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Theme

HEAT TRANSFER IN BOILERS

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Finally, to all the people having participated from near or far in the realization of this work, a big thank you. Without forgetting energy class 2020/2021.

And all those who haven't been named Thank you.

Dedication

I dedicate this modest work to:

My wonderful loving mother, my honorable loving father

My adorable sister Omaima, my dear brothers Bilal and Hossem

My dear grandmother and my dear grandfather

My aunts, uncles, cousins and cousins

My friends

And all those who directly or indirectly contributed to the achievement of this work

Noureddine

Dedication

I dedicate this work

To my dear mother and my lovely father, who are the joy of my life and who give me so much support, love and affection; my least success is the fruit of their sacrifice, dedication and perseverance; I dedicate this work to them as a sign of sincere gratitude and eternal gratitude.

I dedicate this work also to my dear brothers and sisters for their encouragement and support.

Without forgetting to all my friends who I had the most beautiful moments with them.

Ramadhan

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General introduction

General introduction

On the one hand, the intensification of areas in need of energy justifies the rapid development of technologies in recent years. This need is constantly growing and the boiler is one of these building blocks of energy production; a distinction is made between them: domestic, energy-producing and industrial boilers.

The idea of using steam as a driving force dates back to the 1st century AD with the invention of the aeolipilus by Heron of Alexandria. But it's really just from the end of the 17th century engineers developed the steam engines modern.

In the 19th century, the boiler had two distinct parts, the hearth and the boiler; the first is completely lined with refractory which ensures combustion, and the second uses this heat to create steam. In order to increase the heating surface for the same size, we have first used flue pipes inside the boiler and then the water pipe boiler.

The purpose of any boiler is to transfer a quantity of heat to the water in order to: heating, evaporating and / or superheating it all depends on the use (domestic or industrial). One of the most requested and used energies is "steam" which is a fluid extremely modern with performance suitable for strict demands countless industries around the world. Its fields of use are among others the paper and building materials industry, refineries, pharmaceutical industry and industrial-scale food processing. Steam drives turbines to generate power, vulcanizes rubber products and sterilizes packaging. The objectives of our work are to make a thermal balance at the studied boiler.

As in our thermal study of the boiler we have four chapters, the first of which presents general information on boilers, presentation of the boiler then the geometry of a vertical recovery boiler and industrial use for the second chapter we have seen Position of the problem; First, we did the Competitiveness of boiler manufacturers and How a design office works, then and their objective; in the third chapter we are will focus on Theoretical reminder on heat transfer, at first we made a presentation on Heat transfer then a presentation on Combustion.

The last chapter shows a presentation of the MYRA 4000 boiler; at the start, we did the Description and operation of the MYRA 4000 boiler then Practical training part with a general conclusion on the boilers at the end..

Chapter I

Boilers

Introduction

The boiler acts as a heat exchanger to transfer the heat released, after combustion, to the fluid (water) that circulates in the heating circuit usually to produce steam. Steam is an energy source with many domestic uses, including: food, ironing, cleaning and upholstery. Steam is also used in the catapult of an aircraft carrier.

I.1. Definition

The Boiler is a large metal vessel in which to heat (a liquid (a liquid that carries heat or produces energy vapour) is boiled or cooked.

In other words it is a device whose role is to transmit to a thermal fluid, the calories calories released by a combustion. This combustion can be done in the boiler (furnace) or outside (this is the case of recovery boilers). This contribution of heat has the effect either only of heating the thermal fluid, or of heating it and vaporizing it. vaporize it.

Sometimes it is called an evaporator unit, a term that takes into account all the components of a boiler. Components of a boiler [1].

I.2. Boiler classification

Classification is based on the area of use, flow rate and characteristics of the steam or water produced.

I.2.1. Natural circulation

In natural circulation boilers, fluid circulation in the evaporator is provided by the difference in density between the water flowing down from the drum and the water-steam mixture flowing up to the drum (see Figure I.1).

The greater the difference in height between the drum and the vaporizer tubes, the better the natural circulation.

In the drum, there is a separation of the phases: the steam phase is sent to a possible superheater while the water at the base of the drum is sent back to the evaporator [2].

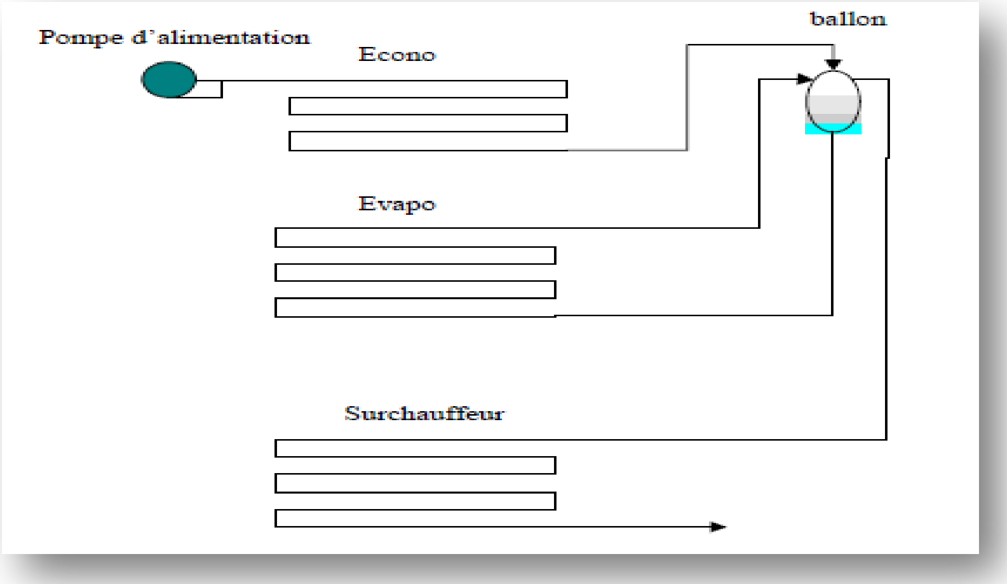


Figure I.1. Boiler with natural circulation [3].

I.2.2. Assisted circulation

When the steam pressure increases, the natural draft in the evaporator tubes becomes insufficient. A circulation pump is then introduced into the evaporator loop to overcome the pressure drop of the water-steam mixture to be moved (see Figure I-2). This is a commonly encountered scheme for pressures between 100 and 180 bar [2].

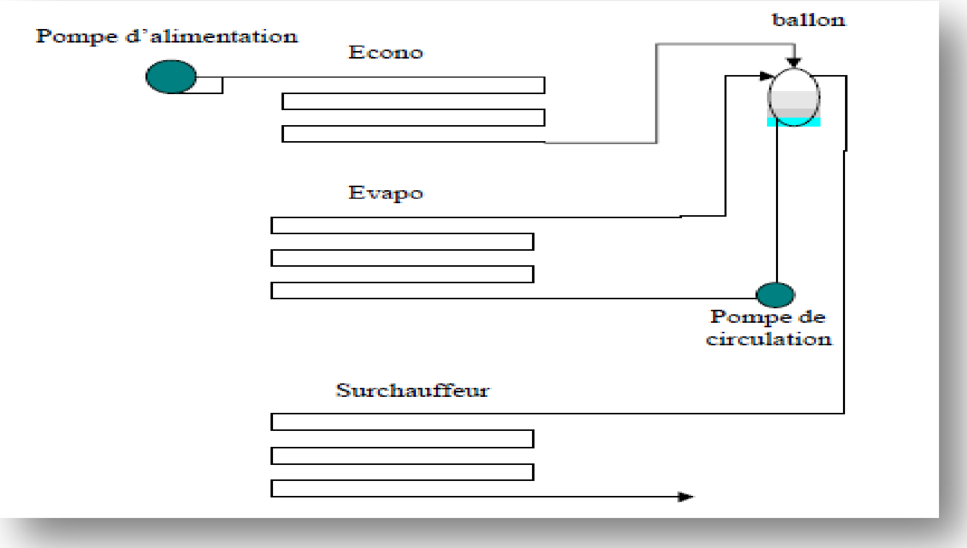


Figure I.2. Boiler with assisted circulation [3].

Pour des pressions supérieures, on rencontrera des chaudières à circulation forcée.

I.2.3. Forced circulation boilers

The most modern boilers can be once-through boilers: they theoretically no longer have a tank to separate the water and steam (see Figure I.3) and are made up of a large number of parallel tubes inside which the water is heated, vaporized and superheated in a single pass.

A forced circulation boiler differs from a conventional boiler, either natural or assisted circulation, in the number of elements that make up the boiler. A conventional boiler consists of an economizer, a vaporizer with separation tank and a superheater. In a forced circulation boiler, it is no longer possible to distinguish between the economizer and the vaporizer, and if a separation tank remains, not only is its size greatly reduced, but its usefulness is mainly limited to the boiler start-up phase, during which the water drawn from the base of the tank is returned to the deaerator, the superheater being operational only when the flow of steam coming out of the tank is sufficient (see Figure I.4) [2].

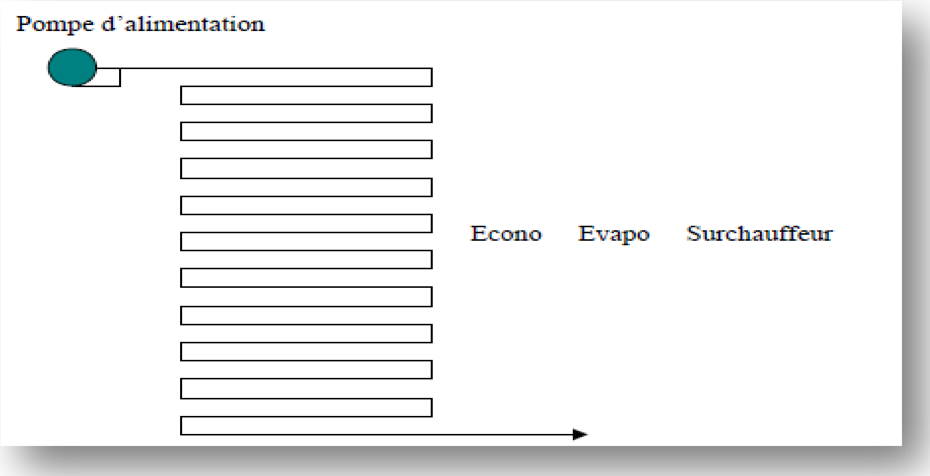


Figure I.3. Forced circulation boiler without start-up tank [3]

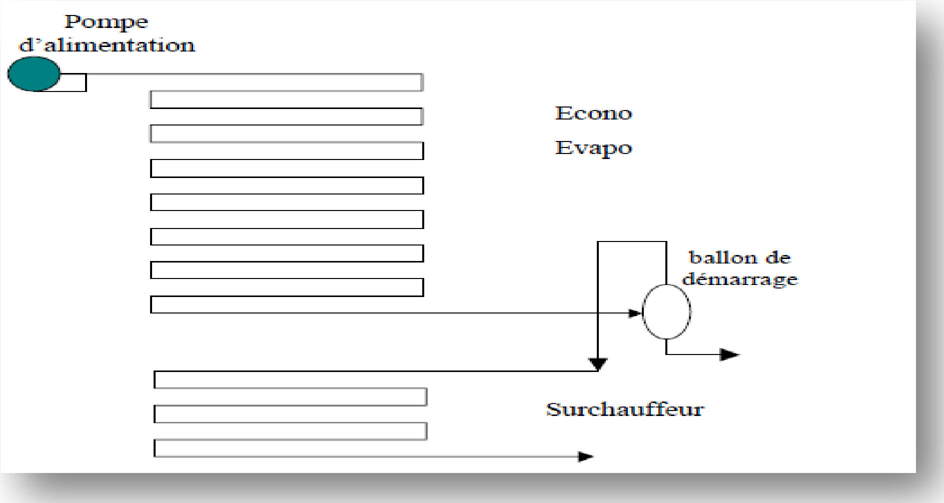


Figure I.4. Forced circulation boiler with start-up tank [3].

I.2.4. Boilers in a high-speed cycle

In a combined cycle, the recovery boilers must be designed to satisfy several objectives

- reduce heat transfer irreversibilities,
- increase heat transfer efficiency,
- minimize the remaining enthalpy loss of the flue gas rejected to the stack,

- allow the adjustment of the outlet temperature of the superheated steam at the steam turbine inlet of the steam turbine,
- be able to be started up quickly so as not to disrupt the combined cycle,
- have a limited pressure drop on the flue side to limit the back pressure at the gas turbine the gas turbine exhaust, which would reduce its efficiency.
- In order to meet these objectives, certain methods are systematically used:
- determining the pressure levels and organizing the general circulation so as to minimize the temperature difference between the flue gas and the water/steam to be heated,
- adopt countercurrent circulation for each exchanger,
- use an air heater when the cycle allows it (no TG) [2].

Consider a recovery boiler composed of an economizer, an evaporator and a superheater. If the water and the flue gas are flowing in counterflow, the minimum temperature difference between the flue gas and the water will define the pinch point of the process.

Two pinch points occur in a single-pressure recovery boiler (see Figure I.5) pressure recovery boiler (see Figure I-5): a pinch point at the superheater outlet (F1, E1) and a pinch point at the pinch point at the evaporator (F3, E3). The pinch point defines the recovery limit corresponding to the The pinch point defines the recovery limit corresponding to the maximum recoverable energy in the flue gas. The enthalpies of the flue gas at points F1 and F3 allows to determine the available energy while the enthalpies of the water at points E1 and E4 allow to determine the flow of the steam flow that can be generated in this boiler [2].

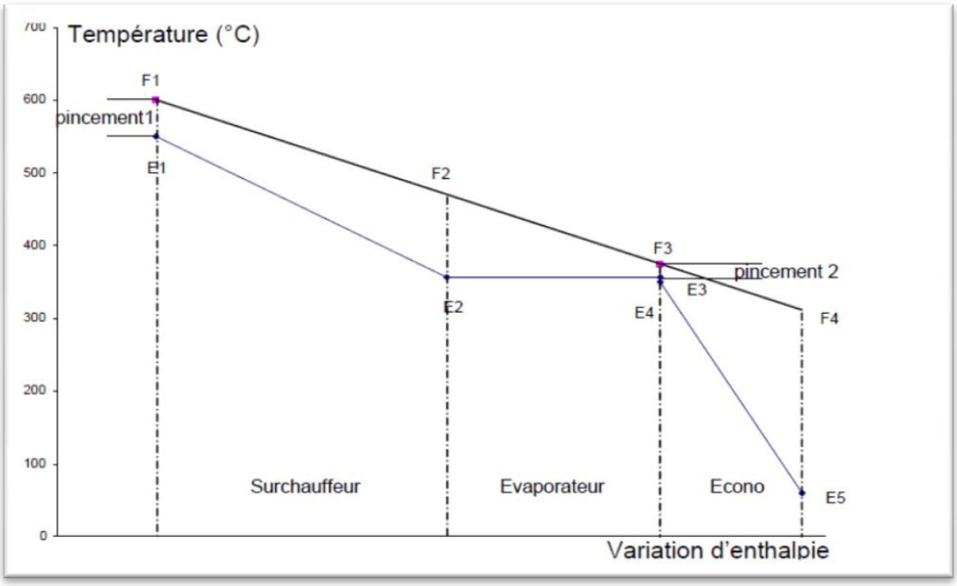


Figure I.5. Temperature evolution in a countercurrent boiler [2].

By definition, the heat exchange is reversible when the temperature curves are superimposed. In practice, it is impossible because even if we imagine infinite exchange surfaces, there would still be a step for the aporization of water. We can visualize the irreversibility of the process by representing the evolution of the enthalpy variation according to the Carnot factor of the Carnot factor (T - T^0) T (see Figure I.6 and Figure I.7). On this diagram, the area between a curve and the horizontal at T^0 (15°C) represents the available exergy. The area between the smoke cooling curve and the water heating curve represents the available exergy. Represents the exergy lost by irreversible exchange. The pockets of irreversibility can be reduced by performing vaporization at different pressure levels. The However, the number of pressure levels is often limited to 3 in order to keep the structure economically viable structure. As an indication, we will evaluate the exergy losses in a boiler with only one pressure level (180 bar) and pressure level (180 bar) and compare them to the losses in a boiler with two pressure levels pressure levels (15 bar and 180 bar). The composition of the fumes is as follows [2] :

Composition of the fumes (% weight)	
O_2	16.92
N_2	75.53
CO_2	3.61
H_2O	2.7
Ar	1.24

Thermodynamic data are calculated from the IAPWS model [4] for water and PTC4 [5] for fumes [2].

I.2.4.1. Boiler 1P (180 bar)

Pour pouvoir produire 1 kg de vapeur HP surchauffée à 540°C, en acceptant un point de pincement de 18°C à l’évaporateur il faut 6.69 kg de fumées à 600°C. Ces fumées ressortent à la cheminée à 151°C. Les profils de température sont représentés à la Figure I.6 [2].

Water (180 bar)			
T (°C)	status	**H(kJ/kg)**	**S (kJ/K/kg)**
15	Liquid	80.05	0.22146
357	Liquid	1732	3.85221
357	Vapour	2509	5.10579
540	Vapour	3389.5	6.3733

Fume		
T (°C)	**H(kJ/kg)**	**S (kJ/K/kg)**
151	128.37	0.58875
600	622.76	1.3688

By setting T0=288.15 K, we calculate:

- ✓ the exergy lost by the smoke: $E_1 = \Delta H - T_0\ \Delta S$ =1804.8 kJ
- ✓ the exergy received by the water : E_2 =1536.8 kJ We deduce the loss of exergy due to the irreversibility of the exchange ΔE = E_1 - E_2 = 268 kJ, that is to say 14.8% of E_1.

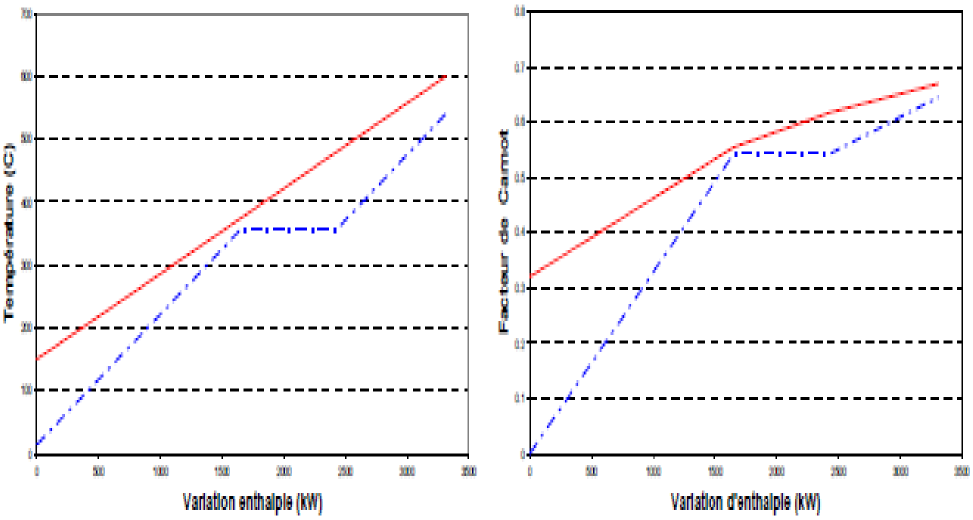


Figure I.6. Boiler with 1 pressure level [2].

The analysis of Figure I.6 (Carnot factor on the ordinate) shows that the losses could be reduced by inserting the production of a new amount of steam below the saturation temperature of the HP steam. This steam must therefore be at a lower pressure and can be superheated to $T<T^{sat,HP}$ [2].

I.2.4.2. Boiler 2P (180 bar and 15 bar)

The addition of a second pressure level allows to decrease the flue gas temperature to 100°C (the flue gas temperature cannot be too low to avoid any risk of acid condensation, source of degradation in the flue). We can see that a second pinch point appears at the BP vaporizer [2].

Water (15 bar)			
T (°C)	status	**H(kJ/kg)**	**S (kJ/K/kg)**
15	Liquid	64.41	0.22424
198	Liquid	844.71	2.31466
198	Vapour	2790.99	6.443
330	Vapour	3104.39	7.03233

Fume		
T (°C)	**H(kJ/kg)**	**S (kJ/K/kg)**
100	76.46	0.45039
600	622.76	1.3688

Keeping a HP steam production of 1kg and a smoke quantity of 6.69 kg, we can produce 0.114 kg of additional BP steam.

Still setting T_0=288.15 K, we can calculate the exergy:

- for smoke: E_1 = ΔH -T0ΔS =1885.4 kJ
- for the water : E_2=1536.8 kJ (HP) + 123.2 kJ (BP) = 1660 kJ We deduce the loss of exergy due to the irreversibility of the exchange

ΔE = E_1 - E_2 = 225.4 kJ, that is 11.95% of E_1[2].

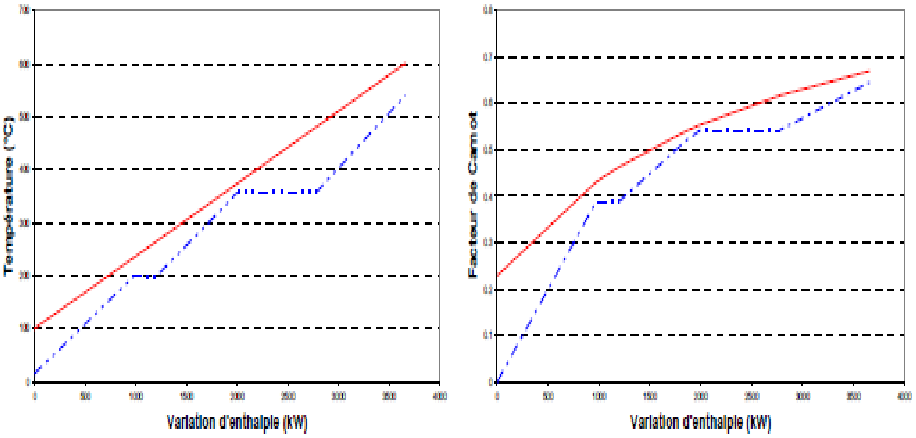


Figure I.7. Boiler with 2 pressure levels [2].

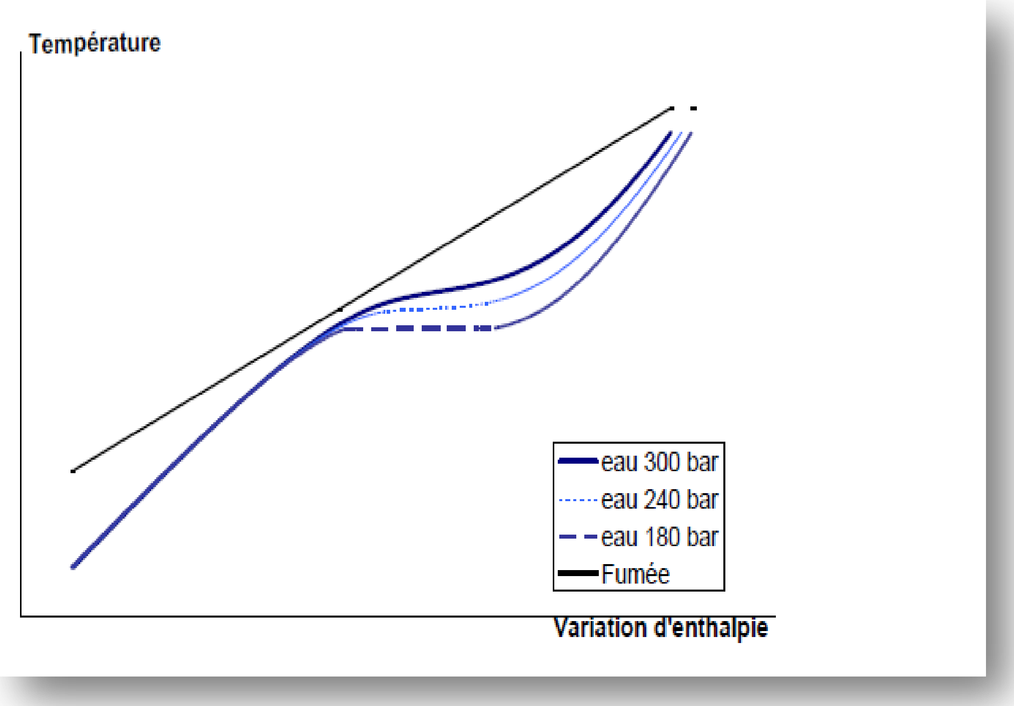


Figure I.8. Evolution of the water temperature in the boiler as a function of pressure [2].

By adding a pressure level we have reduced the irreversibility losses by almost 3%.

Irreversibilities can also be reduced in a recovery boiler by producing supercritical steam (P > 220.64 bar). The vaporization step is reduced and a better match between the curves of hot and cold fluids is observed.

In practice, it is the irreversibilities of the whole HSR cycle that must be reduced, including the irreversibilities due to the expansion of the steam in the turbines. This will be done in particular by adding a steam reheating at the exit of the high pressure turbine [2].

I.3. Geometry of a vertical recovery boiler

The vertical boiler, regardless of its configuration, consists of several heat exchangers. These exchangers include an inlet header, a series of tubes (usually finned to increase heat exchange) and an outlet header.

A boiler element will be completely defined by giving (see figure I.9) :

- the direction of water flow in relation to the flue gas: co-current or counter-current. To be exact, we should speak of cross-flow since the flue gases flow perpendicular to the tubes. However, we will speak of counter-current when the fumes first meet the tubes coming from the outlet collector (CS) of the element and co-current when they first meet the inlet manifold (EC) inlet collector (EC);
- the number of layers of tubes (nrow), a layer being the set of tubes located in the same plane the number of tubes in a bundle (nrow), a bundle being the set of tubes located in the same plane and arranged perpendicularly to the direction of the smoke;
- the number of tubes in a bundle (nelem);
- the arrangement of the tubes: in a row or staggered ;

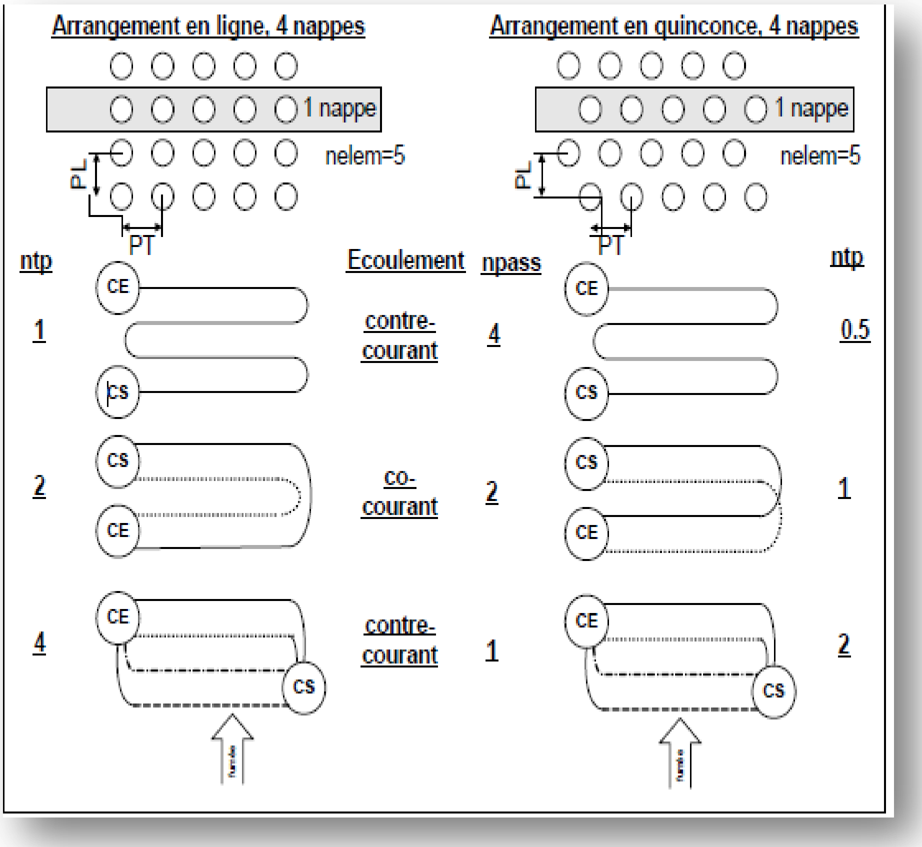


Figure I.9. Geometry of the recovery boiler [2].

➢ the number of tube passes (npass), the number of passes indicates in how many layers the cold fluid circulates during its passage from one collector to another;

➢ the number of tubes in parallel (ntp), i.e. the number of tubes in the same pass and located in the same vertical plane. It should be noted that the calculation of the number of tubes in parallel is not identical depending on the arrangement of the tubes in the bundle.

- If the tubes are in line, we have logically ntp = $\frac{nrow}{npass}$
- If the tubes are staggered, we have ntp = $\frac{1}{2} * \frac{nrow}{npass}$

This is why when there are as many rows as there are passes, the number of tubes in parallel is 0.5 when the tubes are staggered.

➢ the spacing of the tubes in the direction of the smoke flow, defined as the longitudinal pitch (LP);

- the spacing of the tubes in the direction perpendicular to the smoke flow, defined as the transverse pitch (TP);
- the diameter, thickness and length of the tubes and the type of metal used;
- the number of fins per meter of tube as well as the type, diameter and thickness of the type, diameter and thickness [2].

I.4. Industrial use

I.4.1. The high-speed cycle

Today, new power plants for electricity production are frequently of the high-speed cycle type (combined cycle or gas/steam turbine power plant). These cycles combine a gas turbine with a steam turbine (condensing).The high temperature of the fumes at the exit of the gas turbine allows to vaporize and and superheat the water entering the steam cycle. The recovery boiler is physically the interface between the the interface between the gas turbine and the steam turbine [2].

Each boiler is unique. It is directly dependent on the performance and constraints of the TAG, as well as the steam cycle chosen by the plant designers. The final choice is made by evaluating the cost/benefit ratio of the different possibilities. The solution is more interesting from an energy point of view but represents an additional investment The three-pressure level solution is more interesting from an energy point of view but represents an additional investment compared to the two-pressure level solution given the presence of an additional evaporator which is a rather expensive device. expensive device. There is therefore a compromise to be found [2].

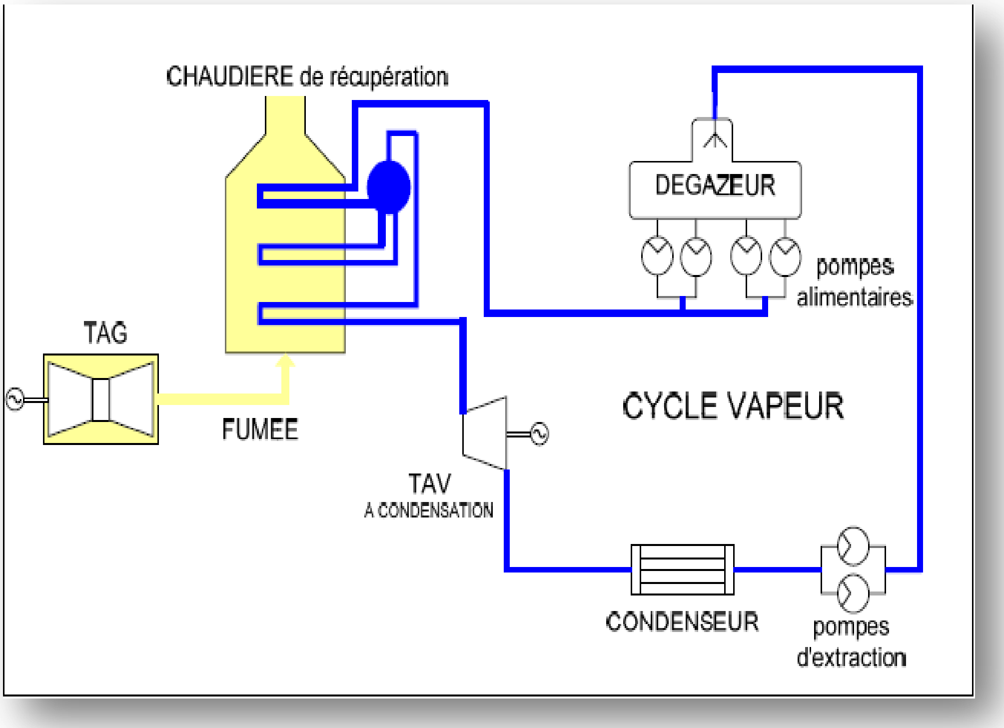


Figure I.10. Example of a combined cycle [2].

The efficiency of a conventional power plant is between 38% and 45%, depending on the size of the plant and the number of steam extractions. The efficiency of gas turbines, which directly influences the profitability of electricity production, is between 35% and 40%, with CO2 emissions less than half of those of a conventional coal-fired power plant of equivalent capacity. In a high-speed power plant, the efficiency of the gas and steam turbines is not as high as in simple cycles, but their combination gives still gives an efficiency of about 55%. The lower efficiency of the steam cycle is due to the The lower efficiency of the steam cycle is due to the lower quality of the steam (produced in a recovery boiler instead of a steam generator where the fumes are hotter) as well as to the simplification of the simplification of the steam cycle (elimination of many intermediate extractions during steam expansion). As for the decrease in the efficiency of the gas turbine, it is due to the high temperature of the gases at the end of temperature of the gases at the end of the expansion, necessary to ensure a sufficient heat exchange exchange in the recovery boiler and to the back pressure induced by the boiler. Boiler [2].

In the recovery boiler of a combined cycle, the heat exchange is mainly done by convection, contrary to the convection, unlike the heat transfer in a conventional power plant steam generator, which steam generator of a conventional thermal power plant, which is not only by convection but mainly by but mainly by radiation [2].

I.4.2. Cogeneration

Cogeneration consists of producing the steam needed for an industrial process by using the exhaust gases from a turbine or a gas engine, instead of a conventional boiler as found on most industrial sites. In its principle, a gas cogeneration is a combined cycle (CCGT) where the steam turbine has been removed (see Figure I.12) [2].

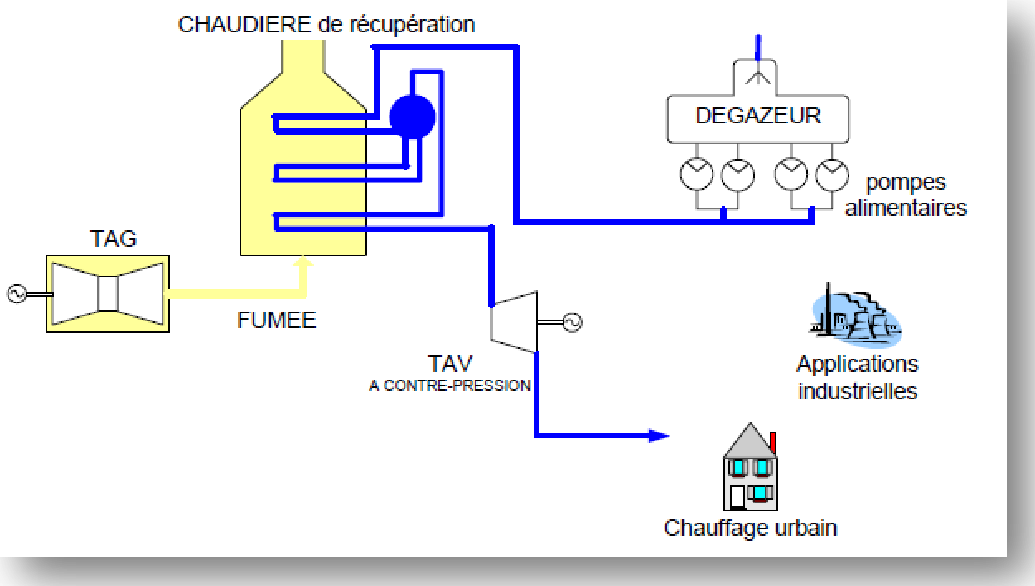


Figure I.11. Example of combined heat and power generation [2].

Cogeneration only makes sense from an energy point of view if the heat produced is put to good use. If the heat produced by a cogeneration plant is not used, the result is an electricity production unit with an efficiency lower than that of the current high-speed power plants.

In cogeneration, the recovery boiler is the interface between the gas turbine and the heat consumer [2].

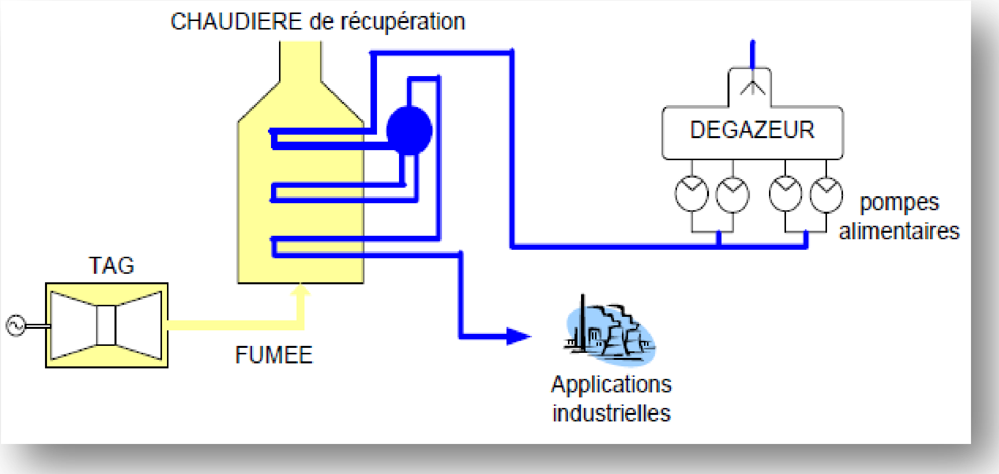


Figure I.12. Example of cogeneration [2].

A combined cycle from which part of the steam is taken from the steam turbine can also be considered as cogeneration. be considered as cogeneration, also referred to as combined heat and power generation. combined heat and power. In this case, the steam turbine will be at back pressure because the steam at the turbine outlet is not the turbine is not condensed but diverted to a steam network for industrial or urban thermal industrial or urban thermal application (district heating) (see Figure I.10). In the past, these district heating units could also be found without a TAG (for example in the unit that was operated by the the unit that was operated by INTERVAPEUR in Verviers) [2].

I.4.3. Repowering

Repowering is an efficient way to improve the performance of an existing conventional power plant (steam cycle only) by adding a gas cycle. The result is a combined cycle (CCGT) whose efficiency is much higher than that of a conventional power plant, while taking advantage of the existing facilities (steam turbine, condenser, cooling tower, etc.). The cost of repowering is therefore moderate compared to the cost of a new HSR plant. During a repowering, the combustion boiler is replaced by a recovery boiler since the enthalpy available at the exit of the gas turbine is used instead of the steam generator [2].

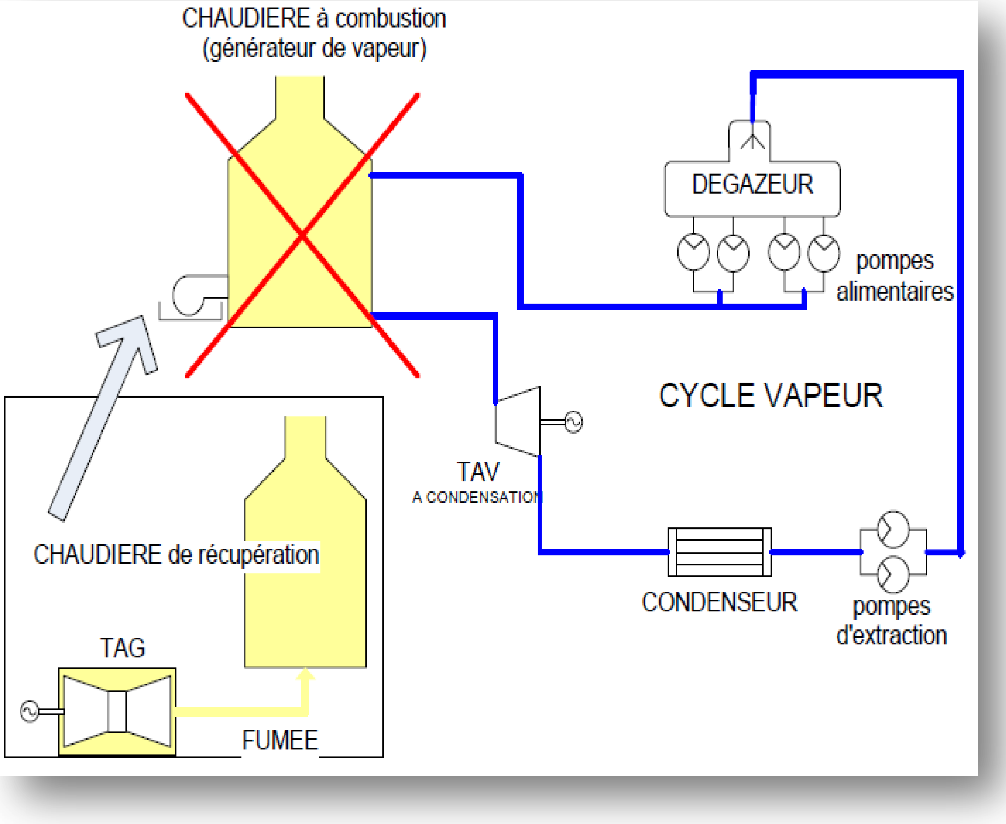


Figure I.13. Example of repowering [2].

Some schemes consider using the effluent of a TAG as a preheated oxidant for a conventional combustion boiler, which then becomes an afterburner unit.

This alternative does not require the use of an air preheater. It is well complemented by district heating system, where the low potential heat that would be used by the conventional air preheater, can be used for the production of hot water [2].

I.5. Market Capabilities

There are two important parameters involved in the recovery boiler market:

- Electricity consumption is increasing;
- The Kyoto agreements, which commit the signatory countries to reduce their greenhouse gas emissions.

Since electricity consumption is growing, the electricity park will have to be expanded. In Belgium, it may be necessary to replace the nuclear power plants that should be phased out by 2015. For essentially economic reasons, the most efficient cycles will be chosen. These are the high-speed cycles for centralized electricity production, while cogeneration appears to be an economically interesting alternative to centralized production, provided of course that there are heat requirements. provided that there is a need for heat in the vicinity. The production of electricity from renewable energies would be ecologically more interesting, but they can in no way ensure the in no way ensure the basic production of electricity in Belgium.

In order to reduce greenhouse gas emissions, conventional coal-fired power plants, which are large producers of this type of energy, are being coal-fired power plants, which are major producers of this type of gas, will have to be adapted. The advanced depollution of is a very expensive solution. Repowering or replacement of power plants by plants by high-speed trains could be considered, but these solutions imply a modification of the fuel modification, which is not always possible. The IGCC plant is a combined-cycle combined cycle power plant which, instead of burning natural gas, burns syngas (CO + H2). This is obtained from the gasification of coal. The raw gas from the gasifier is composed of a number of polluting constituents that must be removed before the removed before the gas is admitted to the gas turbine. The IGCC therefore makes it possible to keep coal as a fuel while coal as a fuel while greatly reducing air pollution.

Regardless of the technology chosen, a recovery boiler will be required at the behind the gas turbine.

It is in this context that the subject of this thesis was chosen. A better control of the internal modelling of the boilers (control of the sizing process of the exchange surfaces for exchange surfaces for non-standard heat exchanges: forced circulation, super critical, etc.) is necessary. It allows a better prediction of the performance of the performance as well as a better prediction of the mechanical design data (Pdesign, Tdesign). The boiler will then be able to optimally take advantage of the enthalpy of the gas turbine flue gas to produce steam. The boiler will then be able to take optimal advantage of the enthalpy of the gas turbine flue gas to produce good "quality" steam for the steam cycle. This also optimize the overall efficiency of the cycle [2].

I.6. Main elements

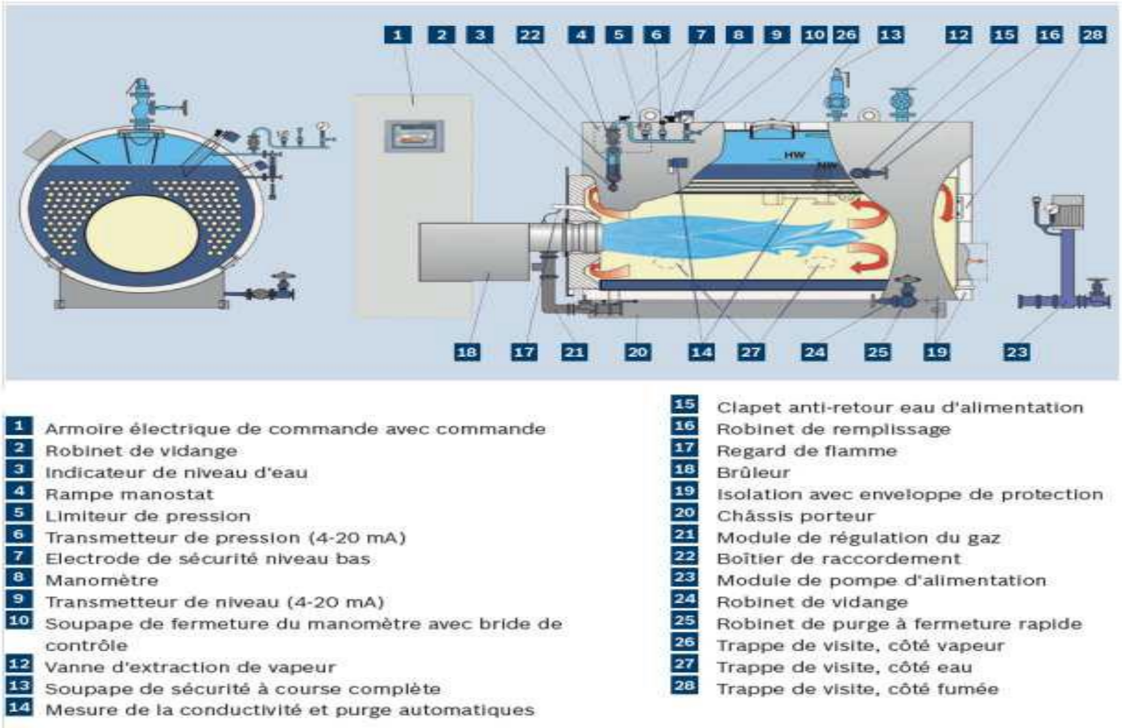


Figure I.14. Schematic of a boiler [6].

I.6.1. The furnace or combustion chamber

It is the main part of the steam generator its role is to ensure the heat exchange of the boiler by releasing a quantity of heat necessary to the vaporization of water. Of the water [1].

I.6.2. The burner

A device that brings together a fuel and an oxidizer, in order to introduce the gas into the combustion chamber in the combustion chamber, to adapt the flame to the use for which it is intended (length, volume, temperature, hardness) and to regulate the combustion at its outlet.

But the fundamental role of the burner is to change the physical state of the fuel so that it goes from from a liquid state to a vapor state or to a state of very fine droplets, so that it can be so that it can ignite [1].

There are two types of burners depending on the fuel used: oil or gas.

I.6.3. Vaporization bundle

This is a set of tubes surrounding the fuel chamber where the water steam emulsion circulates in it. The latter is collected in a tank where the separation between the steam and the water takes place. This steam will then be superheated.

In order to avoid the important losses that resulted from sending them to the chimney, other types of other types of heating surface are still provided, constituting the water heaters or economizers and air heaters [1].

I.6.4. Fan

It ensures the circulation of gases in the steam generator including the fumes, and combustion air [1].

I.6.5. Chimney

The boiler is equipped with a metal chimney through which the fumes are evacuated after having been cooled [1].

I.6.6. Armatures

The boilers include the various registers, valves of Securities, sight glass of flame, taps which are used to taps that serve to open and close the pipes and various steam measuring instruments. steam measuring instruments. The use of these equipments improves the safety and the good functioning of the of the system [1].

I.6.7. Insulation

The outer walls of the boilers are covered with insulation either glass wool or refractory. or refractory [1].

I.6.8. The Balloon

It is a tank where the two liquid-steam phases are located, its role is to separate the water from its steam and to ensure the natural circulation of steam [1].

I.6.9. Electrical cabinet

The electrical cabinet is a box that contains a network of electrical distributions, operating with heating resistances and possibly, at different frequencies. Its essential role is to protect this network from any dangerous incident and it ensures the automatic operation of the automatic operation of the boiler [1].

Chapter II

Position of the problem

II.1. Competitiveness of boiler manufacturers

For a boiler to be competitive it must, at the risk of stating a truism, cost as little as possible while providing the required service. Reducing costs must be done at all stages of the boiler design.

A. Minimize the exchange surfaces

The required heat transfer area is calculated when the boiler is designed. This surface must be minimal without penalizing the efficiency of the gas turbine (by increasing the pressure drop on the flue side), while generating the required steam flows and ensuring an optimal steam superheat temperature (corresponding to the optimal turbine inlet optimum steam superheat temperature (corresponding to the optimum inlet temperature to the steam turbine) [2].

B. Select the most suitable materials for the temperature and pressure ranges temperature and pressure ranges encountered

Simulation models are used to determine the operating conditions in the recovery boiler and to determine the recovery boiler and determine the hot spots. The materials are chosen taking into account taking into account the results of these models in all situations considered by the customer (different firing rates) [2].

C. Choose the best safety margins

When a new boiler is delivered, its operation at nominal load (generally corresponding to the maximum (generally corresponding to the maximum efficiency of the gas turbine) as well as at various various partial loads must be guaranteed. The manufacturer will take safety "margins" on the construction of the The manufacturer will take safety "margins" in the construction of the boiler in order to always be sure that the guaranteed performance.

To control the manufacturing cost of a recovery boiler, it is therefore necessary to to calculate as precisely as possible the operating conditions at each point of the boiler boiler.

The more precise the model representing the recovery boiler, the smaller the margins can be chosen and the margins can be chosen and the more competitive the manufacturer will be [2].

II .2. How a design office works

When a new boiler is ordered, the design office will be in charge of its design. The performance of the gas turbine as well as the characteristics of the produced vapors (flow, temperature, pressure, etc.) are given by the customer. A maximum floor space requirement for the boiler may also be imposed.

The design of the boiler will be done in several steps :

- a "thermodynamic" sizing
- a "geometrical" dimensioning
- the final sizing

The boiler thus designed will have to satisfy the lighting constraints imposed by the customer. The design office will also be in charge of evaluating the main firing rates as well as the performance of the boiler. These performances shall be guaranteed by the manufacturer at the time of sale [2].

II .2.1. Thermodynamic « sizing »

The composition of the flue gas is either known or calculated. By choosing a suitable thermodynamic model, the characteristics of the flue gas (heat capacity, viscosity, conductivity, volume) can be calculated. For water/steam, a thermodynamic model specifically dedicated to water will be chosen and the characteristics of the fluid will also be calculated [2].

First of all, it will be necessary to ensure that the enthalpy available in the flue gas is sufficient to produce the required steam. If we admit an efficiency of the exchange η lower than 1, taking into account the losses to the environment admitted by the manufacturer, we must have [2] :

$$Qsteam * \eta exchange = Qsteam$$

It is then necessary to verify that the recovery of the heat contained in the fumes is possible. To do this, the temperature of the flue gas must always be higher than the temperature of the steam at any point of the boiler. The arrangement of the heat exchangers in the flue gas flow is known (it has been calculated during an optimization calculation of the combined cycle). If pinch points appear on some exchangers, two possibilities can be considered: modify the steam parameters (flow and/or temperature) or use an afterburner. An afterburner raises the temperature of the flue gas by burning an additional amount of natural gas using the residual oxygen contained in the flue gas. The flow rate as well as the characteristics of the flue gas after post-combustion will have to be recalculated [2].

In a recovery boiler, the heat exchange takes place mainly by convection, depending on the properties of the convection, it depends on the transport properties of the fluids in contact (heat transfer coefficients) heat transfer coefficients) and the thermal conductivity of the metal separating the fluids. the fluids. For each heat exchanger, the heat balance can be written [2] :

$$Qi = Ui * Ai * DTLMi$$

with Q, the thermal power (kW)

- A, the exchange surface (m^2)
- U, the global exchange coefficient ($kW/m^2/K$)

- DTLM, the logarithmic temperature difference between the inlet and outlet of the exchanger

Or else :

$$\frac{Qi}{DTLMi} = Ui * Ai$$

The first term of this equation is totally known since the energy balances have been carried out on each identified zone. It remains to determine Ui to know the necessary exchange to know the necessary exchange surface on each of the zones [2].

II .2.2. Geometric « dimensioning »

The heat transfer coefficients depend not only on the type of fluid and the operating conditions but also on the geometry of the operating conditions but also on the geometry of the heat exchanger. It will be necessary to It is therefore necessary to make an assumption about the geometry of the heat exchanger in order to calculate the transfer coefficient. This assumption must be validated at the end of the calculation [2].

It will also be necessary to make an assumption on the number of elements constituting a layer of the exchanger. The heat exchanges in the boiler being of convective type, it is in interest to have a speed of fumes and thus a high Reynolds number to obtain a good transfer coefficient. The number of elements must therefore be as small as possible [2].

This hypothesis will be confirmed by calculating the pressure drop on the smoke side. If this pressure drop is higher than a limit If this pressure drop is higher than a limit previously set by the customer, the number of elements in the the number of elements in the sheet will have to be increased [2].

Finally, the number of parallel tubes in the exchanger must be determined. This number of tubes will depend on the admissible pressure drop on the water side. To do this, we start with the minimum number of parallel tubes, calculate the pressure drop and compare it to a limit set by the customer. As long as the pressure drop is not lower than this limit, 0.5 parallel tubes are added and the calculation is repeated. Finally, it is necessary to check that the stability of the flow is ensured in the vaporizers [2].

II .2.3. The final dimensioning

From the results of the first part, the design engineer will realize a flow diagram. The previous design does not yet show the materials used or the connections between the different exchangers. For each circuit, there may be feed pumps, outlet valves for the different elements. It is necessary to add the connection piping, the collectors at the inlet and outlet of each exchanger, the tank and the circulation pumps on each evaporator circuit. Materials must be selected according to temperature and pressure, tube diameters must be confirmed, thicknesses must be calculated, etc [2].
These calculations will allow an estimate of the boiler price.

II .2.4. Calculation of the flow rates

When all the geometrical parameters of the boiler are fixed, it is possible to determine the performance of the boiler, i.e. the characteristics of the steam (flow, temperature and pressure) at any operating point other than the design point [2].

The flow calculations consist in predicting by means of the simulation model the performance of the the performance of the boiler of fixed dimensions, for different operating regimes of the of the TAG (the flow rate, composition and temperature of the exhaust gases are provided by the are provided by the customer) [2].

II .3. The objective of this work

Previous studies conducted at LASSC have shown that to find a solution to a problem a decision to a given problem, the engineer must apply an iterative procedure which three main steps (immutable process independent of the studies of the LASSC):

- Analyze the objectives and constraints, i.e. define the problem ;
- Generate results ;
- Evaluate the obtained results to estimate if they constitute a solution to the problem posed.

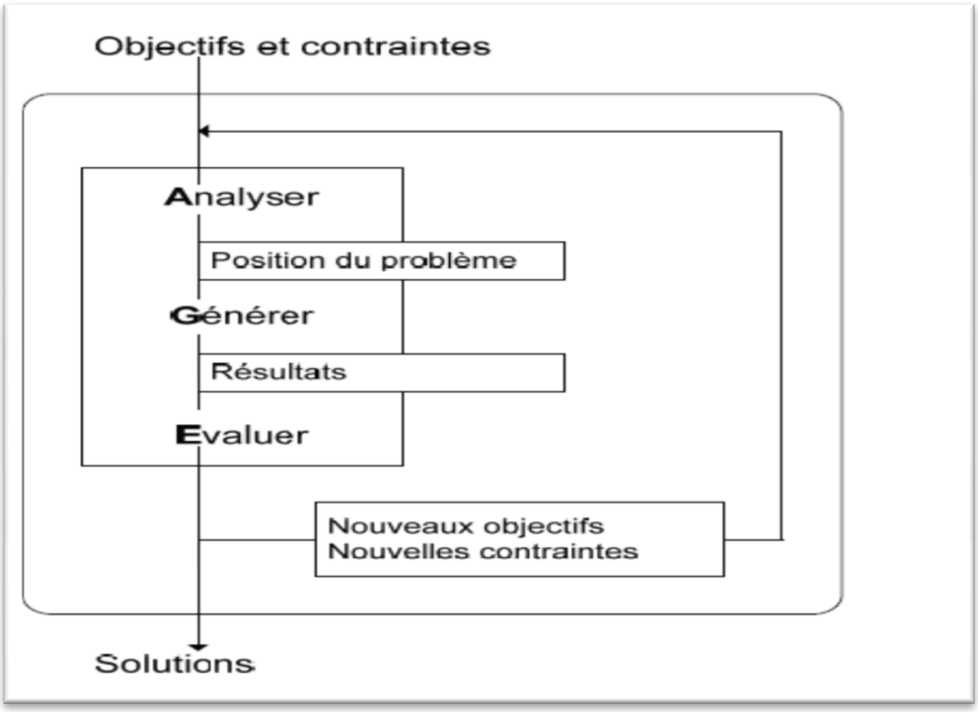


Figure II.1. The engineer's approach.

In the context of this thesis, we were asked to model the behavior of of forced circulation boilers built by CMI. We therefore started by processing the available measurements by means of a validation software and developed mathematical models to mathematical models to generate results. The need to be able to model a whole series of variants quickly highlighted the need to integrate the validation tool directly into the developed module. In addition, the preliminary step to the construction of any boiler being its design, it seemed obvious to us that a design strategy design strategy had to be integrated into the whole. The analysis of the solutions showed that that the results obtained were not only interesting for forced circulation boilers but could be generalized to other but could be generalized to other types of boilers. The module has been further improved to be suitable for all types of vertical boilers types of vertical boilers [2].

Thus, we can clearly see the need for a versatile model combined with commercial software to validate the measurements. This thesis is based on the creation of a unit allowing the calculation of any part of a tube inside an exchanger of a recovery boiler. Its characteristics will be described in detail in another part of this work. This unit has been created within the VALI validation software (Belsim sa) and is called FELVAL. In order to simplify as much as possible the simplify the use of this new model, we have also created a "super model" that automates the creation of model" that automates the creation of the various FELVAL units required to fully represent the representation of the different layers that make up a heat exchanger in a recovery boiler heat exchanger in a recovery boiler, as well as the creation of the necessary connections to to link the different units together. This "super model" is called SUFVAL [2].

II .4. Use of a FELVAL-type unit in a design office design office

The great advantage of FELVAL over other tools available on the market is its flexibility of use: any section of a boiler element can be modeled, allowing the user to can be modeled, allowing the user to verify the state of the fluids present at any point of the of the boiler. This property is particularly interesting when modeling This property is particularly interesting when modeling superheaters and re-superheaters (hot spots problem) [2].

It allows the design office to visualize the evolution of the temperature difference between the fluids at any point of the exchanger and to choose the design temperature according to the hottest the hottest tube.

When there is an afterburner, the exchanger closest to the burner can also be modelled in more detail. also be modeled in more detail and the effect of a local overheating of a part of the first of a part of the first tube sheet on the steam flow in this sheet and on the final temperature at the as well as on the final temperature at the outlet of the superheater. It will be possible to modify the The design can be modified to obtain a uniform flow in all the tubes in parallel [2].

In existing boilers, when measurements are available to map the flue gas temperatures, the FELVAL can be used to recalculate the distribution of steam temperatures and flows to recalculate the distribution of temperatures and steam flows in the different tubes. This will make it possible to identify any local overheating. This will allow us to identify any local overheating and to evaluate the efficiency of the design used. A correction factors can be adjusted to improve the accuracy of the model for future sizing of future design of other boilers (better distribution of flow rates between the different tubes and more homogeneous tube temperatures) [2].

FELVAL will also be used to model the impact of edge effects (preferential by-pass of the flue gases along of the flue gas along the wall) on the temperature of the tubes.

In horizontal boilers, a modeling problem appears in the vaporizer. Indeed, if the liquid is well saturated at the outlet of the tank, it is not the case 20 or 25 m lower at the entrance of the vaporization tube. But the available mathematical models assume that the liquid is always saturated at the vaporizer inlet. FELVAL does not make this assumption this type of assumption and can be used to model the vaporizer tubes by cutting them into as many sections as necessary to have a good idea of the evolution of temperatures and pressures the evolution of temperatures and pressures along the tube, which is particularly important since the important since the pinch point of the recovery boilers is always at the vaporizer. the vaporizer. Currently, the FELVAL model is used during the realization of orders for new vertical boilers at CMI [2].

Chapter III

Theoretical reminder on heat transfer

III.1. Heat Transfer

Heat transfer is the process by which energy is exchanged in the form of heat between between bodies or media at different temperatures T1 and T2.

Heat can be transferred by conduction, convection or radiation. Although all three processes can take place simultaneously three processes can occur simultaneously, one of the mechanisms is generally preponderant. For example, heat is mainly transmitted by conduction through the brick walls of a walls of a house; water in a pot on a stove is heated primarily by convection; the Earth is The Earth receives its heat from the sun mainly by radiation.

The flux generated in the transfer is proportional to the temperature difference $T_1 - T_2$ and to the cross section S of the flow:

$$\Phi = h.S.\,(T_1 - T_2)$$

h is interpreted as a heat exchange coefficient.

However, this relation is only valid to the first order, because the coefficient h depends on the temperature. We will often introduce the quantity / S, which is the density of flux, and which is expressed in W/m^2[7].

III .1.1. Heat exchangers

III .1.1.1. Definition of a heat exchanger

A heat exchanger is a system that allows the exchange of heat between two fluids without mixing. In a heat exchanger, the hot fluid and the cold fluid are separated by a wall (flat or tubular).

The heat is transferred from the hot fluid to the cold fluid. The fluids, heating and heated are heat transfer fluids.

The heat transfer fluid is a fluid in liquid state which is used without phase change for transfer from one place to another a certain amount of heat generated by strange means. It is characterized by its mass heat Cp.

Since the heat exchange power Q is proportional to the mass heat.

This implies the choice of water :

Cp of water= 1Kcal. $\mathrm{Kg}^{-1}\mathrm{K}^{-1}$ and Cp of air=0.25Kcal. $\mathrm{Kg}^{-1}\mathrm{K}^{-1}$

In the field of heat exchangers, the thermal resistances by conduction and radiation are often neglected by radiation are often neglected in front of the global convective resistance of the two fluids. Most of the existing heat exchangers operate at a temperature of 600 °C [7].

Remark

Since the majority of the heat exchangers used are with exchange surface, i.e. the two fluids are separated by a wall, these two fluids can be either two liquids, or two gases or vapors, or a liquid and a gas in addition, the heat exchange in the device is carried out either without change of state (the device is then a simple exchanger), or with change of state (the device is then according to the case, a condenser or an evaporator or a crystallizer) also boilers, in the absence of the separating wall, there is direct mixing between the two fluids (exchanger-mixer) In this case, the two fluids are of the same nature or immiscible.

An exchanger is rarely made up of a single tube, in general, there are a multitude of elements (a set of tubes or plates, etc.) [7].

III.1.1.2. Principle of operation of the exchangers

A heat exchanger has, as its name indicates it, for function to transfer heat of a fluid medium towards heat from one fluid medium to another.

These are elements commonly found around us in the building (radiator) but also in a large number of industrial applications. Each time we want to evacuate to reduce the risk (car radiator, electronic components, nuclear power plants) or to recover heat nuclear power plants) or to recover heat to use it (radiator...) a heat exchanger is used. heat exchanger.

Generally, to ensure this heat exchange efficiently, at least one of the fluids is set in motion (pump, fan). To increase this exchange, and thus the transfer of To increase this exchange, and therefore the transfer of energy, it can be used to change the phase (condensers, evaporators, This system is commonly used in thermal machines or heat pipes. All modes of transfer are involved in heat exchangers [7] :

- **Heat transfer first of all**

Conduction always occurs in the wall that separates the two fluids that need to exchange heat. This wall is usually metallic and of low thickness and therefore has a low thermal resistance.

Radiation is the least prevalent transfer mode due to the low temperature levels. However, for some applications (e.g. boiler with burner) it is far from being negligible.

Convection, because of the fluids involved, is probably the most important mode and the most delicate to estimate. It depends strongly on the type of fluid to be used, the speeds involved and the geometry of the and the geometry of the exchanger.

- **Mass transfer**

The fluids being in movement in order to ensure the transfer of energy, this transfer of mass is the driving force of the mass transfer is the driving force behind the technical analysis of a heat exchanger.

Heat exchangers involve 2 fluids which can have very different properties. different properties. For example the radiator of a room has for internal fluid water and is located in air.

The choice of the fluids is conditioned by criteria of cost (water and air are the most interesting) (water and air are the most interesting), temperature resistance (high or negative), energy transfer performance performance (high heat capacity) and also compatibility with the materials used by the exchanger (corrosion...). exchanger (corrosion...).

Unlike other thermal appliances, the heat exchanger does not contain no moving mechanical parts. The calculation of this device is very complex, we must know its geometry (exchange surface and fluid flow sections), its thermo-physical characteristics, the characteristics, the flow velocities of the fluids, the inlet temperatures of the fluids, etc. temperatures, etc....

In the field of heat exchangers, the thermal resistances by conduction and radiation are often are often neglected in front of the global convective resistance of the two fluids. The majority of existing heat exchangers operate at temperatures below 600°C.

The field of heat exchangers can be considered as a synthesis of the following fields following fields: Heat Transfer, Fluid Mechanics, Corrosion, Fouling, etc.

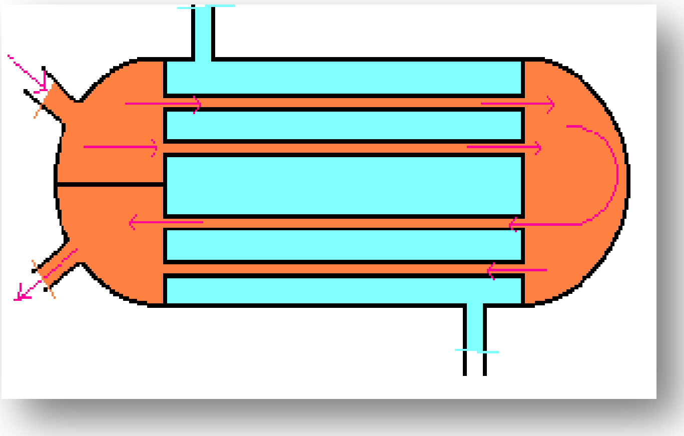


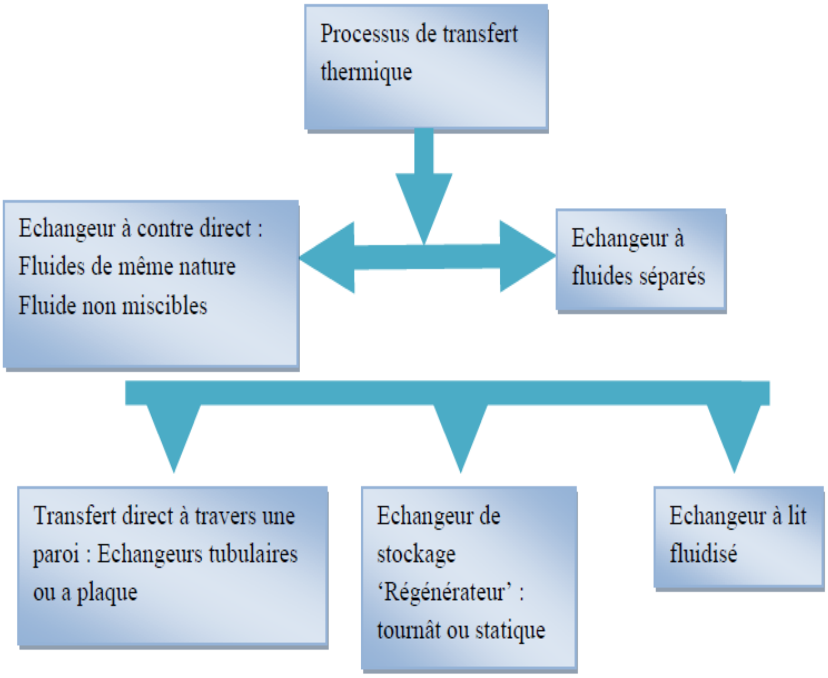
Figure III.1. Operating principle of a heat exchanger. of a heat exchanger [7].

III.1.1.3. Classification and technology of exchangers

Heat exchangers can be classified in many ways, so in the following we will only mention the groups that we consider important [7] :

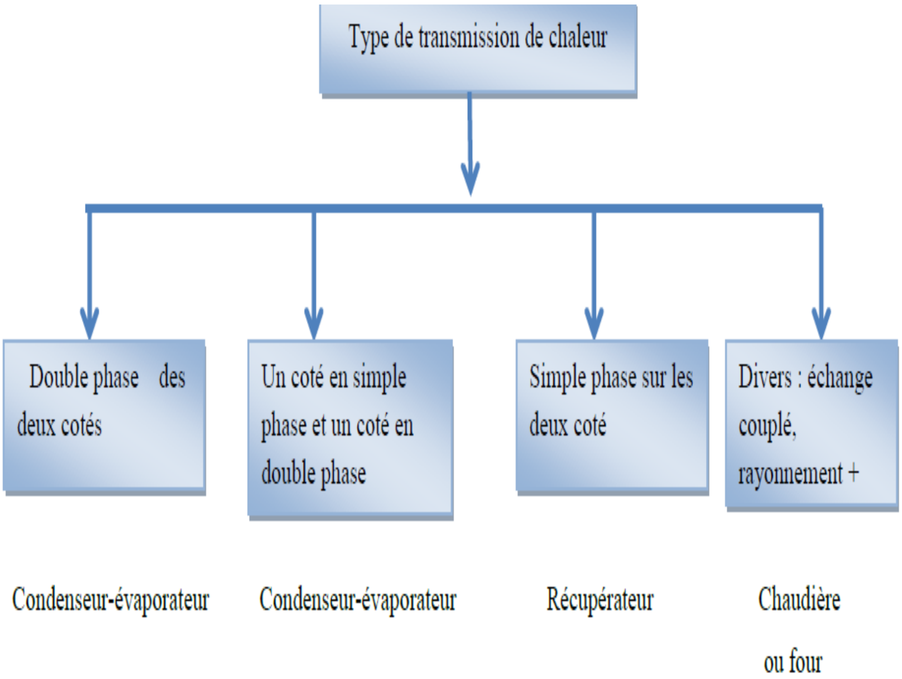
- **According to the heat transfes process**

We find the following devices



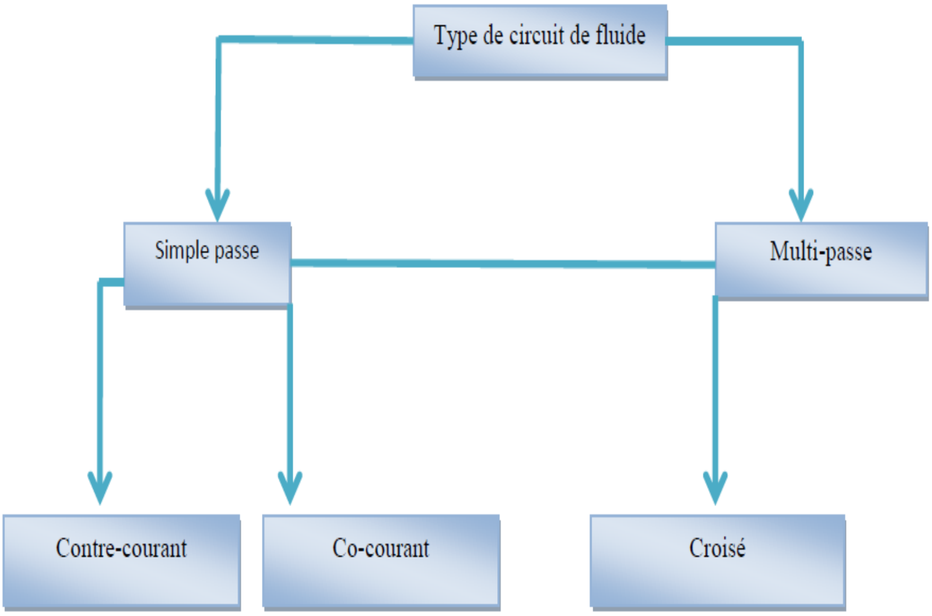
- **Acoordine to the tybe of heat transmission**

We find the following devices



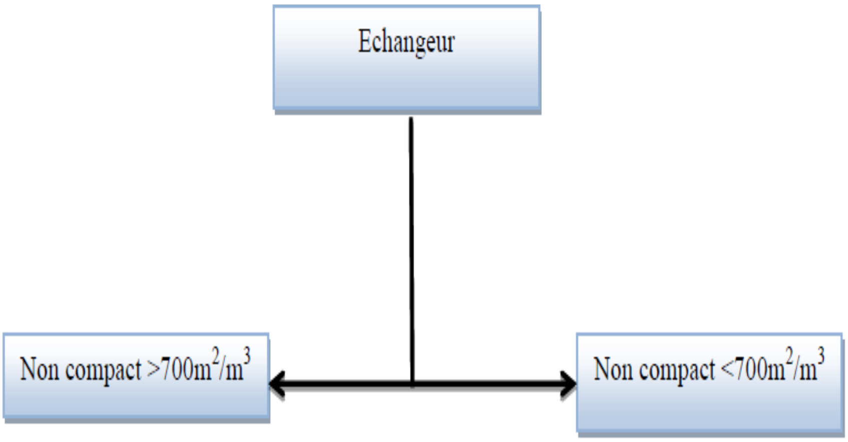
➢ **Accordine to the fluid circuit**

The following devices exist according to this classification



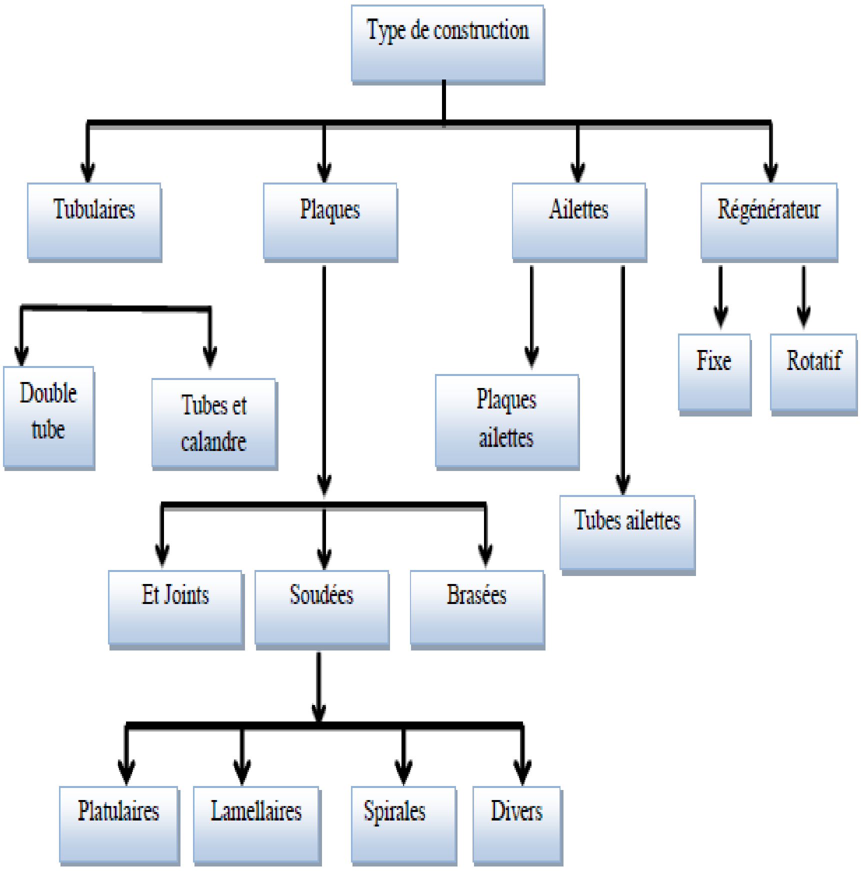
- **Accordine to the compactness of the exchange surface**

The compactness of an exchanger is characterized by the ratio of the exchange surface to the volume occupied. There are two groups of exchangers



- **According to the type of construction**

There are four main familiers of exchangers



III.1.2. Heat transfer

III .1.2.1. History and evolution of the terminology

Heat, in the common language, is often confused with the notion of temperature. Although strictly different from a scientific point of view, the two notions are indeed related and the very history of the genesis of thermodynamics has sometimes induced this confusion. Until the 18th century, scientists thought that heat was made up of a fluid called phlogiston. Called phlogiston (phlogiston theory).

In the XIX th century, heat was assimilated to a fluid: caloric. The progress and success of calorimetry imposed this theory until the middle of the XIX th century. This conception is for example by Sadi Carnot: a heat engine can only work if the heat flows from a body whose temperature is circulates from a body whose temperature is higher to a body whose temperature is lower; this reasoning corresponds to an analogy an analogy with a hydraulic machine that draws its energy from the passage of water from energy from the passage of water from a reservoir of high altitude to a reservoir of lower altitude.

It is only with the advent of statistical thermodynamics that heat will be defined as a transfer of the thermal agitation of particles at the microscopic level. A system whose particles are statistically more agitated will have a higher equilibrium temperature, defined on the macroscopic scale. The temperature is thus a macroscopic quantity which is a statistical reflection of the kinetic energies of the particles at the microscopic scale. During random shocks, the most agitated particles transfer their kinetic energies to the less agitated particles. The balance of these microscopic kinetic energies transfers corresponds to the heat exchanged between systems made of particles with different average thermal agitation.

The temperature is thus an intensive state function used to describe the equilibrium state of a system whereas the heat is a transfer of thermal agitation assimilated to a quantity of energy, associated with the evolution of a system between two distinct or identical states if the transformation is cyclic [7].

III.1.2.2. Generalities on the transport and transfer of thermal energy

From time immemorial, the problems of energy transmission, and in particular of heat, have been of importance for the study and the operation of devices such as steam generators, furnaces steam generators, furnaces, heat exchangers, evaporators, condensers, etc, condensers, etc. But also for the operation of chemical transformations. In Indeed, in some reaction systems, it is the speed of heat exchange and not the speed of chemical the speed of the chemical reactions which determines the cost of the operation (case of reactions strongly endo- or exothermic reactions). In addition, nowadays, due to the relative increase in the cost of the cost price of the energy, one seeks in all the cases to obtain the maximum output of a of an installation for a minimal energy expenditure.

The problems of heat transfer are numerous, and we can try to differentiate them by the goals pursued, the main ones being :

- The increase of the energy transmitted or absorbed by a surface.
- Obtaining the best efficiency of a heat source.
- The reduction or increase of the flow of heat from one medium to another.

The potential that causes the transport and transfer of thermal energy is temperature. If two material points placed in a thermally insulated medium are at the same temperature, we can say that there is no that there is no global thermal exchange between these two points, which are said to be in thermal thermal equilibrium (it is indeed a thermal equilibrium because each of the material points emits a net thermal energy of the same modulus, but of opposite sign) [7].

Description

The most common example of a situation involving heat transfer is the system made of two bodies in contact and having different temperatures. The hotter body The hotter body gives energy in the form of heat to the colder body. There is a heat transfer between the two bodies. It can occur heat transfers towards a system whose temperature remains constant, for example in the case of a change of physical state (example: the melting of ice at 0 °C under atmospheric pressure).

The study of these transfers is carried out within the framework of the discipline of thermodynamics based on the first two principles. Unlike thermodynamics, thermokinetics provides information on the mode of transfer in a non-equilibrium situation as well as on the values of heat flow [7].

Definition

A heat transfer, more commonly called heat1, is a disordered microscopic energy transfer. It corresponds to a transfer of thermal energy between 2 physical bodies by conduction, convection or radiation [7].

III.1.2.3. The modes of thermal transfers

A. Conduction

The transfer of heat by conduction is a transport of heat in an immobile or mobile medium without turbulent eddies. This mode of heat transport is the only one to exist within an opaque solid, so conduction concerns mainly solids. In liquids and gases, the heat transport by conduction is very often negligible compared to the two other types of heat transport.

The heat flux (dimension W/m2) transferred by conduction in a given direction is proportional to the temperature gradient in that direction [7].

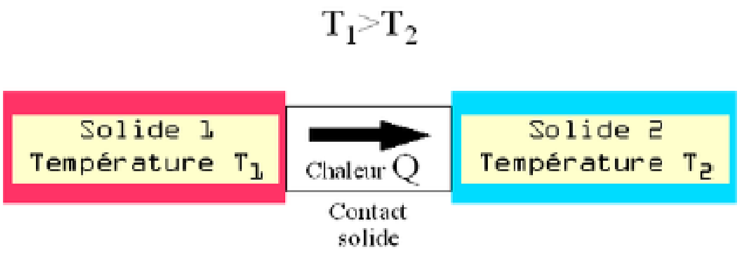


Figure III.2. Schematic representation of heat transfer by conduction [7].

In a simple way, the heat flow which passes in a solid in a monodirectional way is expressed in the following way:

$$\Phi = -\lambda . S n_x . \frac{dt}{dx}$$

Where

- Φ: Heat flux in watts (W).
- λ : Thermal conductivity of the material (in W. m-1. k-1).
- Snx = Surface area perpendicular to the heat flux (normal to the x-axis considered).
- dT: temperature difference (in kelvins).
- x: axis considered.
- This is a diffusion law similar to Fick's law.

Material	λ (W $m^{-1}K^{-1}$)	Material	λ (W $m^{-1}K^{-1}$)
Chrome	449	Slate	2.2
Silver	419	Sandstone	1.8
Copper	386	Glass	0.78
Aluminum	204	Paper	0.48
Zinc	112	Oak	0.17
Iron (pure)	73	Glass wool	0.038
Stainless steel	16	Water	0.556
Mercury	8.2	Air	0.0262

Table III.1. the conductivity of materials [7].

B. Convection

The transfer of heat by convection is due to the movement of molecules of different temperatures, it takes place in a fluid (a liquid or a gas). These molecules moving, they transfer their heat to another place of the system. We can distinguish two types of convection [7] :

- Natural (or free) convection: the heat exchange is due to the difference in mass between the particles composing the fluid; the density varies with the temperature. The heat exchange between the radiators fed by hot water and the air in a room are partly by convection (the rest by radiation). In the case of a vertical plane wall and air at about 20°C, the exchange coefficient is about of 10 watt/m2/K, this means that the thermal power of the heat transfer is of the order of 10 watts for a square meter of surface and a temperature difference of 1 °C. temperature difference of 1 °C.

- Forced convection: the movement of the fluid is forced: fan in front of a radiator (case of radiators for cars). The movement accelerates the heat transfer.

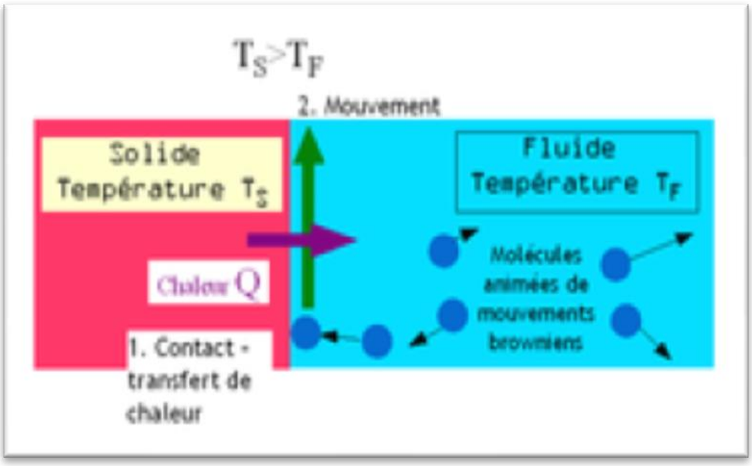


Figure III.3. Schematic presentation of natural convection [7].

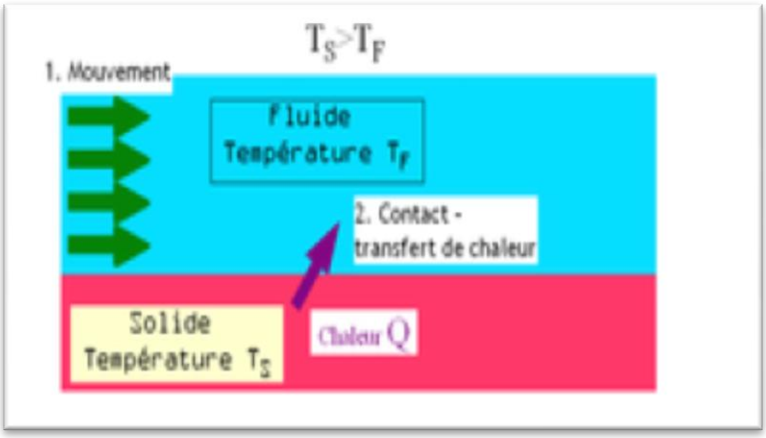


Figure III.4. Schematic presentation of forced convection [7].

C. Radiation

By definition, the transfer is done by electromagnetic radiation. Whatever its temperature, a body emits thermal radiation, which is more or less intense depending on this temperature. The wavelength at which this radiation is emitted also depends on this temperature. Thus, the thermal radiation emitted by the Sun is located mainly in the visible. Colder bodies such as mammals emit in the infrared. The law known as the law of displacement of Wien can give the wavelength of maximum emission as a function of this temperature.

This heat transfer is the only one to be realized in the vacuum, case of solar radiation arriving on Earth. Nevertheless, it also occurs in fluids (air for example) and in some solids (glass). certain solids (glass) [7].

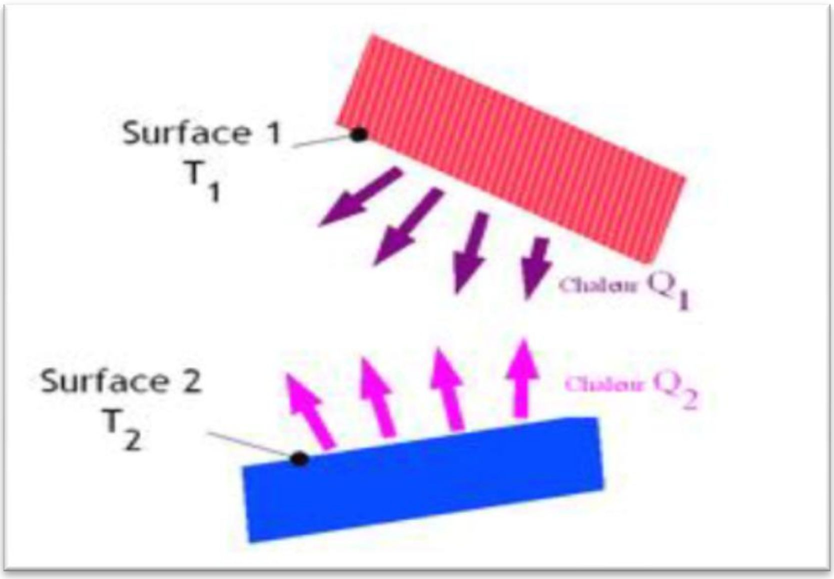


Figure III.5. Schematic presentation of radiation transfer [7].

Examples of transfer by radiation: radiant heating system; the sun.

The Stefan-Boltzmann law (or Stefan's law) allows to quantify these exchanges. The power radiated by a body is given by the relation :

$$P = \varepsilon\, S\sigma T^{4}$$

With :

- σ: Stefan-Boltzmann constant ($5.6703\times10^{-8}\mathrm{W}\cdot m^{-2}k^{4}$).
- ε: emissivity, an index worth 1 for a black body and which is between 0 and 1 depending on the surface condition of the material.

- S: Surface area of the body.
- T: temperature of the body (in kelvin).

If the receiving body reflects certain wavelengths or is transparent to others, only the absorbed wavelengths contribute to its thermal balance. absorbed wavelengths contribute to its thermal balance. If on the other hand the receiver is a black body, i.e. it absorbs all the electromagnetic radiations, then all the radiations contribute to its thermal balance.

III.2. Combustion

III.2.1. Definitions

a. Calorific value

The calorific value of a fuel is the energy per unit of mass, released in the form of heat form of heat by the reaction of its combustion. It is expressed in joules per kilogram (J/kg), it can be volumetric and is then expressed in joule per cubic meter (J/m3). In the field of In the field of construction, the unit of energy used is the kilowatt-hour.

The combustion of a fuel (wood, gas, oil, etc.) produces water vapour, This water vapour will later change from a gaseous state to a liquid state and will give off energy, called latent heat of liquefaction [1].

- The gross calorific value (GCV) of the fuel corresponds to the energy produced by the complete combustion of one kilogram of fuel. by the complete combustion of one kilogram of fuel (or 1m3 for gas), taking into account the the latent heat in the water vapor (condensation of all the water).
- The net calorific value (NCV) is the minimum energy available, i.e. it is the energy produced by the complete combustion of one kilogram of fuel (or 1m3 for fuel (or $1m^3$ for gas), without taking into account the latent heat in the water vapour [1].

GCV = NCV + latent heat of evaporation

We can see that the difference between the GCV and the NCV is the latent heat.

And the GCV is always higher than the LHV with a difference of about 10% (this difference varies slightly depending on the fuel: from 8% for wood to 11% for gas).

b. Coefficient of excess air

In practice, the combustion is far from being stoichiometric, it is always carried out with an excess of air so that it remains complete despite the inevitable fluctuations of the proportions of the proportions of the mixture and its heterogeneities.

This excess of air must be low because it decreases the yield, but on the other hand an incomplete on the other hand, incomplete combustion considerably lowers the latter and can also cause soot deposits [1].

A richness coefficient is noted by ϕ represents the ratio between the amount of air actually sent into the furnace noted D_{re} and the quantity of air which is strictly necessary noted D_{st} i.e. :

$$\phi = D_{re} / D_{st}$$

With:

- D_{re}: The actual dosage.
- D_{st}: The stoichiometric dosage.
- If the burner is working at stoichiometry, $D_{re} = D_{st}$ so the richness is equal to 1.
- If the burner works with more fuel than the stoichiometry, the real dosage will be.

If the burner works with more fuel than the stoichiometry, the real dosage will be higher than the stoichiometric dosage, so the richness will be higher than 1.

Conversely, if the burner works with less fuel than the stoichiometry, the richness will be less than 1.

However, some engine manufacturers prefer to speak of excess air coefficient rather than richness [1].

This coefficient (denoted α) is defined as $\alpha = D_{re} / D_{st} = 1 / \phi$.

By definition, Alpha (α) will therefore behave inversely to Phi (ϕ). When the engine runs with more fuel than at stoichiometry (thus with less air), Alpha will be less than 1, and conversely when the burner is operating with less fuel, thus with more air, α will be higher than 1 [1].

c. Smoke power

This is the amount of smoke that results from the neutral combustion of the unit of fuel [1].

There are two types of smoke power

- DRY smoke power : V_{f_o}
- The WET smoke power : $V_{f_{o'}}$

III.2.2. Definition of combustion

Combustion is a complete or partial chemical reaction of carbon and hydrogen of usual fuels by oxidation of oxygen. The essential products of reactions are heat, CO_2, H_2O and also nitrogen (N_2) which theoretically remains neutral in the neutral in the combustion reaction [1].

Combustion + fuel→ $CO_2 + H_2O + N_2$

Combustion can only occur when three elements are brought together: a fuel, an oxidizer fuel, an oxidizer, and an activation energy. This is called the fire triangle.

The aim of combustion in the boiler is to recover as perfectly as possible of the chemical energy contained in the fuel. This chemical energy will be released in the form of heat, a phenomenon known as exothermic, which often appears in the form of a in the form of a flame, this heat will be recovered in the boiler to produce steam [1].

III.2.2.1. Type of fuel

The fuel comes in several forms: solid, liquid or gaseous [1].

- ✓ A gas (butane, propane, town gas, hydrogen...).
- ✓ A liquid (gasoline, diesel, oil, kerosene...).
- ✓ A solid (wood, paper, cardboard, textile, plastic...).

III.2.2.2. The oxidizer

It is generally ambient air (23% $O_2$by volume, 77% $N_2$by volume and some rare gases) [1].

III.2.2.3. Necessary conditions for a perfect combustion

- ✓ A sufficient quantity of air.
- ✓ A complete mixture of air and gas.
- ✓ A sufficient temperature to maintain combustion.
- ✓ A good combustion depends on the application of these conditions [1].

III.2.2.4. the different types or aspects of combustion

There are three different types of combustion [1].

a. Neutral or stoichiometric combustion

The stoichiometric (or neutral) combustion, which is the reference: it is only theoretical, all advanced techniques try to approach it.

This combustion is carried out only with the necessary quantity of air. The fumes corresponding to this combustion are composed of CO_2, H_2O, SO_2 and N_2 (the fumes do not contain oxygen).

b. Complete combustion with excess air

This is a complete combustion in the presence of a volume of air greater than that of the combustion to ensure that all the elements meet oxygen before being evacuated from the furnace. Before being evacuated from the furnace. Thus oxidizing combustion without production of carbon monoxide.

- The excess air adopted with liquid and gaseous fuels is essentially the same and is lower than that required for than that required for solid fuels.
- This type of combustion is found in most industrial applications. It is also This is also the objective to be reached in the field of boilers.

c. Reductive combustion or lack of air

Combustion is said to be reducing (or lacking air) if the volume of air allowed for the combustion of the fuel unit is combustion of the fuel unit is less than the stoichiometric air volume, the oxygen is nevertheless totally used, therefore no oxygen is present in the fumes but there is formation of carbon monoxide CO. As there is a lack of oxygen there will be formation of the solid unburned.

c. Reductive combustion or in lack of air

The choice of fuel for the proposed study is the natural gas of HASSI-R'MEL which is abundant in our country. These characteristics are represented on the following table [5].

Constituents	Volume content(%)
Methane CH_4	82.52
Ethane C_2H_6	7.92
Propane C_3H_8	2.06
N-Butane N- C_4H_{10}	0.48
I-Butane ISO-C_4H_{10}	0.32
N-Pentane N-C	0.11
Hexane+ C_6H_{14}	0.05
Azote N_2	5.2
Hélium H_e	0.15
Dioxyde de carbone CO_2	1.19

Table III.2. Chemical composition of the natural gas of HASSI R'MEL [1].

III.2.2.5. Density of the natural gas

ρ= 0.796Kg/Nm3 [8].

III.2.2.6. Lower heating value (LHV)

LHV=37770.48 kJ/Nm3 [8].

III.2.2.7. Ignition temperature

The ignition temperature or flash point is defined as the lowest temperature at which a substance can be defined as the lowest temperature at which a combustible substance emits sufficient vapors to form, with sufficient vapors to form, with the ambient air, a gaseous mixture which ignite under the effect of a source of calorific energy such as a pilot flame, but not enough for sufficiently for the combustion to sustain itself (for this, it is necessary to reach the point of ignition). If the ignition does not require a pilot flame, we speak of self-ignition.

For HASSI-R'MEL natural gas, the ignition temperature is around 700℃ à 800℃ [8].

III.2.3. Equations of combustion

The combustion reaction is composed of three elements which are carbon (C), oxygen (O_2) and hydrogen (H).

The quantity of oxygen contained in the air admitted in the reaction determines the nature of combustion.

This combustion can be complete or incomplete, the combustion is said to be complete when there is a sufficient quantity of oxygen which oxidizes the various particles of fuel, all the all the carbon of the fuel combines in the form of carbon dioxide (2) and all its oxygen (2) and all its oxygen (O_2) in the form of water vapor (H_20) [1].

In the opposite case, that is to say the quantity of oxygen of the air is insufficient, we will have a part of carbon which will form will have a part of carbon which will form with oxygen the carbon dioxide (2, and the other part will form the carbon monoxide (CO). The chemical reactions that result from the combustion of natural gas HASSI-R'MEL are the following [1]:

$$C + O2 \rightarrow CO_2$$

$$H_2 + \left(\frac{1}{2}\right) O_2 \ \rightarrow H_2\ O$$

$$C_N H_m \ + \ (n \ + \ m/4)\ O_2 \rightarrow \ nCO_2 + (m/2)\ H_2O$$

$$CH_4 + \ 2O_{2\rightarrow} CO_2 + 2H_2\ O$$

$$C_2\ H_6 + \frac{7}{2} O_2 \rightarrow 2CO_2 + 3H_2\ O$$

$$C_3\ H_8 \ + 5O_2 \rightarrow \ 3CO_2 + 4H_2\ O$$

$$C_4\ H_{10} \ + \frac{13}{2} O_2 \rightarrow 4CO_2 + 5H_2\ O$$

$$C_5\ H_{12} \ + 8O_2 \ \rightarrow 5CO_2 + 6H_2\ O$$

$$C_6\,H_{14}\ +\frac{19}{2}O_2 \rightarrow 6CO_2 + 7H_2\,O$$

III.2.4. Quantity of air required $\mathbf{V_a^0}$

It designates the strictly necessary and sufficient quantity of air that must be supplied to ensure the neutral combustion of the fuel unit. (Course Mr Thierry CHASSIN of University Paul Sabatier of Toulouse). The air in the vicinity of the ground is a gaseous mixture homogeneous gas mixture. It is approximately composed in molar fraction or in volume by neglecting the rare gases contained in the atmosphere of 23% oxygen and 77% nitrogen. We consider that the air is taken at a temperature of 25° c and a pressure of 1.01325 bar [9].

Let's consider 1 mole of fuel and find the quantity of oxygen necessary for the combustion of the different components of the considered fuel, and taking into account the table III.2.

III.2.4.1. Combustion of methane$\mathbf{CH_4}$

$$CH_4\ + 2O_2 \rightarrow CH_2\ + 2H_2O$$

1 mole of fuel contains 0.8252 mole of $\mathrm{CH_4}$ so the volume of oxygen necessary for the combustion of this quantity is $\mathrm{V_{O_2}^{CH_4}} = 1.6504$ mole/ mole of fuel [1].

III.2.4.2. Combustion of ethane $\mathbf{C_2H_6}$

$$C_2\,H_6 + (\frac{7}{2})O_2 \rightarrow 2CO_2\ + 3H_2O$$

1 mole of fuel contains 0.0792 mole of $\mathrm{C_2\,H_6}$ so the volume of oxygen necessary for the combustion of this quantity is $\mathrm{V_{O_2}^{C_2H_6}} = 0.2772$mole/mole of fuel [1].

III.2.4.3. Combustion of propane $C_3\,H_8$

$$C_3\,H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

1 mole of fuel contains 0.0206 mole of $C_3\,H_8$ so the volume of oxygen necessary for the combustion of this quantity is / mole $V_{O_2}^{C_3H_6} = 0.103$ mole/mole of fuel [1].

III.2.4.4. Combustion of butaneC_4H_{10}

$$C_4H_{10} + \left(\frac{13}{2}\right)O_2 \rightarrow 4CO_2 + 5H_2O$$

1 mole of fuel contains 0.008 mole of C_4H_{10} so the volume of oxygen necessary for the combustion of this quantity is$V_{O_2}^{C_4H_{10}} = 0.052$ mole / mole of fuel [1].

III.2.4.5. combustion of pentane C_5H_{12}

$$C_5H_{12} + (16/2)O_2 \rightarrow 5CO_2 + 6H_2O$$

1 mole of fuel contains 0.0011 mole ofC_5H_{12} so the volume of oxygen necessary for the combustion of this quantity is$V_{O_2}^{C_5H_{12}} = 0.0088$ mole/ mole of fuel [1].

III.2.4.6. Combustion ofhexane C_6H_{14}

$$C_6H_{14} + (19/2)O_2 \rightarrow 6CO_2 + 7H_2O$$

1 mole of fuel contains 0.0005 mole of C6H14 so the volume of oxygen necessary for the combustion of this quantity is $V_{O_2}^{C_6H_{14}} = 0.00475$mole/mole of fuel [1].

For helium (He); nitrogen (N2) and carbon dioxide 2 remain inert during the reaction so the number of mole of oxygen needed for combustion is :

$$V_{O_2}^{B} = V_{O_2}^{c_6H_{14}} + V_{O_2}^{C_5H_{12}} + V_{O_2}^{C_4H_{10}} + V_{O_2}^{C_3H_8} + V_{O_2}^{C_2H_6} + V_{O_2}^{CH_4}$$

- Then $V_{O_2}^{B} = 2.0961$mole of oxygen / mole of fuel.
- Where $V_{O_2}^{B} = 2.0961$ Nm3 of oxygen / Nm3 of fuel.
- Therefore $V_{air}^{B} = \frac{1}{0.21} * V_{O_2}^{B} = 2.0961$ Nm3 of air / Nm3 of fuel.

III.2.5. Composition of the combustion results

In a stoichiometric combustion reaction the combustion results are carbon dioxide (CO_2), water(H_2O) and the inert gases nitrogen (N_2) and helium (H_e) [9].

The volume of flue gas is given by the following relationship:

$$V_g^0 = V_{C0_2}^0 + V_{H_2O}^0 + V_{N_2}^0 + V_{H_e}^0 \qquad (\frac{Nm^3}{Nm^3})\ of\ fuel$$

III.2.5.1.Volume of the Carbon dioxide 89

As the content of carbon dioxide present in the air is negligible which is the order of $2 * 10^{-4}$ in volume. The volume of carbon dioxide in the general case is given by the following relationship [1] :

$$V_{CO_2}^0 = C0_2 + CH_4 + \sum nC_nH_m \qquad (Nm^3/Nm^3\ of\ fuel.$$

$C0_2, CH_4$ ......: volume contents of the different components of the gaseous fuel given in (%), taking into account the table.III.2 :

$$V_{CO_2}^0 = 0.0119 + (1 \times 0.8252) + (2 \times .0792) + (3 \times 0.0206) + (4 \times (0.0048 + 0.0032)) + (5 \times 0.0011) + (6 \times 0.0005)$$

So: $V_{CO_2}^0 = 1.0978\ Nm^3/Nm^3$ of fuel.

III.2.5.2. Volume of water vapor $\mathbf{H_2O}$ produced $\mathbf{V^0_{H_!o}}$

By neglecting the moisture contained in the air, thus the vapor that we find in the products of combustion comes from the combustion of the hydrocarbons of the fuel. Its value is expressed by the following relation [1]:

$$V^o_{H_2o} = 2CH_4 + \sum (\frac{m}{2}) C_n H_m \quad (\frac{Nm^3}{Nm^3} of\ fuel).$$

$\mathrm{CH_4}$ ... Volume contents of the different components of the gaseous fuel given in (%), taking into account the table (III.1) one will have the volume of the produced water vapor is:

$\mathrm{V^o_{H_2o}}$ =(2*0.8252) + (3 *0.0792) + (4 * 0.0206) + (5 * (0.0048 + 0.0032))+
(6 * 0.0011)
+ (7 * 0.0005).

So: $\mathrm{V^o_{H_2o}} = 2.0205$ $\mathrm{Nm^3/Nm^3}$ of fuel.

III.2.5.3. Volume of nitrogen $\mathbf{V^0_{N_2}}$

The nitrogen present in the combustion products comes from the quantity present in the air and that present in the fuel, thus air and the one present in the fuel, thus [1] :

$$V^0_{N_2} = 0.79 V^0_a + N_2 \quad Nm^3/Nm^3 \text{ of fuel.}$$

With:

0.79: represents the volume percentage of N_2 in the air.
$\boldsymbol{N_2}$ **:** percentage of N2 contained in the fuel.

$$V^0_{N_2} = 7.9374 \quad Nm^3/Nm^3 \text{ of fuel.}$$

III.2.5.4. Helium volume $\mathbf{V^0_{H_e}}$

As helium it is an inert gas, it comes only from the fuel so

$V^0_{H_e} = 0.0015\ \frac{Nm^3}{Nm^3}$ of fuel [1].

Volume of the products of a stoichiometric combustion

Finally the volume of the products of a stoichiometric combustion will be considering the relation

$$\mathrm{V_g^0} = 11.0572 \qquad \mathrm{Nm^3/Nm^3} \text{ of fuel.}$$

In practice, combustion is far from being stoichiometric. And since the mixing of the air supplied with the fuel cannot be completely achieved in reality, it is necessary to supply more air than is theoretically necessary, so the fireplace operates with an excess of air. Therefore the fireplace works with an excess of air [1].

Too much excess air is unfavorable because it reduces the temperature of the fireplace. To extend the range of use of the boiler where the volume of air sucked in by the fans and injected into the fans injected into the furnace, would change for reasons of voltage drop, we vary the value of the excess air the value of the excess air coefficient is varied by the following values: 1,0 ; 1,05 ; 1,10 ; 1,15 ; 1,20 [1].

Chapter IV

Presentation of the MYRA 4000 boiler

Introduction

The boiler on which our study is based is the MYRA 4000 with flue tubes; Note that it is a 3-path boiler in order to have a maximum efficiency. As its name name indicates, its role is to provide a saturated steam flow of 4000⁄ at a working pressure of of 12 bar. The burner used (dual fuel) can make it work with natural gas or fuel oil, which is the ELCO N7 4500 model.

IV.1. Description and operation of the MYRA 4000 boiler

The MYRA 4000 boiler is a cylindrical and horizontal steam boiler, consisting of a smooth inner hearth tube made of sheet metal (through which the flame and the smoke gases circulate) placed at the bottom of the boiler because the fumes move naturally from the bottom to the top and a and an external smoke return box at the back of the boiler which stores the smoke before it the fumes before they are transported by the fume tubes immersed in water, for which we will see later on the temperature [1].

The smoke tubes are divided into two groups; the first one transports the smoke from the return box to the return box to the front of the boiler and the second one carries the fumes from the front of the boiler to the boiler to the chimney. Thus, the heat is transferred from the flue gases to the water. The water is then vaporized and steam is produced which is released from the "steam valve" [1].

It is closed on both sides by tube plates, on which the tubes are welded. The tubes are welded. Doors mounted on both ends of the boiler allow access to the furnace, the tube plates and the the furnace, the tube plates and the smoke return box [1].

The cylindrical casing (shell) also has openings called inspection holes (fist holes on the sides and manholes on the upper generator) to access and inspect the tube bundles and the inner body [1].

The MYRA4000 is protected from the outside to prevent corrosion by anti-rust paint, as thermal and acoustic insulation in the construction by rock wool (material made of mineral fibers that does not propagate fire and is not carcinogenic) 80mm thick (in two layers) and finally with a stainless steel sheet coating 6/10 mm In addition, it also has the necessary safety accessories for its proper operation [1].

It is manufactured in accordance with the regulations, in application in Algeria, relating to the equipment under steam pressure (Decree n° 90/246 of 18/08/1990). It is placed on a steel beam base which makes the elements of the boiler a united block [1].

The boiler with smoke tubes described above with a diagram made with auto-cad allows to produce steam in automatic operation.

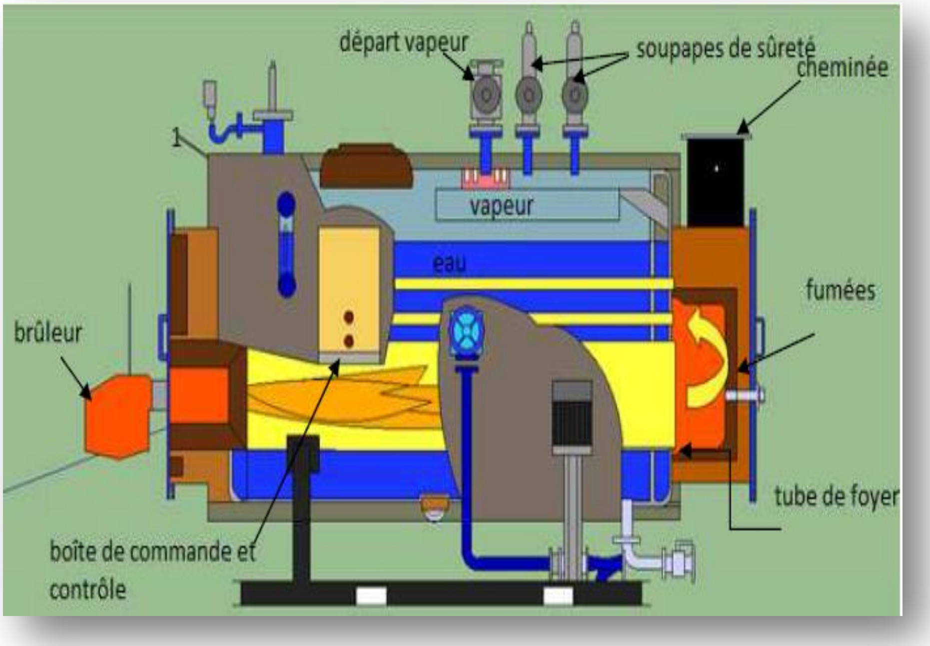


Figure IV.1. Diagram of the main components of the MYRA 4000 boiler [1].

IV.1.1. Main components

IV.1.1.1. Boiler body

The boiler body is composed of [1] :

- A cylindrical body made of boiler quality sheet metal, according to the reference standard.
- A smooth sheet metal hearth, of the same quality, welded on the tube plates and intended to receive the burner with its flame.
- Two pressed tube plates made of sheet metal of the same grade, chosen according to the reference standard, welded to the welded to the body of the boiler.
- Flue tubes of the grade selected in accordance with the reference standard.
- Inspection openings according to the reference standard.

IV.1.1.2. Burner

A burner is a mechanical device which brings together a fuel (oil or gas) and oxygen loaded combustion air in order to allow and regulate the combustion at its outlet. To have a maximum output requires a better adjustment of the mixture. It has therefore a determining role in the quality of combustion, and subsequently in the emission of pollutants or unburned. There are several types of burners depending on the type of fuel (solid, liquid or gas) air burners, modulating operation with the possibility of having a dual fuel burner (gas and liquid) (gas and oil) as in the case of our steam boiler which is equipped with a dual-fuel burner with a high-tech dual-fuel burner of the ELCO type N7 4500 [1].

N : NEXTRON.
7 : size.
4500: power reference.

IV.1.1.3. Water circuit

The boiler make-up water is supplied by a vertical multistage pump installed directly in the pipework. The water is sucked up and delivered to the boiler through pipes with suitable characteristics [1].

IV.1.1.4. Steam circuit

Saturated steam is produced by the heat transferred from the fire tube and flue tubes to the water in the shell. It is directed into the steam pipes with the pressure corresponding to the needs of the user customer [1].

IV.1.1.5. Air and smoke system.

The boiler is started after the first flame torch is triggered. In our case, it is produced by the combustion that has taken place in the burner of natural gas (fuel) + air (oxidizer). These two develop the flame until the maximum flame is reached [1].

In the 1st and 2nd runs, heat is lost as a result of its absorption by the water coming from the tubes. In the 3rd and last path, the temperature of the gases has dropped much more than in the first two [1].

In the third and fourth runs, the heat is lost, as it is absorbed by the water coming from the tubes, but in the fourth run, the heat is lost to the atmosphere through the chimney. For other purposes than our case, the exhaust gases can be used by the superheater to superheat the saturated steam produced [1].

IV.1.1.6. Control and safety devices

- 03 pressure regulation switches 0-17 bar of DAFNOSS brand.
- 01 100 mm dial pressure gauge - scale 0 to 25 bar, glycerine bath pressure gauge type, vertical connection.
- 01 needle valve for manometer flange holder.

- 02 ice level gauges with isolation valves and a purge valve (between axis: 380mm).
- 01 water level regulation and control block made up of a probe with four electrodes (low level, high level, high level) [1].

IV.1.1.6.1. Pressure switches

These are pressure limiters, they are used to transmit the signal to the electrical cabinet in order to cut off the heat supply to the boiler by cutting off the burner, or to adjust the burner stages to save the maximum amount of energy [1].

The MYRA boiler has three pressure switches mounted in series with the pressure gauge on the same manifold, namely [1] :

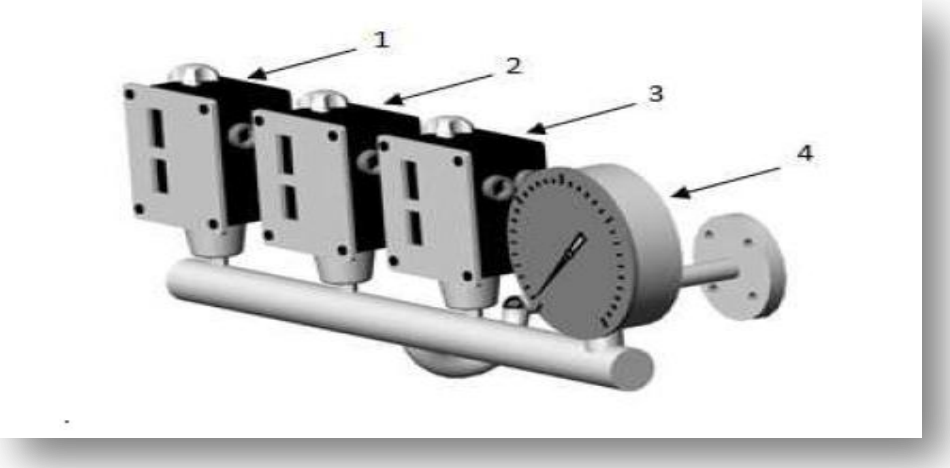


Figure IV.2. Pressure switches [1].

(1) Safety pressure switch: serves to cut off the electric current as soon as the pressure (1) - Safety pressure switch: is used to switch off the electric current as soon as the pressure reaches the working pressure or the pressure gauge (maximum pressure allowed for operation).

(2) Service pressure switch: is used to cut off the electric current as soon as the pressure reaches the pressure desired by the user.

(3) Burner pressure switch: used to adjust the burner settings.

(4) Pressure gauge : placed in the driver's view and graduated to indicate the steam pressure in bars. A very visible mark on the scale of the pressure gauge indicates the limit that the pressure must not exceed [1].

IV.1.1.6.2. Block of probes of water level to electrodes

These are water level sensors inside the boiler, they are used to transmit the signal to the electrical cabinet, in order to proceed with the water level regulation operation.

It is composed of three probes, namely [1]:

- High water level probe: it is used to transmit the signal to the electric cabinet in order to cut off the electric current of the feed water pump.
- The low water level probe: it is used to transmit the signal to the electrical cabinet in order to start the pump.
- The very low water level probe: it is used to transmit the signal to the electrical cabinet in order to cut off the heat supply by cutting off the electrical current to the burner and trigger the alarm. burner and trigger the audible alarm.

IV.1.1.6.3. Safety valves

Each MYRA boiler is equipped with two safety valves. They are of the spring type. They are of the spring type, which prevent any excess pressure according to the reference standard.

Ice water level indicators:
Equipped with two water level indicators, of the refractory safety type.

This device facilitates the visibility of the water level, they are independent of each other, located on the sides of the boiler, arranged in such a way that they can be checked, cleaned and replaced easily and without risk for the operator [1].

There are three marks on the water level indicators [1]:

- ➢ High water level is the level that should not be exceeded and the water pump should stop.
- ➢ Low water level is the level at which the pump must resume supplying water.
- ➢ Very low water level is the level below which the water must not go down under any circumstances.

IV.1.1.6.4. Flame sight glass

A flame sight glass attached to the chimney side door on the side of the burner so that the burner flame can be adjusted [1].

IV.1.1.6.5. Siren

An audible alarm device incorporated with the electrical cabinet which is triggered when the water level is below the very low water level. It also signals faults in the burner. of the burner [1].

IV.1.1.7. Footings (spigots)

- ✓ Steam outlet.
- ✓ Water supply.
- ✓ Sludge draining and extraction.
- ✓ Steam inlet for installation of regulation pressure switches and manometer.
- ✓ Footing for installation of water level electrodes.
- ✓ Steam and water intakes for water level indicators with mirrors.
- ✓ Installation base for safety valves [1].

IV.1.1.8. Command and control panel

It is supplied with the boiler, with the following characteristics [1]

- ✓ Electrical voltage: 3x380 +n.
- ✓ Low level alarm.

✓ Audible alarm for burner failure.

✓ Red warning lights: burner, pump.

✓ Green lights indicating start-up.

✓ Power on light.

✓ Manual/automatic control switches for burner, pumps and generator. generator.

✓ Push button for emergency stop.

IV.1.2. Technical characteristics of the MYRA 4000 boiler

Designation	**MYRA 4000**
Type	Boiler with smoke tube.
Position	Horizontal.
Fluid	Saturated water vapour.
Steam flow rate produced	4000 Kg/h.
Heating power	2560 000 K cal/h.
	2975 KW.
Heating surface	100 m2.
Maximum temperature	175 °C.
Capacity	10020 litres.
Stamp	12 bars.
Test pressure	18 bars.
Outdoor protection	Anti-corrosion: anti-rust paint.
	Heat insulation: rock wool 80 mm thick (in two layers).
	Stainless steel coating 0.6mm.
Space requirement	Length : 5.20 m without burner.
	Width : 2.60 m.
	Height : 3.30 m
Weight when empty	14 000 Kg.

Table IV.1. Technical characteristics of the MYRA4000 boiler [1].

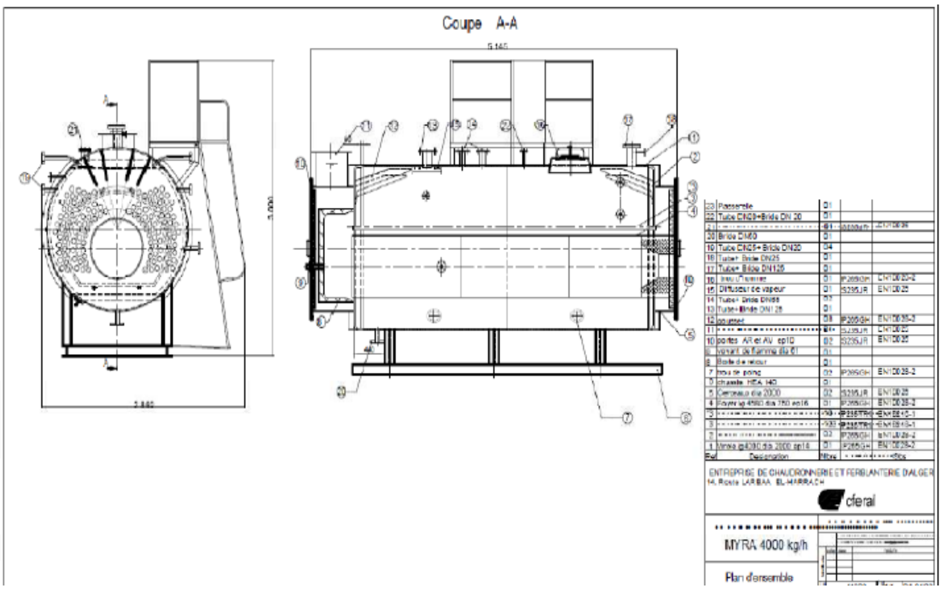


Figure IV.3. Schematic of the MYRA4000 steam boiler with flue tubes [1].

IV.2. Practical training part

During our modest duration of practical training, carried out within the Company of Boilermaking and FERblanterie of ALger (ECFERAL). In what follows, we will quote the most important events noticed and things learned from the practical training [1].

Considering the danger and the volumes occupied by its products and tools; the ECFERAL has of a big workshop where the stages of manufacture take place. It invests to offer the conditions of work to its employees let us quote in priority two lifting lifts (7500Kg ,5000Kg) and entry to the workshop with safety clothing required by the H.S.E. service. (health, safety and environment). The company in all its steps is anxious that its qualified qualified engineers, in persons, to check and follow the stages of realization of the boilers from the design study in their offices, through the manufacturing phase and arriving at the installation and installation and firing at the customer's site [1].

Figure IV.4. Manufacturing workshop [1].

The technical team is motivated and encourages scientific research. that we were allowed to see, to follow the realization of the MYRA4000 and to see other models in progress such as: the boiler with a steam capacity of 1.5T/h, 6T/h, 8T/h with a corrugated hearth; something we have not known before, the manufacture of gigantic and small incinerator and to attend the incineration of some (medical waste) medicines. We had the chance to have an induction of all the company ECFERAL [1].

Figure IV.5. Wavy focus [1].

For the realization of the MYRA 4000, our training course had just begun with the the manufacture of the smooth hearth of the shell and the return box separately.

Figure IV.6.MYRA4000 smooth focus tube [1].

Figure IV.7.return box.

In fact, the tie tubes are used because they contribute to the strength of the steel structure.

The metal plates were ready beforehand to the nearest millimetre, cut with the ultra-modern plasma cutting machine cutting machine, then with the bending machine it was enough to join the ends with precision to get the desired shape, among others (cylindrical) with the desired diameter [1].

Figure IV.8. Shell with tube plates and spigots [1].

After our visit to the store of the company, located in the first big yard, we saw the necessary parts and we saw the necessary parts and accessories that ECFERAL requires to be placed in these boilers boilers such as pressure switches, safety valves and we saw the burner that will be placed on the on the MYRA 4000 on which our work is focused: the dual-fuel burner of the ELCO brand [1].

Figure IV.9. ELCO N7 4500 burner [1].

In our second week of training, the return box, the fireplace and the doors were mounted [1].

Figure IV.10.Boîte de retour, foyer et portes montés [1].

ECFERAL does not leave any detail, the engineers and the technicians in charge of the control of belonging to the company itself, the engineer of the mines depending on the ministry of and mines and the controllers of the ENACT come to check the state of the boiler, in precise stages according to the company with different organizations (IANOR, ISO9001, ISO14001, ISO18001...) in order to give the customer a well finished product. This was done with methods of Non Destructive Testing (N.D.T.) such as the use of thermographic cameras and X-ray which we did not attend for security reasons [1].

After all the parts and safety accessories are mounted, the boiler is lined with rock wool boiler with rock wool: a thermal and acoustic insulating material in two layers then covered with a stainless steel sheet finishing with an anticorrosion paint [1].

Figure IV.11. Boiler lining [1].

ECFERAL ensures the first commissioning and the assistance in any circumstance. We approve it because we were at the customer's place (Le Mercure hotel in Algiers) during the installation of the MYRA4000 but due to time constraints and a problem in the customer's boiler room, we were not present we were not present during the firing [1].

Figure IV.12. Installation of the MYRA4000 boiler at the customer's site [1].

A food tank placed high in the boiler room to supply the boiler with water which explains the natural circulation in the latter.

Figure IV.13. Food tarp [1].

Conclusion

✓ The boiler must be maintained, operated and monitored by a qualified and trained boiler operator. Trained boiler operator.

✓ The customer must ensure that the water circulating in the boiler is treated "lime free". This could pose a dangerous problem for the boiler, its surroundings (fatal) and thus slow down its and therefore slow down its usefulness. A huge hernia as on the picture below or even an explosion.

Figure IV.14. Hernia formed on an old German boiler of the customer [1].

✓ It is suggested to the company to introduce an energy cell, because it was found that there is no thermician in the technical team. The association of the energeticians and the mechanical constructors will possibly lead to make the company's products more ecological than they products more ecological than they are and make them enter the international market [1].

General conclusion

General conclusion

In this project we were primarily interested in boilers in general studying them and classifying them in various ways to allow us to have a global idea on the architecture but also on the operation which has served us a lot.

This study showed how often boilers are needed in industry. Water vapor, because of the advantages it provides, is widely used for heat transport. The fuels used in these boilers are organic in nature, i.e. say they are made of carbon. They contain combustible components (carbon, hydrogen, sulfur) and other components (oxygen, nitrogen, sulfur, etc.).

The nature of the fuel used in a boiler conditions the construction of this boiler. It also influences the mode of operation. One kilogram of water vapor allows to carry around 500kcal. Saturated steam covers the temperature range between 100 ° C and 260 ° C, superheated steam 150 ° C to 550 ° C. Proper treatment of boiler feed water is an important part of the operation and maintenance of the system. The treatment and conditioning of boiler feed water must meet three main objectives:

- ✓ Continuous heat exchange ;
- ✓ Corrosion protection ;
- ✓ High quality production of steam.

External treatment is the reduction or removal of impurities from the water out of the boiler. In general, external treatment is used when the amount of such or such impurities in the feed water is too high to be tolerated by the boiler system in question. There are different types of external treatment (softening, evaporation, deaeration, membrane contractors etc. ...) that can be used for the supply water.

Internal treatment is the treatment of impurities inside the boiler system. The reactions take place in the feed lines or in the boiler. Internal treatment can be used alone or with external treatment. Its purpose is to react properly with the hardness of the feed water, remove sludge, reduce oxygen and prevent foaming of boiler water.

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Summary

In its simplest form, a boiler is a vessel with a large heating surface area of water in which a heat source is used to raise the temperature of the water to a boiling point and produce a limited amount of steam.

We aim through this work to be able to identify the operational difficulties of the boiler and allow adequate maintenance and rehabilitation to renew this equipment and make the necessary future modifications to improve its performance

Résumé

Dans sa forme la plus simple, une chaudière est un récipient avec une grande surface de chauffe d'eau dans laquelle une source de chaleur est utilisée pour élever la température de l'eau à un point d'ébullition et produire une quantité limitée de vapeur.

Nous visons à travers ce travail à être en mesure d'identifier les difficultés de fonctionnement de la chaudière et permettre une maintenance et une réhabilitation adéquate pour renouveler cet équipement et apporter les modifications futures nécessaires pour améliorer ses performances

الملخص

المراجل في أبسط صورة هي عبارة عن وعاء ذو مساحة سطح تسخين واسعة من المياه وفيه يستخدم مصدر حراري لرفع درجة حرارة المياه إلى درجة الغليان وإنتاج كمية محدودة من البخار

الهدف من خلال هذا العمل هو إمكانية تحديد الصعوبات التشغيلية للمرجل والسماح بالصيانة الكافية واعادة التأهيل لتجديد هذه المعدات وإجراء التعديلات المستقبلية اللازمة على تحسين أدائها