C this increase is accentuated to reach inadmissible values, this is explained by the rapid increase in the rate of crystallization of the salts present in the crude.

The admissible value of pressure drops in the preheater is 0.9 bar on the tube side.

To ensure continuous operation of the preheater and therefore of the treatment train, the optimum temperature is 68°C entering the preheater for which the pressure drop does not exceed 0.9 bar (design value).

III.5. Calculation of theoretical pressure drops:

$$\Delta P = \frac{n_s \cdot n_t \cdot GT^2}{3.75 \cdot 10^{12} \cdot spg(60/60)} \times \left[\frac{f_t \cdot l}{d_i \cdot \left(\frac{\mu}{\mu_t}\right)^{0.14}} + 2 \right] \quad \text{and} \quad \Phi_t = \left(\frac{\mu}{\mu_p}\right)^{0.14}$$

$$d_i = d_o - 2e \quad \text{and} \quad Ft = 0.00280 + 0.250 \text{ Re}^{-0.32}$$

n_s : number of passes on the shell side.

n_t : number of passes on the tube side.

GT: Mass Velocity.

f_t : Friction factor inside the tubes as a function of Reynolds number.

d_i : internal diameter of the tubes

L : = the length of the tubes

ϕ_t : Corrective tube side.

➤ **Shell side:**

$$\Delta P_s = \frac{n_s \cdot f_{sT} \cdot G^2 \cdot ct(Nc+1)}{3.75 \cdot 10^{12} \cdot d_i \cdot De \cdot \left(\frac{\mu}{\mu_t}\right)^{0.14}} \Phi_s = \left(\frac{\mu'}{\mu_p}\right)^{0.14}$$

$$F_{st} = 0.00280 + 0.250 \text{ Re}^{-0.32} \quad De = \left(\frac{4 \cdot p^2}{\pi \cdot d_o}\right) - d_o$$

n_s : number of openings on the front shell.

Nc : number of chicanes

GcT : Mass speed.

F_{st} : Friction factor of the shell according to Reynolds number.

De : equivalent diameter.

D_s : diameter of the shell.

ϕ_s : Patch on the front shell.

(spgr60/60).

First case before review

➤ **Tube side:**

$$f_t = 0.00280 + 0.250 \text{ Re}^{-0.32}$$

$$\text{Re} = 11367.768 \quad f_t = 0.00280 + 0.250 (11367.768)^{-0.32} = 0.01539285$$

n_s : 2

n_t : 4

GT : 628,400395 m/s

$d_4^{15} = 0.7986$

d_i : $d_0 - 2e = 0.02\text{m}$

L: 6,096 m

ϕ_t : 1,00044625

$$\Delta P_t = \frac{4 \times 2 \times (628.400395)^2}{3.75 \times 10^{12} \times 0.7986} \times \left[\frac{0.01539285 \times 6.096}{1.00044625 \times 0.02} + 2 \right] = 1.3562 \cdot 10^{-5} \text{ pascal} = 1.3562 \text{ bar}$$

➤ **Shell side:**

$$Re = 14894,8121 \quad Ft = 0,00280 + 0,250 (14894,8121)^{-0,32} = 0,01434965$$

$$De = \left(\frac{4 \cdot p^2}{\pi \cdot d_o} \right) - d_o$$

n_s : 2

N_c : 17

$G_s T$: 655,160535

De : 0,025 m.

D : 1,2.

ϕ_s : 0,99969234

$d_4^{15} = 0,8042$

$$\Delta P_s = \frac{2 \times 0,01434965 \times (655,160535)^2 \times (17+1) \times 1,2}{3,75 \cdot 10^{12} \times 0,8042 \times 0,25 \times 0,99969234} = 8,22855 \cdot 10^{-06} \text{ pas} = 0,8228551 \text{ bar}$$

➤ **Tube side:**

$$Ft = 0,00280 + 0,250 Re^{-0,32}$$

$$Re = 11709,1469 \quad Ft = 0,00280 + 0,250 (11709,1469)^{-0,32} = 0,01527418$$

n_s : 2

n_t : 4

GT : 647,581777 m/ s

$$d_4^{15} = 0,778.$$

$$D_i: d_0 - 2e = 0,02 \text{ m.}$$

$$L: 6,096 \text{ m}$$

$$\phi_t: 1,00044281$$

$$\Delta P_t = \frac{4 \times 2 \times (647,581777)^2}{3,75 \cdot 10^{12} \times 0,779} \times \left[\frac{0,01527418 \times 6,096}{1,00044281 \times 0,02} + 2 \right] = 0,9558 \cdot 10^{-5} \text{ pascal} = 0,9558 \text{ bar}$$

➤ **Shell side:**

$$Re = 12921,3287 \quad Ft = 0,00280 + 0,250 (12921,3287)^{-0,32} = 0,01488709$$

$$De \left(\frac{4 * p^2}{\pi * d_o} \right) - d_o$$

$$n_s: 2$$

$$G_{sT}: 568,563432$$

$$De: 0,025 \text{ m.}$$

$$D_s: 1,2$$

$$\phi_s: 0,99971956$$

$$d_4^{15} = 0,8029$$

$$\Delta P_s = \frac{2 \times 0,01488709 \times (568,563432)^2 \times (17+1) \times 1,2}{3,75 \cdot 10^{12} \times 0,025 \times 0,9991656} = 8,0918 \cdot 10^{-6} \text{ pascal} = 0,8091804 \text{ bar}$$

The evolution of head losses as a function of time:

After Revision

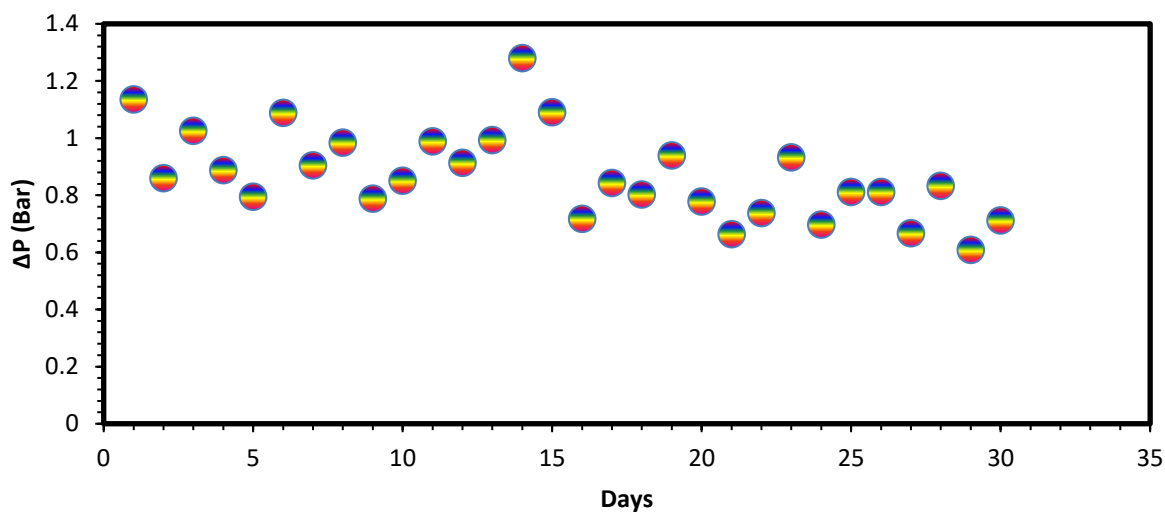


Figure III .15): The evolution of pressure drops on the tube side during the month of August.

According to the figure, the pressure drops on the tube side as a function of time during the month of August just after the revision is not constant, this fluctuation is due to the variation in flow, it varies between 0.6 and 1, 1 bar almost the design value (0.9 bar) because the tubes are clean.

Before Revision:

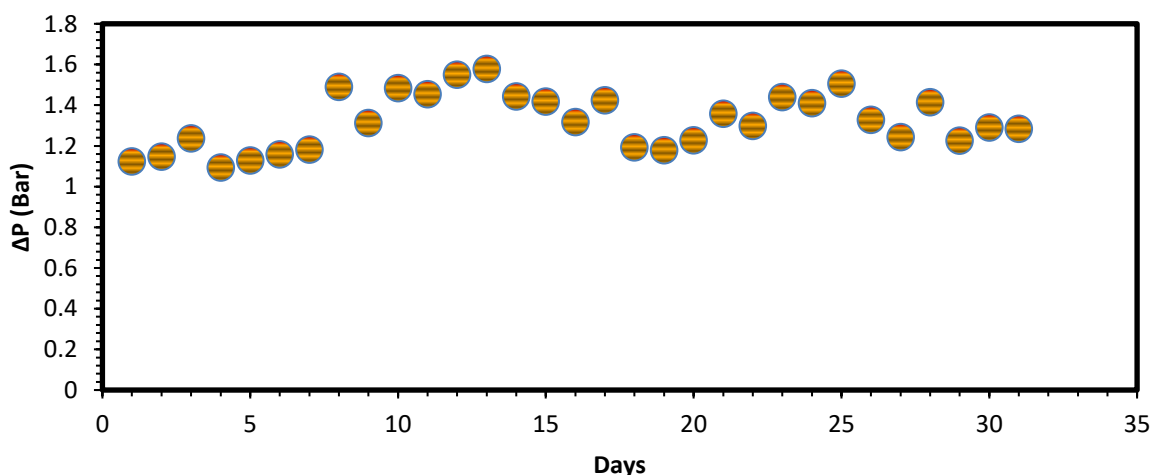


Figure III .16): The evolution of pressure drops on the tube side during the month of January.

According to the figure, the pressure drop on the tubes side as a function of time during the month of January before the revision is not constant, it is much lower than that of design. This is explained by the presence of deposits inside the tubes.

III.6. Calculation of pre-heater efficiency:

We define the efficiency (ϵ) of the pre-heater battery as follows

Design case :

$$\epsilon = Q/Q_{max} = (t_2 - t_1) / (T_1 - t_1) \quad T_1 = 160c^\circ, \quad t_1 = 68,1c^\circ, \quad t_2 = 114c^\circ$$

$$\epsilon = Q/Q_{max} = (114 - 68,1) / (160 - 68,1) = 50 \%$$

T_1 : input grille

t_2 : tube side output

t_1 : entered on tube side

Current Case:

1st case after revision:

$$\epsilon = Q/Q_{max} = (t_2 - t_1) / (T_1 - t_1) \quad T_1 = 151,83 c^\circ, \quad t_1 = 75,95 c^\circ, \quad t_2 = 100,9 c^\circ$$

$$\epsilon = Q/Q_{max} = (100,9 - 75,95) / (151,83 - 75,95) = 33\%$$

2nd case before revision:

$$\epsilon = Q/Q_{max} = (t_2 - t_1) / (T_1 - t_1) \quad T_1 = 133,52 c^\circ, \quad t_1 = 70,33 c^\circ, \quad t_2 = 89,12c^\circ.$$

$$\epsilon = Q/Q_{max} = (89,12 - 70,33) / (133,52 - 70,33) = 29\%$$

We note that there is a significant gap between the efficiency case design and current case, this is justified by the fouling and low flow compared to the design.

III.7. Calculates the unsterilized crude oil flow (tube side):

Knowing the heat load released, we can calculate the flow rate of unstable crude oil accord Where:

$$Q = CpG_1(T_1 - T_o) = G_2. Cp(t_o - t_i)$$

$$G_2 = \frac{Q_1}{Cp(t_o - t_i)} \quad \text{and} \quad Q_1 = G Cp (T_1 - T_o)$$

Q: The amount of heat released by the stabilized crude oil.

Cp: The specific heat.

T_1, T_o : Inlet and outlet temperatures of stabilized crude oil (shell side).

t_i, t_o : Inlet and outlet temperatures of stabilized crude oil (shell side).

1st case before review:

$$Q = G_1 Cp (T_2 - T_1) = 72117,49 \times 2,108 \times (151,47 - 123,53) = 21\,921\,620,233 \text{ KJ/h}$$

➤ **Shell side:**

$$G_1 = 72117,49 \text{ kg/h}, \quad Cp = 2,108 \text{ kJ/kg}, \quad T_1 = 151,47c^\circ, \quad T_2 = 123,53c$$

➤ **Tube side:**

$$C_p = 2,0261 \text{ KJ/Kg}, T_1 = 73,250 \text{ c}^\circ, T_2 = 100,470 \text{ c}^\circ.$$

$$G_2 = 21921620,233 / 2,026. (100,47 - 73,25) = 397497,082 \text{ kg/h. } G_2 = 397497,082 \text{ kg/h.}$$

2nd case after the revision:

$$Q = G_1 C_p (T_2 - T_1) = 415008 \cdot 2,108 (151,830 - 128,570) = 21\,897\,452,709 \text{ KJ/h}$$

➤ **Shell side:**

$$G_1 = 415008 \text{ kg/h}, C_p = \text{KJ/Kg}, T_1 = 151,830 \text{ c}^\circ, T_2 = 128,570 \text{ c}^\circ.$$

➤ **Tube side:**

$$C_p = 2,0048 \text{ kJ/kg}, T_1 = 75,950 \text{ c}^\circ, T_2 = 100,910 \text{ c}^\circ.$$

$$G_2 = 21897452,709 / 2,0048. (100,91 - 75,95) = 437590,349 \text{ kg/h.}$$

III.8. Comparison between the current market and the design market:

Table. 5: Comparison between the current parameters and the design parameters

	Design case	current case
Stabilized crude oil flow (kg/h)	539081 ,1	437590,349
T ₁ inlet (c°)	160	151.830
T ₂ outlet (c°)	119.8	128.570
ΔT _{lm} corrected (c°)	46.1	50.73
ΔP (bar)	0.9	0.8
ε the efficiency (%)	50	33
Unstable crude oil flow (kg/h)	455041,8	397497,082
t ₁ input (c°)	68 ,1	70.950
t ₂ output (c°)	114.1	95.910
V (m /s)	1.08	1.2
ΔP (bar)	0.9	1.3
U _s (w/m ² k)		235.08
U _p (w/m ² k)	380	341.879
Fr (m ² / k .w)	0.00035	0.00300

*General
Conclusion*

General Conclusion:

The objective of this work is to study the dynamic and thermal behavior of two flows in a heat exchanger in the current case of a tube and shell exchanger and the design case in the fluid flow vein.

Beyond this study, particular attention was paid to the battery of the preheaters (A and B) of train 30, the incoming fluids: the unstabilized crude and the stabilized crude respectively (Tube side and Shell side) have a heavily foul and pose significant challenges to efficiency and service life.

The monitoring of heat exchangers allows good knowledge of the evolution of the thermal and dynamic parameters of the two fluids under the specific conditions of the process. This is the purpose of this study. The formation of deposits (fouling) is a thermal resistance that causes disturbances in these parameters.

The study carried out on this Tube-Shell exchanger shows that it encounters problems which are manifested by the presence of additional resistors and an increase in pressure drops. This change results in the inability to ensure heat exchange. hence the need to increase its exchange surface.

This study makes it possible to optimize the current operating parameters and compare it with those of design cases, thus estimating the various possible methods to eliminate the fouling of the tubes to improve the efficiency of the heat exchanger.

A complementary study, in other words a qualitative analysis of the deposits, is more than necessary to better understand and control the fouling phenomenon.

Recommendations

This study helped us to detect the malfunctioning of the preheaters. To overcome this situation, we need to:

- Follow the evolution of fouling since its appearance by establishing a maintenance program.
- Carry out mechanical and chemical cleaning
- Follow the thermal and dynamic input operating parameters.
- Analyze the deposits removed at each cleaning to determine the exact causes of its formation. and program the appropriate type of cleaning.
- Place suitable filters upstream of the preheaters.

Reference lits :

- [1] : G. Rigot, Echangeurs ; l'évolution technologiques des échangeurs ailetés, Rev pratique froid conditionnement d'air, 1993, 770, pp.30-34.
- [2]: R. M. Manglik, A. E. Bergles. E Advences in Heat transfer, 2002, 36, pp. 183-266
- [3] : Laid. N, Merine. L (Etude du problème d'encrassement au niveau du refroidisseur de MEA E-504) Master Thésis Université de Mostaganem2018/2019.
- [4] : BENYAHIA. N, LAHMAR. M (Etude d'encrassement des échangeurs de chaleur à faisceau et calandre) Master Thésis (chapitre I : Généralités sur le transfert et les échangeurs de chaleur) Univ. Tlemcen 2017.
- [5] : <http://tonepi.com/>.
- [6] : BENYAHIA. N, LAHMAR. M Etude d'encrassement des échangeurs de chaleur à faisceau et calandre Master Thésis (chapitre I : Généralités sur le transfert et les échangeurs de chaleur) Univ. Tlemcen 2017.
- [7] : Amirat. Z (Bilan thermique du circuit de solvant lourd et étude de l'encrassement du réfrigérant E112 de la raffinerie d'Alger) Master Thésis Université Blida 2015.
- [8] :(Cengel, Yunus.A, Transfert de chaleur : une approche pratique, McGraw-Hill (Tx), 2e édition, Université du Nevada Reno, octobre 2002).
- [9] : Pierre Tramboz, Matériel et Equipement, Editions Technip, Mars 1999.
- [10] : André BONTEMPS et al, Groupement pour la Recherche sur les Echangeurs Thermiques (GRETh), Echangeurs de chaleur, description des échangeurs, techniques de l'ingénieur (B 2341, B 2342).
- [11] : Pierre Wuithier, André Giraud, Raffinage et Génie Chimique, (Tome II) (2 éditions), Paris : Editions Technip, 1972.
- [12] : Modélisation des Échangeurs de Chaleur (M. Bennejah, N. Chaouni "Echangeur de Chaleur", Technologie, calcule et design- Edition Techip, Paris, France, 2014).
- [13] : G. Hoyon, Etude thermodynamique de l'encrassement des échangeurs de chaleur application à la géométrie plane simulation expérimentale par dépôt de glace, Université Henri-Poincaré, 1997.
- [14] : T. Petot, Modélisation du couplage thermique entre la combustion et l'encrassement des tubes d'un four de raffinerie. Thèse de doctorat de l'université de Toulouse, Janvier 2012.
- [15] : Epstein, N << Encrassement des échangeurs de chaleur >> Encrassement du transfert de chaleur, 1981.
- [16]: Knudsen J.G, Somerscales E, F, C Equipement, Hemisphere, Wash, DC, 1975.

- [17]: Bott, M, N, Process Engineering P76, 1975.
- [18]: Somerscales, E, F, C, Knudsen, J, G, Communication personnelle, (1), 1977), pp 1-4.
- [19]: Nancollas, G.H. Reddy, M.M « The gristallization Of Calcium Carbonate: Part Ii- Calcite Growth Mechanism », J.Colloid Interface Sci 37, 824-830, 1971.
- [20] : Rodier, J « L'analyse Chimique Et Physicochimique De L'eau » Edition Dunod,1971.
- [21]: Anastasios, J Karablas "Scale Formation In Tubular Heat Exchangers Research Priorities" Research Institute, 2002.
- [22] : Leconte, J << Protection contre la corrosion ». Thechnique de l'ingénieur A830.
- [23] : Epstein, N « encrassement : Aspects techniques de l'encrassement de l'équipement de transfert de chaleur >> Somescales Efc, Kundsem JG. Hémisphères WASHDC P3, 1981.
- [24] : Memento <<< Technique De L'eau De Degremont et Nalco >> Water Hand Book-Mac Grawn Hill Book Company.
- [25] : Froment, G, F. "Encrassement des surfaces de transfert de chaleur par formation de coke dans un réacteur pétrochimique" Idem P144, 1991.
- [26]: Lund, D. Sandhuc, N « Chemical reaction Fouling Due To Foods Staffs ». Idem P437, 1998.
- [27] : Etude thermique de l'échangeur de chaleur a faisceau et calandre e05 existant dans le complexe gazier de rhourde nous (sonatrach algerie) (chapitre iii)
- [28] : Duffau, C, Grillot, J, Navorro, J, M, Vidilr, R, Echangeurs de chaleur,
L'encrassement dans les échangeurs : description, prévention et remèdes-Paris Edition Tec et Doc1991.
- [29] : A. BONTEMPS, A. GARRIGUE, C. GOUBIER, J. HEUTZ, C. MARVILLET, P. MERCIER, R. VIDIL, « Description des échangeurs », techniques de l'ingénieur (B 2341).
- [30] : Etude d'encrassement des échangeurs de chaleur à faisceau et calandre (Chapitre II).
- [31]: N, Epstein; Thinking about heat transfer fouling: a5x5 matrix, Heat Transfer Engineering, 4 (1), 1983, pp 43-56.
- [32]: N.F, Glen; S. F, Flynn; J.M, Grillot; P, Mercier; Measurement and modelling of fouling on finned tubes. Fouling mechanisms: Theoretical and Practical aspects,
Eurotherm Seminar 23, Grenoble, , 1992. pp 181-188.
- [33] : J.M, Grillot ; Etude du dépôt de particules en phase gazeuse dans des canaux D'échangeurs thermiques à plaques, Thèse de l'Institut Polytechnique de Grenoble,1989.

[34]: J.M, Grillot; G, Icart; Fouling of a cylindrical probe and a finned tube bundle in a diesel exhaust environment, Experimental Thermal and Fluid Science, 14, ,1997; p 442-454.

[35] : Etude d'encrassement des échangeurs de chaleur à faisceau et calandre.

[36]: R-H Perry. Chilton Engineer Handbook, 5 ème edition.

[37] : J.P Wauquier. Pétrole brut et produits pétroliers, TOME1, Edition Technip.

[38] : ANDRE BONTEMPS « ECHANGEUR DE CHALEUR » Université Joseph Fourier, Institut universitaire de Technologie, Département Génie thermique et Énergie (Grenoble)

[39] : Echangeurs de Chaleur Dr. A. ZIOUCHI (UFR Maintenance Industrielle).

[40] : Appareils statiques SH/IAP SKIKDA Mr : M. Silini (séminaire 2009).

[45] : Support de Formation Exploration & Production Les Équipements Les Echangeurs Dernière Révision : TOTAL France ; 2007.

[46] : GRETH. Echangeurs de chaleur : description des échangeurs. -Techniques de l'ingénieur (N° B152, B2341), Génie énergétique, 5-1995.

[47] : P. WUITHIER. Raffinage et génie chimique, (tome I) 1987.

Annex :

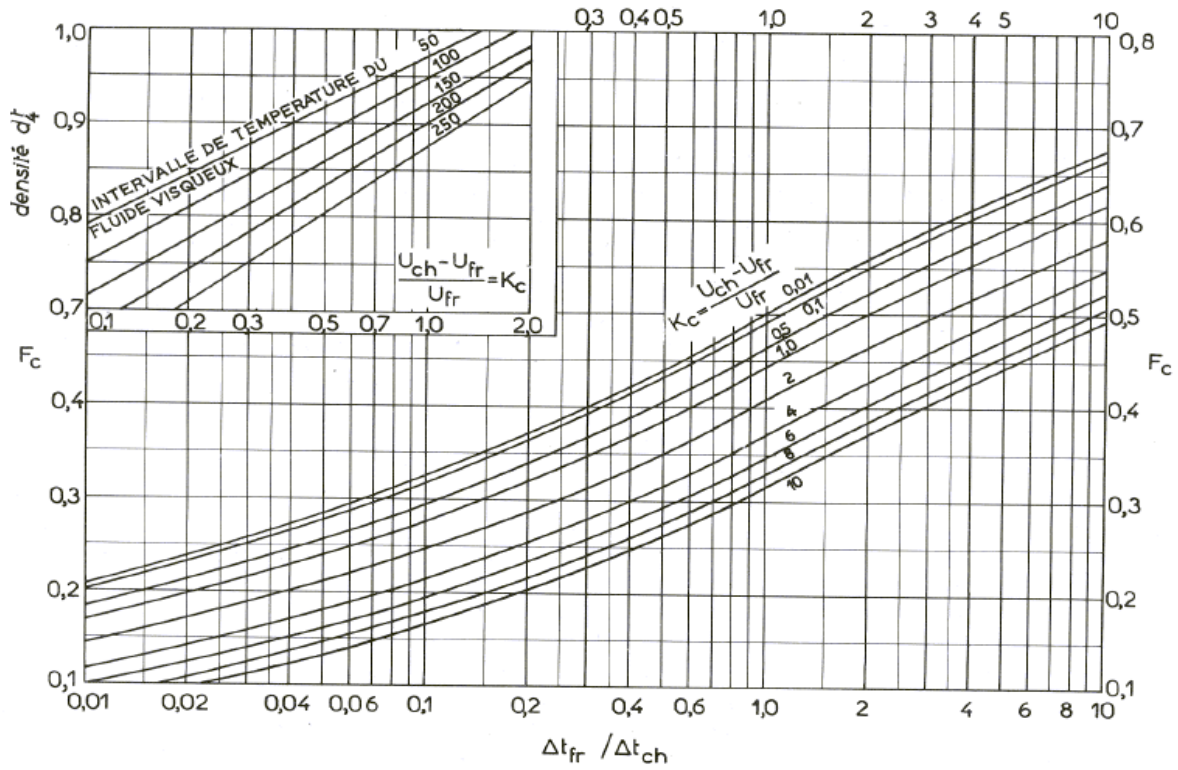
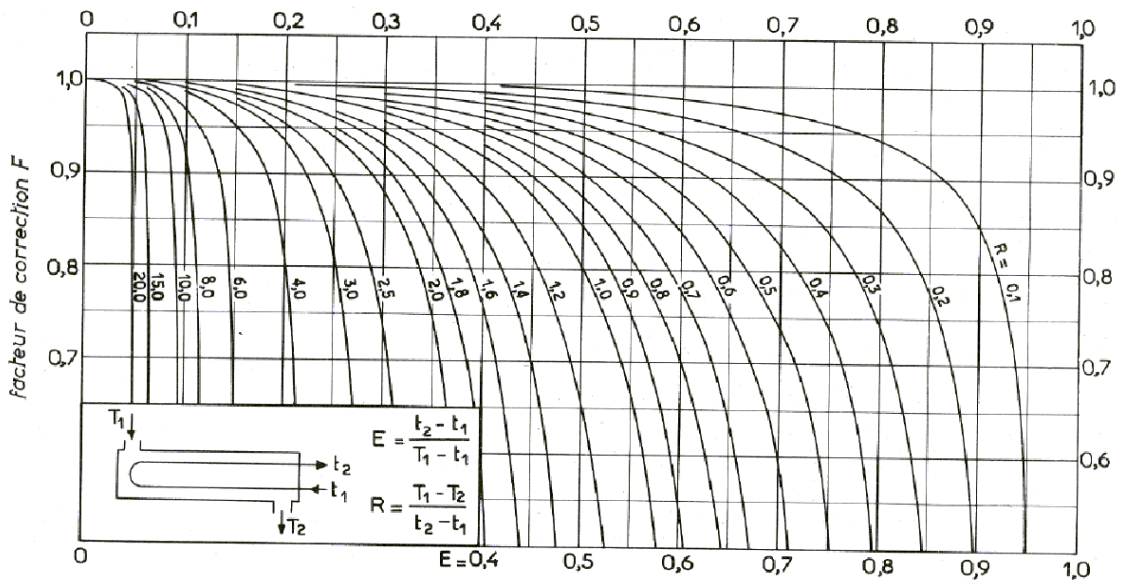
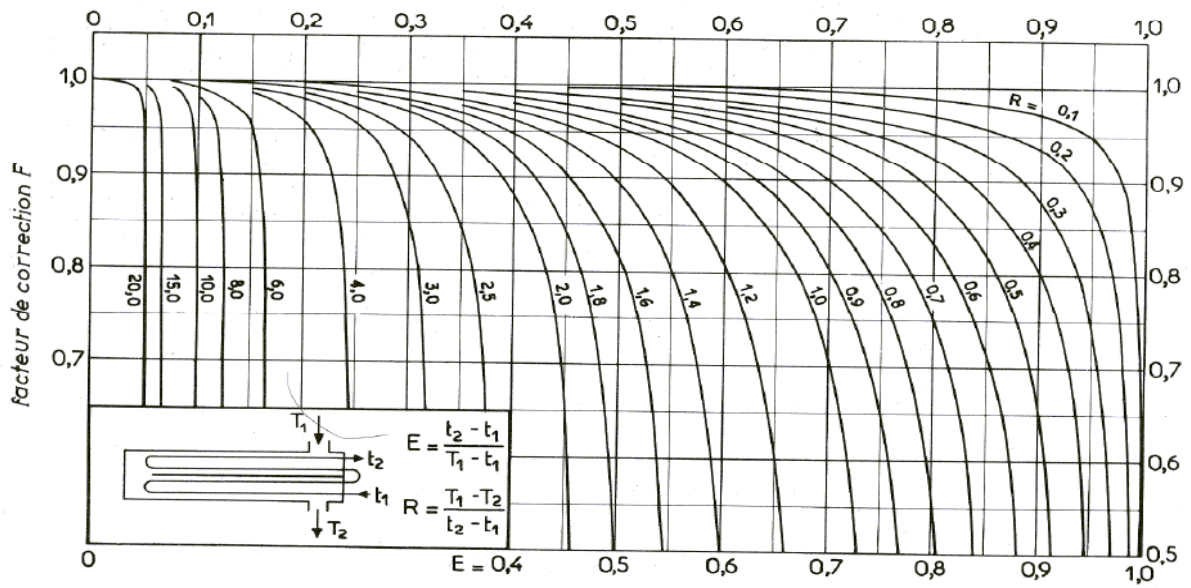


Figure 1.1. Determination of caloric temperatures. [46]



a. une passe côté calandre, deux passes (ou plus) côté tubes.

Figure 1.2. Abacus a and b: Determination of correction factor from R&E [47]



b. deux passes côté calandre, quatre passes (ou plus) côté tubes.

Figure 1.3. Transfer coefficient and fraction coefficient as a function of modified Reynolds number inside the tubes. [47]

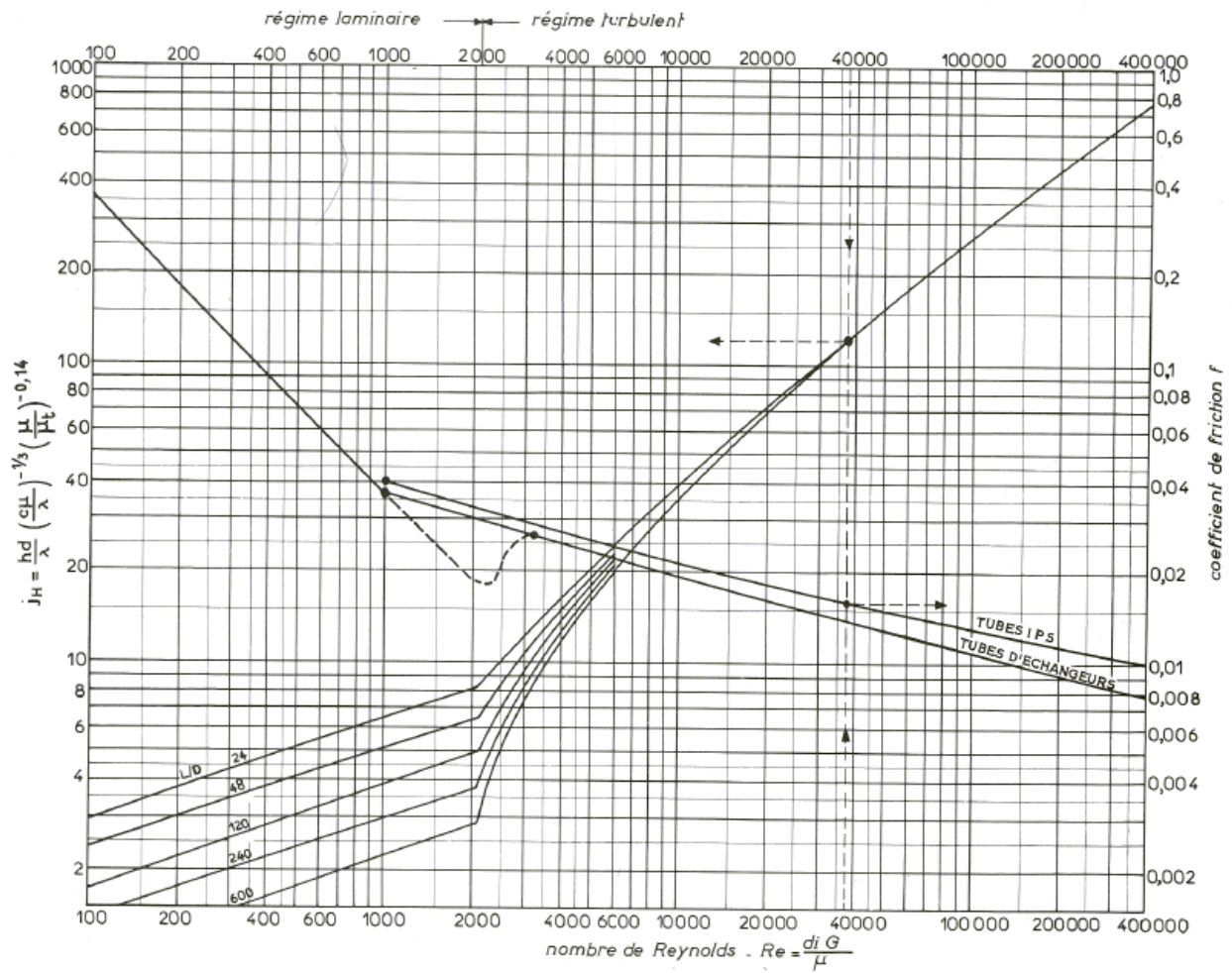
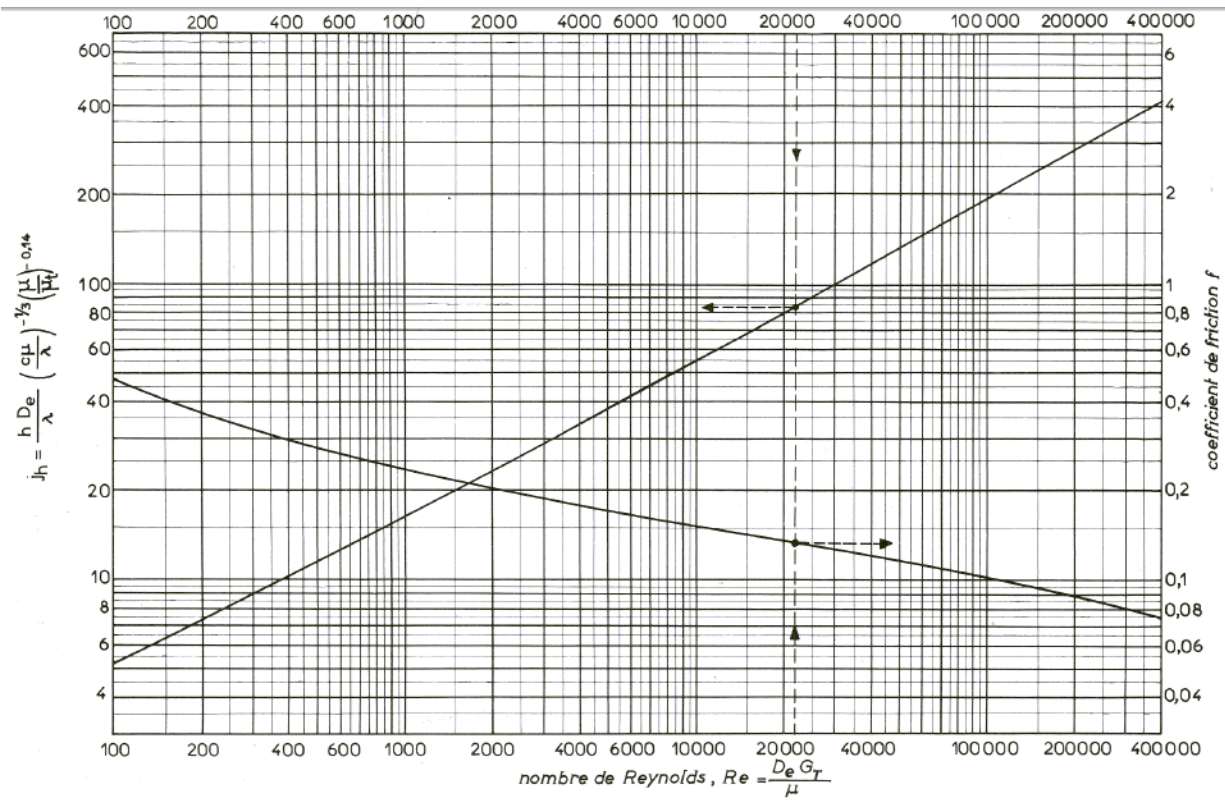


Figure 1.4. Transfer coefficient and friction coefficient as a function of modified Reynolds number outside the tubes. [47]



ECHANGEUR TUBULAIRE
 SHELL & TUBE HEAT EXCHANGER
 FEUILLE DE DONNEES THERMIQUES
 THERMAL DATA SHEET
 REPERE / ITEM

F10077-SSA-EQP-DTS-02720-E
 N° à rappeler / Ref. Number

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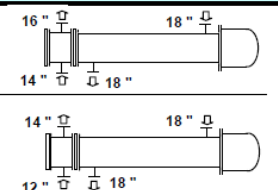
P10/P20/P30-GA-21-01A/B

CLIENT :	SONATRACH	REFERENCE CLIENT :	146W-UTBS-FA-MS-21GA-2720
LIEU :	ALGERIE - HASSI MESSAOUD SUD	CLIENT REFERENCE :	
LOCATION :		UNITE :	UNITE DE TRAITEMENT DE BRUT
		PLANT :	

rev.

1	SERVICE:	STABILIZER FEED PRE-HEATER (summer2015 case) (1) (7)		
2	DIMENSION / SIZE :	1200 x 6096 mm	TYPE :	AES
3	SURFACE PAR APPAREIL (Eff.):	851 (2) m ²	Nb CORPS PAR APPAREIL :	
4	SURFACE PER UNIT (Eff.)	N° SHELL PER UNIT		SURFACE PAR CORPS (Eff.): 425.5 (2) m ²

CARACTERISTIQUES DES FLUIDES / FLUID CHARACTERISTICS		COTE CALANDRE / SHELL SIDE		COTE TUBES / TUBE SIDE	
FLUIDE CIRCULANT / FLUID CIRCULATING	-	PRODUCT OIL		INLET CRUDE OIL	
DEBIT TOTAL A L'ENTREE / TOTAL FLOWRATE ENTERING	kg/h	539 081,1 (3)		455041,8 (3)	
DEBIT VAPEUR HC / HC VAPOR FLOWRATE	kg/h			14 974,5	
DEBIT LIQUIDE HC / HC LIQUID FLOWRATE	kg/h	539 081,1		454 452,2	
DEBIT VAPEUR D'EAU / STEAM FLOWRATE	kg/h			504,3	
DEBIT EAU / WATER FLOWRATE	kg/h			589,6	
DEBIT INCONDENSABLES / NON CONDENSABLE FLOW RATE	kg/h			0,0	
EAU VAPORISEE OU VAP. COND. / VAPOR'D OR COND'D STEAM	kg/h				
MASSE VOLUMIQUE / DENSITY	V/L	684,0	721,5	750,4	11,7
VISCOSITE / VISCOSITY	V/L	0,332	0,499	0,770	0,0107
MASSE MOLAIRE VAP. / MOL. WT VAP.	g/mole			50,30	
MASSE MOL. INCONDENS. / MOL. WT NON CONDENSABLE	g/mole				
CAPACITE THERM. MASS. / SPEC. HEAT	kJ/kg.K	2,548	2,400	2,224	2,145
CONDUCTIVITE THERMIQUE / THERMAL CONDUCTIVITY	W/m.K	0,086	0,106	0,113	0,027
CHALEUR LATENTE / LATENT HEAT	kJ/kg				
TEMPERATURE	°C	160,0	119,8	68,1	114,1
PRESSION ABS. A L'ENTREE / ABS. INLET PRESSURE	bar a	6,60		7,85	
VITESSE / VELOCITY	m/s	0,7		1,8	
PERTE DE CHARGE / PRESSURE DROP	bar	0,90 (6)	0,70 (6)	0,90 (6)	0,60 (6)
FACTEUR D'ENCROUSSEMENT / FOULING FACTOR	m ² .K / W	0,00035		0,00035	
CHALEUR ECHANGEE / HEAT DUTY	MW	14,9 (3)		DTML CORRIGEE / MLTD CORRECTED : 46,1 °C	
COEFF. GLOBAL D'ECHANGE / OVERALL EXCHANGE COEFF.	W/m ² .K	SERVICE 380,0		PROPRE / CLEAN	

CONSTRUCTION / CONSTRUCTION DATA		CALANDRE / SHELL		TUBES / TUBES		ORIENTATION TUBULURES / NOZZLES LOCATION	
PRESSION DE CALCUL / DESIGN PRESSURE	bar eff.	8,8 / FV		23 / FV			
TEMPERATURE DE CALCUL / DESIGN TEMP.	°C	206 / -5°C		160 / -5°C		shells in series not stacked	
PRESSION D'ESSAI / TEST PRESSURE	bar eff.	BY CODE		BY CODE			
SUREP. CORROSION / CORROSION ALLOWANCE	mm	3,0		3,0			
DPEM APPLICATION / DPEM APPLICATION		YES		YES			
CODES DE REFERENCE / REFERENCE CODES		ASME VIII div1 / TEMA R / API 660 / DPEM					
TUBULURES / NOZZLES :		ENTREE / INLET		SORTIE / OUTLET			
(DN / ND - PN / RATING)		18" / WN 150# RF		14"(A) 16"(B) / WN300# RF			
NB PASSES / N°PASSES		1		2			

NB TUBES / N°TUBES :	915	- Øext :	25,40 mm	- EP / Thk :	Mini. X	Moyl/Avg :	2,77 mm	LONG. / LENGTH :	6096 mm
MATERIAU TUBES / TUBES MAT. :	CS / A179 (10)	- PAS / PITCH :		- ORIENTATION :	30°	60°	X	45°	90°
CALANDRE / SHELL :	CS (10)	FOND CAL. / SHELL COVER :		CS (10)					
BOITE / CHANNEL :	CS (10)	FOND BOITE / CHANNEL COVER :		CS (10)					
PLAQUE TUB. FIXE / FIXED TUBESHEET :	CS (10)	PLAQUE TUB. FLOTTANTE / FLOAT.TUBESHEET :		CS (10)					
FOND FLOT. / FLOATING HEAD COVER :	CS (10)	DEFLECTEUR / IMPING. PROTECTION :		YES / CS (10)					
CHICANES / CROSS BAFFLES :	CS (10)	- TYPE SINGLE SEG.		- ESPAC. / SPACING :	716 (13) mm	- COUPE/CUT (% Ø) :	Ver.	Hor.	X
CHICANES LONG. / BAFFLES LONG. :	-	- ETANCHEITE / SEAL TYPE :		-					
DEFLECTEURS LONG. / BY PASS SEAL ARRANG. :	YES / CS (10)	- LIAISON TUBES - PLAQUE / TUBE - TUBE SHEET JOINT :		EXPANDED					
TYPE DE BRIDES / FLANGES TYPE :	- CAL. / SHELL :	WN RF	- TUBE :	WN RF					
TYPE DE JOINT / GASKET TYPE :	- CAL. / SHELL :	(10)	- TUBE :	(10)					
pv ² - TUB. ENTREE / INLET NOZZLE :	1580 kg/m ²	- ENTREE FAISCEAU / BUNDLE INL. :		kg/m ²	- SORTIE FAISCEAU / BUNDLE OUT. :				kg/m ²
POIDS PAR CALANDRE / WEIGHT PER SHELL :	(14) VIDE / EMPTY :	~ 17430 kg	- FAISCEAU / BUNDLE :	~ 10900 kg	- PLEIN D'EAU / WATER FILLED :	~ 25000 kg			

REMARQUES / REMARKS:
 SEE NOTES PAGE 5

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MECHANICAL DATA SHEET

HEAT EXCHANGER

F10077-SSA-EQP-DTS-02721-E

REF. NUMBER

ITEM

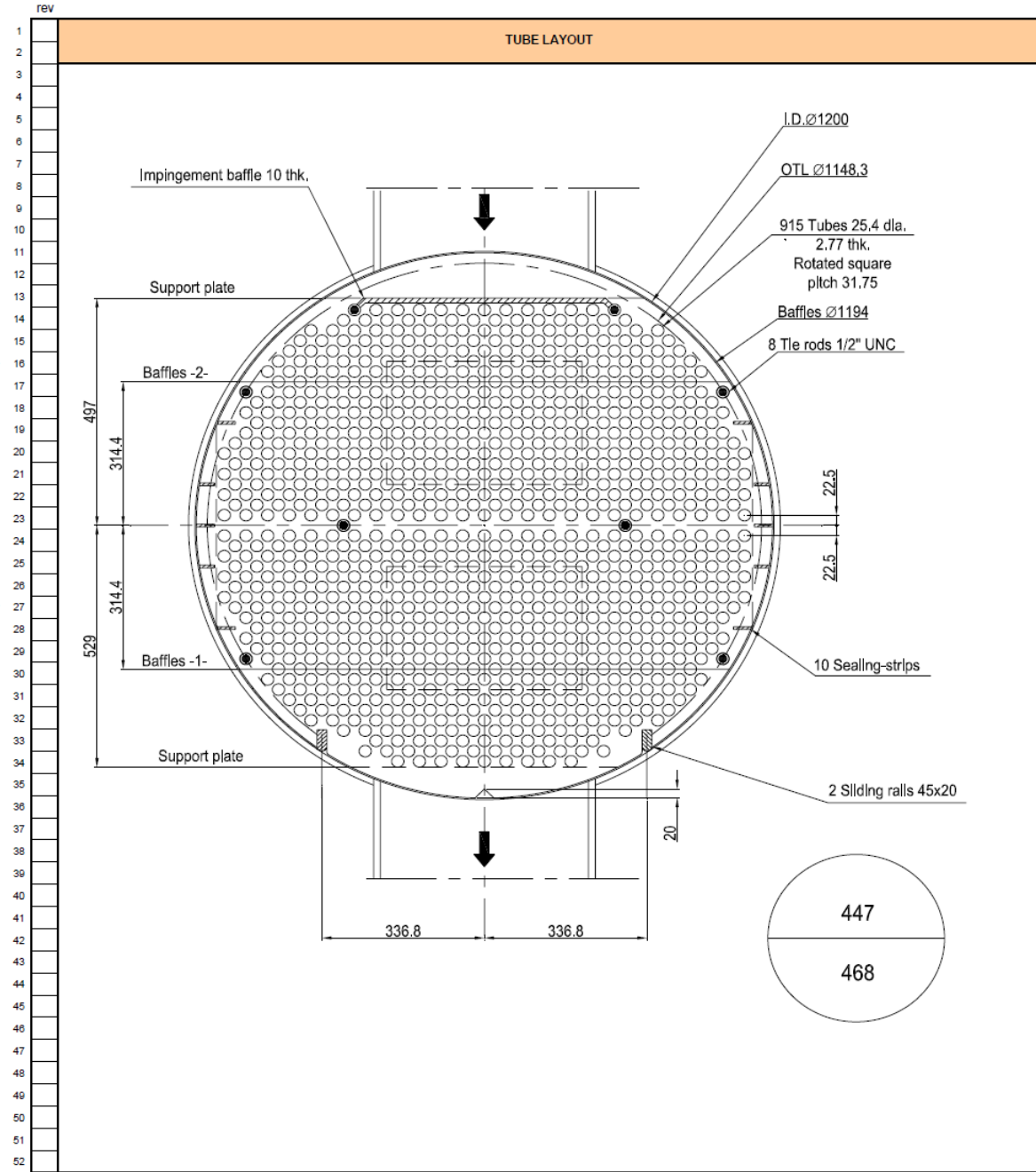
P10/P20/P30-GA-21-01 A/B

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CLIENT :	SONATRACH	CLIENT REFERENCE :	146W-UTBS-FA-MS-GA-02721
LOCATION :	ALGERIE - HASSI MESSAOUD SUD	PLANT :	UTBS

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ملخص أظهرت الدراسة التي أجريت على مبادل Tube-Shell P30-GA-21-01 A/B

أنها تواجه مشاكل تتجلى في وجود مقاومات إضافية وزيادة في انخفاض الضغط. ينتج عن هذا التغيير عدم القدرة على ضمان التبادل الحراري. تتيح هذه الدراسة تحسين معايير التشغيل الحالية ومقارنتها مع تلك الخاصة بحالات التصميم، وبالتالي تقدير الطرق المختلفة الممكنة للقضاء على تلوث الأنابيب لتحسين كفاءة المبادل الحراري. تتيح هذه الدراسة تحسين معايير التشغيل الحالية ومقارنتها مع تلك الخاصة بحالات التصميم، وبالتالي تقدير الطرق المختلفة الممكنة للقضاء على تلوث الأنابيب لتحسين كفاءة المبادل الحراري.

كلمات مفتاحية: مبادل الحرارة، انسداد، تدفق.

Abstract: The study carried out on the Tube-Shell exchanger P30-GA-21-01 A/B shows that it encounters problems which are manifested by the presence of additional resistors and an increase in pressure drops. This change results in the inability to ensure heat exchange. This study makes it possible to optimize the current operating parameters and compare it with those of design cases, thus estimating the various possible methods to eliminate the fouling of the tubes to improve the efficiency of the heat exchanger.

This study makes it possible to optimize the current operating parameters and compare it with those of design cases, thus estimating the various possible methods to eliminate the fouling of the tubes to improve the efficiency of the heat exchanger.

Key words: Heat exchanger, fouling, flow.

Résumé : L'étude réalisée sur l'échangeur Tube-calender P30-GA-21-01 A/B montre qu'il rencontre des problèmes qui se manifestent par la présence de résistances supplémentaires et une augmentation des chutes de pression. Ce changement entraîne l'incapacité d'assurer l'échange de chaleur. Cette étude permet d'optimiser les paramètres de fonctionnement actuels et de les comparer avec ceux des cas de conception, estimant ainsi les différentes méthodes possibles pour éliminer l'encrassement des tubes afin d'améliorer l'efficacité de l'échangeur de chaleur.

Cette étude permet d'optimiser les paramètres de fonctionnement actuels et de les comparer avec ceux des cas de conception, estimant ainsi les différentes méthodes possibles pour éliminer l'encrassement des tubes afin d'améliorer l'efficacité de l'échangeur de chaleur.

Mots clés : Echangeur de chaleur, encrassement, débit.