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Department Of Industrial Maintenance
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of the Requirements for the Degree
Master in Mechanics and engineering systems

TOPIC

Thermodynamic analysis of a condenser vacuum from the central Ras-Djinet

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Abstract:

In this work we studied the influence of the temperature and flow of sea water, therefore the inlet air, exchange surface, impassibility on the vacuum of the condenser.
We have applied the thermal NUT method in order to evaluate the thermal exchange of the gas condenser. And we have realized a thermodynamic analysis of the overall water vapor circuit. We found that the temperature of sea water increases, the condensation temperature increase while the pressure of the condenser of the cycle efficiency decrease.

Résumé :

Dans ce travail nous avons étudié l'influence de la température et le débit d'eau de mer, l'entrée d'air, la surface d'échange et l'étanchéité sur le condenseur à vide.
Nous avons appliqué la méthode thermique NUT afin d'évaluer l'échange thermique du condenseur à gaz. Et nous avons réalisé une analyse thermodynamique du circuit global de vapeur d'eau. Nous avons constaté que la température de l'eau de mer augmente, la température de condensation augmente tandis que la pression du condenseur de l'efficacité du cycle diminue.

ملخص:

في هذا العمل الذي قمنا بدراسة تأثير درجة الحرارة وتدفق مياه البحر، ودخول الهواء، وسطح التبادل، على المكثف الفراغي. لقد طبقنا طريقة NUT الحرارية من أجل تقييم التبادل الحراري لمكثف الغاز .وقد أدركنا تحليل الديناميكا الحرارية لدائرة بخار الماء بشكل عام .وجدنا أن درجة حرارة مياه البحر تزيد، مع زيادة درجة حرارة التكثيف في حين أن ضغط المكثف ينخفض بانخفاض كفاءة دورة.

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To all teachers in the mechanic department who provided our training during our cycle study

We would like thanks every one who gives as support and help to make this work

Dedication

I have the great honor to dedicate this work
To the woman who has devoted her live so that the crumb is better, by the help and support she has given me, so that I can continue my studies from the bottom of my heart, I thank you, my dearest mother
To my father who brought me all the help I needed.

To my dear brothers Mohammed, Hafid, Salim and his wife
To my dear sisters Rawya , Amina and her husband.
To my whole family

To all my close or far friends, especially:

My best friend « Nesrine »
My best friend « Mehdi »
My best binomial « abdou »

To my lovely nephews
Haythem and rasim
Ranim
Rama Miral
Rana ilin

To all my friends of group Mis15

Soumia

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To my dear sisters Manel and Ilhem

To my whole family

To all my close or far friends, especially:

My best friend « Kader»

My best friend « Amine »

My best friend « Djamel »

My best binomial « Soumia »

To my lovely nephew Iyad

To all my friends of group Mis15

Abdou

Summary

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General introduction

General introduction:

The energy sector is one of the most strategic for the economy. The importance of its role in the development of a country is enormous. Most developed countries are very interested in this sector.

The production of calorific energy and electric energy is always a very interesting need for the operation of a machine or where the industry of a country.

The thermal power plant is an important source of electrical energy which operates on a thermodynamic cycle, the efficiency of which depends particularly on the temperatures of the hot source and the cold source

The thermal central of Cap-Djinet was built in order to produce this electrical energy from the steam in a closed circuit, this steam will undergo three major transformations, the first transformation of the chemical energy into calorific energy by Combustion, the second transformation of heat energy into mechanical energy in the turbine and the third transformation of mechanical energy into electrical energy using the alternator.

In order for the plant to ensure continuous production of electricity and with high efficiency this requires knowledge of the influence of the various organs of the installation, and among the essential organs that affect cycle performance.

Given our objective to study the importance of condenser, we will study the different parameters that influence on a vacuum, and the state of condenser for steam power plant which operates with a lower pressure than atmospheric pressure. We divided our study into four chapters:

- The first chapter of our study is devoted to the generalities of condensers.
- The second chapter is concerned by a thermal analysis of the gas condenser with application of the NUT method.
- In the third chapter, we have studied the thermodynamic aspect of the overall water vapor circuit.
- In the last chapter, we present a study of the influence of condenser parameters on the plant efficiency.

Finally, the study ended with a conclusion of the work we have accomplished during our final project study.

Chapter I

Generalities of condenser

I.1. History and fundamental: [1]

Has condense is a device that changes a vapor into a liquid state by cooling it. They can just as easily be called a heat exchanger, because they extract the heat from a space, like a room, and send the heated air out into the atmosphere. Condensers are one of the core pieces of equipment in air conditioning systems and refrigeration units. They are most recognizable by their tube and end arrangement on the back of refrigerators, inside a window air conditioning box, or as part of the exterior check box in a central HVAC air unit.

Has condense can be any machine, year apparatus or any structure that changes a gas vapor into a liquid. In HVAC units, the gas is a condenser which is converted to a liquid before going to the evaporator. Purpose until the advent of artificial cooling devices that used a special type of cooler, condensers were used to obtain water from the environment.

Condensation is an integral part of living on the planet earth. It humid summer mornings, you can see condensation at work by looking at the dew that has condensed on low level plants. This phenomenon is called the dew point, and it is directly related to the surrounding atmospheric temperature, at which the air can no longer hold all of the water that has been mixed in with the air. As the air temperature lowers, the water vapor turns into a liquid and makes everything wet to the touch.

It was molecular level, it goes like this. Heated air molecules expand, and when they expand, the spaces between them are greater. If large amounts of water vapor are present in the atmosphere, it will fill in those spaces, and as long as the temperature remains high enough the air will be saturated with water. That's called humidity. As the air temperature cools, the spaces between the air molecules decrease literally, squeezing out the water vapor, which gets deposited on plants, animals, and innate objects. Once deposited, this water vapor is called dew.

Artificially condensing gas to liquid has been known for centuries. Steam, from boiling water in a flask, is just heated air that has been saturated with water vapor. The steam can be condensed by running it through a chilled pipe, lowering the air temperature and squeezing the water droplets out of the air, exactly the way the dew forms. In this way, any impurities in the water remain in the flask, while pure water is condensed and collected in another container. Salt water is turned into pure drinking water in this way. The salt, and other impurities in sea water, are too heavy to boil and evaporate. Those particles remain behind when the water is turned to steam, and in this way, only pure water is collected as it condensed.

Throughout history, the principles of condensation have been used mainly to collect water for drinking or irrigation.Because the earths atmosphere always contains some water vapor, even in the driest and most arid regions, in theory, this water can be "mined" and collected. You *can* understand this concept if you have a basement or if you have ever entered a cellar. Basements and cellars are inherently always damp inside. That's because warm humid air from outside, that makes it's way into these spaces, will become chilled below it's dew point. It will then condenses, sometimes leaving damp areas on the floor gold objects, and it will make the space moist and clammy.

Passive various buildings, called Air wells, were built to collect water through condensation. The most famous one, called Knapen's aerial Well, after the inventor Achille Knapen, was actually built in France during the 1930's. It worked like this.

Warm outside humid air would enter the nearly 600 foot tall tower, and come into contact with a solid concrete column in the center. The design of the structure always kept the column shaded, so it was always at a lower temperature than the surrounding tower walls. (Think of this as an above ground basement.) As the warm air came into contact with the cooler column, the air was cooled below its dew point. Beads of DEW would then collect on the column and run down into a collection trough. Although the air well was proven to work, it wasn't very efficient, and only a few liters of water per day was ever produced.

Purpose the principles of condensation, in all of these examples, apply directly to a condense in virtually any air conditioning unit. It doesn't matter if it is a standalone model, a commercial model or if it is part of an integrated HVAC system. As heat is removed from the Condensing coils, the dew point is lowered and refrigerant inside condensed from a gas into a liquid. Just like in a test tube, year air well or a basement, as the dew point drops, the refrigerant vaporized turns back into a liquid state.

Of course fans and electric motors aid this process and make it more effective and more efficient. The amount of tubing and purposes connected to a condense also aid in the process as well. Smaller window air conditioners have small condensing boxes, while larger central air units have Condensers that are integrated into the exterior casing. Commercial Gold industrial condensers are sometimes bare stand-alone units built in rows or banks, usually located on roofs or other out of the way spaces, so that they remain undisturbed and unharmed while doing their job.

Condensers have come a long way since humans first began seeing dew on plants, Goal This simple action of changing vapor into a liquid is one of the prime reasons that modern air conditioning works.

I.2. Introduction:

The condenser of the thermal plant is an important element in the water circuit-Steam, in this point of circuit or he will have the phase change of the Steam .What Allows us to win a important work.

We will see in this chapter the condensers and its types and problems encountered during The exploitation of the condensers and their solution.

I.3.definition of a condenser:

The condenser is a device whose main function is to condense the steam, the reheating mandatory from the fluid auxiliary cold being only a consequence (sometimes harmful), by opposition to the heat exchangers (heaters) where the condensation of steam is only a means to obtain the desired goal: the heating of a certain fluid. We can classify the condensers in two major families:

The condensers by surface, without contact between the steam to condense and the refrigerant, a surface of an exchange interposing itself between them;

The condensers by mixing with, as their name indicates, total mixture between the steam to condense and the refrigerant. These remain very little used because of the impossibility of mixing between the steam and water cooling, in general of the raw water.

To condense a saturated vapor, Physics teaches us that we must extract to this steam a certain quantity of heat, called the enthalpy of vaporization, and give it to a cold source. A condenser is therefore a need for a source of cold which is, in the most general case, a liquid good market. Given the heat flows put in game, it has proved that the cold source the least expensive was the water, but it also uses the air as a refrigerant. We can classify refrigerants as follows:

- Freshwater (river);
- Sea water
- Air

the major areas of employment of condensers are:

- The production of energy
- The chemical industry
- The technique of the cold

I.4.Role of the condenser: [2]

It is a heat exchanger in which the refrigerant gas, after compression, is condensed in constant temperature by releasing in the medium (air or water), the heat Retrieved to the evaporator more the heat of compression.

The condenser is divided into three parts delimited by the operating parameters:

- the area of desuperheater
- the area of condensation
- the area of under cooling

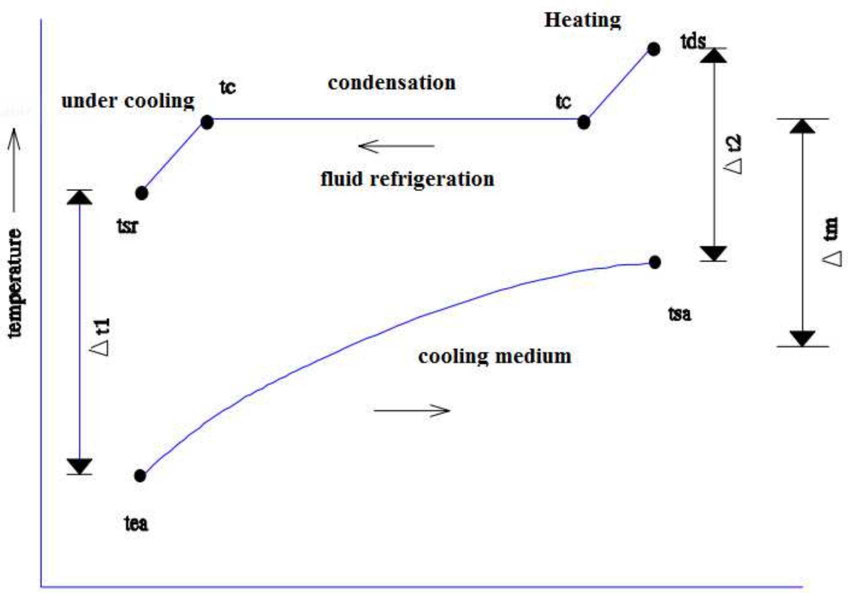

Figure I.1: operating parameters of condenser

I.5. General principle of a condenser:

The principle the more general is to circulate the two fluids through the ducts which put in thermal contact. In general, the two fluids are placed in thermal contact through a wall which is the more often this metal which promotes the exchange of heat. It was a hot fluid who transfers heat to a fluid cold. In other 21 words, the fluid hot cools to the contact of the cold fluid, and the cold fluid warms on contact of the fluid hot. The two fluids exchange of heat through the wall of where the name of the device.

It can be seen that the general principle is simple, but it gives rise to a large number of different achievements by the geometrical configuration. The main problem is to define a surface of sufficient exchange between the two fluids to transfer the quantity of heat necessary in a given configuration. It has just been said, the quantity of heat transferred depends on the surface of an exchange between the two fluids but also of Many other parameters which makes a precise study of these devices quite complex. The heat flow transferred will also depend on the inlet temperatures and thermal characteristics of the fluids (specific heats, thermal conductivity, viscosity...) as well as the coefficients of exchange by convection. The evacuation of the heat in a condenser is performed in 3 steps see Figure **I.2**

1-The desuperheater vapors of refrigerant fluid (section 1-2)

2- The condensation of vapors (evacuation by latent heat; main step segment 2-3)

3-The sub cooling of the refrigerant liquid (section 3-4)

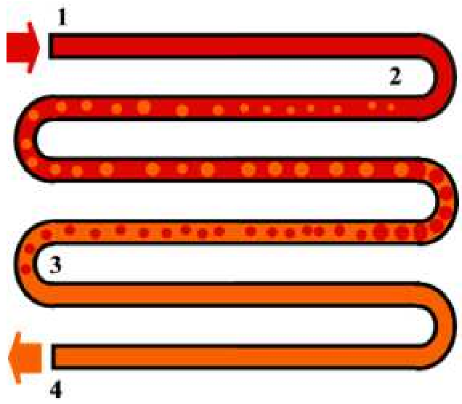

Figure I.2: Evacuation of the heat of a condenser [3]

I.6.The types of condensers: [4]

The condenser of the turbine is part of the circuit of condensation and the auxiliary circuits (installation of vacuum). It ensures the condensation of vapor from the exhaust of the turbine and increase its relaxation. There are two types of condenser:

- Condenser by surface.
- Condenser by mixture.

I.6.1 Condenser by surface:

Without contact between the steam to condense and the cooling water, a surface the exchange interposing itself between them. The exhaust steam of the turbine condenses in the Contact with the cold tubes of the tubular harness travelled internally by the water of Cooling this condensed steam is collected in the form of water in the wells of Condenser.

The condenser by surface includes mainly:

- A body of Condenser
- A tubular plate; the ends of the tubes are located in the openings of the tubular plates
- A headline connecting the body of the condenser to the exhaust flange of the turbine
- A well located at the lower part of the body of the condenser, which collects the condensed

water

- Two boxes to water: the water of movement penetrates by the two boxes before.

I.6.2 The condensers by mixture:

The contact is made in a direct manner that is to say that the mixture contains steam and The refrigerant. The condensation is done by spraying of cold water in the steam. The condensed steam (pure water) is mixture to the cooling water. The steam Will be recovered if the waters are of the same nature.

I.7. The condenser of the central Cap-Djinet:[5]

The condenser of the central Cap-Djinet is a condenser by surface which means That the water movement is sucked in by the walls of the tubes. It is located under the body BP. The passage of water circulation in the tubes is perpendicular to the turbine. This Provision encourages the supply and the evacuation of the water circulation.

I.7.1. **sizing of condenser of the Cap-Djinet Central:**

The characteristics of the condenser of Cap-Djinet are represented in the table next:

Table I.1: Sizing of condenser of the central Cape Djenet [5]

types	feature
manufacturer	SGP, subcontractor (engimeer.KWV)
Type of Condenser	To box
Execution	Single course divided
Disposition	Transverse to the axis of the turbine
Materials of tubes	titanium
Water circulation	Sea water
Outside diameter	19 mm
Tube thickness	0.7mm
Exchange area	10101 m^2
Speed of water in tubes	1.8 m/s
Steam flow	98.25 Kg/s
Cooling water flow rate	6500 Kg/s
Number of tubes	14500 tubes
Length of tubes	14490 mm
Height of the water box	2600 mm
Length of the steam jacket	6700 mm
Mass of vacuum condenser	285.51 tonne
Pressure in the condenser	0.05 bar
Cooling water temperature	20°C
Condenser protection	Engagement, cathodic protection

Vacuum packing	Steam side: Single-stage start for 2 ejectors Two –stage service for 2 ejectors Brand : kortings
	Water side: 2 vacuum pumps Brand: simens

I.7.2. **Constitution of the condenser of the central Cap-Djenet :**

In general a condenser by surface includes mainly:

- A body.
- A tubular plate to each of the ends of the body.

- A tubular harness brass or other alloy (the ends of the tubes are Outputs in the holes of the tubular plates).
- A headline connecting the body of the condenser to the exhaust flange of the Turbine.
- A well located at the lower part of the body of the condenser, which collects the water Condensed.

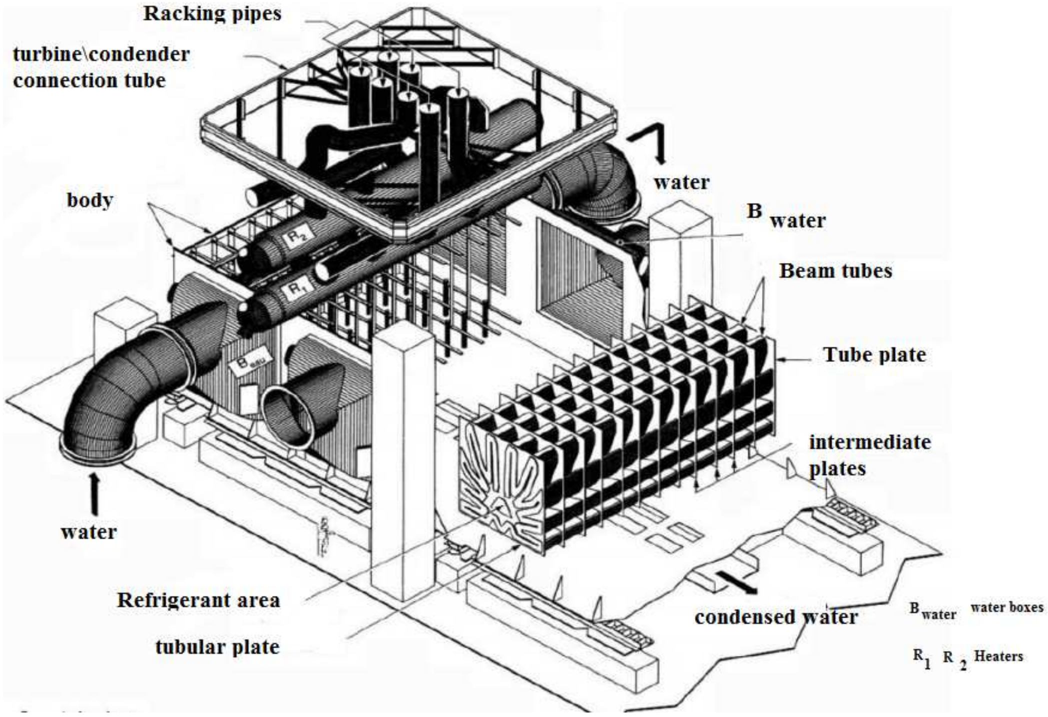

Figure I.3: Exploded view of a condenser by surface [5]

The condenser consists of the following elements:

I.7.2.1. **coolant (particularity of sea water)**

The sea water is indeed a source of cold virtually unlimited, well Adapted to the Refrigeration in open circuit of large power plants, in Against part of its physical-chemical characteristics and biological action in general, The constructor and the operator of condensers, of specific provisions and Expensive to protect themselves:

• On the one hand, against the risks of accidental entries of sea water, including as a result of corrosion and erosions of the tubes. In effect, the materials of modern slices bear very poorly any introduction of water loaded in salts in the water vapor from the cycle.

• On the other hand, against degradation of the conditions of the water flow of refrigeration and the characteristics of an exchange of heat.

I.7.2.2. **the water box:**

The condenser is a journey of which the flow of the water of movement is Shared. The water of movement penetrates by the two boxes to water before, crosses the two halves of the condenser in two streams with the same importance and spring by the two boxes to Rear water.

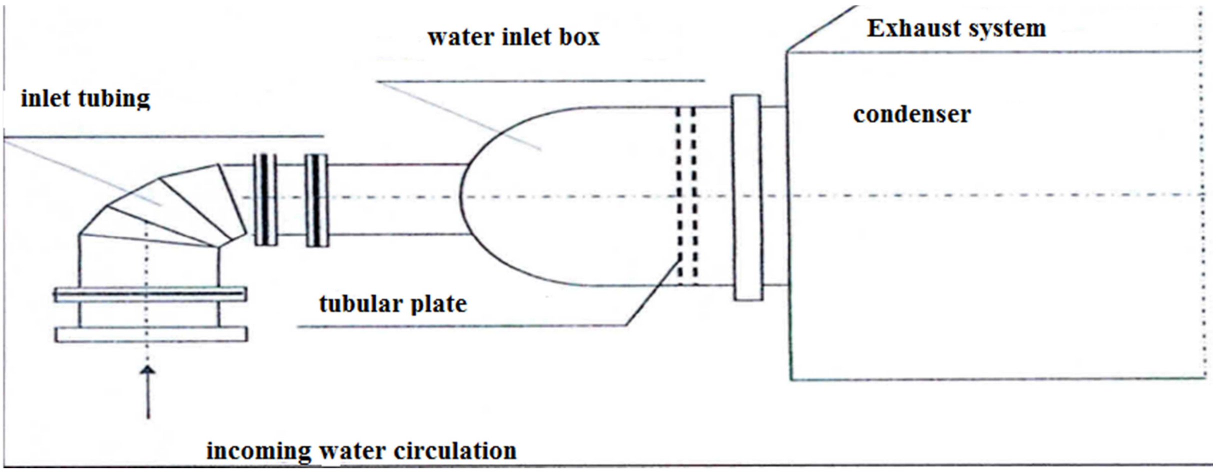

Figure I.4: water box of the condenser [5]

I.7.2.3. **Surface Protection of gearbox to the water:**

The boxes to water, which are steel, are equipped with a rubber coating on the wall In contact with the water circulation, which protects it from corrosion. It exists in addition to a cathodic protection that operates according to the method of current external to the Means of rectifier element and resistant anodes.

The tubular plates in an alloy of copper and aluminum, are resistant to water of movement.

I.7.2.4. **body:**

The condenser consists of two corps, each in a form of shoe.

The interior decomposes side condensate/ steam in three main parts: the headline , the steam compartment and the wells.

The headline is the part located above the tubular harnesses. The Wells is the part Bottom of the Steam compartment collects the condensed water.

The exhaust steam of the turbine crosses the headline is restarted regularly in all the steam compartment descending by bleeding where it Penetrates laterally in the tubular harnesses. The condensed water is conducted to the Wells by of the plate of flow. Springs are placed between the foundations and the body of the Condenser for receive its weight and compensate for the dilations

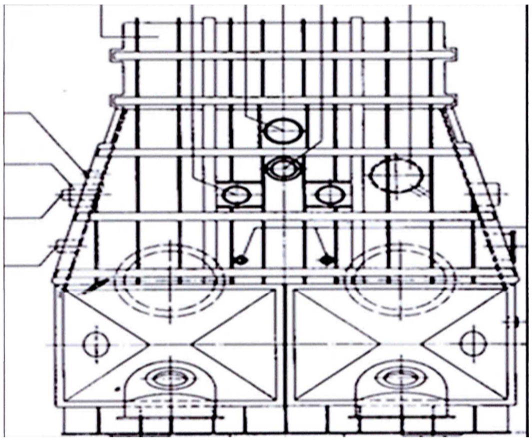

Figure I.5: body of Condenser [5]

I.7.2.5. **Tubing:**

The tubes are rights and with a smooth surface. They are loaded transversely to the axis of the Turbine and are supported on their length by the spacers, which prevent deformations and The vibrations in the course of service. The tubes are grouped into tubular harness. The outer diameters of the tubes of condensers vary between 16 mm and 28 mm, for of the tubes, normal thickness of 1mm approximately. This thickness, also depends on the nature Of the materials used, for tubes in titanium the thickness varies from 0.6mm to 0.8mm (this is to poor conductivity of titanium). Although the ability of drawing of the tubes Cuprous, either currently 25 m approximately, it is not desirable to have tubes too Long This for two reasons:

- For a question of non jibbing of the central: it should be a free space of Length equal to that of the tubes.

- In order to minimize the losses of load (friction of the water movement in the Tubes) water side of movement. This loss of load being all things being equal, In proportion to the length of the tubes

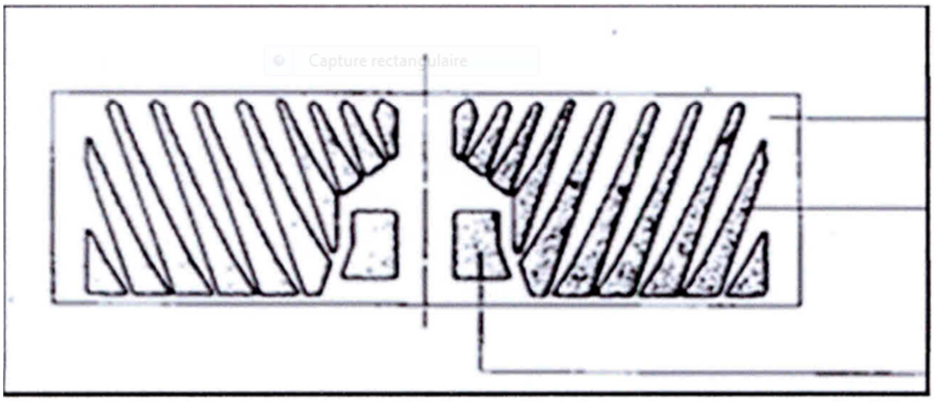

Figure I.6: condenser tubes [5]

I.7.2.6. **measurement tube level:**

The level of condensate in the condenser is captured by the intermediary of the measurement tube.

I.7.2.7. **ball of bursting of the drains:**

Different circuits are connected to the condenser through three balls of bursting which are connected to the condenser side steam and condensate side.

I.7.2.8. **vacuum:**

What is the vacuum for science? It is colloquially which occupies a volume Delimited by watertight walls in which the density of particles is much less than in the atmosphere that surrounds us. It is a shortcut to indicate a lower pressure that the atmospheric pressure.

It is the German physicist *Otto von Guericke*, which by studying the properties of the air and the Creation of empty, invented the air pump in 1650, after having had knowledge of the Experiments of the French scientist *Blaise Pascal,* and Italian scientists *Galilee* and *Evangelista Torricelli Acts* on the atmospheric pressure. The engineer and French Industrial *Maurice Leblanc* studied more particularly the pumps and the turbines and develop a air pump to intended to produce the theoretical vacuum in a condenser.

I.7.2.8.1. **Production of the Empty:**

Make the empty or achieve the vacuum in a room of work or an enclosure is to Decrease the number of molecules of different gases present of this volume. To the pressure Normal atmospheric 1, 01325.105 (Pa), in a volume of one liter to 0°C, there is 2.7. 1022 molecules and atoms of gas. In primary vacuum, that is to say 10 Pa, it is therefore still 2, 7.1018 molecules, or 99.99 per cent of empty. It is the nature of these molecules remaining (or 2.7. 1018 per liter) which is of interest to the operator, because they are sources of poor quality of a product or malfunction in a system. If it goes to a level of pressure of 10-4 Pa, IT Still remains 2, 7.1013 molecules.

It has taken the habit to delineate the range of pressures below the pressure Of atmospheric 105 Pa to 10-13 Pa in several areas defined arbitrarily and whose The limits are approximate:

- Field of coarse empty: 105 Pa at 102 Pa;
- Field of empty medium: of 102 Pa at 10-1 Pa;
- Area of high vacuum: 10-1 Pa at 10-5 Pa;
- Field of the UHV: 10-5 Pa at 10-8 Pa;
- Field of the extreme-empty: less than 10-8 Pa.

I.7.2.8.2.**The vacuum in the condenser:**

In a condenser, the pressure is very sensitive uniform. Differences in pressure does Could exist that during the load losses of the vapor at the crossing of the wiring harnesses The tubular. However, speeds are very low and diminished more and more as the Condensation. In the case or Li there is no entry of air, it would have the following relationship between the pressure and the temperature:

$P = F(T)$.

There is however inevitable receipts of air that come from the imperfections of circuits In all parties where the latter is the lower pressure than the pressure Atmospheric. In all parties where the fluid is in contact with the atmosphere, a certain quantity of gas is absorbed by the solutions. The atmosphere of the condenser is therefore composed of a mixture of air and steam, so we will apply the law of Dalton:

1° in a vase closed, the elastic force of the maximum emitted vapor is the same as in the

vacuum at the same temperature.

2° A mixture of gas and vapor has a spring force equal to the sum of those

That would have these gases if they occupied only the volume considered.

$$P = P_{air} + P_{steam}$$

The partial pressure P steam being in function of the temperature.

$$P_{steam} = f(t).$$

The air is a incompressible fluid, it is recommended to not leave accumulate because this fact gradually increase the pressure (P) to the inside of the condenser and subsequently Cause the degradation of empty. It is therefore necessary to extract the air to maintain the Partial Pressure peer-to-values as low as possible.

I.7.2.9.**The ejectors:[6]**

These are machines to compress the gas. For the start of the installation, an ejector is sufficient. For the reports of higher compression to 8, they use two ejectors in series

I.7.2.9.1. **Principle of the ejectors**

In an ejector the drive of a fluid is obtained by the rapid displacement of another Fluid. An ejector is constituted essentially (Figure I.7) :

- A pipe bringing the fluid has to result, that we assuming to be in the air.
- Tubing which leads in the pipe work the engine fluid b used for the drive on the air.
- A nozzle converges prepared at the end of the tubing.

The air arrives in the annular space between the piping and tubing. The fluid B fate of the choke converge with a high speed, it pushes the air content in the piping to the end of this last.

It results in the area of the choke converge a vacuum which causes the influx of the outside air in the piping.

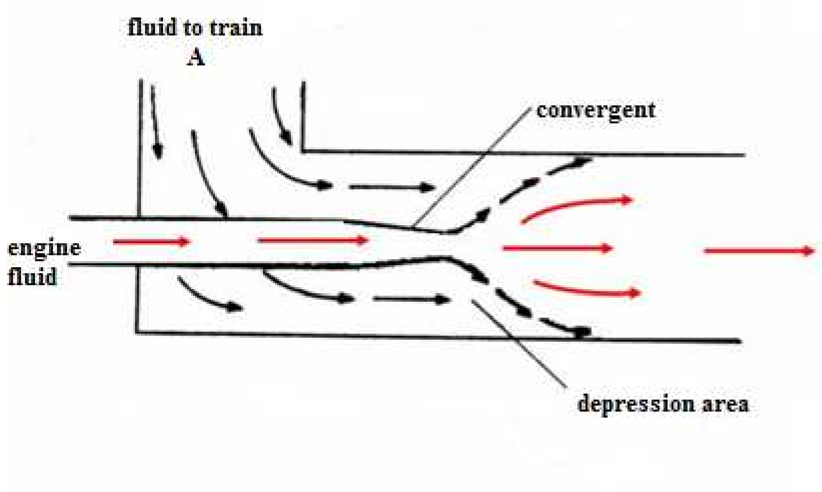

Figure I.7: constitution of an ejector

The ejectors have many applications. Regardless of their employment in the power plants, they are used in particular in the steam locomotives or the passage of the air Burning through the grid and the layer of coal, as well as the rejection of the smoke from the Fireplace, are obtained by the injection at the base of the chimney of the exhaust steam Of the cylinders.

The ejectors of extraction of the air condensers constitute a wrong consisting of Two nozzle (Figure I.8) , the converged A by which arrives the engine fluid B, to its output If performs the mixture and the drive of the fluid sucked a, the mixture of the two fluids passes Then in a divergent spout, the speed of the mixture decreases during the crossing of this Discharge spout while its pressure increases, contrary to what happens in the spout Convergent, or the speed of the engine fluid increases when it the cross member while its Pressure decreases.

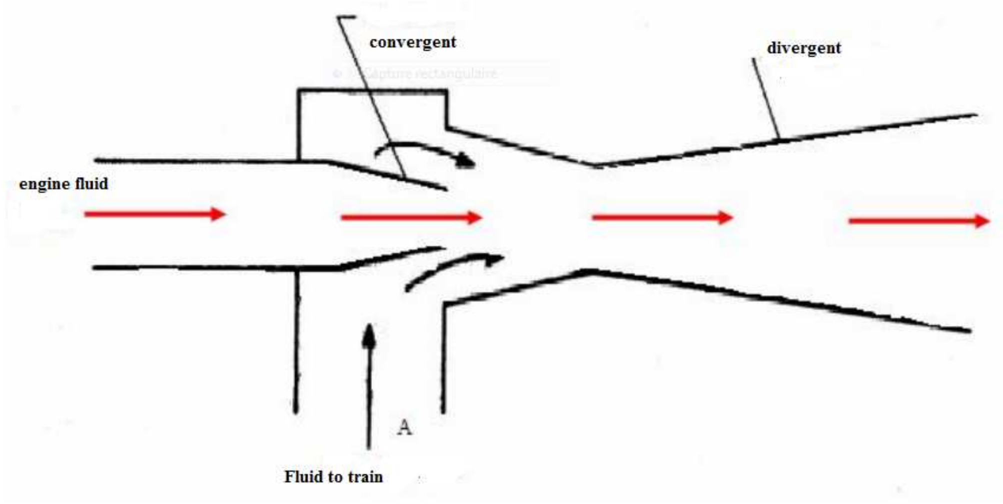

Figure I.8: an ejector constituting a wrong.

I.7.2.9.2.**Role of the ejectors:**

The role of the ejectors is to extract the incondensable gases brought in the condenser, By steam either by the inflow of air through the seals waterproof imperfectly of the Parties Under vacuum of the installation. This extraction from gas incondensable must be performed in a manner continues, otherwise it in Would be a gradual decline of the vacuum in the condenser and the pressure of exhaust of the Machine could reach values incompatible with the proper functioning and The economy of operation of the equipment.

There are 04 ejectors in the central Cap-Djinet:

Two ejectors on starting and two Ejectors on service .The ejector to start is used to vacuum of the turbine capacity more condenser In a reasonable time and this, at the start of the turbine.

The Ejector of service must be able to maintain the vacuum normal to all loads of the Group in Walking.

I.7.2.9.3.**Characteristics of the four ejectors:**

- ***Ejectors of service (2x100%)***

-Flow rate of air extracted 19 kg/h;

-empty to the condenser 0.05 bar absolute;

-Flow rate of steam 350kg /h.

- ***Ejectors on startup (2x50%):***

-Flow rate of air extracted 550 m3 in 25mm to 0.5 bar.

I.7.2.9.4. **Casse-empty:**

The vacuum breaker has the function to increase the pressure to the condenser by introducing The atmospheric air during the normal stops or in the case of triggering of the group. The increase in the pressure in the condenser is reflected by an increase in the ventilation Of the blades of the turbine, which slows down the group and shortens the time of shut-down, as well That the time of crossing critical speeds.

I.7.3 **operation of condenser of the central:**

In this condenser there is no contact between the steam to condense and the water of Cooling, a certain surface of exchange intervenes between the two fluids.

The exhaust steam of the turbine condenses the contact outside of the tubes the cold of the tubular harness, travelled internally by the cooling water (water from gross sea), and this condenser works as a heat exchanger at cross-current.

The condensed steam is collected in the form of water in the wells of the condenser then she is drawn by the pump of extraction. It is used again to Supply to the boiler.

The water movement, a sufficient flow for the condensation of the steam, is Outlet to the sea. A circulating pump sucks this water and conveys it to the inside of the Tubes of tubular harness by the water box to enter.

The temperature of the water in circulation increases during its crossing of the harness Tubular, up to its output in the water box output. The water then returns to the sea.

The difference between the temperature of the water circulation in its output of condenser and the temperature of the condensed water to the saturation pressure is a characteristic of important design. It is between 2 and 5 °C for a condenser clean.

The air that is introduced in the condenser is sucked by eductors.

The condensers may be to one or more routes. The flow of the water of Movement can be single or divided (condenser at simple or double body). And in Our case the condenser is double body and a journey. This allows us to perform of the maintenance work. For this we can reduce the load without having to stop the group

I.8. Technologies of the condensers: [7]

There are three technologies that are:

- Following the coolant.
- Following the circulation of the fluid.
- Following the design.

I.8.1. Following the coolant :

The condenser to water*:*

The water as the air absorbs the heat flow of refrigerant in the form of heat Sensitive, which translates to a heating of the water used in the condensation. This Heating affects the flow of water to ensure to the condenser, and as the price of Returns per cubic meter of water is relatively high, it may seem interesting to decrease the Water flow necessary to condensation in accepting a warm up more important to The latter in order to reduce the costs of consumption. The against part of this economy of Consumption will be a rise in the temperature of condensation of the refrigerant and A correlative decline of the overall performance of the installation.

The condensers to air:

The air condenser are the most widespread for low and medium capacity of refrigeration because The medium of cooling (air) is a natural resource and free they are dimensioned from The average temperature of the air and their energy performance are governed by the heat Exchanged with the air as the air is not a good medium of cooling , this generates a Consumption of Energy and a quantity of fluid refrigerant important used The performance of These systems which therefore depend heavily on climate condition ,decreased when the temperature Increasing external, with a decline in the efficiency of refrigeration and an increase in the Electrical consumption.

I.8.2. Following circulation of the fluid:

Condenser has natural circulation:

They are only used for very low power installations. Primarily executed in finned tubes, they are no longer made in this form because the tubes with wings would dust very quickly because the very low air velocity favors the deposit of dust on the fins. They are currently made by a tube serpentine form apply on a sheet of sheet form unique and perforated fin to avoid the resonance.

Condenser has forced circulation:

For refrigerated powers greater than those installed on cabinets or furniture Household, it is essential to use a footprint compatible with powers In heat to evacuate, it therefore uses one or several Electro fans which ensure the Movement of the air on the harness fin. The crimping of the fins on the tubes can be realized by processes (mechanical, hydraulic). Two types of provisions are used to know:

- The vertical beam.

- The horizontal beam.

I.8.3. Following the Design:

The condensers to tubes:

There are several types of condensers to enumerate tubes:

Condensers to disposal:

This are the oldest condensers to water achieved. They were used at the beginning of The refrigeration industry for machines with ammonia, sulfur dioxide or of chloride Methyl in the form of coiled tubing in coiled steel in vertical spirals and immersed in a Tank to cylindrical water very bulky requiring a free space important above the Tank To remove the coils, they have been abandoned for the industrial machines for the benefit of the other types. They are nevertheless always used under form allowing combining the condenser and the fluid reservoir. They can achieve in version horizontal or vertical. In the horizontal version, the condenser has a bottle in steel plate coiled and Welded, or incorporated by a steel tube stretched without welding closed by two funds stampings Welded. The fluid condenses on the outside of serpentine of water circulation, constituted by a Copper tube smooth or extruded fins spiral wrapped to horizontal axis. The fluid Condensed is collected in the bottom of the bottle. Has the calorific power of EQUAL, they are more Bulky than in the vertical version. Also their ability of condensation does not exceed Little 8000 W. In Vertical version they ensure the continuity of the first in having a range Of capacity of condensation of the order of 12000 to 70000 W.

Coaxial condensers and counter-current:

In order to increase the speed of the water in contact with the wall of the tube in which circulates the Fluid, they had recourse to a simple solution of placing concentrically Two Tubes. The fluid circulating in the annular space and water in the inner tube, It is possible to circulate the two fluids counter-current giving a better exchange of heat. For the industrial machines, tube in which circulates the fluid are met between them By the headlines, welded, these tubes being themselves welded to their ends on the tubes Water circulation. The elbows or tubular plates comprising the tubes of water are Demountable to allow easy cleaning of the water circuit. In their designs For commercial machine these condensers are executed in the copper tubes of a single Length. The two tubes placed in one another are then curved, which avoids any elbow Reported. The surface of these condensers is obviously limited by the right length of Tubes.

Multitubular condensers:

They are the logical culmination of the condensers to double tube and against the current. In order Of avoided to put in parallel of the many elements of double condenser tube, which Disadvantage of multiply the seals, they have grouped in parallel to the inside of a shell of Large diameter tubes of the circulation of water. The condensation of the fluid is done on the outside of the tubes of water, and the lower part of the shell can be used as a reserve of liquid Condensed.

The condensers to plates:

One distinguishes following the geometry of channel used the condensers to Primary surface and the Condensers to secondary surface. Among the condensers to Primary surface, the type of the most common is the condenser to plates and seals, whose applications are limited by the Maximum pressure of service and by the differential pressure between the two fluids. It can achieve industrially today condensers operating at pressures of the Order Of 15 to 20 bar; the maximum service temperature is limited by the nature of the seals. The Condensers with welded plates allow you to use these surfaces of primary exchanges to The levels of temperature and pressure higher than the condensers with plates and seals. All fluids can be conveyed in these condensers, but the fluids fouling are for Use with caution. 24 The condensers to secondary surface Use of the fins Wrinkled wavy or which are inserted between the plates. For cryogenic applications Aeronautical or, the materials used are of the aluminum or stainless steel, Assembly In doing so by means of a technique of brazing under vacuum.

I.9. problems encountered during the operation of the condensers: [5]

The Exploitation of condensers needs a particular care because the performance of the cycle Depends on the length of life of equipment, three major problems are encountered when the exploitation of the condensers.

I.9.1**The clogging:**

Often the sea water is used to cool the condensers, the condenser of our power plants are cooled to the sea water.

The sea water contains algae maritime, of the shell, salt, and Limestone.

• **Algae Maritimes:**

In spite of the filters placed has the aspiration of a circulation pump algae passes through the filters is they are expelled by the pmp to the condenser, these algae mouths the condenser tubes which fact decreased the exchange surface of the condenser, as well the performance of the condenser decreases and it is translated by the elevation of the vacuum to the condenser.

• The molds:

despite the implementation of filters to the between the condensers of the cooling water but The filters let microscopic larvae which will grow further in the circuit, and Stopper the tubes condenser which leads to the decrease of the surface of an exchange this, se Result in the elevation of the vacuum to the condenser.

The use of filters more end is does not recommend because it leads to other problems such as the decrease in the flow of cooling water and increase the pressure to the suppression of the circulation pumps.

• The Limestone:

The warm of the tubes will attach the salts and limestone on the inner walls of the tubes which reduce the section of the water flow of cooling as well increase the thickness of the tubes leading to a bad heat exchange be steam to condensed and the cooling water.

I.9.2 **the entries of the air:**

Au and as the steam condenses, air accumulates around tubes constraining the Transmission of the heat between the steam and water cooling.

I.9.3. **the entries of sea water:**

It consists of the mixture of the cooling water (water of movement) with the water of extraction And it is reflected by the increase in the rate of chloride in the water extraction.

The sea water contains corrosive salts which degrades the status of equipment in particular the boiler tubes.

Consequences:

• Plugging of boiler tubes.

• Drilling of boiler tubes.

The entries of sea water are among the problems most met in our plants and by Result The degradation and frequent boring of the tubes boilers.

I.10. cleaning of condensers:

I.10. 1 continuous during operation:

The deposit causing the clogging, and evolves in time, can be made up of Crystals, biological residues and products of corrosion. Under the effect of the temperature Deposits may harden and thus become more and more difficult to eliminate during the regular cleaning. The mechanical processes of prevention or elimination of the clogging during operation can significantly improve the Performance of the device and also allow increasing the service time between two judgments of maintenance. Various techniques are available for cleaning in continuous the internal surface of exchanges tubular.

It is of the following processes:

- To 65 balls
- With the help of tools

I.10.1.1 Process to balls *:*

The cleaning of the internal surface of the tubes is done by means of a permanent circulation (Discontinuous in some cases) of balls in sponge rubber (Figure). The Process is to inject into the circuit, upstream of the tubular harness of the balls with a diameter slightly higher than the internal diameter of the tubes.

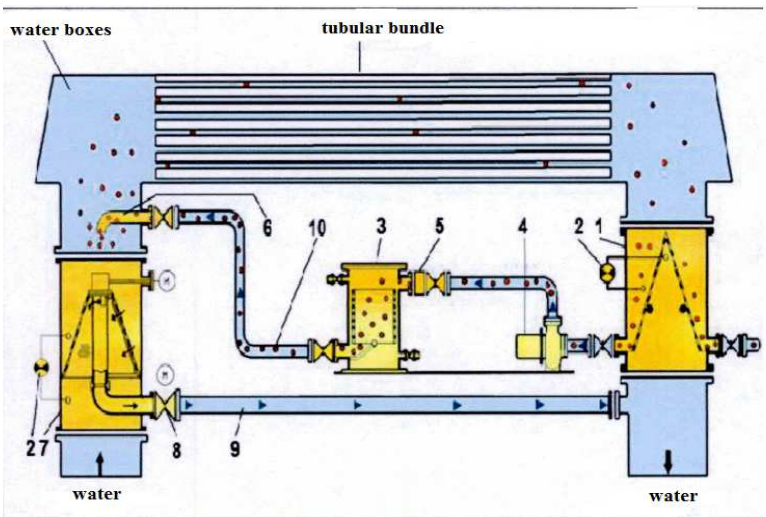

Figure I.9: cleaming device

1. Grid system
2. Monitoring of grids
3. Ball lock
4. Recycling pump
5. Monitoring the circulation of balls
6. Injection of balls
7. Cooling Water Filter
8. Wastewater Valve
9. Wastewater management
10. Conduct of transport of balls

This device can be used for tubes with a diameter between 11 and 30 mm. The diameter of the brushes is greater by some tenth of mm to the one of the tubes.

Figure I.10: the balls in sponge rubber

I.10.1.2. process with the help of tools*:*

This technique is used to remove the deposits, even very hard, to the inside of tubes straight of condenser or other heat exchangers. In the case of deposits not members you can use nylon brushes.

. The cleaning may be purely manual or carried out with the help of machines. The drive or the implementation of the tools is carried out by an electric motor resulting in a flexible transmission in rotation at the end of which is mounted tools.

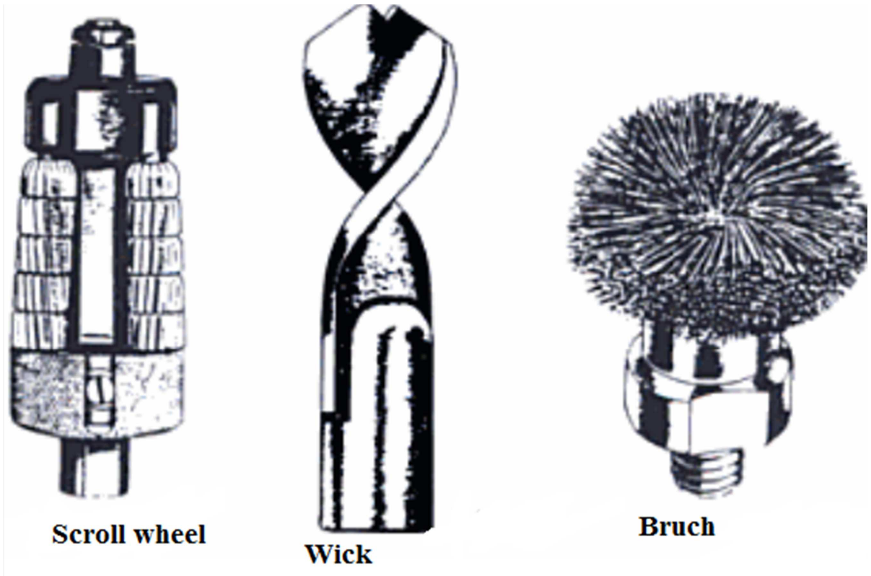

Figure I.11: system of cleaning with the help of tools

I.10.1.3 chemical cleaning during stops:

The acid cleaning with traffic is particularly suitable when the mechanical cleaning in continuous has been inadequate or when the mechanical cleaning to the judgments becomes too expensive as a result of technical difficulties too important immobilizing too long the installation. The chemical cleaning presents many advantages:

- It is a relatively quick operation and effective.

- The exchange surfaces do not suffer mechanical damage important

- The chemical solutions penetrate up to the inaccessible by the mechanical means of the exchanger and the treatment of the entire surface is well realized.

- It is an operation that requires less of labor that the mechanical cleaning and which, moreover, can be achieved without disassembly of the appliance, in insulation of the whole of the installation.

Many chemicals can be used, alone or in a mixture. You can as well use the circles acids, alkaline, or nearly neutral, organic solvents, sludge, mosses, cleaning agents in the vapor phase.

Chapter II

Analyses of the gas condenser

II.1. Introduction:

The calculation of exchangers of various configurations has long been modeled on that of Parallel flow heat exchangers with a large number of original corrective terms experimental. There is, however, a more structured and much more, its applications, the NUT method. We will use it exclusively after.

II.2. Definition of the NUT method: [9]

The number of transfer units relative to the fluid has the smallest heat capacity flow rate C min and is usually designated by NUT

The NUT method consists of expressing the efficiency E of the exchanger as a function of the two parameters R and NUT for each exchanger configuration. There is then a general function independent of the particular conditions of temperature or flow rate which makes it possible to quickly calculate the flows involved without knowing the outlet temperatures. Note that the three quantities used here E, R, NUT are dimensionless which makes all the efficiency the method.

We calculate:

$$R = \frac{Qc\,min}{Qc\,max} \quad \text{.................................} \quad \textbf{(II.1)}$$

The following are determined:

$$NUT = \frac{U\ .\ A}{qt\ \ min} \text{..} \quad \textbf{(II.2)}$$

II.3. Calculation method: [10]

II.3. Calculation of sea water resistance:

Cp (Kj /Kg*°C)	P(Kg/ m)	λ (W/m*°C)	Pr	μ (Kg/ S *m)
4179,5	997,1597	60,9086*10²	6,1095	890,3427*10

Table II.1: property of cold fluid at T_f = 25 ° C

II.3.2.Calculation of the speed of water circulation in the tubes:

$$V = \frac{\dot{m}f}{\rho.Nt.S} = \frac{\dot{m}f}{\rho.Nt.\frac{\pi}{4}.D^2int} \quad \text{..} \quad \textbf{(II.3)}$$

AN: $\mathbf{V} = \frac{6500}{997{,}1*14850*\frac{\pi}{4}*(0{,}0176)^2} = 1,8$

V = 1, 8 m/s

II.3.3.Reynolds number of water calculation:

$$R_{ef} = \frac{\rho .V .Dint}{\mu} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(II.4)}$$

P: density of circulating water

Dint: inside diameter of the condenser tubes

AN : $R_{ef} = \frac{997,1*1,8*0,0176}{890,3427*10^{-6}}$

R_{ef} = 32, 22 $*10^{-3}$

Nuselet number calculation:

R_{ef} > 2300 turbulent regime.

Cylinder; Internal tubular flow:

0.6 <Pr <160 Re> 10000

Nu = 0.023 * Re $^{4/5}$ * Pr ^{n}

n = 0.6 when the surface temperature> at the fluid temperature (heating)

n = 0.4 when the surface temperature <at the fluid temperature (cooling).

As seawater uses to cool the steam, we take n = 0.4 for:

Pr ≥ 0.66

Re <105

(L / D)> 60

On to Nu = St * Re * Pr with St = 0.023 * Re-0.2 * Pr-0.6

So Nu_F = 0.023 * Re0.8 * Pr0.4

A.N: Nu_F = 0.023 * (32.22 * 10^{-3}) 0.8 * (6.1095) 0.4

Nu_F = 191,703

II.3.4.**Calculation of the exchange coefficient of the cold fluid:**

$$\mathbf{H_F} = \frac{\mathbf{Nu.\lambda}}{\mathbf{Dint}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(II.5)}$$

A.N: $H_F = \frac{191,703*60,9086*10^{-2}}{17,6*10^{-3}}$

$H_F = 6634,296 W/m^2 C°$

II.3.5.**Calculation of circulating water resistance**:

$$R_F = \frac{1}{H_f} \quad \text{(II.6)}$$

A.N: $R_F = \frac{1}{6634,296}$

$$R_F = 1,5073*10^{-4} W^{-1} m^2 C°$$

II.3.6.**Calculation of the vapor resistance:**

Cp (kJ/Kg*C°)	ρ(Kg/m³)	λ(W/m*C°)	Pr	μ(Kg/s*m)
4178,5	0,035468	$1,9652*10^{-2}$	0,9135	$9,5626*10^{-6}$

Table II.2: Property of hot fluid at $T_C = 32.8976$ C °

II.3.7. **Calculation of the speed of vapor:**

$$V = \frac{\dot{m}_v}{\rho.Nt.S} = \frac{\dot{m}_v}{\rho.Nt.\frac{\pi}{4}.(Dfec^2 - Dext^2)} \quad \text{(II.7)}$$

A.N: $V = \frac{98,25}{0,03547*14850*\frac{\pi}{4}*(24*10^{-3})^2-(19*10^{-3})^2}$

$$V = 1105 \text{ m/s}$$

II.3.8.**Calculation of Reynolds number**:

D hyd = D ext – D ext

D fect = D ext + (1/2)

YEAR:

D fect = D ext + l = 19 + 5 D fect = 24mm

D hyd = D fect-D ext = 24-19 D hyd = 5mm

$$R_e = \frac{\rho.V.Dhyd}{\mu} \quad \text{..} \quad \textbf{(II.8)}$$

A.N:

$$R_{ec} = \frac{0{,}03547*1105*5*10^{-3}}{9{,}5626*10^{-6}}$$

$$R_e = 20493,\ 56$$

$R_{ec} > 2300$: Turbulent regime outside the tubes.

The geometry of the cap-Djanet condenser tubes is staggered as shown in the following figure:

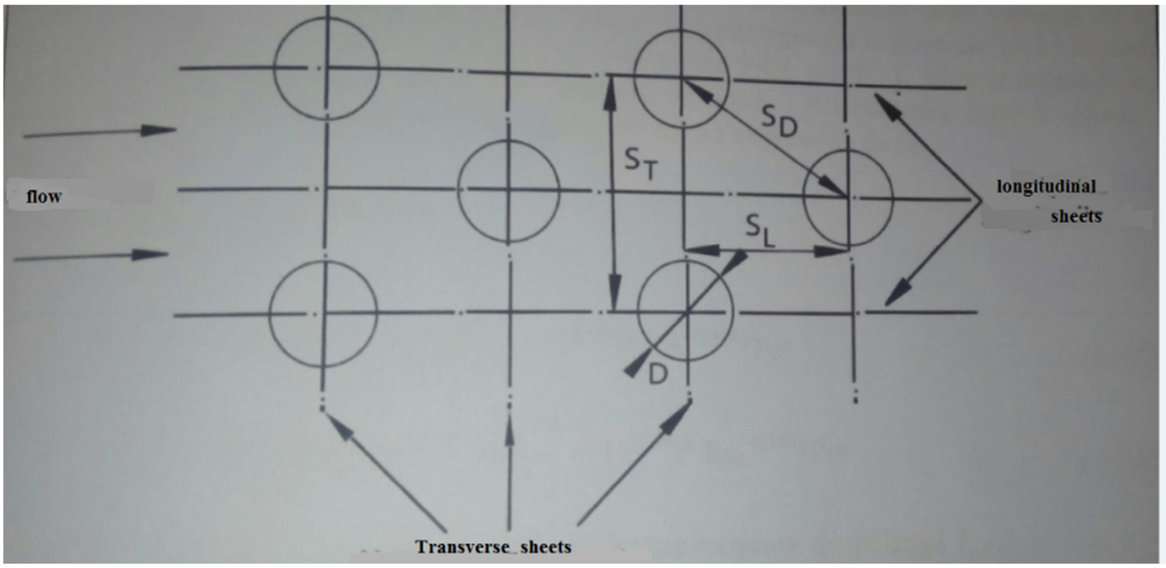

Figure II.1: Layout of the tubes in the condenser of the cap-Djanet power plant

- ✓ Characteristic parameter:

The quantities representative of the geometry of a staggered tube bundle are listed below:

D: External diameter of the tubes.

SL: Longitudinal pitch (between axes in the direction of flow).

ST: Transverse pitch (between axes perpendicular to flow).

SD: Not diagonal (for staggered beam).

$e^{+l} = \frac{Sl}{D}$; $e^{+T} = \frac{ST}{D}$; $e^{+D} = \frac{SD}{D}$;

L: Length of the beam.

NL: Number of longitudinal sheets (row of tubes parallel to the flow).

NT: Number of transverse sheets (row of tubes perpendicular to the flow).

- It should be noted that the conventional reference length chosen for the flow in the 1beam is the outside diameter of the tubes D and the Reference velocity V is the frontal flow velocity in the empty calendar. The tubes being assumed to be removed; Either, by calling the right section of the grille

- ✓ Beam staggered:

We are led here to introduce an additional dimensionless parameter

$$\Psi = \frac{e^{+T} - 1}{2(e^{+D} - 1)}$$

The value of Ψ is representative of the place where the fluid crosses its minimum cross-section

S_L	0.0416
S_T	0.020
S_D	0.024

Table II.3: dimensions of the condenser tubes of the Cap-Djanet power station.

We have:

Ψ = 0.1

$e^{+l} = \frac{Sl}{D} = 2.189$

$e^{+T} = \frac{ST}{D} = 1.052$

$e^{+D} = \frac{SD}{D} = 1.263$

So:

Ψ = 0.1

For a cold fluid: α = -0.6

For a hot fluid: α = -0.7

- $\Psi \leq 1$: $S_t = 0{,}023*[(1+ (\frac{29*e^{+T}}{e^{+T}-1} -1)^{0.66})*R^{-0{,}346}*Pr^{\propto}$

- $\Psi > 1$: $S_t = 0{,}023*[(1+(\frac{29*\Psi^{1,2}e^{+T}}{e^{+T}-1}-1)^{0.66})*R^{-0,346}*Pr^{\propto}$

$\Psi = 0.1 \Rightarrow St = 0.053$

II.3.9.Calculation of the exchange coefficient of the hot fluid:

$$Nu = \frac{Hc*Dhyd}{\lambda} = St * Pr * Re$$

$$H_C = \frac{St*Pr*Re*\lambda}{Dhyd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(II.9)}$$

A.N:

$$H_C = \frac{0{,}053*0{,}9135*20493{,}56*1{,}9652*10^{-2}}{5*10^{-3}}$$

$$H_C = 3899.76\ w^{-1} / m^2°C$$

II.3.10.Calculation of circulating vapor resistance:

$$R_C = \frac{1}{H_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(II.10)}$$

A.N:

$$R_C = \frac{1}{3899.76}$$

$$R_C = 0.256*10^{-4} \quad w^{-1}\ m^2\ °C$$

II.3.11. **Calculation of the wall resistance:**

$$R\,p = \frac{e_{wall}}{\lambda_{titan}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(II.11)}$$

A.N:

$$Rp = \frac{0.7*10^{-3}}{15.6}$$

$$R_P = 0{,}823*10^{-4} \quad w^{-1}\ m^2\ °C$$

II.3.12. **Calculation of the resistance of the fouling:**

$$R_{encra} = \frac{e_{encr}}{\lambda_{encr}} \quad \text{.......} \quad \textbf{(II.12)}$$

A.N:

$$R_{encra} = \frac{0.3*10^{-3}}{0{,}84}$$

$$R_{encra} = 3{,}57*10^{-4} \quad w^{-1}\ m^2\ °C$$

II.3.13.**Calculation of the number of transfer units:**

$$NUT = \frac{U\ A}{(\dot{m}\ cp)min} = \frac{U\ A}{\dot{m}_F\ cp_F}$$

U: global exchange coefficient.

A: lateral exchange surface.

$\dot{m}$: mass flow of circulating water.

Cp: specific heat of circulation water.

$$A = A_m * N_t \quad \text{.......} \quad \textbf{(II.13)}$$

A_m : average area.

N_t : number of tubes.

II.3.14.Calculation of the exchange surface:

$$A_m = \frac{Dext+Dint}{2} * \pi L = (Dint+e) * \pi L$$

A.N:

$$A_m = (17{,}6 + 0{,}7) * \pi * 11490$$

$$A_m = 660573{,}26 \ mm^2$$

$$A = A_m * N_t = 660573{,}26 * 14850$$

$$A = 9809{,}5 \ m^2$$

II.3.15.Calculation of the global exchange coefficient:

$$U = \frac{1}{R_F+R_c+R_p+R_{enc}} \qquad \text{(II.14)}$$

A.N

$$U = \frac{1}{(1{,}5073 + 0{,}258 + 0{,}823 + 3{,}57) * 10^{-4}}$$

$U = 1623{,}824 \ w/m^2 \ °C$

$$NUT = \frac{U\,A}{\dot{m}_F \, cp_F}$$

A.N

$$NUT = \frac{1623{,}824*9809{,}5}{6500*4{,}1795*10^3}$$

NUT =0,586

II.4.The efficiency of an exchanger:

The efficiency of an exchanger is the ratio of the actual heat exchanged to the theoretically possible maximum exchange power, with the same fluid input conditions (nature, flow rate, ..) in the exchanger.

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

$$E = \frac{1-\exp\{-(1-R).NUT}{1-R.\exp\{-(1-R).NUT}$$

E = 1- expo (- NUT)

II.5.Calculation of the efficiency of the condenser:

E = 1- expo (- NUT) ……………………………………………… **(II.15)**

A.N:

E = 1- expo (- 0,569)

E= 43, 38%

II.6.Calculation of the condenser temperature:

$$T_C = \frac{Tf_S - Tf_e}{E} + Tf_e \qquad \text{(II.16)}$$

For a better exchange we take $Tf_s - Tf_e < 3°C T_C$

A.N :

$$T_C = \frac{3}{0.4339} + 25$$

T_C = 31.91 °C

II.7. Conclusion:

There is a relationship between efficiency E and the number of NUT units.
This general relationship applies to interchanges or involves transfers of Heat with or without change of state of the fluids

Chapter III

Overall water vapor circuit

III .1.Introduction:

Performance is a report that demonstrates the effectiveness of a installation and condition, on the one hand, the height of the investment and the cost of supplying the fuel. Yield also determines certain essential parameters of the installation.

III.2.The various stages of water-steam thermal circuit:

1 → 2: the steam relaxed in the HP body of the turbine.

2 → 3: reheat one part of the steam relaxed and another directed towards the withdrawal S6.

3 → 6: the steam enters the body MP with two racks 4 and 5.

6 → 10: the steam enters the LP body with three racks 7, 8 and 9.

10 → 11: the condenser.

11 → 12: the extraction pump.

12 → 13: it passes through alternator refrigerant, condenser of steam, cooler of Purging, BP1, BP2 and BP3 heaters and the tarpaulin.

13 → 14: feed pump.

14 → 15: heater HP5, HP6.

15 → 1: the boiler.

The different cycle points are represented in the following diagram:

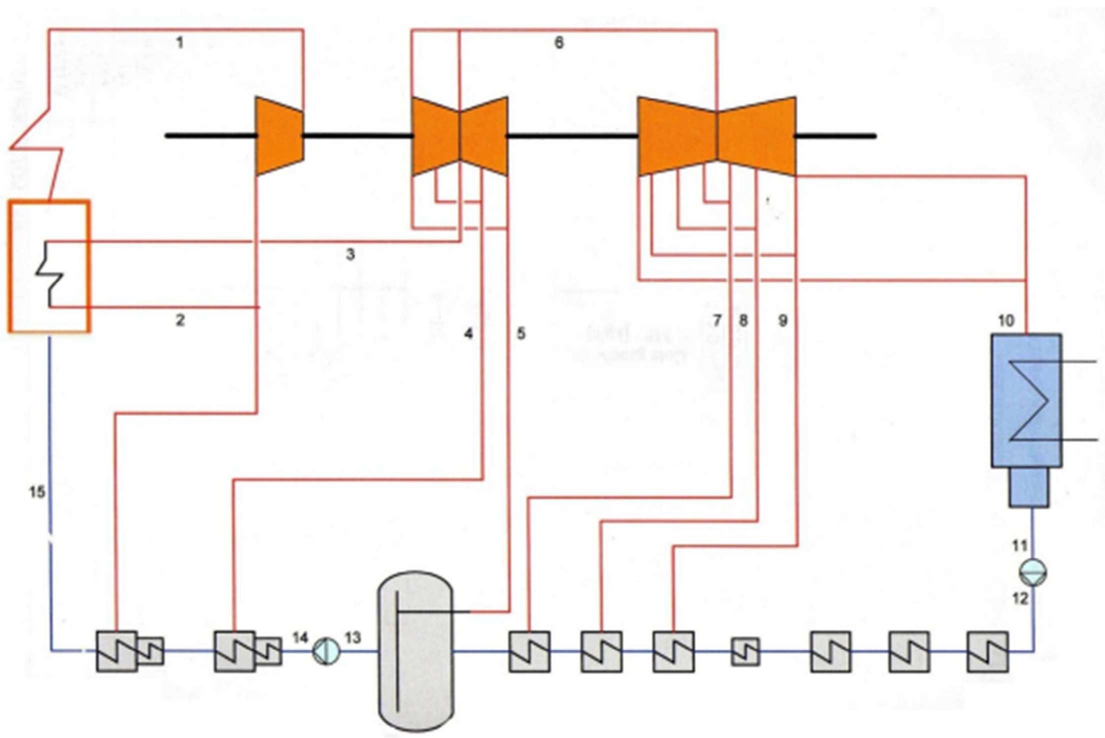

Figure III.1: Representation of the deferent points of the cycle

Description of different stages of the water-steam circuit:

The cycle first comprises an evolution (15-1) which supplies at constant pressure (P = 145 bar) of the superheated steam (point 1).

It is then relaxed in the HP body of the next entropy turbine (1-2) growing. One part is directed towards the HP6 heater following the withdrawal S6, and the other part of the steam is re-heated in the re-heater at decreasing pressure (2-3).

The latter goes into the body MP the turbine, so that it is relaxed following (3-6). Two withdrawals 5 and 4 leave body MP and pass respectively through the heater HP5 and the tarpaulin.

The steam leaving the body MP and the leakage vapor recovered in the HP body, Undergo in the BP body of the turbine, a detent represented by the path (6-10) and there, they render in condenser. The body MP comprises three racks 7, 8 and 9 feed respectively the heaters HP3, HP2 and HP1.

The steam condenses (10-11) and is transformed into water at a pressure of about 0.05 Bar which is recovered in the well of the condenser. As a result the water is pumped by the pump , From point 11 to 12on increasing its pressure from 0.005 bar to 16.8 bar.

From item 12 to 13:

The water is heated by the alternator cooler from 33 ° C to 37.6 ° C under pressure decreasing from 16.8 bar to 8.862 bar.

The temperature of the water (main condensate) increases from 37.6 ° C to 38.2 ° C at constant pressure through exchangers which are respectively the condenser of the steam ejector.

The auxiliary condensate of the BP heaters cumulated in the purge cooler heats the main condensate from 38.8 ° C (point 10) to 40.3 °C (point 11) at constant pressure.

The heating of the main condensate is ensured by the heat which is ceded to it by the Steam samplings (three withdrawals 7, 8 and 9), carried out in different stages of the LP body, And its temperature (main condensate) increases from 40.3 ° C to 113.4 ° C at decreasing pressure.

The main condensate flows at this temperature and at a pressure of 6.9 bar in the tarpaulin, where the mixture of the superheated steam taken from the body MP (Withdrawal 4), the auxiliary condensate (secondary) of the HP heaters and the condensate main.

The feed water is pumped from 4.93 bar to 177 bar and its 151.4 ° C (point 13) to 154.3 ° C (point 14).

From point 14 to 15 the supply water is heated by two HP5 and HP6 heaters at decreasing pressure

III.3. Representation of the various parameters for 100% load:

The characteristics of various water-steam circuit points in the plant are shown in the following table

Circuit points	T(°C)	P(Bar)	H(KJ/kg)	Q(Kg/s)
1	535.00	138.2	3421.0	145.34
2	357.20	40.00	3112.9	129.96
3	535.0	35.9	3528.6	129.96
4	423.7	16.508	3305.4	10.01
5	282.2	5.5287	3026.5	7.33
6	282.2	5.5287	3026.5	12.92
7	173.2	1.8615	2817.0	5.96
8	88.7	0.6695	2652.1	6.46
9	56.2	0.1665	2464.6	2.40
10	33.9	0.050	2364.8	98.25
11	32.9	0.050	137.8	114.41
12	33	16.800	139.9	114.41
13	151.4	4.9393	638.1	145.34
14	154.3	177	661.2	145.41
15	246.3	175.04	1069.1	145.41

Table III.1 Representation of the various parameters for 100% load

The entropy diagram of the water-steam cycle of the power plant is shown in diagram following:

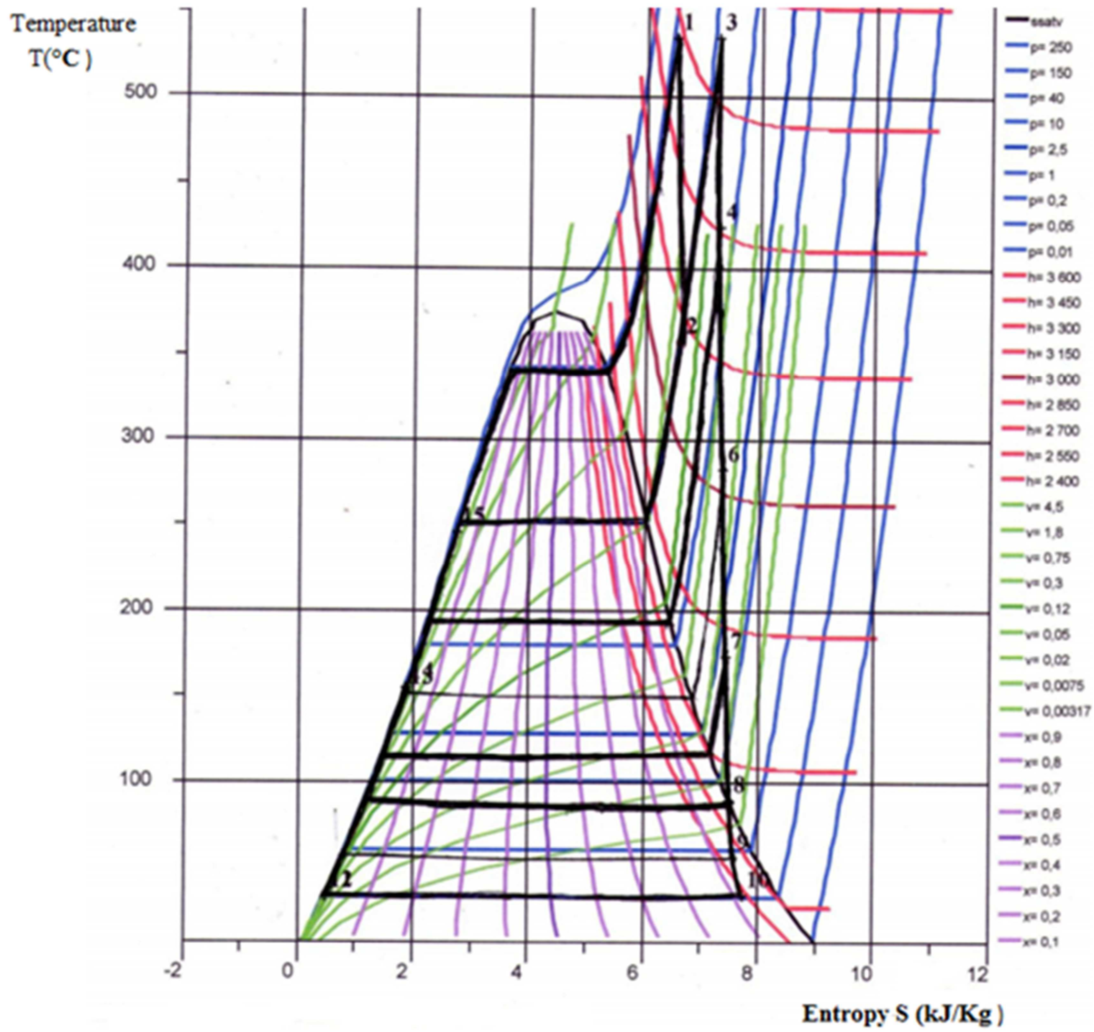

Figure III.2: T-S diagram in normal operation (with six racks)

III.4. Water-to-steam flow rates:

- **The operating flow rate:**

It is the flow that leaves the boiler and enters the body of the high-pressure turbine HP her Value is: Qm = 145.34 kg / s

- **Leak rates:**

Several leaks exist at the level of the three bodies of the turbine, their flow rates are noted In the following table:

Left side of HP (kg/s)	Right side of HP (kg/s)	Left side of MP (kg/s)	Right side of MP (kg/s)	Left side of BP (kg/s)	Right side of BP (kg/s)
$T_{L\ HP}$ =0.006	$T_{R\ HP}$ =0.006	$S_{L\ HP}$ =0.006	$P_{R\ HP}$ =0.006	$P_{L\ HP}$ =0.006	$P_{R\ HP}$ =0.006
$S_{L\ HP}$ =0.201	$S_{R\ HP}$ =0.006	$S_{L\ HP}$ =0.006	$R_{R\ HP}$ =0.006	$R_{L\ HP}$ =0.006	$R_{R\ HP}$ =0.006
$R_{L\ HP}$ =0.672	$R_{R\ HP}$ =0.006	$S_{L\ HP}$ =0.006			

Table III.2: Leak rates

- **Racking rates:**

There are flows extracted at an intermediate stage of the turbine, a part of total flow of steam already converted into work some of its internal energy is directed towards a condensed water heater, the latent heat of this steam instead of being

The sea water is thus transmitted to the water intended for supplying the boiler. Her values Of flows are:

R1 = 2.405 Kg / s

R 2 = 6,460 Kg / s

R 3 = 5.987 Kg / s

R 4 = 7.336 Kg / s

R 5 = 10.012 Kg / s

R 6 = 13.674 Kg / s

III.5. Turbine efficiency calculation:

The overall efficiency of the turbine is expressed by the following formula:

ηt = ηis ηvol ηmec

ηt: turbine efficiency

ηis: isentropic efficiency (internal)

ηvol: volumetric efficiency

ηme: mechanical efficiency.

ηme = 98%

5.1. **Calculation of volumetric efficiency:**

The volumetric efficiency is expressed by the following formula is:

$$\eta_{vol} = \frac{Q_{m-\sum losses}}{Q_m}$$

$$\eta_{vol} = \frac{Q_m[(S_L+T_L)_{HP}(S_R+T_R)_{HP}+(P_L+R_L)_{MP}+(P_R+R_R)_{MP}+(P_L+R_L)_{BP}+(P_R+R_R)_{BP}]}{Q_m}$$

$$- \frac{S_1+S_2+S_3+S_4+S_5+S_6}{Q_m}$$

η_{vol} = 66.38%

5.2. **Calculation of internal efficiency of the turbine:**

The internal efficiency is an important quantity for the control of the state of a steam turbine. Changes in the internal state are variation in internal efficiency.

The internal efficiency is determined by the ratio between the actual enthalpy drop and the theoretical (isentropic) enthalpy drop.

Internal efficiency (turbine) = Sum of actual work / sum of work isentropic.

The turbine consists of three bodies. For this purpose, the internal efficiency of the three bodies.

- **Calculation of internal efficiency of the HP high pressure body:**

HP settings	unit	Value
Power supplied by the alternator	MW	176
Absolute pressure input	Bar	138.20
Absolute temperature input	°C	535
H input	KJ / Kg	3421
The S entropy	KJ / Kg. K	6.52007
Absolute pressure output	Bar	40
Absolute temperature output	°C	357.2
H outlet	KJ / Kg	3112.9
ΔH=H input – H output	KJ / Kg	308.1
H isentropic output	KJ / Kg	3054.332
ΔH isen =H input – H output,isentropic	KJ / Kg	366.668
ηis HP = ΔH / ΔH isen	%	83.99

Table III.3 : Calculation of internal performance of the body HP

- **Calculation of internal performance of the body average pressure MP:**

MP settings	unit	Value
Power supplied by the alternator	MW	176
Absolute pressure input	Bar	35.9000
Absolute temperature input	°C	535
H input	KJ/Kg	3528.6
The S entropy	KJ/Kg. K	7.24509
Absolute pressure output	Bar	5.5287
Absolute temperature output	°C	282.2
H outlet	KJ/Kg	3026.5
ΔH=H input – H output	KJ/Kg	502.1
H isentropic output	KJ/Kg	2971.108
ΔH isen =H input – H output,isentropic	KJ/Kg	557.492
ηis MP = ΔH / ΔH isen	%	90.06

Table III.4: MP Internal Body Calculation

- **Calculation of internal efficiency of the low-pressure body LP:**

LP settings	Unit	Value
Power supplied by the alternator	MW	176
Absolute pressure input	Bar	5.5287
Absolute temperature input	°C	282.2
H input	KJ/Kg	3026.5
The S entropy	KJ/Kg. K	7.49883
Absolute pressure output	Bar	0.0500
Absolute temperature output	°C	33.9
H outlet	KJ/Kg	2364.8
ΔH=H input – H output	KJ/Kg	661.7
H isentropic output	KJ/Kg	2287.146
ΔH isen =H input – H output,isentropic	KJ/Kg	739.354
ηis LP = ΔH / ΔH isen	%	89.49

Table III.5: Calculation of internal efficiency of the body LP

- **Calculation of internal efficiency of the turbine**

Power supplied by the alternator	MW	176
Sum of actual work	KJ/Kg	1471.9
Sum of isentropic work	KJ/Kg	1663.514
Internal efficiency	%	88.48

Table III.6: Calculation of internal efficiency of the turbine

So the internal efficiency of the turbine is: η_t **=58.35 %**

III.6.Cycle Performance Calculation:

The efficiency of the cycle (ηc) measures the rate of conversion of the calorific energy Received from the hot source in mechanical energy:

The work (W) results from the difference between the internal works of the machine (Turbine) and the receiving machine (pump) $W = \int W_t - \int W_P$

The losses in the turbine and the pumps are taken into account:

$$\eta_c = \frac{W_t\,\eta_{me} - \left[\frac{W_{Pf}}{\eta_{Pf}} + \frac{W_{Pe}}{\eta_{Pe}}\right]}{\frac{Q_{ba}}{\eta_{ba}}} \qquad \text{(III – 1)}$$

Such as:

Wt: Turbine work.

η_{me} = 0.98 (mechanical efficiency of the turbine).

W_{pf}: working the food pump.

η_{pf} = 0.77 (efficiency of the feed pump).

W_{pe}: working of the extraction pump.

η_{pe} = 0.78 (efficiency of the extraction pump).

Q_{ba}: quantity of heat supplied by the boiler.

η_{ba} = 0.86 (boiler efficiency).

η_{al} = 0.99 (efficiency of the alternator).

Definition of the first principle of thermodynamics:

- **For a transformation:**

Let (W, Q) be the work and heat respectively exchanged by a system with the external medium during its evolution from an initial state (1) to an end state (2).

The first principle states that this amount of energy exchanged in the form of work is expressed by:

$Q + W = \Delta h + \Delta Ec + \Delta Ep$

We can also write:

$Q + W = \Delta H + \Delta Ep$

$\Delta H = \Delta h + \Delta Ec$

Such as:

Δh: the enthalpy variation.

ΔEk: the variation of kinetic energy.

ΔEp: the potential energy variation.

ΔH: the total enthalpy variation.

- **For a cyclic transformation:**

A cycle is a succession of transformation with the initial state equal to the final state during a transformation, the heat received by a system is equal to the sum of works supplied by the system: Q + W = 0

- It is considered that the transformations are adiabatic in the turbine and

The pumps: Q = 0

- We neglect the variation of potential energy: ΔEp = 0

- Knowing that there is no production of work in the boiler: W = 0

With these hypotheses the expression of the first principle becomes:

For the turbine and pumps: W = | ΔH | ………………………………… **(III – 2)**

For the boiler: Qba = ΔH ……………………………………………... **(III – 3)**

6.1. Calculating work:

The work per unit mass of the steam leaving the boiler and taking the leakage, withdrawal flow rates and the recovered flow rates equation will be expressed by

$W=\sum_{i=1}^{n}(H_{i+1}-H_i)\left[\frac{Q_m-(Q_l+R)}{Q_m}\right]$ ……………………………………..… **(III – 4)**

- Qm: flow rate of the steam leaving the boiler.

- Ql: flow rates of leaks.

R: flow of racking.

I: the input of the body (HP, MP, LP).

6.1.1. Work of the turbine:

W T = W HP + W MP + W LP

W T: total work of the turbine.

- W HP: HP body work.

- W MP: body work MP.

- W BP: body work LP.

We apply the relation to the three bodies of the turbine.

- **Working of the high pressure body:**

$$W_{HP}=(H_1+H_2)\left[\frac{Q_m-(Q_{HP}+R_R+S_R+T_R)_{HP}}{Q_m}\right]$$

$$W_{HP} = 296.890\ KJ\ /\ Kg$$

- **Medium pressure body work:**

$$W_{MP}=(H_3 - H_4)\frac{Q_m-[(R_R+S_R+T_R)_{HP}+(R_L+S_L+T_L)_{HP}+S_6]}{Q_m}$$
$$+(H_4 - H_5)\frac{Q_m-[(R_R+S_R+T_R)_{HP}+(R_L+S_L+T_L)_{HP}+R_5+R_6]}{Q_m}$$

W_{MP} = 429.716 KJ / Kg

- **Body work low pressure :**

$$W_{BP} =(H_5 - H_6)\frac{Q_m-[(S_R+T_R)_{HP}+(S_L+T_L)_{HP}+R_4+R_5+R_6+(P_R+R_R)_{MP}+(P_L+R_L)_{MP}]}{Q_m}$$
$$+=(H_6 - H_7)\frac{Q_m-[(S_R+T_R)_{HP}+(S_L+T_L)_{HP}+R_3+R_4+R_5+R_6+(P_R+R_R)_{MP}+(P_L+R_L)_{MP}]}{Q_m}$$
$$=(H_7 - H_8)\frac{Q_m-[(S_R+T_R)_{HP}+(S_L+T_L)_{HP}+R_2+R_3+R_4+R_5+R_6+(P_R+R_R)_{MP}+(P_L+R_L)_{MP}]}{Q_m}$$
$$+=(H_8 - H_9)\frac{Q_m-[(S_R+T_R)_{HP}+(S_L+T_L)_{HP}+R_1+R_2+R_3+R_4+R_5+R_6+(P_R+R_R)_{MP}+(P_L+R_L)_{MP}]}{Q_m}$$

W_{BP} =475.456 KJ / Kg

So : W_t = 1202.062 KJ / Kg

6.1.2. Working the extraction pump:

$$W_{PE}=(H_{11} - H_{12})\frac{Q_m-(R_4+R_5+R_6)}{Q_m}$$

W_{PE}=23.1 KJ / Kg

- Working the feed pump

W_{pf} = (H_{13}-H_{14})
W_{pf} = 23.1 kJ / kg

6.2.Amount of heat supplied by the boiler:

$$Q_{ba}=(H_1 + H_{15}) +(H_3 - H_2)\frac{Q_m-[(R_R+S_R+T_R)_{HP}+(R_L+S_L+T_L)_{HP}+R_6]}{Q_m}$$

Q_{ba}=2723.63 KJ / Kg

6.3.Condenser efficiency

The condenser yield is calculated by the following relationship.

$$\eta con = \frac{Q_e-Q_S}{Q_e}$$

$Q_e = \frac{Q_{10}}{Q_m} * H_{10}$

$Q_S = \frac{Q_{11}}{Q_m} * H_{11}$

$\eta_{con} = \frac{Q_{10}H_{10} - Q_{11}H_{11}}{Q_{10}H_{10}}$

η_{con} = 93%

6.4.Cycle Performance:

In fact a numerical application for equation **(III -1)**

η_c = 36.18%

6.5.Calculation of power:

Calculates the power by the following formula

Pt = Wt * Qm * ηm * ηalt

Pt = 169.5 MW

III.7. Conclusion:

It can be seen that with the increase of the remaining condenser pressure, the total efficiency of the Cap - Djinet plant has decreased. The condenser must be maintained at much lower pressures, To increase the total efficiency, the best operation used to obtain a good vacuum is the operation of two ejectors and two circulation pumps. In the next chapter we will study the various parameters that influence the vacuum.

Chapter IV

Influence of condenser parameters on plant efficiency

IV.1.Introduction:

In the previous chapter, the usefulness of vacuum-condenser in a steam-power plant has been shown. And we cited the factors that influence the vacuum rate. In order to clearly visualize this influence and the influence of depression on the specific consumption and therefore on the efficiency of the plant, data were recorded on paper by the statistical office in collaboration with the control room.

IV .2.Notion on specific consumption:

In order to use common terminology in thermal will often abandon the word yield and adopt that of specific consumption

The efficiency of a plant is equal to the ratio:

$$\eta_c = \frac{KWh_{provider}}{Kcal_{consummate}}$$

Specific consumption (Csp) of the plant is the inverse of this yield, it is equal to the number of kcal of fuel required to produce 1 kwh of electrical energy.it is expressed in $Kcal/Kwh$

We have:

$$C_{SP} = \frac{Q_{gas}*(p_{hc})}{FT}$$

Q_{gas}: gas flow (m3 / h).

P_{hc}: higher calorific value (kcal / m3).

FT: The load at the factory terminal (MW).

So:

$$\eta\ (\%) = \frac{860}{C_{SP}} * 100$$

IV.3. Factors affect the empty rate:

Before seeing the influence of these parameters on the vacuum rate, the load must be fixed because the latter is in function of the vacuum which prevails in the condenser. This shows us the following Figure **IV**.1.

And we have plotted this graph, assuming that all factors are fixed.

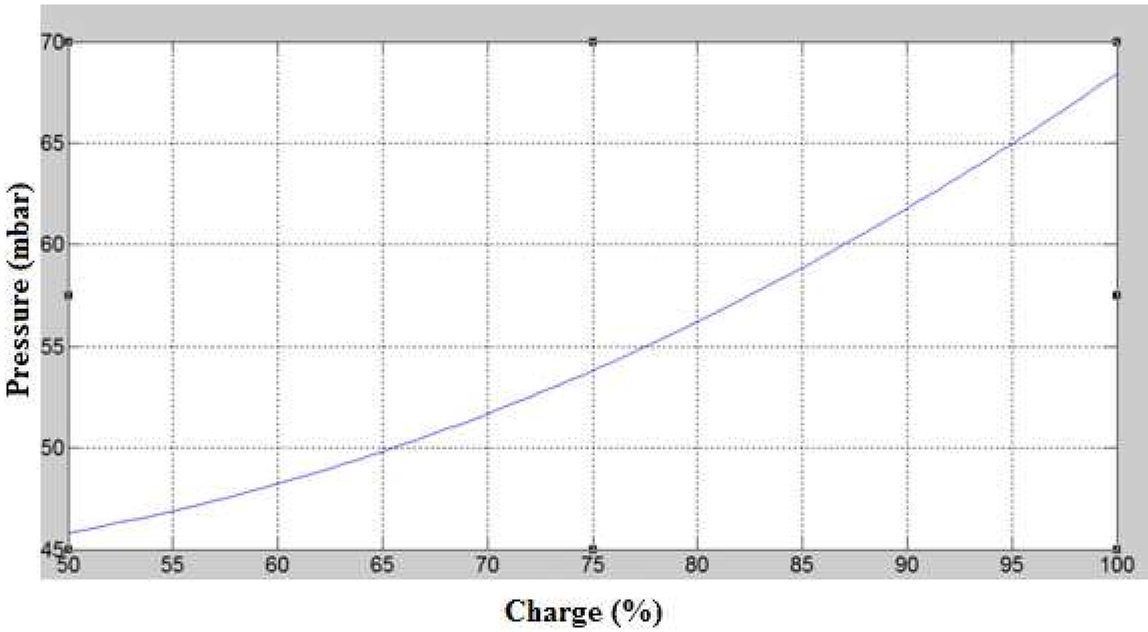

Figure IV.1**:** Vacuum as a function of load **[5]**

It is noted that the evolution of the pressure in the condenser is proportional to the load. This is due to the quantity of the vapor introduced into the condenser, The higher the volume of the steam increases, the higher the pressure at the condenser.

IV .3.1.**Sea water temperature**:

Graph IV.2 shows the condenser vacuum curve as a function of power

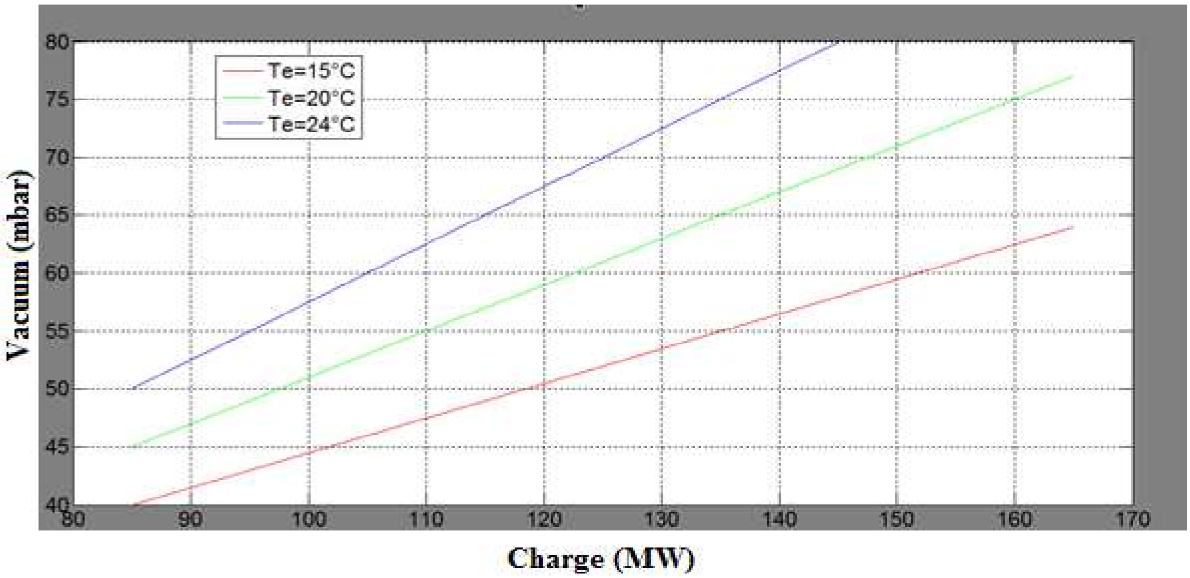

Figure IV.2**.**Vacuum depending on the load for different sea water temperatures [5]

Note in this graph:
A temperature change of circulating water 15 ° C to 20 ° C, the plant can operate at full load 165 MW. For high temperatures, reaching the maximum of the load becomes impossible, due to vacuum degradation, and risk of group tripping.
And for a constant load, the temperature of the sea water (circulation water temperature) increases, the heat exchanged decreased. This results in a degradation of vacuum.

IV .3.2.Fouling of tubes:

To show the influence of soiling, different pressures were taken for different days after and before cleaning. This makes it possible to plot the following graph.

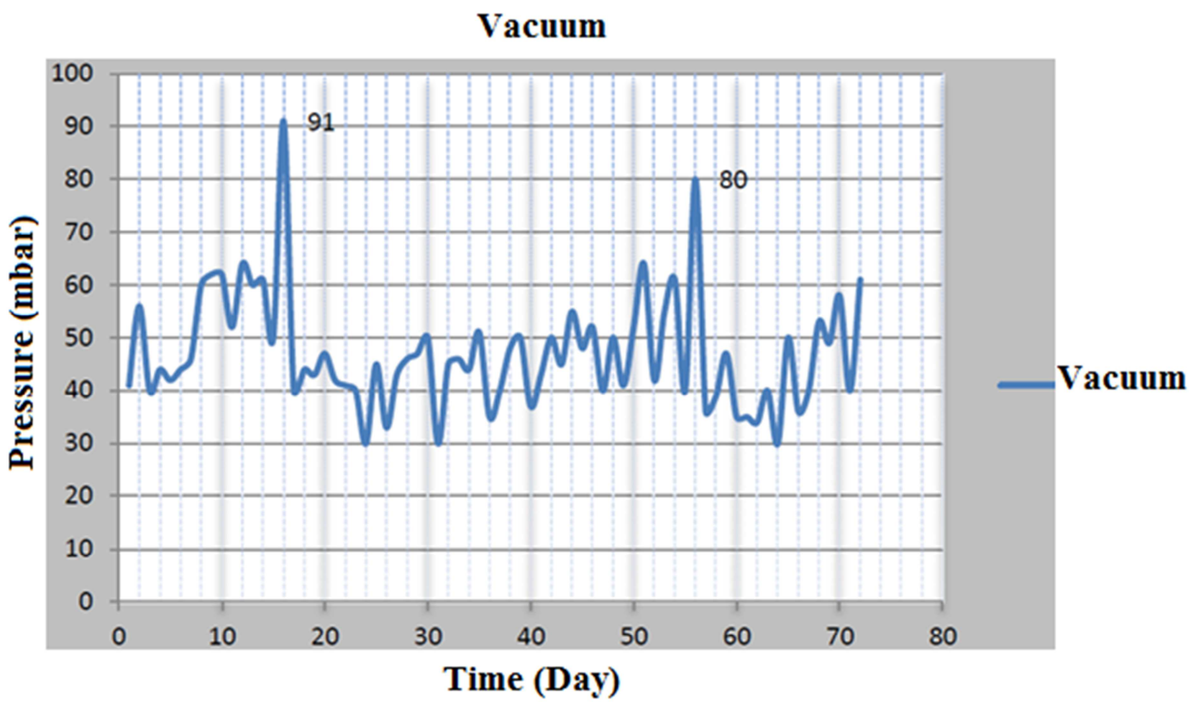

Figure IV.3. Vacuum-condenser curve according to degree of soiling [5]

According to the graph, the normal vacuum degradation in the condenser is observed on the day of cleaning. It was due to:

- Load limitation up to 80 MW (avoid group trip).
- Stop a half-condenser (avoid group shut down).

What interests us here is the beach just before and after the day of cleaning.

For the days before there is a degradation of vacuum despite the commissioning of the two half-condensers. But just days after cleaning, we see the vacuum improvement.

For small changes in the pressure in the condenser, either after or before cleaning is due to other parameters that influence the vacuum (load, sea water temperature, air inlets,……….).
It is concluded that condenser fouling or soiling adversely affects the vacuum rate.
The condenser tubes are cleaned manually by means of a wire brush: they are cylindrical brushes with tube diameters which are inserted into the tubes with a special device which moves them inside the tubes. The process is performed during the half-condenser shutdown.
This work takes a lot of time.
Proposed solution to fight against the soiling of tubes: this is the Taproge process.

- **Taproge process**

This system consists of connecting to the refrigeration water circuit an auxiliary circuit in parallel (see figure below) where small balls of coated rubber circulate, which, because of the pressure drop in the tubes, are distributed among all Tubes and pass through them continuously, cleaning them as they pass. At the exit, a grid recovers the balls which are reinjected into the input circuit.

IV .3.3.The air inlets:

The operation to check the condenser efficiency performed by the test and control office allows us to plot the following graph:

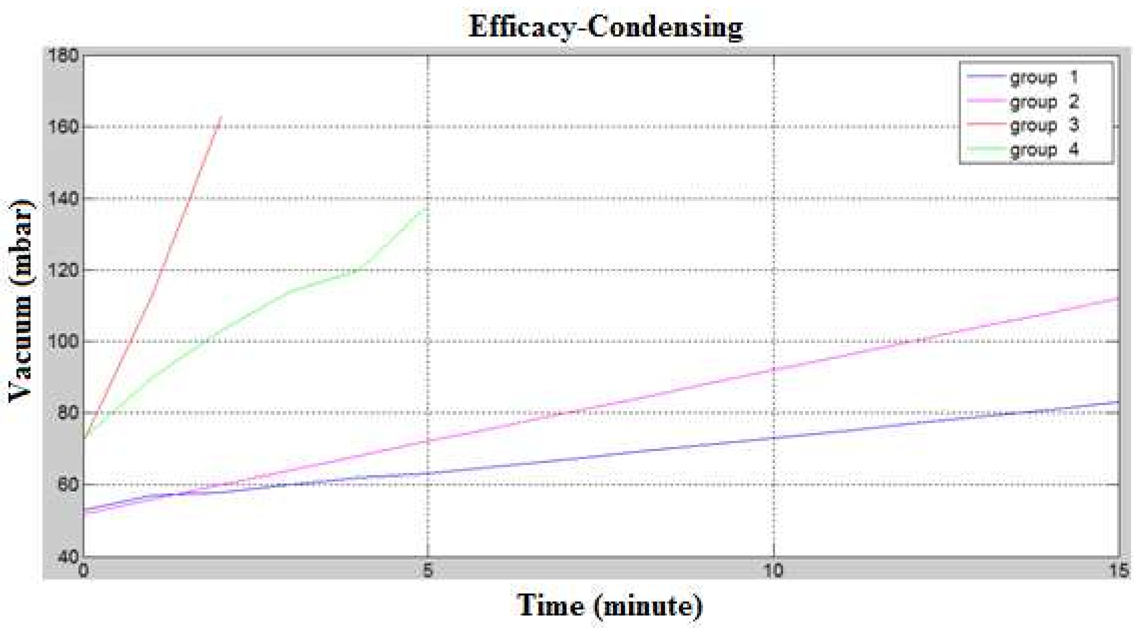

Figure IV.4**:** Checking the air inlets [5]

This test operation is carried out:

- for a duration of 15 minutes
- With the stop of all ejectors.
- With the stop of all ejectors.

The comparison of the air inlet velocities of the four groups allows us to see the degradation of vacuum as a function of time due to a leakage problem.

For groups 1 and 2, the normal pressure difference between the condenser exterior (atmospheric pressure) and the inside (the vacuum in the condenser), in addition to the absence of a perfect seal, the rate of degradation is low.

On the other hand, for groups 3 and 4, they reach high pressures before five minutes. Stopping test before 15 minutes is as a precaution; Avoid group tripping at high pressure values (maximum 120 mbar).

For the last two groups the maintenance operation is mandatory.

IV .4.Influence of the depression on the saturation temperature:

Next graph shows vacuum influence on saturation temperature of water vapor within condenser.

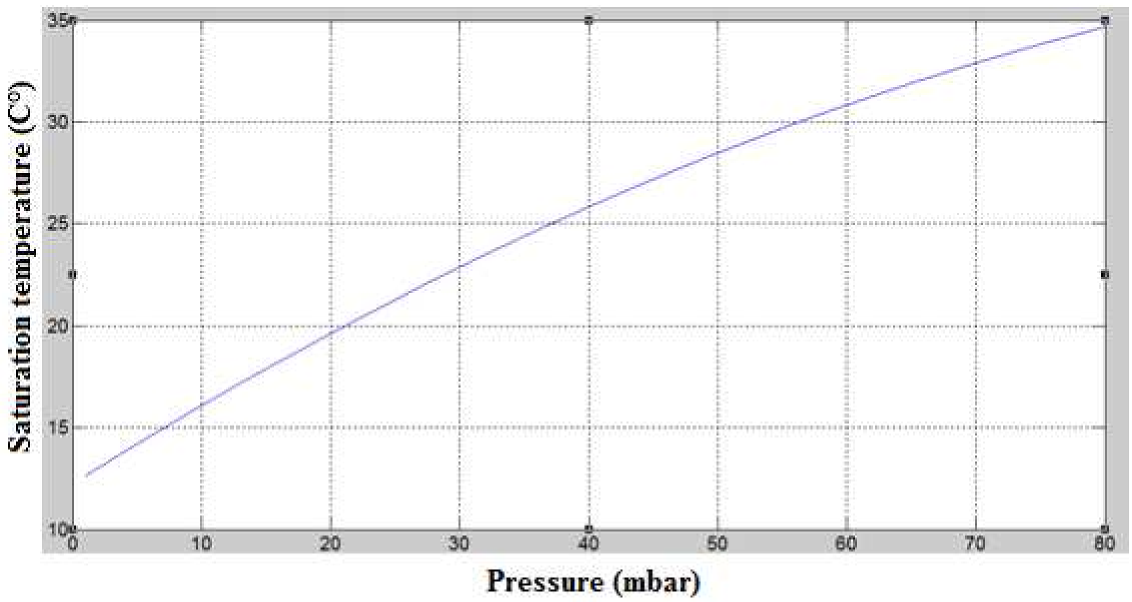

Figure IV.5**:** Evolution of saturation temperature as a function of pressure [5]

It was concluded in the second part of this chapter that different factors influence depression. And from Figure IV.6, the pressure in the condenser increases, the saturation temperature increases. Therefore, these factors indirectly influence the saturation temperature.
The objective here is to have a good vacuum to reach low saturation temperatures.

IV .5. Parameters that affect specific consumption:

All the factors acting on the vacuum, and therefore on the saturation temperature, also act on the specific consumption.
In order to plot these graphs below, one chooses as a fixed load which is equal to 75%.

IV .5.1.Sea water temperature:

The graph shows the evolution of the specific consumption as a function of sea water temperature.

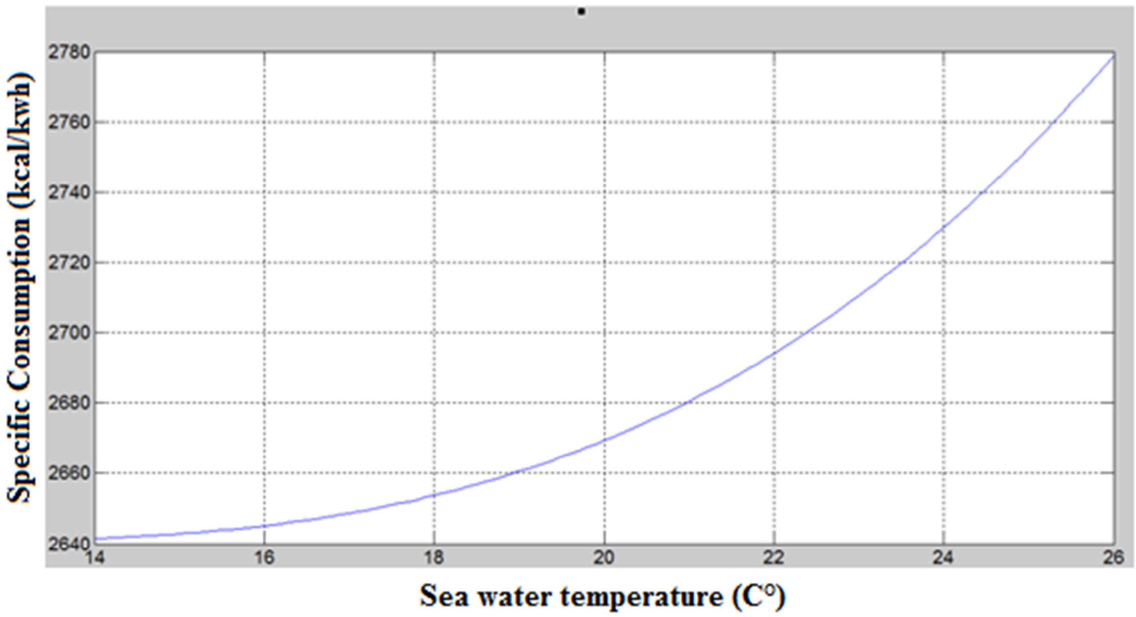

Figure IV.6 specific consumption as a function of sea water temperature [5]

This curve represents the evolution of the specific consumption which is proportional to that of the sea water temperature.

IV .6. Condenser depression:

The following curve shows the evolution of the specific consumption as a function of the pressure prevailing in the condenser.

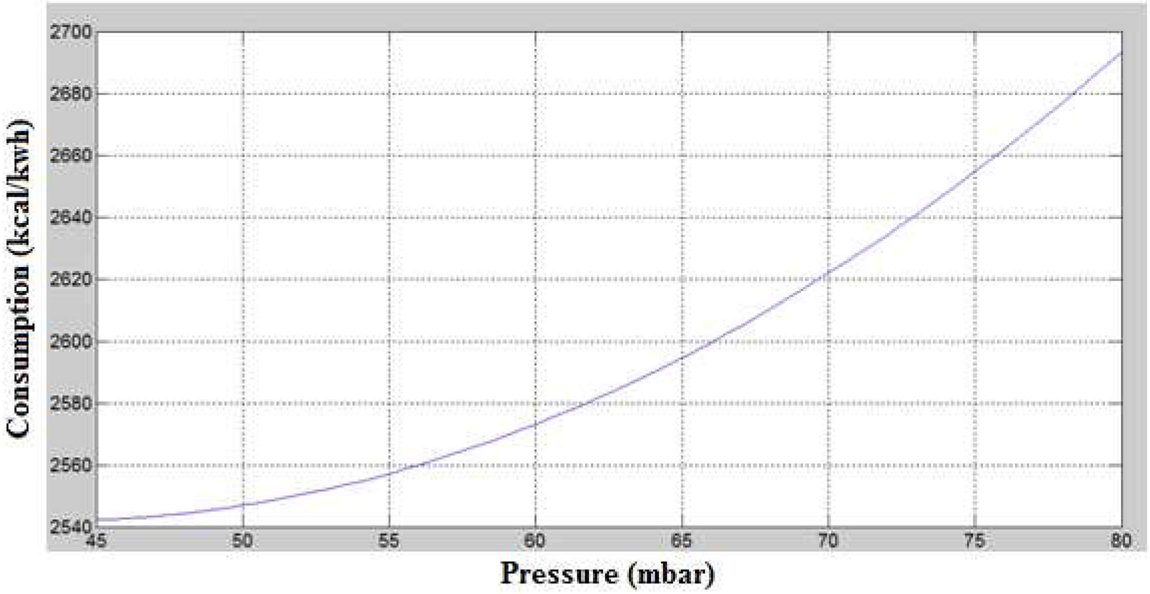

Figure IV.7: The specific consumption as a function of the pressure in the condenser [5]

The degradation of vacuum within the condenser caused by the various factors, results in an increase in consumption for a constant load.

It was noted that the specific consumption is as a function of: gas flow, higher calorific value, and load. The last two are fixed, the only variable is the gas flow.

An increase in the specific consumption is related to the gas flow consumed.

IV .7. the influence of vacuum on the efficiency of the plant:

To see clearly the deviation of the specific consumption as a function of vacuum, one uses the yield, because the latter and relation with the specific consumption

Finally, the following curve represents the variation in efficiency which is inversely proportional to that of the pressure.

The graph below shows the influence of vacuum in the condenser on the efficiency of the plant.

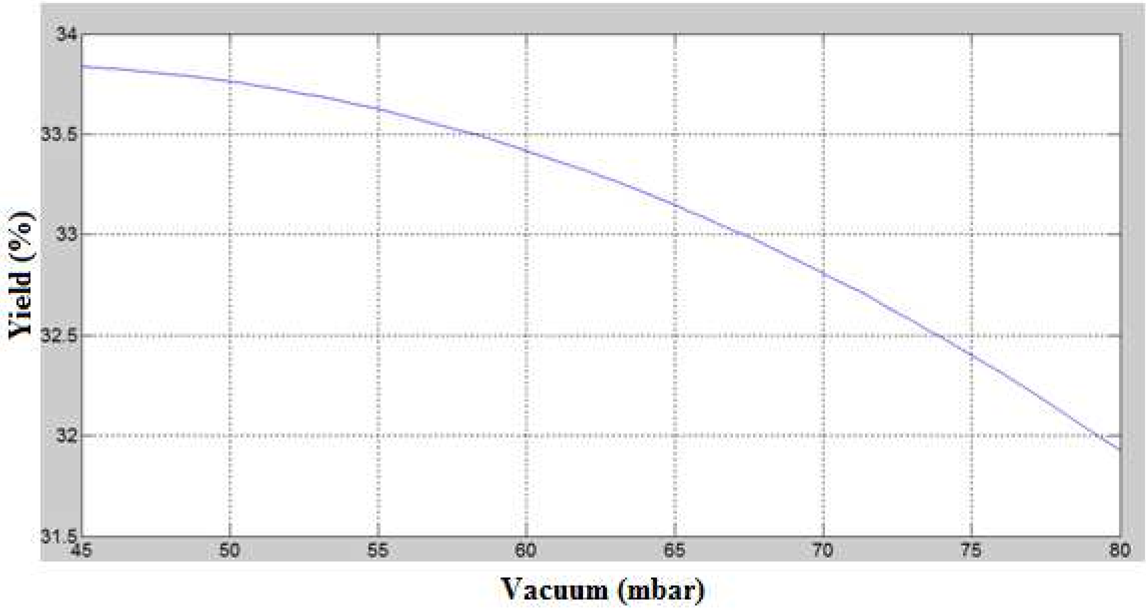

Figure IV.8: The efficiency as a function of the condenser pressure [5]

According to this graph, a vacuum degradation of 45 mbar at 80 mbar is observed, generates a yield reduction of about 2% at constant load caused by a single factor, in our case it is the water temperature of sea.

In the beginning, this yield reduction value appears to us negligible. To do this, we will do a simple economic study.

IV .8. Economic aspects:

In the Cap-DJENET thermal power plant, natural gas is often used as a fuel. This is an essential element that plays a major role in the production of electric power, since the cost of fuel gas represents 90% of the the power plant. Performance degradation has a direct impact on annual spending.

The formula for calculating the annual cost of gas per unit of production.

Cost = Qmg x Pcs x H x D x Price (gas)

Qmg: gas flow rate for a load of 132 MW (75) per hour.

Qmg = qXCsp / m power

Csp: specific consumption.

Csp = 2690 kcal / kwh at a yield of 31.9%

Pcs: higher calorific value

Pcs = 9600 kcal / m3 = 0.38 Th / m3 (th: thermie)

YEAR:

Qmg = 36987.5Nm3 / hr

H = 24 hours per day.

J = 365 day numbers per year.

Price (gas) = 0.15 DA / th

N.A:

Cost = 36987.5x 0.38x24x365x0.15

Cost = 19238123, 44 DA

The deviation from the maximum value is:

$\eta\Delta = \eta max - \eta min$
ηmax = 3 3,8%
ηmin = 31 ,9%
$\eta\Delta$ = 1,9 %

The relative value is:

$\Psi = \eta\Delta/\eta max$

Ψ = 0,056

Loss:

Loss:= Ψ x cost

Loss = 1081432, 97 DA (For a single group).
For the four loss groups =4325731.88 DA

IV.9.Conclusion:

Each factor can cause a considerable degradation of vacuum which leads us to a saturation temperature higher than normal, the latter acts on the enthalpy at the exit of the low pressure body of the turbine, Enthalpy between the terminals of the turbine, consequently a reduction in the efficiency of the plant. And to maintain a constant load at the factory terminal, it is necessary to add gas flow, thus losses of money.
And meeting all these factors at once certainly leads us to group triggering, where to restart it and before putting the turbine into operation it is necessary to produce dry steam (ejecting the wet steam out doors).So losses of gas consequently losses of money in addition.

General ***conclusion***

General conclusion:

The Condensers are of major importance in the industrial field, in particular the installation of thermal power plants, their technologies, their designs and their influential developments in the performance of these installations.

In fact, the condenser of the central, which is a condenser per surface, is often subjected to the problem of vacuum.

The degradation of the vacuum is caused mainly by:

- Increasing the temperature of sea water.
- Reduced sea water flow.
- The soiling of the tubes.
- The air inlets in the condenser

In order to maintain good efficiency, the condenser must be operated with the conditions which make it possible to continuously grad a good vacuum, namely:

- Fight against the air intakes a condenser by the valves and the instrumentation of measurement, the latter are in the majority of cases in the valves and the seals.
- Maintaining the flow of seawater has its initial design value. This is controlled by the pressure measurement at the discharge of the seawater circulation pump. If this pressure has decreased, a fault is suspected on this pump which will have to be repaired.
- Fight the dirt in the condenser tubes with a dirty control of the tubes to initiate a cleaning operation when the saturation pressure increases.
- It was also proposed to install an automatic tube cleaning system

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