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Theme

Experimental investigation of single - basin solar still using solid iron fins for enhancing productivity

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Aknowledgments

(Whoever makes praise the end of grace, God will make it the beginning of more for him.) Praise be to God. I thank God for our success in our academic journey, praise be to God always and forever. May God's peace and blessings be upon our master Muhammad, may God bless him and grant him peace.

I thank my dear and generous parents who gave me moral and material support throughout my academic journey. May God make my resut's work in the balance of their good deeds, Amen Lord. I also thank Mr: BEN OUDINA Belkheir, my persistent and careful supervisor, who performed his role with his presence in the field, and for providing advice and information. We also thank discussing professors on their head, Mr: KHATTARA Abdelouhab and Mr: SEBA Hadj Yahia for accepting to discuss and correct the article. I finally thank everyone from near or far who helped us to release this work by providing information, equipment or lab discussing. I am really grateful

and i thank them very much.

Abderezzak – Mohamed

Dedication

I dedicate this work to my parents, may God protect them, to my brothers, without forgetting Ben Khatta and Daouadi families. My dedication touches also all the professors who taught me throughout my academic career .

Finally, this work is dedicated to colleagues, friends and all those whom my heart loved and forgotten by my pen.

Abderezzak – Mohamed

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِيمِ

اِقْرَأْ بِاسْمِ رَبِّكَ الَّذى خَلَقَ ﴿١﴾ خَلَقَ الاِنسانَ مِن عَلَقٍ ﴿٢﴾ اِقْرَأْ وَرَبُّكَ
الأَكْرَمُ ﴿٣﴾ الَّذى عَلَّمَ بِالقَلَمِ ﴿٤﴾ عَلَّمَ الاِنسانَ مالَمْ يَعلَمْ ﴿٥﴾

سورة العلق

الملخص :

تعتبر مشكلة نقص المياه من المشاكل المؤرقة للكثير من دول العالم، خصوصا أن المياه هو عنصر الأساس للحياة، فلا يمكن للزراعة والصناعة وغيرها من المشاريع الأخرى أن تزدهر وتنمو إلا بوجود المياه، لذلك تعد المياه من أهم مكونات الطبيعة وأكثرها طلبا. كحل لهذه المشكل تقدم هذه الدراسة طريقة بسيطة و غير مكلفة لتحلية المياه هي التقطير الشمسي, إن هذه الطريقة تعاني من عيب كبير و هو المردود الضعيف المقطر, ويجري الآن بنجاح ممارسة تحلية المياه في العديد من البلدان لأن الإمداد بمياه الشرب مشكلة متنامية في معظم أنحاء العالم. وقد اعتمدت الجزائر بشكل عام عمليتين لتحلية المياه (عمليات الأغشية وعمليات التقطير (التي تتطلب تغيير المرحلة، التبخر / التكثيف). ولرفع مردود المقطر الشمسي قمنا ب 3 تجارب باستخدام زعانف حديدية مختلفة من نوع (14-16) في كل تجربة و بأعداد مختلفة في كل مقطر شمسي. نستعمل 4 مقطرات شمسية . كما يحتوى كل مقطر شمسي على 3 من المستشعرات الحرارة و رطوبة من نوع DHT11 و 2 من المستشعرات حرارة مقاوم للماء من نوع WATERPROOF DS18B20. و مستشعر للصوت ULTRASON. **التجربة 1:** نستخدم الزعانف (14) مقطر شمسي الأول يحتوي على ماء فقط والمستشعرات هو كشاهد فقط. المقطر الشمسي الثاني على 3 زعانف حديدية طول زغنف الواحد 50 سنتم. المقطر الثالث يحتوى على 6 زعانف حديدة . المقطر الرابع يحتوى على 9 زعانف حديدية . **التجربة 2 :** نستخدم الزعانف (16) نقوم بنفس التجربة فقط تغيير في نوع الزعانف الحديدي من 14 إلى 16 . **التجربة 3 :** نستخدم الزغانف (16) مع الزعانف (14) نقوم بنفس التجربة نضغ في حوض الاول الماء فقط شاهد و الحوض الثاني فيه 9 زغانف 14 والحوض الثالث في 9 زغانف 16 الماء مستعمل 2.5 لتر في كل حوض. أثبتت تجربتنا فعاليتها في المردود المقطر بشكل جيد

الكلمات المفتاحية : التقطير الشمسي – المردود – التبخر – التكثيف - زغانف الحديدية – الرطوبة – فعالية .

Abstract

The problem of water shortages is a problem that haunts many countries of the world, especially since water is the foundation of life, agriculture, industry and other projects can only flourish and grow with water, Water is therefore one of nature's most important and demanding components. As a solution to this problem, this study offers a simple and inexpensive way to desalinate solar distillation, This method suffers from a major disadvantage, which is the poor distilled yield, desalination is now practiced successfully in many countries because drinking water is a growing problem for most regions. Algeria adopted generally two desalination processes (membrane processes and distillation processes (which require a phase change - evaporation / condensation), To raise the yield of the solar distiller, we have conducted 3 experiments using different iron rods of the type (16-14) in each experiment and in different numbers in each solar distiller, . We use four solar distillations. Each solar distiller also contains 3 DHT11 heat sensors and 2 WATERPROOF DS18B20 waterproof heat sensors, Ultrason sound sensor. **Experience 1:** We use the penis (14): The first solar distiller contains only water and the sensors is as a witness only, The second solar distiller on 3 iron bars, the length of one penis is 50 centimeters long , The third distiller: contains 6 iron bars. The fourth distiller contains 9 iron bars. **Experience 2:** We use penis (16): We only do the same experiment change in the type of iron penis from 14 to 16. **Experience 3:** We use penis (16) and (14) toghter We do the same experiment the first basin is a witness. The second basin contains 9 type 14 fins and the third basin contains type 16 fins.and the amount of water used 2.5 liters. Our experience has proven to be effective in well distilled yields and the results were:

Keywords: Solar distillation - yielding - Evaporation - condensation - Iron bars - Humidity - Efficiency

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Nomenclature

Symbole	designation	unit
m_d	Mass flow of distilled water	Kg/s
L_y	Latent heat of vaporization	J/KG
G	Global solar radiation	w/m
S	glass surface	m^2
η_i	Internal efficiency	%
η_g	Transmission coefficient of the glass	/
η_e	Coefficient of water transmission	/
α_w	Water absorption coefficient	/
α_f	Coefficient of absorption of the bottom of the distiller	/
α_t	Fictitious absorption coefficient of the distiller	/
F.P.B	Gross performance factors	/
F.P.H	Hourly performance factors	/
F.P	Performance factor	/
Q_W	Thermal flux actually received by the body of water	w/m2
Q	Heat flux density	w/m^2
$Q_{re\ g}$	Radiation heat flux between the water film and the glazing	w/m^2
$Q_{ce\ g}$	Convection heat flux between the water film and the glazing	w/m^2
Q_{Evp}	Evaporative-condensation heat flux between the water film and the flux glazing	w/m^2
Qc.d.b_iso.	Conductive heat flux between the tank and the thermal insulator	W/m^2
Q_{cd}	Heat flux lost by conduction of the tank	W/m^2
Pe	Power absorbed by the water table, it is negligible for seawater	w
H_{evap}	Transfer coefficient by evaporation-condensation between the water film and the glazing	W/m^2C°
λ_{tcg}	Thermal conductivity of the glass	W/m c°
Gh	Incident solar power	W/m^2
V	wind speed	m/s
K	Thermal conductivity of the fluid (water)	W/ (m.K)
L	length	m
S g	Sensor area (glass area)	m^2
h	Heat transfer coefficient	$W/(m^2.K)$
M	Condensate mass	KG
P	Saturation pressure	Pa
Tem	temperature	C°
OT	Temperature difference	Δt

T_w	Water temperature	C°
T_g	Glass temperature	C°
ε_w	Water emissivity	/
ε_g	Emissivity of the glass	/
ξ	Steffan's constant – Boltzman	
g	Gravitationnel field = 9.81	m/ s^2

GREEK LETTERS

α	**absorption coefficient**	m^2/s
β	Coefficient of thermal expansion of the fluid (water)	1/K
ε	Emissivity coefficient	/
τ	Transmission coefficient	/
μ	Dynamic viscosity of the fluid (water)	Kg/(m.s)
ρ	Density of the fluid (water)	Kg/m^3
δ	Thickness (glass)	m
ϑ	Variante Thêta	/
σ	Stephane–Boltzman constant = 5.6697×10^8	W/(m^2 .k^4)
γ	Gamma	/
θ	Thêta (Angular)	/
ω	omega	/
φ	phi	/
λ	Length of absorbent tank	

DIMENSIONAL NUMBERS

Gr : **Number of GRASHOF**	Gr= $\frac{\beta g \rho^2 L^3 \Delta T}{\mu^2}$
Pr: **Number of PRANDLT**	$\mathbf{Pr} = \frac{\mu Cp}{K} = \frac{\nu}{\alpha}$
Nu: **Number of NUSSELT**	$\mathbf{Nu} = 0.27\,(GrPr)^{0.25}$

Indexe

A	**Ambient**	C°
B	basin	
C	Convection with Q and condensate with m	
Evap	Evaporation	
g	glass	
W	Water	
I	insulator	
R	radiation	
cond	conduction	
conv	convection	
Eff	Effectif	
w- g	Water - glass	
w-t	Water - tank	
C	Specific Heat Capacity	J/(kg.K)
C_p	Specific heat	J/ (kg.K)

DSSS	Double slope solar still
U_I	Overall coefficient of thermal losses of the insulation
i	interest rate
n	Economic life of the investment
T	Time
Dis	Distiller
T_y	Year
T_0	Sunrise time
T	Sunset time

General introduction

General introduction

Globally, the demand for good quality drinking water is growing. Indeed, the population is growing rapidly and the water needs of industry and agriculture are increasingly high. To meet this demand, desalining is now practiced successfully in many countries of the Middle East, North Africa, the southern and western United States and Southern Europe to meet industrial and domestic needs. The supply of drinking water is a growing problem for most parts of the world. These days, in a number of countries, including western India islands, Kuwait, Saudi Arabia, Mexico and Australia, this type of distillation units exist. At the local level, Algeria has the largest solar deposit in the Mediterranean basin, it is subject to unfavourable physical and hydro climatic conditions, accentuated by periods of chronic drought. Observed climate change and decades of drought in North Africa have had a negative impact on water resources. Faced with this problem, Algeria has generally adopted two desaling processes (membrane processes and distillation processes (which require a change of phase - evaporation/condensation) the latter is the subject of our study.

Currently solar distillation is the subject of several research laboratories around the world and each research team tries to make studies to improve the efficiency of distillation systems by playing on geometric and meteorological parameters. Despite the diversity of research and the different techniques used, the researchers have the same objective: to improve the productivity of solar distillers. The main objective of this work is based on a purely experimental study and the design of 04 solar greenhouse distillers to obtain distilled water that can meet the drinking water needs of a Saharan community. This work will respond quite clearly to problems in the process of solar distillation.

- What is the most favorable season for solar distillation?
- Does double glazing have a positive or negative impact on distillation?
- To what extent is the influence of a refractor on distillation?
- If black insulation is used, what will be the production of distilled water from solar distillation?

This work consists of 4 chapters :

CHAPTER I: Bibliographic And Generalities About Solar Distillation

This chapter is devoted to the presentation of general knowledge on solar distillation, as well as a brief illustration of some types of distillers.

CHAPTER II: The Physical Phenomena Associated With Solar Distillation

This chapter devotes general knowledge about the physical phenomena (Conduction-Convection- Radiation) that occur inside and outside the solar distillery to get (evaporation/condensation).

CHAPTER III:Technology And System Control Of Arduino

This chapter explains the use of technology and the use of the Arduino Mega 2560 card in an experiment to record our values and curves throughout the day.

CHAPTER IV: The Exprimental Study Of Solar Distillation And Results - discussion.

This chapter presents the preparations for 3 solar distillation experiments. Each experiment has 4 solar distillations. We do this in the summer, from sunrise to evening , And show results and discussion.

CHAPTER I

BIBLIOGRAPHIC AND GENERALITIES ABOUT SOLAR DISTILLATION

I.1 Introduction

Solar distillation has become a very common phenomenon both domestically and industrially. Every year thousands of distillers are designed around the world for different purposes either personal use or in research laboratories for academic studies.

Algeria has the largest solar deposit in the Mediterranean basin. The average duration of sunshine in The Algerian territory exceeds 2000 hours per year, reaching nearly 3,500 hours of sunshine in the Sahara Desert. According to S. Nafila [1],

The first distiller in Algeria dates from 1953 designed by Mr. Cyril Gomélab to understand this phenomenon, we need to have a complete idea of the factors that play into distillation. This chapter gives first a brief bibliographical study on solar distillation and secondly it explains some important definitions, it also shows some of the most common solar distillers are those of the greenhouse type; they have the advantage of being simple, easy to make, inexpensive and ultimately it explains some factors that influence distillation.

I. 2 Definition of the solar distiller :

Solar distillation is a technique that uses solar radiation to heat brackish water in a tray covered by a slanted glass [OUT 2006]. The salt water in the bin will heat up (especially as the basin is black) and with the increase in temperature some of the water evaporates and the water vapour liquefies on the inner surface of the transparent glass. Eventually drops of water will form, run on the surface of the glass and fall into the waste picker located in the corner. The basin should be regularly cleaned to remove salt, see figure above (Figure 1-1).

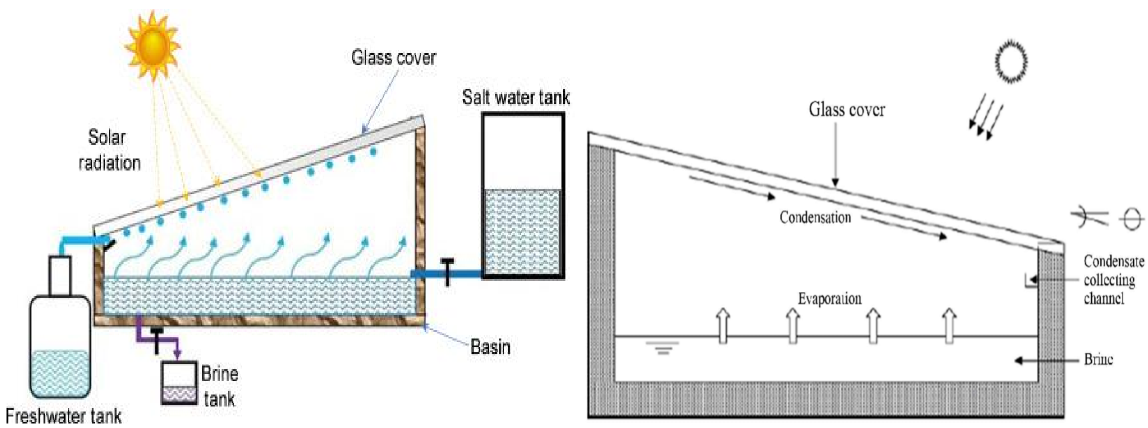


Figure I-1 : Building and operating principle

a single solar distiller (Source [EKO 2006] and [OUT 2006])

I.3 A brief bibliographical study

Currently, solar distillation is the subject of several research laboratories around the world and each research team is trying to do studies to improve the performance of distillation systems by playing on geometric and meteorological parameters.

I.3.1 Nationally

Several laboratories in Algeria and researchers have started the field of solar distillation and each with objectives that sometimes come closer but differ in the way to do it. Cite some recent studies as an example. De Bellel et al. (2015) [2], which conducted a study on the production and simulation of a greenhouse waterfall solar distiller for the production of distilled water. Figure 1.1 represents the sketch of its realization and Figure 1.2 represents the variation in the amount of the cumulative distillate

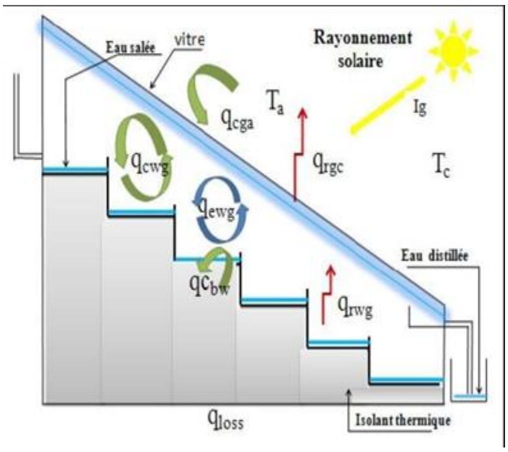


Fig I-2 : Solar waterfall distiller

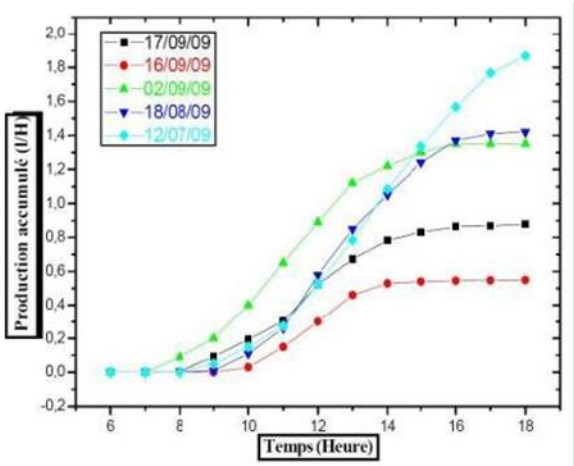


Fig I-3 : Change in the amount of distillate

It has resulted in the daily yield of its solar distiller is about

1.8 litres per day for an absorbent surface of 0.436 m2.

- Fedali (2011) [3] conducted a theoretical and experimental study of a Solar Distiller under the climatic conditions of Batna.

Figure 1.3 represents the sketch of its realization and Figure 1.4 represents the variation in the temperature of the basin water.

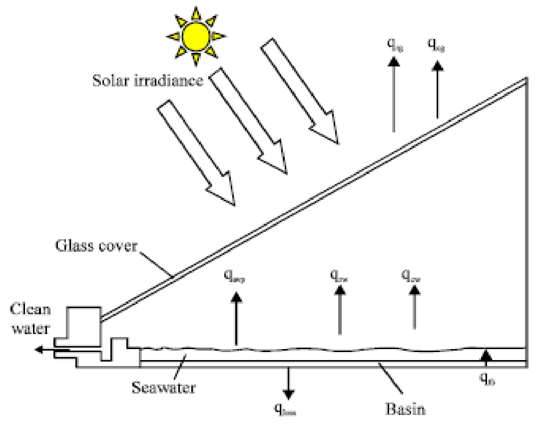


Figure I-4 : Solar distiller

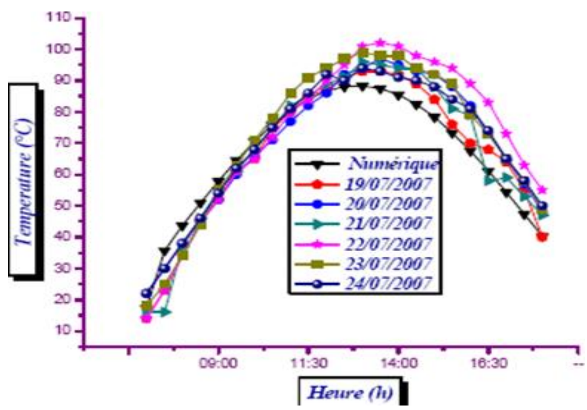


Figure I-5: Change in water temperature

It arrives at a daily yield of 2.5 litres per day for an area of the absorbent of 0.54 m^2 The numerical results found are consistent with the experimental results.

- Tahri's study al. (2010) [4], focuses on the concept combining the greenhouse with the desalination of seawater. The main objective of this research is to analyze the production of fresh water using solar energy in desalination of seawater in the greenhouse.

Figure I-6 depicts the installation sketch and Figure I-7 shows the Wind speed in the greenhouse.

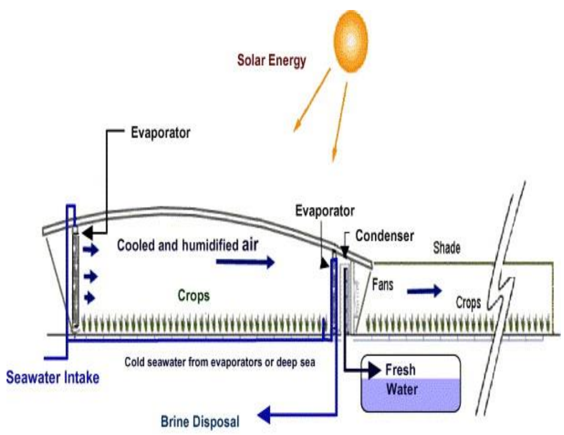


Fig I-6 : Principle of desalination of seawater In the greenhouse

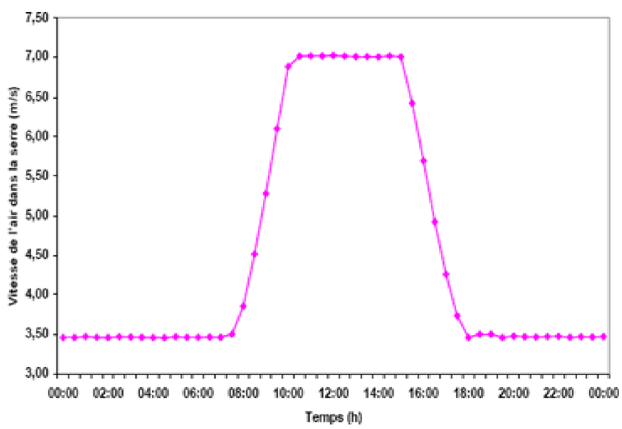


Fig I-7 : The change in Wind speed in the greenhouse

They concluded that the three parameters (solar radiation, air temperature and relative humidity in the greenhouse) directly affect the flow of the condensate, which peaks between 08:00 and 18:00 h.

- At the University of Ouargla, Mr. Bouchekima 2003 [5-7], has created a small underground geothermal water desalination plant in the arid regions south of Algeria, His studies aim to improve the performance of a solar distillation station under real insulation. The solar station has a daily capacity of more than 15 l/m2.

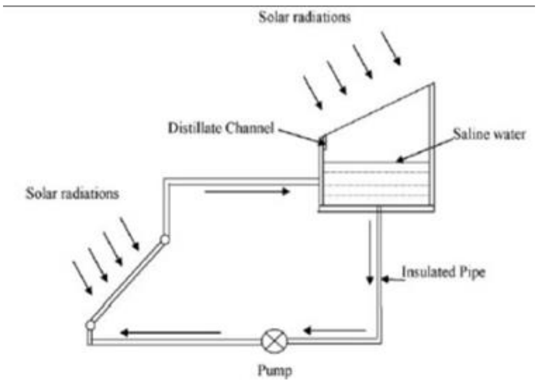
I.3.2 Globally

Global studies and experiments are constantly progressing and every day articles are published in different newspapers to launch a new method or technique. Quote a few recent studies:

- M. Shashikanth And al. (2015) [08], is interested in using Sodium Sulfate as a storage medium to improve the performance of the solar distiller. Figure I-8 depicts the sketch of its distiller and Figure I-9 represents the variation in water temperature in the distiller.

He observed that temperatures are higher in all parts of the distiller if he uses Sodium Sulfate as a storage medium

- Another job the Mardlijah And al. (2015) [09], involves studying a solar distiller and then doing mathematical modeling using Runge-Kutta's numerical method. Figure 1.9 depicts the sketch of its distiller and Figure I-10 represents the comparison of the distiller's indoor water temperatures with and without the solar sensor.



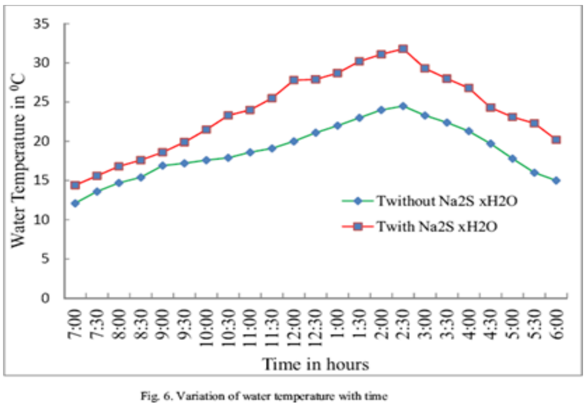


Fig I-8: Solar distiller with solar sensor ' Fig. I-9: The variation in the distiller Water temperature

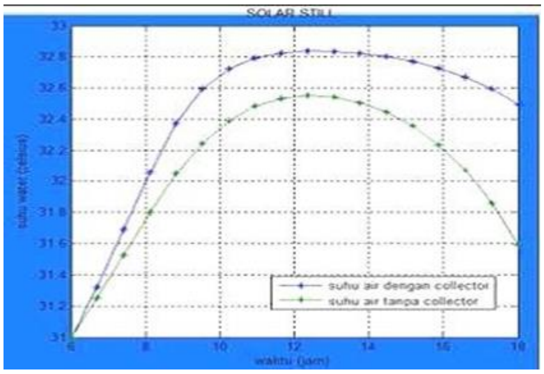


Fig I-10: Comparing the distiller's indoor water Temperatures with and without the solar sensor

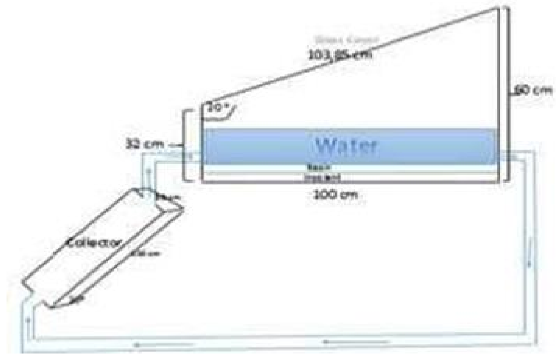


Fig I-11: solar device with solar sensor

As a conclusion, he observed that the distiller's production without the sensor is 4.54109 liters in 12 hours of sun exposure against the distiller with the sensor produced 8.8289 liters.

• The work of Koilraj and al (2011) [10], aims to analyze and compare evaporation rates and the condensation rate of a solar distiller with nanofluids and the other with conventional water. Figure 1.11 represents the sketch of its distiller and Figure 1.12 represents the comparison of the distiller's water productivity with and without the nano fluids.

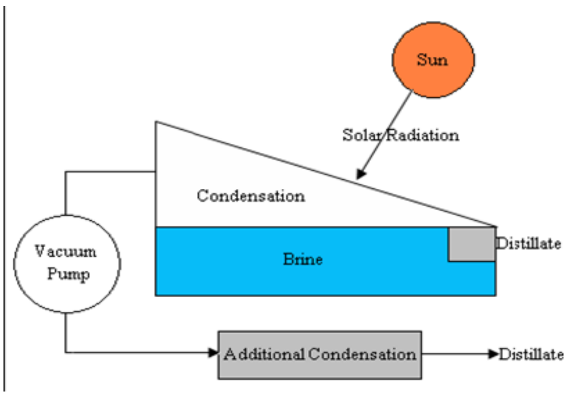


Fig I-12: Solar distiller for nano-fluids

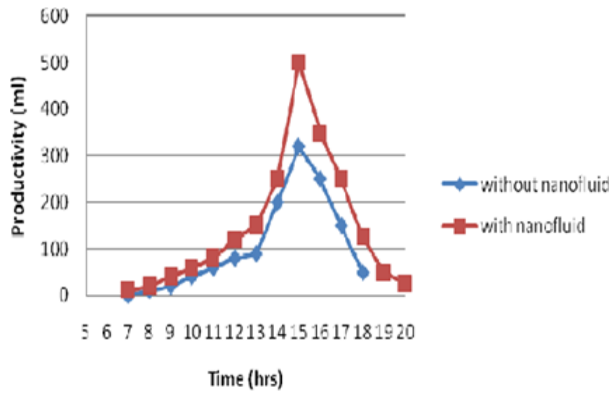


Fig I-13:distiller's water productivity With and without the nano fluids

The conclusion of his work is that water productivity is higher and faster in the solar distiller containing nano fluids.

• On the other hand Murugavel et al. (2006) [11], are interested in studying the effect of transmittance of different thickness (2 to 6 mm) of the glazing of a solar distiller. So, Elango et al. (2015) [12], are interested in the variation of the depths

Water 1 to 5 cm in both isolated and non-isolated conditions. The depth of 1 cm gives maximum productivity compared to other depths.

- Finally, the study by Arunkumar and al. (2015) [13], presents a modification of a parabolic solar concentrator into a solar distiller using a storage tank to increase the productivity of distilled water.

I. 4. History of solar distillation:

Since prehistoric times, the sun has been drying food and evaporating seawater to extract salt so people started thinking to find ways to use this energy. During the nineteenth century, many attempts were made to convert solar energy into other forms that depended on the generation of vapor with low pressure. to run vapor machines

The scientist (Archimede) made the first breakthrough in the field of using solar energy by inventing glass material, where he was able to exploit it in the manufacture of lenses and mirrors to contribute to the exploitation of these solar radiation. It was the first actual exploitation of solar energy in the field of distillation by the English scientist (Harding) in 1872 in the North Chilean desert (LAS SALINAS). [14]

In the year 1950, research started heading towards improving the techniques of obtaining fresh water using solar energy, and using solar distillers, which have multiple types. Research is still underway in designing a study of new types of solar distillers. In 1965, Florida decided to build four solar distilleries. [15]

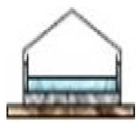
In 1980 Wibulswas and his group studied cylindrical solar distillers with vertical absorption and evaporation surfaces with a diameter of 0.1m and a height of 1m covered with a cylinder of 0.3m diameter and obtained daily productivity of up to 1.7 l / m2 where the solar radiation rate was 17 MJ / m2d. [15]

In 1987, the researcher (Kiatsiriroat) and his group presented an analysis of evaporation and absorption in the one-side distillates as well as the distillates with two sides covered with glass, the theoretical results were completely consistent with the practical results, then they simulated the performance of the distillator for a whole year and for different distances between the absorption surface and the glass cover.

In 1998 (A. EL-Sebaii) studied the factors affecting the productivity of the vertical solar distiller and found that the productivity increases with increasing Wind speed (to some extent) and decreases with the increase of the distance between the absorbent surface and the glass cover . The productivity increases with increasing the distillation area down to 3.5m2 [15]

In 2004, the researchers (M.Boukar and A. Harmim) studied the factors affecting the performance of the vertical solar distillers under desert climatic conditions, and they found that productivity depends closely on the intensity of the solar radiation and the temperature of the atmosphère and on the direction and obtained productivity ranging from (0.5-2.3). L m2 [15]

In 2008 in the Egyptian city of Alexandria, the researcher (Kabeel) studied the performance of the filament solar distillate. This distillate has a concave basin with four transparent covers forming a pyramid above the concave basin in order to increase the entry of solar radiation to it, where the average productivity 4l/m2and the system efficiency 38%. [16]

The place where the achievement was made	Achiev-ement	Productivity L/ m2 /j	Productivity L/jour	Solar radiation W/m2	The Shape used in the achievement
Muresk(Australia)	1966	4.03	2.2	246	
Coober (Pedy)	1966	3.987	3.22	246	
Caiguna	1966	4.03	-	246	
Hamelin (pool)	1967	3.87	-	-	
Las Salinas(Chili)	1872	3.99	-	-	
Bhavnagar(India)	1965	-	1.5	-	
Aldabra(Ind.ocean)	1969	3.8	-	250	
Bakharden(USSR)	1969	4	1.75	-	
Shafrikan (USSR)	1970	4	1.75	-	
(Natvidad Mexico)	1969	-	0.41		
Chakhmou (Tunisia)	1967	1.8	0.75		

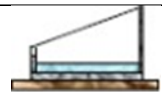
Mahdia	1968	5.23	4.48	400	
Haiti(Caribbean)	1969	4.03	0.81		

Table I-1: The following Table is characterized by the development of the productivity of some distillates throughout history

I. 5 Definition of the solar distiller:

Solar distillation is a technique that uses solar radiation to heat brackish water in a tray covered by a slanted glass [OUT 2006]. The salt water in the bin will heat up (especially as the basin is black) and with the increase in temperature some of the water evaporates and the water vapour liquefies on the inner surface of the transparent glass. Eventually drops of water will form, run on the surface of the glass and fall into the waste picker located in the corner. The basin should be regularly cleaned to remove salt, see figure above (Table I-1).

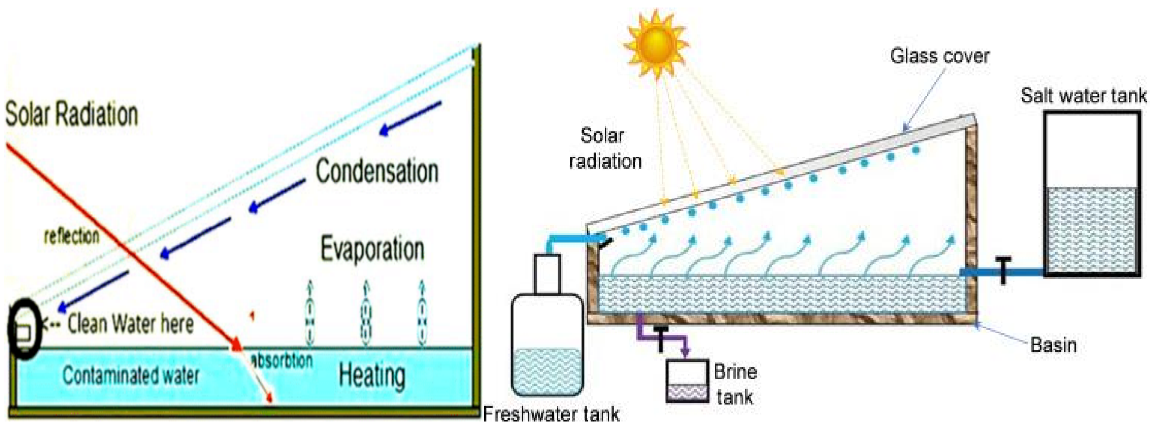


Figure I-14 : Building and operating principle

a single solar distiller (Source [EKO 2006] and [OUT 2006])

I. 6 Generality on Solar Radiation :

I. 6.1 The sun

The sun is a gaseous sphere, its diameter of about 1.39 × 109 m, and its mass is in the order of 2 x 1030 kg, its age is about 4.6 x 106 years, its average distance to the earth is 149500000 km, this star is the seat of thermonuclear reactions transforming every second 564 million tons of hydrogen into 560 million tons of Helium and the 4 million tons whose sun is also lightened every second are transformed dispersed in the form of radiation. The temperature of the heart is around 107K while the sun's surface temperature is 5760 K

I. 6.2 The Earth

The earth moves around the sun of an ecliptic trajectory, the complete revolution takes place in a sidereal year of 365 days 6 hours 9 minutes, 10 seconds. This revolution varied the relative durations of day and night to the rhythm of the seasons limited by the two equinoxes and the two solstices.

- Spring Equinox is March 21
- Autumn Equinox corresponds to September 23
- Summer Solstice corresponds to June 22
- Winter Solstice corresponds to 22 December

The distance between the sun and the earth can be calculated by the following relationship:

$$\mathrm{d(n)} = 1 - 0.017\cos\left[\frac{360}{365}\,(\mathrm{n}-2)\right] \qquad (\mathrm{I}.1)$$

d (n): Given in AU.

n: is the number of the day in the year counted from 1^{st} January.

I. 7 Principle of solar distiller :

The solar distiller is the oldest and simplest desalination process since it uses the energy of the sun to distill water. This process also removes impurities such as salt, heavy metals and micro- organismes The solar distiller consists of a closed glass greenhouse exposed to the sun. The water to desaler is carried into the greenhouse, the thickness of the water being a few centimeters. Solar "UV" radiation passes through the glass roof and is absorbed largely by water and the bottom of the tray, to be converted into thermal energy. The interior of the greenhouse heats up and emits "IR" radiation. Because the glass is opaque to the "IR" rays, this radiation cannot come out and its energy causes the temperature of the greenhouse's indoor air to rise, overheated and saturated with water vapour, which eventually condenses on contact with the glass wall. The condensate (fresh water) descends by gravity along the wall to be collected at the bottom of the glazing [18].

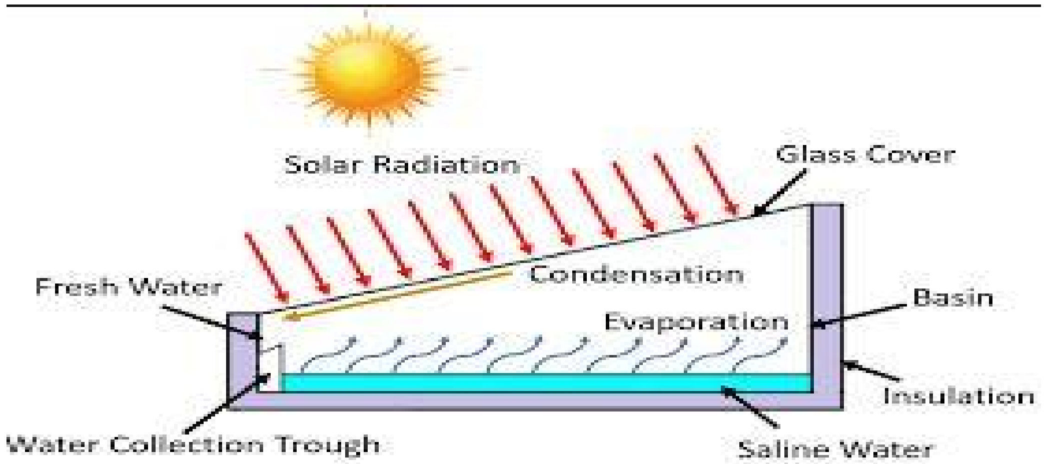


Figure I-15: Single greenhouse solar distiller [8]

I. 8 Types of solar distillers:

I. 8.1 Simple distiller :

It is the most used distillater in the world. It contains a basin with a black-coated base for capturing the largest amount of solar radiation. This basin is filled with water and covered with a transparent glass. The glass cover should be tilted to condense the vapor in its inner part. The simple distiller is distinguished by its ease of construction and maintenance, as well as its small cost, but its main disavantage is its poor production of water for distilled water. [4]

I. 8.1.1 Single slope distiller :

It is the simplest solar distiller ever. Any middle-level person can manufacture and maintain its components. See Figure I-2. [4]

The solar distillate consists of one of the following:

Wooden box-Glass cover- Water collecting tube-Water collecting vessel

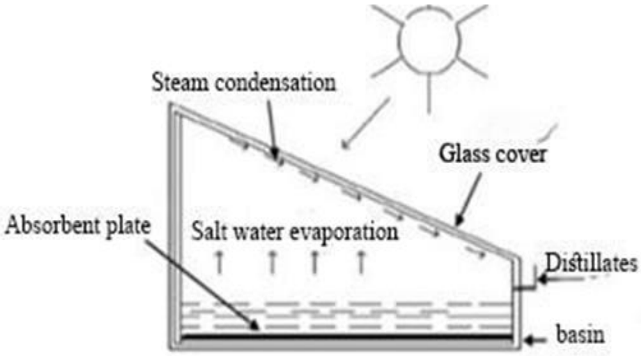


Figure I-16: single slope distiller [4]

I. 8.1.2 Double slope distiller :

It has the same principle as the single slope distiller, except that it has two covers, each one at an angle β among its advantages is that one of the covers is directed to the sun and the other is directed to the shade to increase the area of solar radiation capture and to accelerate the condensation process. [4]

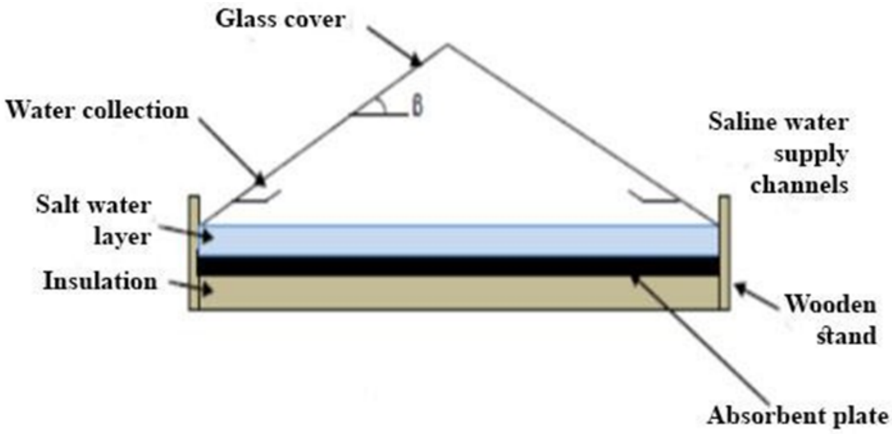


Figure I-17: double slope distiller [4]

I. 8.2 Solar distiller Earth-Water :

A large quantities of moisture are stored in the ground to return to the atmosphere in dry areas during the hot season to complete the natural hydrogen cycle; For this, we use the solar distillater (Earth - Water) which resembles the double slope only replacing the black basin with Earth. [5]

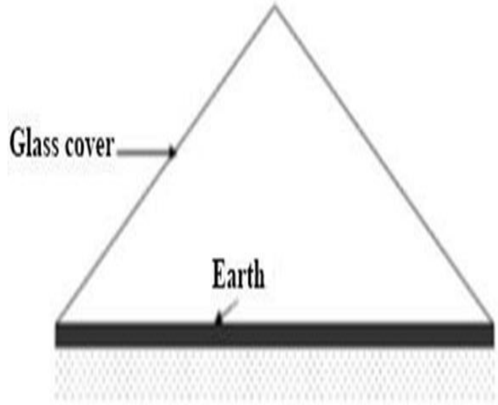


Figure I-18: solar distiller earth- water [5]

I. 8.3 Distiller water pyramid :

The Dutch company (AAWS) has developed a "water pyramid" (Water Pyramid) (Figure 1.19) that can be installed in countries where water as it is is generally unfit for human consumption, a system with an area of 600 m2, will produce a maximum of about 1,250 litres of distillate daily.

Figure I-19: Distillateur water pyramid

I. 8.4 Spherical Solar Distillater :

The spherical solar distiller is in the form of a transparent ball made of glass inside it contains a circular basin that has a black color that works as a thermal radiation absorbent in which salt water is placed to evaporate and then the condensation of vapor to rise until it touches the inner surface of the glass and then collect at the bottom of the spherical shape and to make the inner glass transparent we use a scanner electrician. [4]

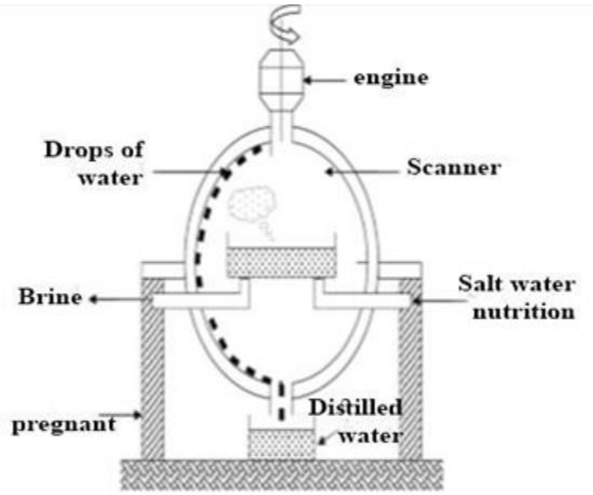


Figure I-20 : The spherical solar distillation [4]

I. 8.5 Solar vertical distillation:

The vertical solar distillers consist of an aluminum absorption plate covered with a black cotton cloth. The distiller is feeded with salty water to be distilled from a main tank connected to the distiller by a plastic tube whose flow rate is controlled by parameters. Salt water is introduced into the vertical distiller through the tube in the upper channel with a specific depth in which the upper end of the black cotton cloth is to be saturated with water. Due to gravity and water absorption of the cloth, the entire piece is wet with water, distributed almost evenly and subjected to vaporization, then the vapor condenses on the inner surface of the glass and the water is descended to the water collection channel (Figure I-6).

The excess water from evaporation collects in the lower channel where the lower end of the piece of cloth is located to help also wet the cloth from the bottom and its rise with the capillary properties feature. In addition, it comes out of the excess salty water exit tube attached to the lower channel. [5]

A) _Vertical solar distillers witn one side

B) _ the vertical solar distiller , with two sides

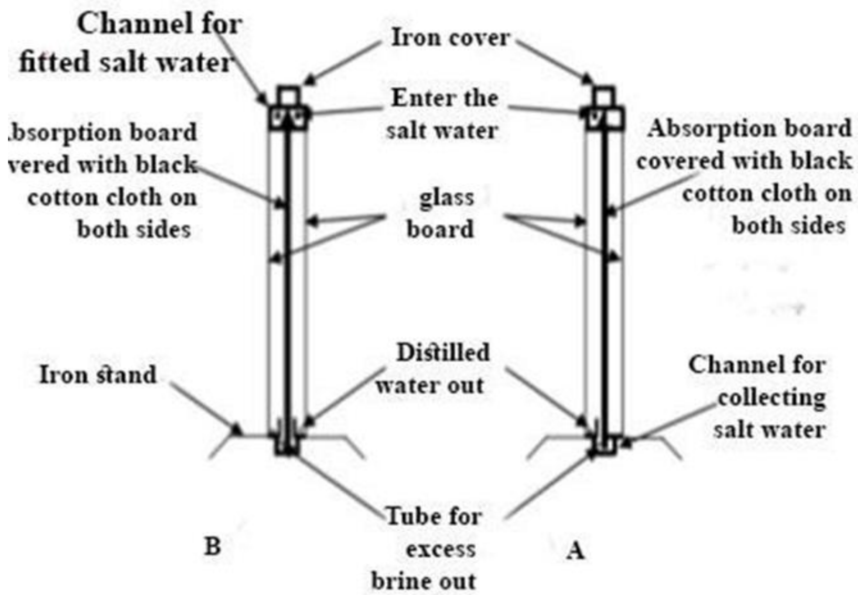


Figure 1-21: vertical solar distiller [5]

I. 8.6 Concentration Distiller :

Concentrated solar distillers operate on the principle of concentration and reflection of the sun's rays. They use a reflective surface whose shape allows the reverberation of energy to be concentrated at the same point. Many models of reflectors exist:

- **Cylindro-parabolic** : this geometry allows a linear focus, it is used in the case of vacuum tube collectors or Luz type solar thermal power plants.

Figure I-22: cylindro-parabolic concentrator

❖ **Spherical**: the spherical reflector concentrates solar radiation on a moving linear focus carried by a radius of the sphere oriented towards the Sun.

Figure I-23: spherical concentrator

❖ **Parabolic**: this is the most used type of geometry. It allows the light rays to be concentrated at one point to obtain very high temperatures. It is often used in the case of solar cookers or coupled with a Stirling engine

Figure I-24: parabolic concentrator

❖ **Plan**: the reflector plane is usually mobile in order to follow the Sun, then we speak of heliostat plane. This system is used in the case of solar thermal power plants in turn or coupled with a parabolic mirror as in the case of Odeillo-type solar furnaces

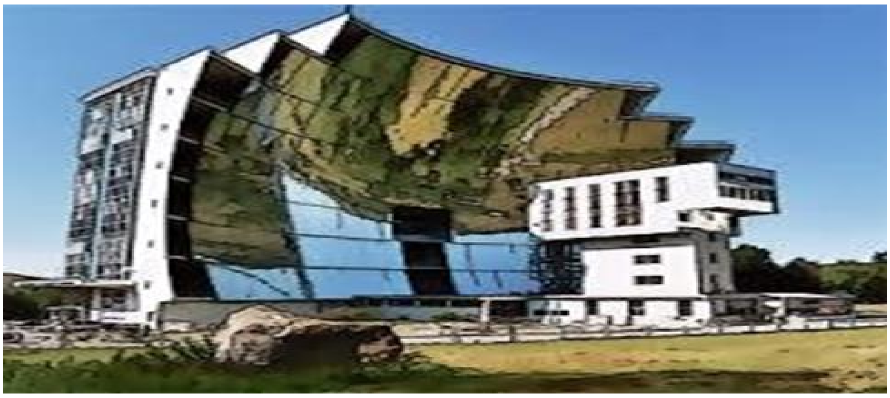


Figure I-25: The Solar Oven

I. 8.7 Waterfall Distiller:

A solar waterfall distiller consists of a waterproof capacity surmounted by a glass (Figure 1.21), the same principle applied in a plan distiller, except that the absorber has a cascading shape. The salt water poured into the distiller is spread over several small basins, so if the water mass is low, the water heats up faster and evaporates [23].

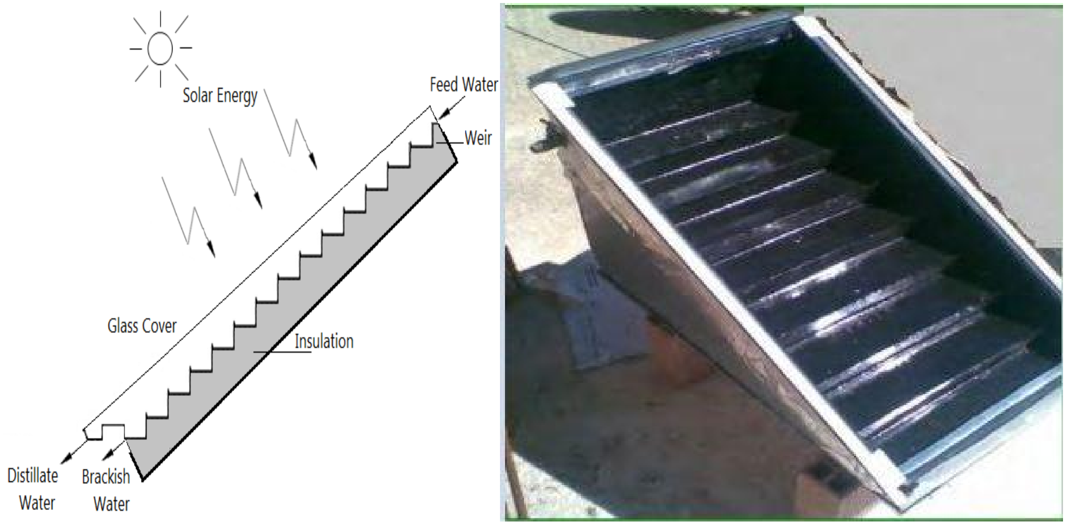


Figure I-26: A diagram of a cascading solar distiller

I. 8.8 Wick distiller:

In a wick distiller (Figure 1.22), feed water flows slowly through a porous filling, absorbing radiation (wick).

Two advantages are claimed on basin distillers. First, the wick can be tilted so that the feed water has a better angle with the sun (reducing reflection and having a large and efficient surface area). Second, less feed water is in the distiller at all times so the water is heated faster and at a high temperature [24].

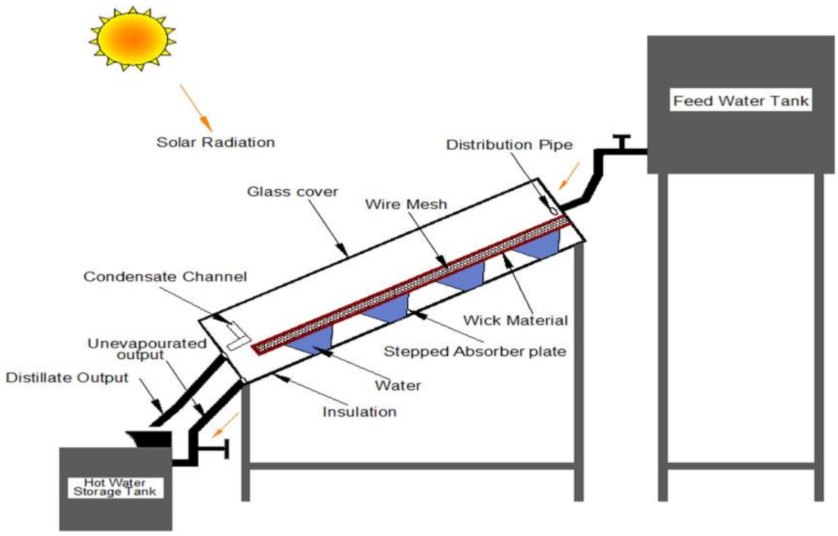


Figure I-27 : A wick solar distiller's

I. 8.9 Multi-effect solar distiller – MED:

In the energy mechanical research unit of the National School of Engineers of Tunis URME-ENIT of El Manar University, we have the opportunity to see and test this type of multi-effect distiller as part of an international internship.

This process is based on the principle of evaporation of seawater preheated to a temperature between 70 and 80oC.

Water evaporation takes place on an interchange surface, or is provided by a relaxation with in successive floors. The heat transferred through this surface is brought either by a steam produced by a boiler or by solar collectors. The steam this produced in the first effect is condensed to produce fresh water in the second effect where there is a lower pressure, so the condensation heat it yields allows to evaporate some of the seawater contained in the second effect and so on (Figure1.24) So only the energy needed for evaporation in the first effect is external.

Several multiple evaporator technology effects exist, the evaporator with multiple effects horizontal tube watered are the most used devices currently, the heating fluid, the heating fluid flows into the tubes while the seawater to evaporate is watered so as to flow in the form of film as uniform as possible on the outside of the tube. The steam produced in the cylinder or cell is then sent into the tubes of the next effect or it will give way to its condensation energy. These evaporators have a very good exchange coefficient thanks to the uniform flow in film [26].

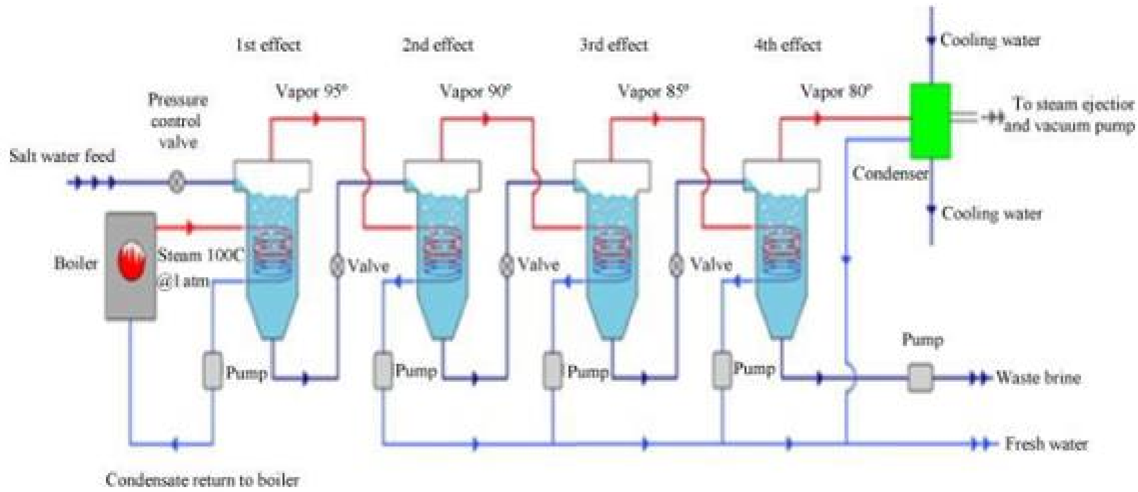


Figure I-28 multi-effects distiller

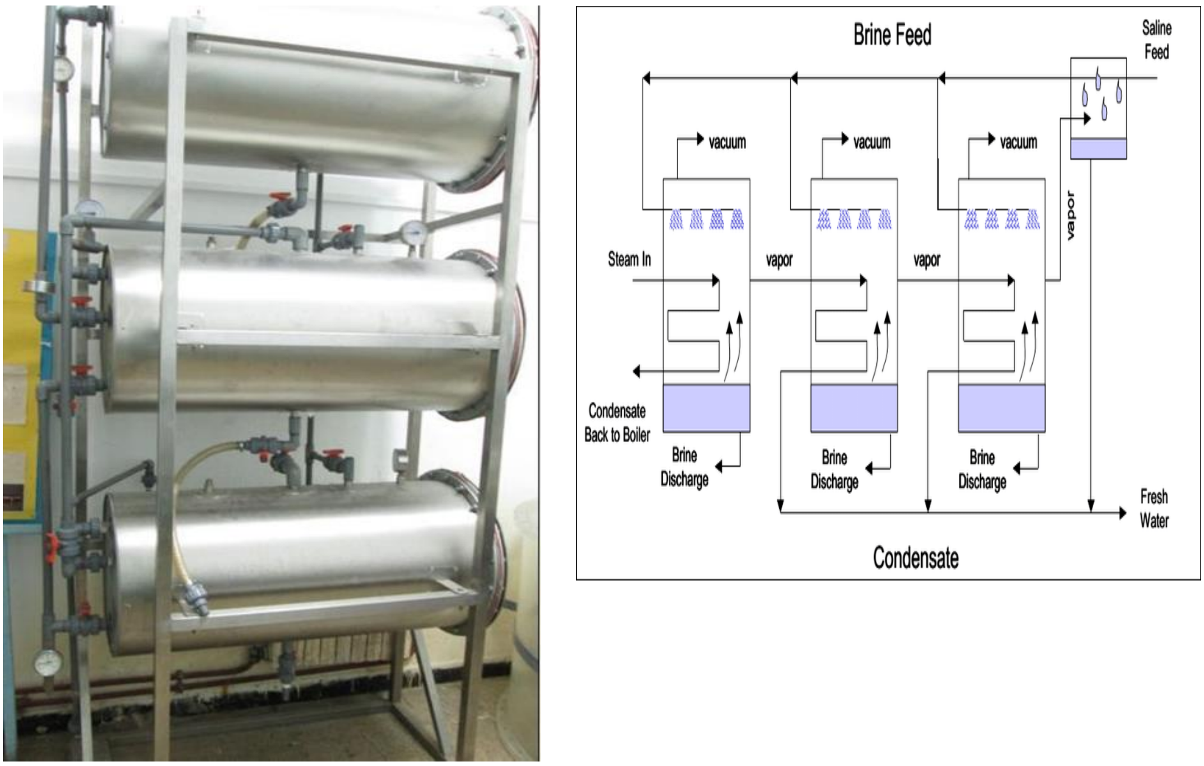


Figure I-29: ENIT-Tunisia URME multi-effects distiller

I. 9 Parameters Affecting The Operation Of The Distill: Two types of parameters affecting the distillation system for a given site must be taken into account [16] :

- External parameters in relation to the distillation system.
- Internal parameters in relation to the distillation system.

I. 9.1 External parameters :

These are parameters that affect the proper functioning and performance of the distiller, these parameters are site-related [16].

- **Intensity of solar radiation :**

This is the Key factor in this study. It is a radiating energy of short wavelength (0.17 to 4 μm) [2].

The maximum intensity is obtained for the wavelength 0.47 μm in the visible spectrum. The overall intensity of solar radiation reaching the edge of the atmosphere on a perpendicular surface is constant, equal to 1.35KW/m2. However, energy arriving near the Earth's surface is weakened by the absorption of some of the radiation through the atmosphere [2].

The transmission coefficient is fairly constant during the year and is between 0.7 and 0.9 Several studies show that global irradiation remains the most influential parameter the operating characteristics of a solar distiller [5], [6], [14].

- **Wind speed:**

Cooper, 1960, demonstrated that the distillation yield increased by 11.5% with an average wind speed 2.15m / s, while it increased by 1.5% for wind speed values in the range from 2.15 to up to 8.8 m / s and thus we could say that the excess wind speed has a slight effect on the distillation rate.[6]

- **Ambient air temperature:**

The value of this temperature is used to determine the thermal exchanges between the inner part and the external environment.

- **Weather parameters**:

Air humidity, rainfall and cloud intermittency must be taken into account as these two factors alter the distiller's thermal balance.

- **Geographical parameters**

Such as the longitude and height of the sun.

- **The nature of the water to be treated:**

Pre-processing choice, conversion rate and performance ratio, as well as the nature and socio-economic status of the site: choice of materials, degree of system automation, infrastructure, labour [9,18].

I. 9.2 Internal parameters :

❖ **Position parameters :**

- **The location of the distiller**: where distillers must be placed in such a way as to avoid obstacles "the mask effect", which prevents solar radiation from reaching the catchment surface.
- **Orientation:** it depends mainly on the operation of the distiller during the day in which it is distinguished:
  1. -Operating during the morning $\longrightarrow$ East orientatio .
  2. -Operating in the afternoon $\longrightarrow$ West orientation.
  3. - Running all day $\longrightarrow$ South orientation.
- **The inclination :** it depends on how the distiller works during the year :
  1. Summer operation $\beta = \theta -10°$
  2. Winter operation $\beta = \theta +20°$
  3. Annual operation $\beta = \theta +10°$

$\boldsymbol{\beta}$: The inclination.

$\boldsymbol{\theta}$: The Angular

❖ **Construction parameters :**

- **Couverture:**

  Coverage essentially includes: [5], [7]

-Its nature.

-Its wetting by water.

-Its transparency to solar radiation.

-Its opacity to the infrared radiation of long wavelengths.

-Its resistance to attacks from wind and solid particles.

-The number of windows in case the cover is glazed.

- Its inclination in relation to the horizontal.

An experimental study by C.D.E.R. shows that the glass remains the most suitable despite the production of the Plexiglas distiller (plexiglas =2.63litre/day, glass = 2.23litre/day) since the installation of the latter requires more frequent maintenance (deformation of Plexiglas, detachment of the ends). [14].

- **Tilt:**

Its inclination relative to the horizontal, to determine the amount of solar energy introduced into the distiller and to minimize the distance between brine and glass, the angle of inclination must be the subject of a wise choice. The inclination also influences the equations of the energy balances of the different components of the distiller. Expressions will be given in the next chapter [5], [7]

- **The absorber :**

Tests conducted by some researchers have shown that the absorbent surface can be constructed of several materials (wood, metal, concrete, synthetic material or ordinary glass). The choice of the material of the absorbent surface or black bin depends on its thermal inertia, resistance to oxidation by water and mineral deposits [16]

- **The distance between the evaporation surface and the condensation surface:**

This parameter determines the intensity of lateral thermal losses by convection, and the size of the buffer layer that slows the exchange between the evaporation surface and the condensation surface. Research has shown that reducing this parameter increases the gross performance factor [5], [7].

❖ **Brine parameters :**

The thicker the water table, the larger the water table, the less its temperature fluctuates during production. Thermal inertia increases with thickness, and nocturnal running time also increases with thickness, however average production 24 hours decreases as thickness increases. Experiments have shown that this production follows the law: [5], [7]

$$\mathrm{Y} = \frac{a}{\mathrm{X+b}} + c \qquad \text{(I.2)}$$

-**Y**: production .

-**X**: the thickness of the brine .

-**a, b, c** : parameters depending on the shape of the device and local conditions .

- Brine temperature: the experiment done in the Algerian Sahara on greenhouse solar distillers have shown that instantaneous flow according to temperature follows a hyperbolic law according to:

$$Y = \frac{51.607}{117-\mathrm{T}} - 0.613 \qquad \text{(I.3)}$$

With:

-**Y**: instantaneous flow, expressed in litre per hour.

-**T**: the temperature, in centigrade degree of brine in the top layer.

When the temperature of the brine rises; a deposit on the free surface of water due to the formation of insoluble carbonates in brine has been observed; salt deposition acts on the absorbent power of the black surface and causes production to drop significantly

❖ **Concentration of salt:**

Distiller production decreases as concentration increases, saline deposition acts on the absorbent power of the black surface and causes production to drop significantly.

❖ **Optical parameters :**

The parameters are the emissivity, the absorptivity, the reflectivity and the transitivity of the absorbent surface and the cover.

❖ **Thermo-physical parameters:**

The thermo-physical parameters are :

-The thermal conductivity, the specific heat and thermal scatterivity of the cover and the absorbent surface.

-Thermal conductivity, specific heat, kinematic viscosity, latent vaporization heat, thermal dilation coefficient and thermal spreadivity of brine .

- Thermal conductivity, specific heat, dynamic viscosity, kinematic viscosity and thermal dilation coefficient of the steam air mixture.

I.10 Characteristics and performance of destiller:

A solar distiller is essentially characterized by the following magnitudes [5], [7]

I.10.1 Production (distillate flow):

Which is the amount of distilled water produced daily by evaporation surface.

$$m_d = \frac{q_{ev}}{l_v} \qquad \text{(I.4)}$$

$\mathbf{m_d}$: Distillate flow.

$\mathbf{q_{ev}}$: : Amount of heat used for evaporation per unit of time.

$\boldsymbol{l_v}$ **:** Latent vaporization heat.

I. 10.2 Overall efficiency:

Representing the ratio of the amount of energy evaporated by (m2), to the amount of global energy incidental by (m^2) on a horizontal surface. It is defined by the report [5], [7]

$$n_g = \frac{q_{ev}}{G.A} = \frac{m_{d\times} l_v}{G.A} \qquad \text{(I .5)}$$

With :

S: Sensor area (window area)

G: Incident global solar energy per m^2 on a horizontal surface for one day

I.10.3 Internal efficiency:

Which represents the ratio of the amount of energy evaporated by (m2) of surface, to the amount actually absorbed by brine by (m^2) surface [5], [7].

$$n_i = \frac{q_{ev}}{\varphi_{water}} = \frac{m_d l_v}{G.A\ \alpha_t} \qquad \text{(I .6)}$$

$\mathbf{G.A}$ = The amount of heat absorbed by the water

$\boldsymbol{\alpha_t}$ **:** The thermal absorption coefficient for global G intensity

$$\varphi_{water} = \left(\tau_w \alpha_w + \tau_v \tau_w \alpha_f\right) \times G.A \qquad \text{(I .7)}$$

$\boldsymbol{\tau_w}$ **:** Water transmission coefficient.
$\boldsymbol{\tau_v}$ **:** Glass transmission coefficient.
$\boldsymbol{\alpha_w}$ **:** Water absorption coefficient.
$\boldsymbol{\alpha_f}$ **:** Absorption coefficient of distiller's bottom**.**
By posing :

$$\alpha_t = \tau_v \alpha_w + \tau_v \tau_w \qquad \text{(I .8)}$$

$$\varphi_w = \alpha_t\, G.A \qquad \text{(I .9)}$$

The result is: $$\eta_i = \frac{\eta_g}{\alpha_t} \qquad \text{(I.10)}$$

The coefficient α_t depends on the angle of impact of the incident radiation relative to the glass. (See Table I.3 .for the angle of incidence of radiation between 0° and 30 α_t= 0.8)

Radiation incidence angle in degrees		0-30	45	60
Windows	Reflection	5%	6%	10%
	Absorption	5%	5%	5%
	Transmission	90%	89%	85%
Tablecloth water	Reflection	2%	3%	6%
	Absorption	30%	30%	30%
	Transmission	68%	67%	64%
Background Distiller	Reflection	5%	5%	5%
	Absorption	95%	95%	95%
	Transmission	0%	0%	0%

Table I-2: Reflection, absorption, transmission of solar radiation for different parts of a distiller (source [1]).

I. 10.4 Performance :

In order to characterize a still more absolutely, we have been led to define the gross (F.P.B) and hourly (F.P.H) performance factors: [19]

$$FPH = \frac{Amount\ of\ water\ produced\ within\ one\ hour}{energy\ entering\ after\ an\ hour}$$

$$FPB = \frac{Amount\ of\ water\ produced\ out\ of\ 24\ hours}{energy\ entering\ after\ 24\ hours}$$

FPH = Quantity of water produced after one hour/ amount of energy entered after one hour

FPB = Quantity of water produced after 24 hours/ Amount of energy entered after 24 hours

At some point in the day, the FP performance factor is given by the relationship:

$$FP = \frac{m_d}{\alpha_t \; G.A} \qquad (I.11)$$

FP : performance factor.

I.10.5 Yield:

This is the amount of water produced per unit of plan area per day**.**

The major disadvantage of this criterion is that it does not mention the solar energy which arrives on the distiller. [19]

The performance of a single distiller is :

$$\eta = \frac{m_d}{G.A} \, h_{evp} \qquad (I.12)$$

h_{evp} **:** Is Enthalpy of evaporation

η : Yield or efficiency

I. 11 Objective Design For An Efficient Solar Distiller:

For a high efficiency the solar distiller should maintain:

- High water (water temperature)
- A large temperature difference between the feed water and the condensation surface
- low steam leak**.**

A large difference in temperature can be made if :

- The condensation surface absorbs little or nothing of the incoming radiation
- Condensation water absorbs heat that needs to be removed quickly from the condensation surface, for example, from a second flow of water or air, or by condensation at night, [ITD 2006]

In addition, we must monitor the following :

- **Location :**

Solar distillers operate using direct solar energy without additional energy.

- **Consumption and additional space :**

Distilled water from distiller can range from hot to lukewarm. It is best to refrigerate the water in a glass pitcher (compared to plastic) to cool and store it.

- **Taste :**

Distilled water is tasteless due to the absence of minerals. Depending on your personal preferences, cooling the water could improve the taste

- **Cleaning ease** :

Choose a model with an easy-to-clean absorber

- **Composition of distillers :**

Distillers are recommended to be galvanized iron, aluminum or plastic

I. 12 Conclusion :

We have seen in this chapter a brief bibliographical study on solar distillation at the nationally and also on a globally to get a clear idea of this area. According to the work of the researchers noted the diversity of methods and the technique used to improve the phenomenon of solar distillation.

We have also seen the different types of solar distillers and their operating principles.

We have chosen a single type of solar greenhouse distiller to be the subject of our study in the following chapter. We chose the single-slope (or single-slope) solar distiller.

The reasons for the choice are:

- The low cost of the system.
- The ease of construction.
- The ease of maintenance.

CHAPTER II

THE PHYSICAL PHENOMENA ASSOCIATED WITH SOLAR DISTILLATION

II. 1 Introduction:

Energy has many different forms, the most important of which is thermal energy, which expresses how atoms are transported inside objects, The heat is classified as invisible properties, yes we can feel it around us through the phenomenon of the transition between bodies from the hotter body to the body with the lowest temperature until the two bodies become at the same temperature in order to reach the state known as thermal equilibrium between them. The science of heat transfer is the science that examines the methods of heat transfer between materials due to the difference in temperature and the nature of materials in terms of their resistance to heat transfer.The heat is classified as a type of energy that enters and exits a system.Theoretical study of distillation gives the relationship between the physical amounts, we find the heat transfer (conduction, load, radiation) .The main source of energy is the sun so that the radiation coming from it ensures the survival of the organisms and also enables the human to generate Thermal energy. [35]

II. 2 Thermal notes :

- **Thermal flow**: The thermal flow is the amount of thermal energy that passes through an insulated surface per unit of time. $q=\frac{\partial Q}{\partial t}$ (II.1)
- **Thermal conductivity**: Thermal conductivity (noted λ) is the ability of a material to conduct heat. It represents the amount of heat transferred per unit of surface and unit of time, under a temperature gradient $\lambda = q\ \frac{e}{\Delta T}$ (II.2)
- **Thermal resistance**: Thermal resistance (noted k) is the ability of a material to withstand cold and heat. It is determined by dividing the thickness of the material by the thermal conductivity of the material λ. $R\frac{e}{\lambda}$ (II.3)
- **Thermal transfer coefficient**:The thermal transfer coefficient (noted h) characterizes the thermal loss of a material or wall. This is the opposite of thermal resistance (R)

  $$h = \frac{1}{R} \quad \text{(II.4)}$$
- **Mass thermal capacity**: Mass thermal capacity (Cp) is the amount of heat that must be applied to 1kg of material to raise its temperature by 1K.
- **Heat capacity**: Thermal capacity is the energy that must be brought to a body to increase its temperature by a 1K. She speaks in (J/K). It is an extensive grandeur [41].

$$C = C_P \times m \qquad \text{(II.5)}$$

II. 3 Basic physical phenomena in distillation:

II. 3.1 Definition of temperature:

Heat is a form of energy, measured in joule (J) and in the traditional silk unit (1cal = 4,1855J) and silk is the heat needed to raise the temperature of 1 g of water1°C and we know the heat: the energy produced by the physical medium [34].

The heat is the energy produced from the material medium by the motion of its composite particles (molecules -atoms). These particles exchange heat energy, losing or gaining kinetic energy.The transfer of heat is the movement of the amount of heat from one point to another with a gradient of heat, and the transfer takes place regardless of the type of medium [34].

II. 3.2Forms of heat transfer :

The three types of heat transfer: Heat is transfered via solid material (**conduction**), liquids and gases (**convection**), and electromagnetical waves (**radiation**). Heat is usually transfered in a combination of these three types and seldomly occurs on its own. For example, the thermal environment of a building is influenced by heat fluxes through the ground (conduction), and the building envelope (mostly convection and radiation). So types of heat transfer:

- Conduction
- Convection
- Radiation

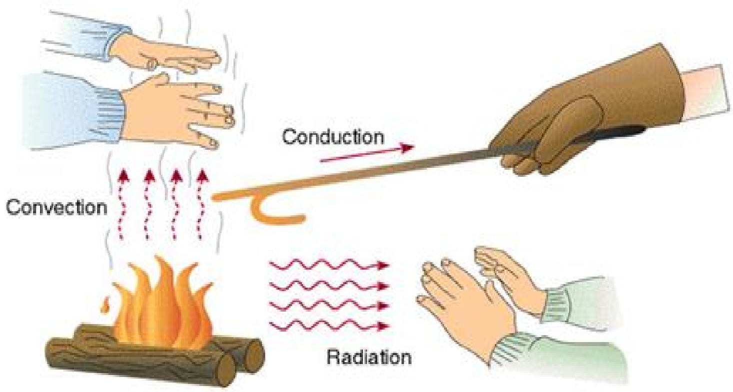


Figure II-1: Heat transmission methods

II.4Thermal transfer modes:

II.4.1 Transfer by conduction:

Conduction is the means by which heat flows from near to near in a material or passes from one body to another in direct physical contact, by simple molecular interaction. The molecules of the hottest sector collide strongly with each other and transmit their vibration energy to the neighbouring molecules. The heat flow always goes from hot to cold areas When molecules heat up on the surface of a body under the effect of solar radiation. They transmit this heat to the neighbouring molecules, and from near to near, the heat captured is distributed throughout the mass of the body, until thermal equilibrium. The rate at which heat flow progresses through a body, its thermal conductivity, depends on the ability of its molecules and electrons to receive and transmit heat.For example, a metal will appear colder to the touch than a piece of wood, yet at the same temperature. This is because the metal has a higher conductivity and the heat flows from the surface inwards faster than into the wood. The feeling of cold is all the more intense as the heat removed from the hand to the metal by conduction is greater. Gases are usually bad conductors. Also materials with demin air cells in large numbers are usually bad conductors and therefore good insulators. The insulation materials used in the construction illustrate this, they contain a multitude of small spaces of air and are characterized by their lightness. [41]

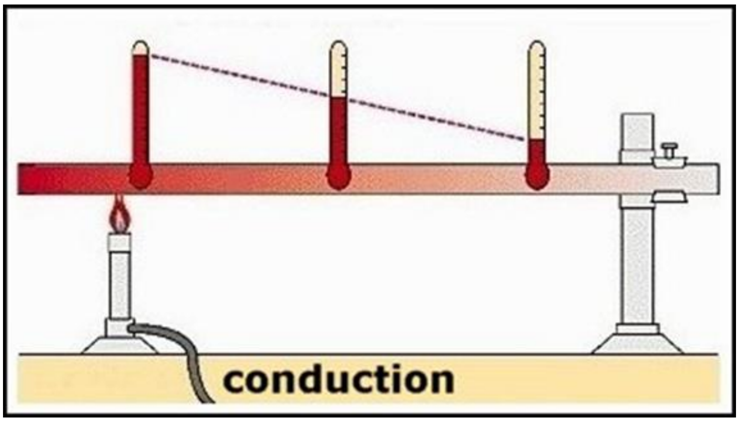


Figure II-2 : Heat transfer by conduction

II.4.1.1 Fourier's Law :

In 1822, Jean-Baptiste Joseph Fourier (1768-1830) proposed the law of conduction now known as the Fourier Law. This relationship indicates that the heat flow is proportional to the temperature gradient and is done in the direction of the decreasing temperatures.

The theory of conduction is based on Fourier's hypothesis: the density of flow is proportional to the temperature gradient

$$\vec{\boldsymbol{\phi}} = -\boldsymbol{\lambda S}\overrightarrow{\boldsymbol{grad}}(\boldsymbol{T}) \quad \text{(II.6)}$$

Or in algebraic form:

$$\boldsymbol{\phi} = -\boldsymbol{\lambda S}\,\frac{\partial \mathbf{T}}{\partial \mathbf{x}} \quad \text{(II.7)}$$

With :

$\boldsymbol{\phi}$**:** Heat flow by conduction **[W].**

$\overrightarrow{\boldsymbol{grad}}$**(T) :** to the temperature gradient.

$\boldsymbol{\lambda}$ **:** Thermal conductivity of the environment **[W/m C°].**

S: Area of the heat flow passage section [$\mathbf{m^2}$]**.**

X: Space variable in the direction of the flow **[m].**

A good thermal insulator is a material that has the lowest possible thermal conductivity (example: air) A good thermal conductor is a material that has a high thermal conductivity (example : copper).

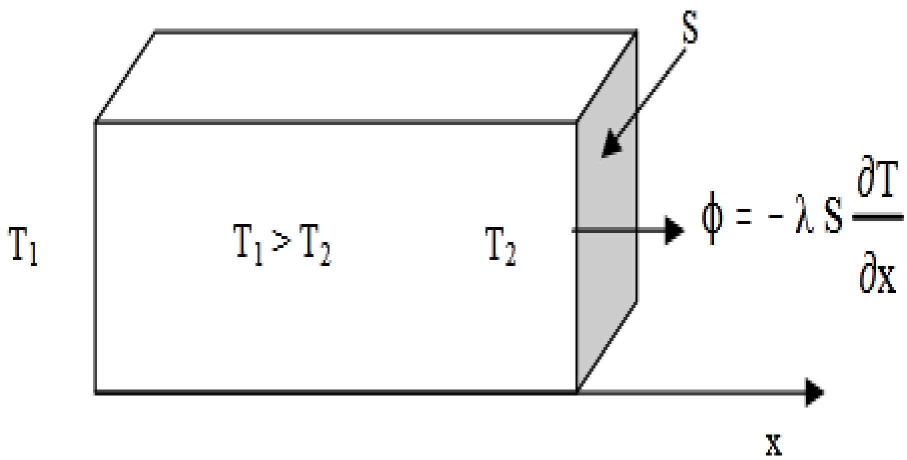


Figure II.2: Schema of heat transfer by conduction

Table 1.1 shows the values of thermal conductivity - of certain materials among the more common.

Metals	$\boldsymbol{\lambda(w.m^{-1}.°C^{-1})}$	**Metals**	$\boldsymbol{\lambda(w.m^{-1}.°C^{-1})}$
Silver	419	Plaster	0.48
Copper	386	Amainte	0.16
Aluminium	204	Wood (hardwood)	0.12-0.23
Soft steel	45	Cork	0.044-0.049
Stainless steel	15	Rock wool	0.038-0.041
Ice	1.88	Glass wool	0.035-0.051
Concrete	1.4	Polystyrene	0.036-0.047
Terracotta brick	1.1	Polyurethane (foam)	0.030-0.045
Glass	1.0	Extruded polystyrene	0.028
Water	0.60	air	0.026

Table II.1 Thermal conductivity of certain metals.

II. 4.1.2 The Fins :

The fins are good conductors of heat whose size is large compared to the others. They are used to improve heat evacuation from a confined solid system in which heat flow densities are high.

Figure II.3 Winged heating resistance.

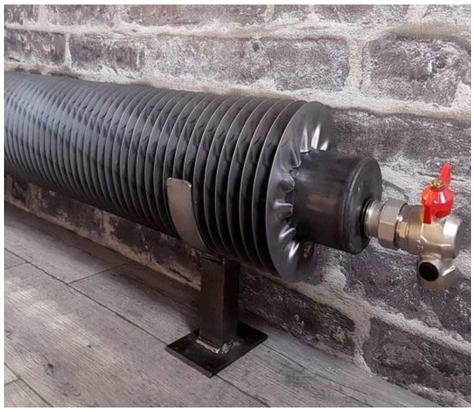


Figure II.4 Wing tube (radiator).

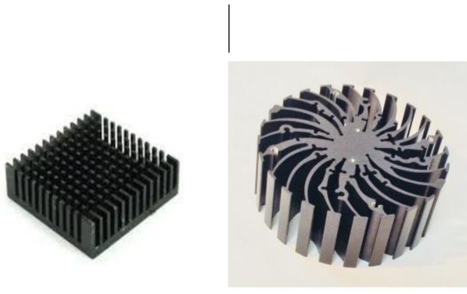


Figure II.5: Heat sinks.

Figure II.6 Motorcycle engine.

Figures II (4.5.6.7) : Examples of winged systems used in different application sectors.

In the previous paragraphs, the transfer of heat by conduction into the solid and the transfer of heat by convection from its borders occurred in the same direction .In winged systems, the direction of the convective heat flow is perpendicular to the main direction of the heat flow in the solid.

Consider the wall plan of Figure 2 (a). The flow of heat removed from the wall by convection is expressed by Newton's law:

$$\boldsymbol{\varphi}_{\mathbf{conv}} = \mathbf{h}\mathbf{S}_{\mathbf{ech}}(\mathbf{T}_{\mathbf{p}} - \mathbf{T}_{\infty}) \qquad \text{(II.8)}$$

If T_p is fixed, there are two ways to increase the flow of heat evacuated:

- Increase the convective exchange coefficient h, by increasing the speed of flow and/or decreasing the temperature of the T_∞ fluid. In most applications, h increasing the amount of heat is not enough to drain the desired heat flow and often the cost is too high (installing powerful and cumbersome pumps or fans). Reducing T_∞ is often unfeasible in the installation.

- The second solution is much simpler to implement: it is to increase the exchange area,$\boldsymbol{S_{ech}}$, using fins extending from the solid in the surrounding environment (see Figure II.8 (b). The thermal conductivity of the material that makes up the wing must be elevated to minimize temperature gradients between the base and the tip of the wing. The increase in heat flow will be maximum if the fins are at uniform temperature at $\boldsymbol{T_P}$ (infinite conductivity).

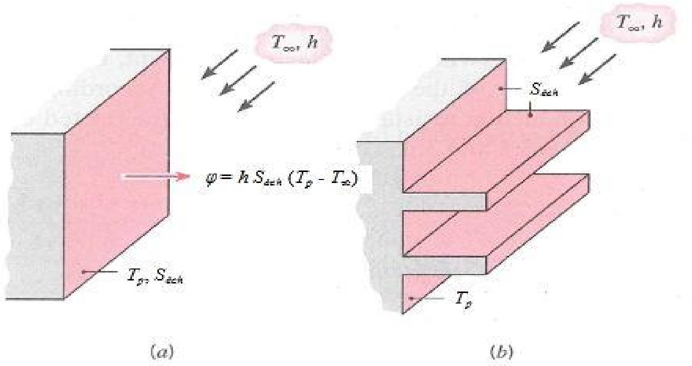


Figure II.7 : Use of fins to increase the flow of heat evacuated from the wall: (a) wall plan, (b) wall equipped with fins.

There are several configurations of fins (see figure below), the choice of which, in practice, is conditioned by many criteria: the space available in the system, weight, manufacturing defects, costs, It is also necessary to take into account the disturbance of the flow caused by the presence of fins (loss of load).

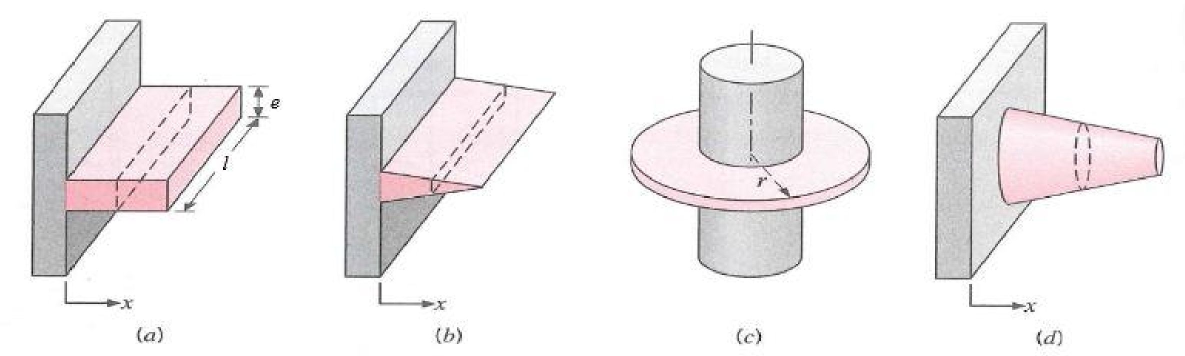


Figure II.8: Different types of fins: (a) right wing with constant section, (b) right wing variable section, (c) ring wing, (d) needle-shaped wing with variable section.

1 The heat equation for constant-sectioned fins:

The question is to what extent the presence of fins can improve the transfer of heat from a solid surface to the surrounding fluid .Consider the constant section wing schematic on the figure (Figure 4) bathed in a moving fluid at T_∞ temperature.To quantify the heat transfer associated with this wing we must first determine the temperature distribution along the wing from an energy balance that we will establish by making the following assumptions :

- The diet is permanent and there is no internal heat dissipation.
- The thermal conductivity of the fins is constant.
- The convective exchange coefficient, h, is uniform across the surface of the wing.
- The transfer of heat by radiation is neglected.
- The problem is monodimensional, it means the heat flow only spreads in one direction (the x direction).It is considered that the temperature is uniform in a given section of the tlet in x, which is usually ensured by the use of thin fins.

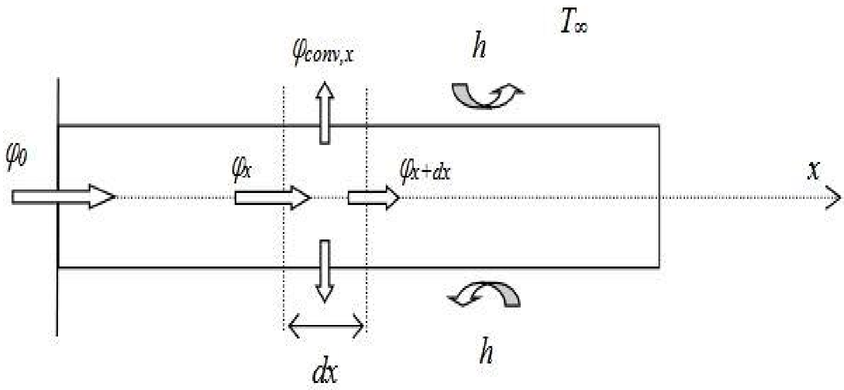


Figure II.9: Energy balance on a slice of dx-thick wing.

Let's do an energy check on the system consisting of a slice of the wing between x and x +dx :

$$\boldsymbol{\varphi_x = \varphi_{x+dx} + \varphi_{conv}} \qquad \text{(II.9)}$$

$\boldsymbol{\varphi_x}$: Heat flow transmitted by conduction in x :

$$\boldsymbol{\varphi_x = -\lambda S \left(\frac{dT}{dx}\right)_x} \qquad \text{(II.10)}$$

$\boldsymbol{\varphi_{x+dx}}$: Heat flow transmitted by conduction in x+dx :

$$\boldsymbol{\varphi_{x+dx} = -\lambda S \left(\frac{dT}{dx}\right)_{x+dx}} \qquad \text{(II.11)}$$

$\boldsymbol{\varphi_{conv}}$: Flow evacuated by convection at the border between x and x+dx:

$$\boldsymbol{\varphi_{conv,x} = h\, p\, dx\, (T(x) - T_\infty)} \qquad \text{(II.12)}$$

- **"S"** is the area of the passage section of the conduction flow.

- "**p**" is the perimeter of the wing (the exchange perimeter of the convective flow).

$$\lambda S \left(\frac{dT}{dx}\right)_{x+dx} - \lambda S \left(\frac{dT}{dx}\right)_x = h\, p\, dx\, (T(x) - T_\infty)$$

$$\Leftrightarrow \qquad \left(\frac{dT}{dx}\right)_{x+dx} - \left(\frac{dT}{dx}\right)_x = \frac{hp}{\lambda S}\, dx\, (T(x) - T_\infty)$$

$$\Leftrightarrow \qquad \frac{d^2 T}{dx^2}\, dx = \frac{hp}{\lambda S}\, dx\, (T(x) - T_\infty)$$

Because :

$$\left(\frac{dT}{dx}\right)_{x+dx} - \left(\frac{dT}{dx}\right)_x = d\left(\frac{dT}{dx}\right) = \frac{d^2T}{dx^2}\, dx$$

$$\Rightarrow \qquad \boldsymbol{\frac{d^2 T}{dx} = \frac{hp}{\lambda S}\,(T(x) - T_\infty)} \qquad \text{(II.13)}$$

The temperature field in the wing T(x), is thus determined by the resolution of this equation (sometimes called the bar equation) associated with two boundary conditions, written at the base and end of the wing.

Note: If the wing section is not constant : S = S(x) And p = p(x) The balance sheet equation is then written:

$$\left(S\frac{dT}{dx}\right)_{x+dx} - \left(S\frac{dT}{dx}\right)_x = \frac{h}{\lambda}\, p(x)dx(T(x) - T_\infty) \Leftrightarrow \frac{d}{dx}\left(S\frac{dT}{dx}\right) = \frac{h}{\lambda}\, p(x)(T(x) - T_\infty)$$

Ask $\theta(x) = (T(x) - T_\infty)$ And $m^2 = \frac{hp}{\lambda S}$ The Equation IV.1 becomes

$$\boldsymbol{\frac{d^2\theta}{dx^2} - m^2\theta = 0} \qquad \text{(II.14)}$$

- **h :** convective exchange coefficient (W.$m^2.k^{-1}$).
- $\boldsymbol{\lambda}$: thermal conductivity of the material that makes up the wing (W.$m^{-1}.k^{-1}$).
- **S :** section of the wing (m^2).
- **p** : perimeter of the wing (m).

For a rectangular wing of ***e*** thickness and width ***l*** : ***S***= ***e l*** And ***P*** = **2** (***e*** + ***l***).

For a cylindrical R-ray wing : $\boldsymbol{S = \pi R^2}$ And $\boldsymbol{p = 2\pi R}$

The differential equation IV.2, of a linear and homogeneous order 2 with constant coefficients, admits a general solution of form.

$$\boldsymbol{\theta(x) = C_1 e^{mx} + C_2 e^{-mx}} \qquad \text{(II.15)}$$

$$\boldsymbol{\frac{d\theta}{dx} = m(C_1 e^{mx} - C_2 e^{-mx})} \qquad \text{(II.16)}$$

Resolution of the 2-order linear differential equation with constant coefficients (EDL2) $\theta'' - m^2\theta = 0$

(≪ " ≫) refers to the second derivative versus x). The solution of a first-order EDL with constant coefficients (EDL1) $\theta' - a\theta = 0$ (≪ " ≫) refers to the first derivative in relation to x and has actual constant) is of the form

$\theta(x) = Ke^{ax}$ (K constant). We are looking at whether there are EDL2 solutions in the same shape as those of an EDL1 it mean form $e^{\alpha x}$ the EDL2 will be written in this case $\theta'' - m^2\theta = \alpha^2 e^{\alpha x} - m^2 e^{\alpha x} = 0 \ \forall x \leftrightarrow$

$\alpha^2 - m^2 = 0$ (characteristic equation) $\leftrightarrow \alpha = \pm m$ with in our real m case. Thus e^{mx} *And* e^{-mx} are solutions to the equation. Any linear combination of these solutions is also a solution. The general form of the EDL2 solution is therefore $\theta(x) = C_1 e^{mx} + C_2 e^{-mx}$ (C_1 *And* C_2 constant).

The C_1 and C_2 constants are determined from the conditions at the limits at the base and end of the wing.

- At the base of the wing (*x=0*) : $\theta(x) = (T(0) - T_\infty) = (T_0 - T_\infty) = \theta_0$

$$\boldsymbol{\theta(0) = C_1 + C_2 = \theta_0} \qquad \text{(II.17)}$$

- At the end of the wing (x = L): several cases can be considered:

a. temperature imposed at the end (condition to The Dirichlet-type limits) :

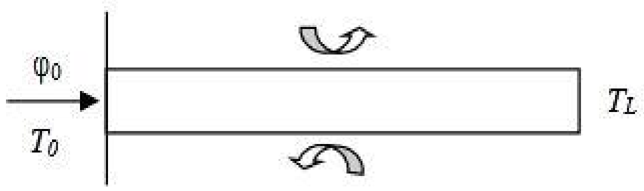
$$\boldsymbol{\theta(L) = (T(L) - T_\infty) = (T_L - T_\infty) = \theta_L} \qquad \text{(II.18)}$$

Special case: **infinitely long wing :** T(L) ≈ $T_\infty \rightarrow \theta(L) \approx 0$

b. wing subjected to a convective heat flow at its end (condition at Neumann-type limits).

Special case: **thermally isolated wing** (a condition of adiabaticity).

2. Heat flow evacuated by an infinitely long and constant section wing :



For a wing of "infinite" length, the temperature at the end will be equal to the temperature of the surrounding environment, T_∞ . thus $\theta_L \rightarrow 0$ so L→ ∞ . The condition for the limits in (x= L) is then written : $\boldsymbol{\theta(L) = \theta_L = C_1 e^{mL} + C_2 e^{-mL}}$ $\boldsymbol{, L} \rightarrow \infty$ (II.19)

$\leftrightarrow C_1 \rightarrow 0$

The condition to limits in x = 0 (Eq. IV.4) is then written: $C_2 = \theta_0$

The temperature field inside the wing is given by the (IV.3) equation with $C_1 = 0$

$C_2 = \theta_0$

$$\frac{\boldsymbol{\theta(x)}}{\boldsymbol{\theta_0}} = \boldsymbol{e^{-mx}} \qquad \text{(II.20)}$$

- The heat flow removed from the solid by the wing , $\boldsymbol{\varphi_0}$, becomes:

$$\boldsymbol{\varphi_0} = -\boldsymbol{\lambda S}\left(\frac{\boldsymbol{d\theta}}{\boldsymbol{dx}}\right)_{\boldsymbol{x=0}} = -\boldsymbol{\lambda S\,\theta_0}\left(\frac{\boldsymbol{d\theta}/\boldsymbol{\theta_0}}{\boldsymbol{dx}}\right)_{\boldsymbol{x=0}} = \boldsymbol{\lambda S m \theta_0} \qquad \text{(II. 21)}$$

Replacing **m** with its expression (m = $\sqrt{\frac{h\,p}{\lambda\,S}}$) , you get

$$\boldsymbol{\varphi_0} = \sqrt{\boldsymbol{h\,\lambda\,S\,p}}\,\boldsymbol{\theta_0} \qquad \text{(II.22)}$$

It is therefore possible to introduce thermal resistance of the infinite wing, R, such as :

$$\boldsymbol{\varphi_0} = \frac{\mathbf{(T_0 - T_\infty)}}{\mathbf{R}} = \frac{\boldsymbol{\theta_0}}{\mathbf{R}}$$

$$\Rightarrow \mathbf{R} = \frac{\mathbf{1}}{\boldsymbol{\lambda}\,\mathbf{S\,m}} = \frac{\mathbf{1}}{\sqrt{\mathbf{h}\,\boldsymbol{\lambda}\,\mathbf{S\,p}}} \qquad \text{(II.23)}$$

- **Under what condition can the approximation (L → ∞) be considered valid?**

In practice, the (L → ∞) hypothesis will be considered valid if $\frac{\theta_L}{\theta_0} < 0.01 (= 1\%)$ (Or TL = 0.99 T_∞), either $mL \geq 2\ ln\ (10)$ or $L \geq \frac{4.6}{m}$ with m = $\sqrt{\frac{h\,p}{\lambda\,S}}$.

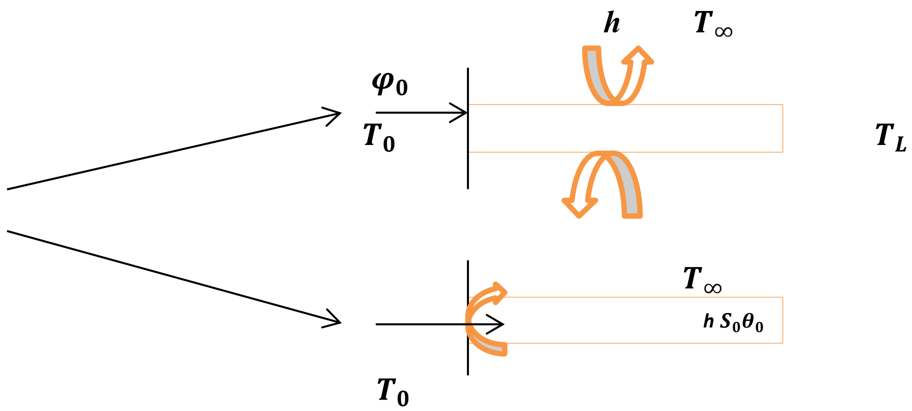
Example: cylindrical bar in Copper, Aluminium or Steel (processed in progress)

3. Efficiency and performance of a wing :

Remember that the fins are used to increase the flow of heat transferred from the solid to the environment. It should be noted, however, that the fins itself have thermal resistance. This could be in the event that, if the fins are not properly sized, their presence will not contribute to the increase in the transfer.

The effectiveness of a wing is defined as the relationship between the heat flow drained by the wing φ_0 and the heat flow that would be evacuated without a wing :

$$\varepsilon_0 = \frac{\varphi_0}{h\, S_0\, \theta_0}$$



- S_0 is the section of the base of the wing (in x = 0, contact with the solid).
- $\theta_0 = T_0 - T_\infty$ Or T_0 is the temperature of the base of the wing or the surface of the solid.

- **In the case of the "infinite" wing**, efficiency is written :

$$\boldsymbol{\varepsilon_{0.\infty} = \frac{\sqrt{h\,\lambda\, S\, p}\,\theta_0}{h\, S\, \theta_0} \leftrightarrow \varepsilon_{0.\infty} = \sqrt{\frac{\lambda\, p}{h\, S}}} \qquad \text{(II.24)}$$

The effectiveness of a wing is proven if $\boldsymbol{\varepsilon_0} \geq 1$ .Thus the efficiency of the fins is improved by

- the choice of a high conductivity material.
- the choice of the geometry of the wing, such as High $\boldsymbol{\frac{p}{s}}$ (use of fine fins).
- the choice of a "relatively" low convective exchange coefficient (while ensuring a high evacuated flowφ_0). Thus the use of fins will be more justified in cases where the flowing fluid is a gas rather than in the case of a liquid, and when the transfer of heat occurs by natural convection.

Another measure of a wing's performance is provided by calculating the performance of a wing.This is defined as the ratio between the heat flow drained by a wing φ_0, and the maximum heat flow that a wing could evacuate. This maximum heat flow is achieved if the temperature difference between the wing and the surrounding fluid is maximum i.e. when the entire wing is at the base temperature:

$$\boldsymbol{\varphi_{max} = hS_{ech}^{wing}(T_0 - T_\infty) = hS_{ech}^{wing}\theta_0} \qquad \text{(II. 25)}$$

So S_{ech} wing is the exchange surface between the wing and the surrounding fluid
The performance of a wing is then written:

$$\boldsymbol{\eta_0} = \frac{\boldsymbol{\varphi_0}}{\boldsymbol{h\, S_{ech}^{wing} \theta_0}} \qquad 0 \leq \eta_0 \leq 1 \qquad \text{(II.26)}$$

In many practical applications, the analysis of the thermal behaviour of a system equipped with fins becomes complex if the fins used do not have a constant section. Getting the temperature field in the wing becomes difficult and thus the calculation of the heat flow evacuated by the complicated wing . Abaques or analytical expressions of performance,$\eta_0$and the exchange surface, $\boldsymbol{S_{ech}^{wing}}$, wing of common-shaped fins are then available in the literature, which can be used to determine the flow of heat evacuated by the wing $\boldsymbol{\varphi_0}$, knowing the temperature at the base of the wing $\boldsymbol{\theta_0}$.

4. Efficiency and performance of a surface with fins:

The efficiency of a surface with fins is defined as the ratio between the total heat flow drained by the winged system φ_T and the total heat flow that would be evacuated by convection without a wing:

$$\boldsymbol{\varepsilon_T = \frac{\varphi_T}{h S_T \theta_0}} \qquad \text{(II.27)}$$

Or $S_T = NS_0 + S_{inside-wings}$ is the total surface area of the system without a wing in contact with the surrounding fluid, $S_{inside-wings}$ being the surface between the fins .In practice, of course, the aim is to design a system for which $\boldsymbol{\varepsilon_T \geq 1}$**.**

$\boldsymbol{\varphi_T}$: Flow evacuated by the fins - flow evacuated by convection between the fins

$$\boldsymbol{\varphi_t = N\, \varphi_0 + h\, S_{inside-wings}\, \theta_0} \qquad \text{(II.28)}$$

- $\boldsymbol{\varphi_0}$: heat flow evacuated by 1 wing.
- **N :** number of fins (all identical, section at the base,S_0) arranged on the S_T surface.
- $\boldsymbol{\theta_0 = T_0 - T_\infty}$ Or $\boldsymbol{T_0}$ is the temperature of the base of the wing or the surface of the solid

$$\varphi_T = N\, \varphi_0 + h\,(S_T - NS_0)\theta_0$$
$$= \mathrm{N}\, \eta_0\, h\, S_0\, \theta_0 + h(S_T - NS_0)\theta_0$$
$$\boldsymbol{= h\, S_T\, \theta_0 + N\, h\, S_0\, \theta_0\, (\varepsilon_0 - 1)} \qquad \text{(II.29)}$$

- $\boldsymbol{\varepsilon_0}$: effectiveness of a wing (see previous paragraph).

$$\Rightarrow\ \boldsymbol{\varepsilon_T = 1 + N\, \frac{S_0}{S_T}\, (\varepsilon_0 - 1)} \qquad \text{(II.30)}$$

Another measure of the performance of a surface with fins is provided by calculating the performance of the system .This is defined as the relationship between the heat flow drained by the system with fins $\boldsymbol{\varphi_T}$, and the maximum total heat flow

$$\boldsymbol{\eta_T = \frac{\varphi_T}{h\, S_{ech}^{Total} \theta_0}} \tag{II.31}$$

$$\boldsymbol{So\ S_{ech}^{Total} = N\, S_{ech}^{wing} + S_{inside-wings}} \tag{II.32}$$

is the total exchange area of the system equipped with fins with the surrounding fluid.

$$\varphi_T = N\,\varphi_0 + hS_{inside-wings}\,\theta_0 = N\,\varphi_0 + h\left(S_{ech}^{Total} - NS_{ech}^{wing}\right)\theta_0$$

$$= N\eta_0\, h\, S_{ech}^{wing}\theta_0 + h(S_{ech}^{Total} - NS_{ech}^{wing})\theta_0$$

$$= h\, S_{ech}^{Total}\,\theta_0 + Nh\, S_{ech}^{wing}\,\theta_0(\eta_0 - 1)$$

$$\Rightarrow \quad \boldsymbol{\eta_T = 1 - N\frac{S_{ech}^{wing}}{S_{ech}^{Total}}\,(1 - \eta_0)} \tag{II.33}$$

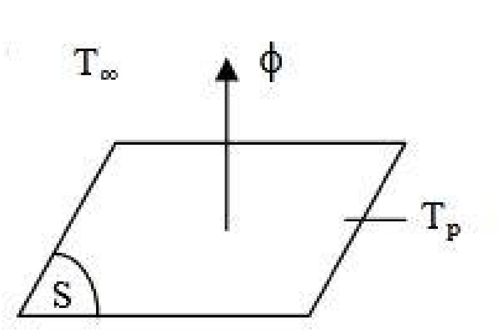
In practice, knowing $\boldsymbol{\eta_0}$ from the abaques, one can calculate $\boldsymbol{\eta_T}$ attached to the system studied, and then access the total heat flow evacuated.

II. 4.2 Transfer by convection :

In this case the thermal phenomenon is complicated by material movements and heat transfer is superimposed the mass transfer. convection heat transfer occurs between two phases, one of which is usually at rest and the other in motion in the presence of a temperature gradient. As a result of the existence of heat transfer from one phase to another, there are fractions of the fluid (or aggregates) in the mobile phase with different temperatures. the movement of the fluid may result from the difference in density due to temperature differences (then spoken of **free or natural convection**) or purely mechanical means (**then called forced convection**).[9]

Convection phenomena occur in the transmission of heat each time a fluid moves in relation to fixed elements. When the fluid occurs within the currents from simply to the density differences resulting from temperature gradients, it is said that the convection is natural or free. On the other hand, if the movement of the fluid is caused by a pump or fan, the process is called forced convection [35].

Forced convection refers to convective movements that appear under the action of an external source, such as a pump or the movement of an object in the fluid, movements induced by a pressure difference are forced convection movements where the flow persists even in the absence of a temperature gradient [40] . In forced convection, the fluid owes its movement to an external cause (pump, fan, agitator, etc.). In forced convection proper, Archimedes' thrust is negligible in front of the forces used to set the fluid in motion. This is the case, for example, with the cooling of internal combustion engines: the water pump pushes the cooling liquid through the engine and then into the interchange [41].



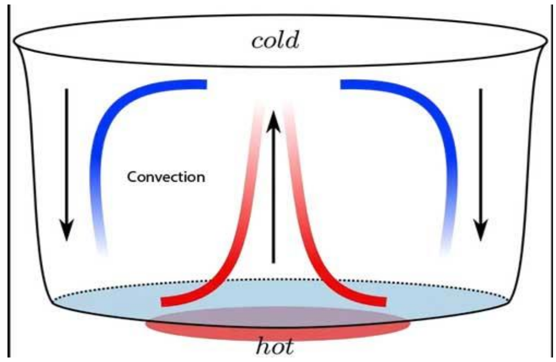


Figure II-10. Convective heat transfer scheme Figure II-11. : Heat transfer by convection

II. 4.2.1 Fundamental Law of Convection (I. Newton's Law):

The fundamental law of convection is the law of Isaac Newton (1643-1727), translated by the experimental relationship of heat flow exchanged by convection between a fluid and a solid wall .

$$\emptyset = \boldsymbol{h}.\boldsymbol{S}\ (\boldsymbol{T_P} - \boldsymbol{T_\infty}) \qquad \text{(II.34)}$$

$\boldsymbol{h}$: K_{fluid}/δ.

As such:

ϕ : Heat flow transmitted by convection [W] .

h : represents the coefficient of heat transfer by convection $[\mathrm{w/m^2}.°C^{-1}]$, Or $[KCAL.\mathrm{h.m^2}.C]$

$\mathbf{T_P}$: Solid surface temperature [°C].

$\mathbf{T_\infty}$: Temperature of the fluid away from the surface of the solid [°C].

S: Solid/fluid contact surface area $[\mathrm{m^2}]$.

δ : Represents the thickness of a thin fluid adhered to the solid wall.

$\boldsymbol{K_{fluid}}$: The thermal conductivity of the fluid.

II.4.2.2 Types of heat transfer by convection:

A-Natural convection :

The heat is carried by the load in the fluids (liquids and gases) due to the movement of the fluid and its mixing with each other by moving particles of matter from hot to cold places, carrying with them the heat where the particles of matter are free the movement [35].

B- Forced convection:

In forced convection due to an external effect, it moves on a surface that is higher or lower than it in a temperature [35]

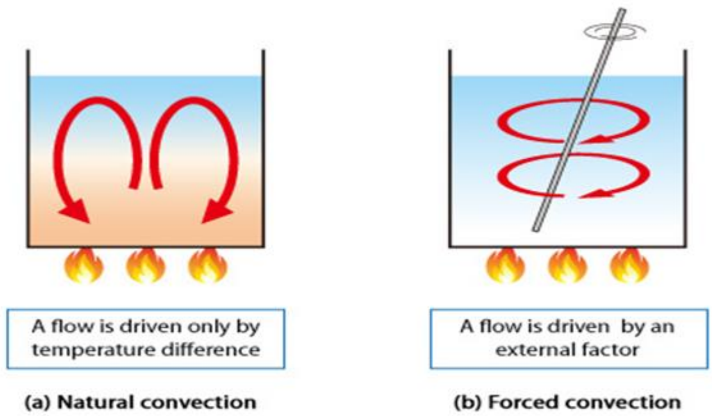


Figure II-12: Transfer by convection (a-Natural convection / b-Forced convection)

II. 4.3 Radiation transfer :

Thermal radiation is a phenomenon characterized by an exchange of electromagnetic energy, without the intermediate medium necessarily participating in this exchange for example, solar radiation is able to warm the earthly that the medium crossed is at a lower temperature than the earth [42]

Environment

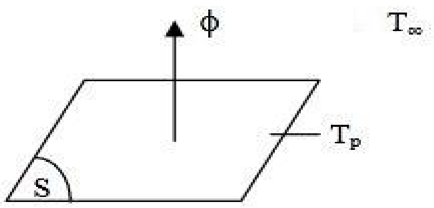


Figure II-13 : Radiative Heat Transfer Scheme

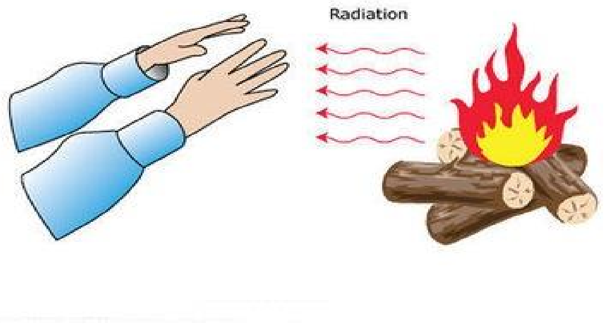


Figure II-14. Heat transfer by radiation

II. 4.3.1 Fundamental Law of radiation (-Stefan-Boltzman Law) :

The Stefan–Boltzmann law, also known as Stefan's law, states that the total energy radiated per unit surface area of a black body in unit time (known variously as the black-body irradiance, energy flux density, radiant flux, or the emissive power), j*, is directly proportional to the fourth power of the black body's thermodynamic temperature T (also called absolute temperature).The law of heat flow emitted from the transmitting surface as following:[35]

$$\phi = \sigma \varepsilon_p s(T_p^4 - P_\infty^4) \qquad \text{(II.35)}$$

With:

- ϕ : Radiation-transmitted heat flow (W).
- σ : Stefan's constant $(5{,}67.10^{-8}\ W\mathrm{m}^{-2}K^{-4})$.
- ε_P : Surface emission factor.
- T_P : Surface temperature (K).
- T_∞: Temperature of the environment surrounding the surface (K).
- S: Surface area (m^2).

II. 5 Energy study of the solar still :

II. 5.1 Introduction :

Since ancient times, it is known that the sun has enormous energy, and through the phenomenon of heating the basins, this great energy has been discovered so that the relationships that link the transmission of matter and heat give us an idea of the physical.

When the distiller is exposed to radiation, it is exposed to heat transfers and flows. We will study on each level separately as follows: [35].

-1-Transfers at the level of the glass cover:

As shown in Figure (III-4), we mention the transitions that occur through the glass cover as following: [35].

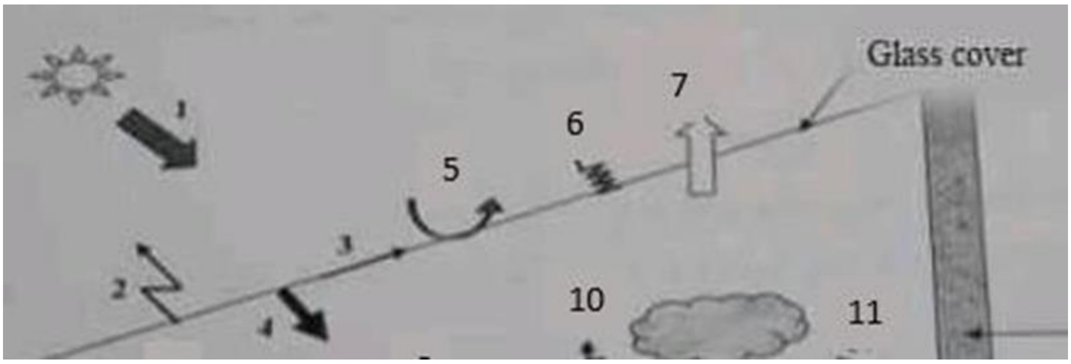


Figure II-15: A drawing showing transitions at the level of the glass cover. [42]

-1.1 Solar radiation received by the glass:

It is the amount of radiation to which the glass cover is exposed. Solar energy supplied to the glass during the day and its relationship is as follows: [35].

$$\mathbf{G} = \int \boldsymbol{qs(t)dt} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.36})$$

-1.2 Reflected radiation on the glass level:

The rays contained on the glass do not absorb them all, but a small part of them is reflected, which gives the following statement [35].

$$\boldsymbol{Q_r} = \boldsymbol{P_g}\,\mathbf{G} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.37})$$

$\boldsymbol{P_g}$: Reflection coefficient of glass.

-1.3The radiation absorbed by the glass:

Part of the incident solar energy is absorbed by the glass cover. And give as follows: [35]

$$Q_a = \alpha_g G \qquad (w/m^2) \qquad (II.38)$$

Q_a : Coefficient of absorption of the glass cover.

-1.4 Radiation Transition of the Glass Cover:

The transparency of the glass that allows the passage of radiation received by the basin represents the largest part of this radiation, and it is given by the following words [40]

$$Q_t = \tau_g G \qquad (w/\mathrm{m}^2) \qquad (II.39)$$

τ_g : Pass coefficient for the glass cover.

-1.5 Convective heat transfer between the glass cover and the outer medium (air):

The movement of the outside air affects the heat flow of the mutual convection between the outer cover of the glass and the outer medium: [40**].**

$$Q_c. g_a = h\ c.g_a (T_{ge} - T_a) \qquad (II.40)$$

h c.g_a : : Coefficient of convection.

T_{ge}: The temperature of the outer surface of the glass cover (k).

T_a : External temperature (air) (k).

-1.6 Heat transfer by radiation between the glass cover and the outer medium (air):

The outer medium has an effect on the mutual radiation between the outer surface of the glass cover and the outer medium. [35].

$$Q_r\ g_a = \varepsilon_{g\sigma} (T^4_{g\ ex} - T^4_{sky}) \qquad (II.41)$$

ε_g : Coefficient of emission of the glass cover.

$T^4_{g\ ex}$: Glass cover temperature.

T^4_{sky} : Planetarium temperature is given by the following phrase:

$$T_{sky} = T_a - 12 \qquad \text{(II. 42)}$$

-1.7 Thermal transfer by conduction between the outer medium and the inner medium:

The heat that the basin is exposed to from the inside can cross this glass by conducting through the glass surface [35].

$$Q_{cd} = \frac{\lambda g}{eg}\left(T_{g.i} - T_{g.e}\right) \qquad (w/\mathrm{m}^2) \qquad \text{(II.43)}$$

e_g : Glass thickness.

λ_g: Thermal conductivity of the glass.

$T_{g.i}$: The internal surface temperature of the glass.

$T_{g.e}$: Temperature: the outer surface of the glass.

- 2 Transfers at the basin level:

The phenomenon of evaporation occurs on the level of boiling salt water. Condensation is a process in which water is transferred from the gaseous state to the liquid state, [35]

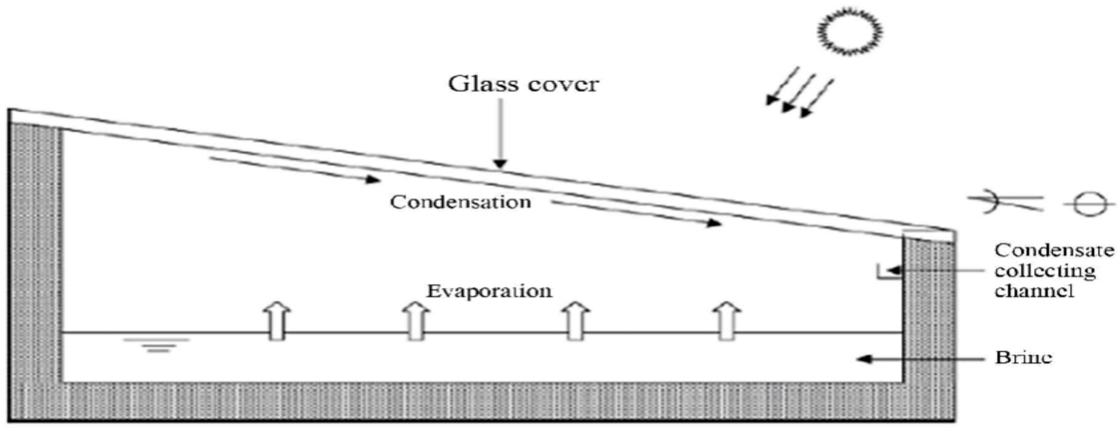


Figure II-16 A drawing showing transitions in the middle of the basin Heat transfer.

-2.1 Between salty water and glass cover:

The thermal transfer by mutual radiation between the salty water layer and the glass cover and its relationship are as following: [35].

$$\mathbf{Q_{r.w.g}} = \mathbf{F_{wg}}\boldsymbol{\sigma}\left(\mathbf{T_w^4} - \mathbf{T_{g.i}^4}\right) \qquad (\mathrm{W/m^2}) \qquad (\mathrm{II.44})$$

$\mathbf{F_{wg}}$: Form factor between the water layer and the glass cap.

$\boldsymbol{T_w}$ **:** Water temperature**.**

-2.2 Heat transfer by natural convection inside the distiller (water and glass cover):

Convection thermal flow coincides with evaporation flow, and this is due to a rise in salt water temperature inside distilled and given by the following relationship. [35]

$$\boldsymbol{Q_{c.w.g}} = \boldsymbol{h_{c.w.g}}\left(\boldsymbol{T_w} - \boldsymbol{T_{gi}}\right) \qquad (\mathrm{W/m^2}) \qquad (\mathrm{II.45})$$

$\mathbf{h_{c.w.g}}$: Convection naturel coefficient.

$\mathbf{T_{gi}}$ **:** Inner glass cover temperature.

-2.3 Thermal flow due to evaporation:

The heat flux due to evaporation results from the movement of vapor from the salt water basin that condenses on the inner surface of the glass cover is given as follows: [35].

$$\boldsymbol{Q_{e.w.g}} = \boldsymbol{m_w}.\boldsymbol{L_v} \qquad (\mathrm{W/m^2}) \qquad (\mathrm{II.46})$$

-2.4 Radiation reflected at the water level:

The radiation that crosses the glass cover towards the salt water inside the distillate is reflected in it and is given in the phrase: [35].

$$\boldsymbol{Q_{\rho w}} = \boldsymbol{\rho_w}\,\boldsymbol{\tau_g}\boldsymbol{G} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.47})$$

$\boldsymbol{\rho_w}$: Reflection coefficient.

-3. Transfer at the bottom level of the distillate:

Transitions occurring at the bottom level of the distillate as shown in Figure III

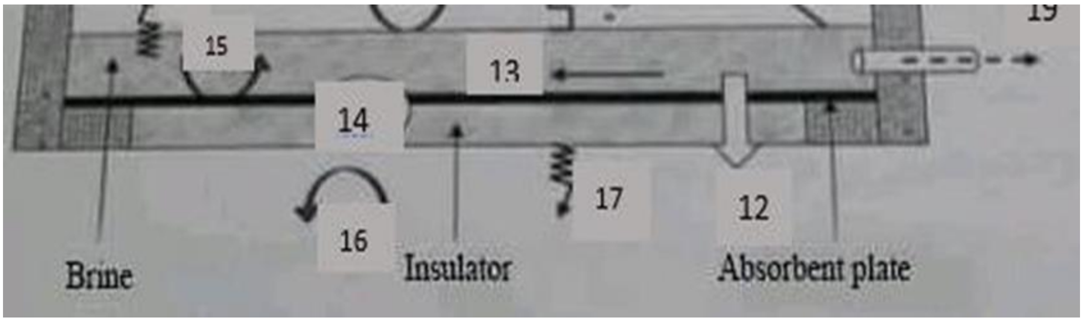


Figure II-17: A drawing showing transitions at the bottom level of the distillate. [35]

-3.1 Thermal loss through the absorbent plate:

There is an amount of heat lost through the absorbent plate and given as follows: [35]

$$\boldsymbol{Q_{cb}} = \frac{\boldsymbol{\lambda b}}{\boldsymbol{eb}}(\boldsymbol{T_b} - \boldsymbol{T_i}) \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.48})$$

$\mathbf{T_b}$: Absorbent surface temperature.

$\mathbf{T_i}$: Insulating temperature.

-3.2 Heat absorbed by the salty water:

Sunlight that passes through the glass cover towards the salt water in the basin, one part is absorbed by water and the other part is absorbed by the absorbent plate and given as follows: [35].

$$\boldsymbol{Q_{aw}} = \boldsymbol{a_w \tau_g G} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.49})$$

$\boldsymbol{a_w}$: Absorption Coefficient of water.

-3.3 Heat absorbed by the absorbent plate:

When heat passes through the glass cover towards the water in the basin, the absorbent plate absorbs a quantity of heat and its relationship: [35].

$$\boldsymbol{Q_{ad}} = \boldsymbol{a_d \tau_w \tau_g G} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.50})$$

$\boldsymbol{a_d}$: Absorbent plate absorption coefficient.

-3.4 Convective heat transfer between water and absorbent plate:

The heat transfer by convection between water is caused by a difference temperature between them. And it's Phrase [35].

$$\mathbf{Q_{c.w.b} = h_{c.w} (T_{ab} - T_w)} \qquad (\text{w/m}^2) \qquad (\text{II.51})$$

-3.5 Convection heat transfer between the insulate and the outer medium:

The outer medium helps to heat exchange by convection between the insulator and the outer medium and is expressed as follows: [35].

$$\boldsymbol{Q_{c.ia} = h_{c.ia} (T_{ie} - T_a)} \qquad (w/m^2) \qquad (\text{II.52})$$

-3.6. Heat transfer by radiation between the insulator and the outer medium:

The heat transmitted by radiation between the insulator and the outer medium is given: [35].

$$\boldsymbol{Q_{r.ia} = \varepsilon_i \sigma (T_{ie}^4 - T_a^4)} \qquad (\text{w/m}^2) \qquad (\text{II. 53})$$

-4. Transitions at the level of insulators on both sides of the distillate:

Among the transitions to which insulators are exposed to distillation are as follows:

-4.1 Thermal loss with distilled water resulting:

Water carries a portion of the heat, exits from the distillation channel and writes with. [35].

$$\boldsymbol{Q_{out} = m_w C_{Pw} (T_{dist} - T_a)} \qquad (w/m^2) \qquad (\text{II.54})$$

-4.2 Heat loss with feeding water:

The percentage that evaporates from distilled water from the water, which is compensated by a quantity of feed water until the heat is acquired to evaporate. This is called thermal loss, given as follows: [35].

$$\boldsymbol{Q_{in} = m_w C_{Pw} (T_w - T_{fw})} \qquad (w/m^2) \qquad (\text{II.55})$$

-5. Thermal balance simple solar distillers:

The thermal equations to which the solar distillate is exposed and written by: [35].

$$C_{PI}\ \frac{m_i}{s_i}\frac{dT_i}{dt} = \sum_i^N \mathbf{1}\ Q_{ij} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.56})$$

At the level of the outer face glass cover: [35]

$$C_{Pg}\frac{m_g}{s_g}\frac{dT_{ge}}{dt} = G + \rho_g G + \alpha_g G + Q_{rga} - Q_{cga} - Q_{cd} \quad (\mathrm{w/m^2}) \qquad (\mathrm{II.57})$$

At the level of the gnner face of the glass cover: [35]

$$C_{Pg}\frac{m_g}{s_g}\frac{dT_{gi}}{dt} = \ Q_{ewg} + Q_{cwg} + Q_{rwg} - Q_{cd} \qquad (\mathrm{w/m^2}) \qquad (\mathrm{II.58})$$

At the water surface level

$$C_{Pw}\frac{m_w}{s_w}\frac{dT_w}{dt} = a_w\tau_g G + Q_{cwd} - Q_{ewg} - Q_{rwg} - Q_{in-}Q_{ou} \quad (\mathrm{w/m^2}) \quad (\mathrm{II.59})$$

At the level of the absorbent surface (absorbent plate):

$$C_{Pd}\frac{m_b}{s_b}\frac{dT_b}{dt} = \ a_b\tau_w\tau_g G - Q_{cb} - Q_{cwb} \qquad (w/m^2) \qquad (\mathrm{II.60})$$

CHAPTER III

TECHNOLOGY AND SYSTEM CONTROL OF ARDUINO

III. 1-Introduction

Since electronics have been around, its growth has been meteoric and continues to this day. So much so that making electronics has become accessible to all people with the desire. But, the lack of simple courses on the net or in bookseller prevents the satisfaction of future amateur or professional electronics and sometimes prevents certain geniuses to reveal themselves.

What we will learn is a mix of electronics and programming. We are going to talk about on-board electronics, which is a sub-domain of electronics and has the ability to unite the power of programming with the power of electronics. We will first see what electronics and programming are all about. Then we'll follow up on the Gripino system. [42]

III. 2-History of the Arduino:

The Arduino was originally a student project of the Ivrea School of Interaction Design in Italy. In the early 2000s, project design tools in the field of interaction design were expensive, close to a hundred euros. Most of these tools were designed for engineering and robotics. Mastering and using these components took a lot of time and learning and greatly slowed down the creative process for these young students. [43]

III. 3- Introducing Arduino :

III. 3.1Definition:

The Arduino module is a free hardware circuit board (control platform) whose plans of the map itself are published in free license, some of which are components of the card :such as the microcontroller and complementary components that are not in free license a programmed microcontroller can analyze and produce signals to perform a wide variety of tasks. Arduino is used in many applications such as industrial and on-board electrical engineering, modeling But also in different fields such as contemporary art and piloting a robot, controls engines and plays lights, communicate with computer, order mobile devices (model), Each Arduino module has a 5-V voltage regulator and a 16 MHz quartez oscillator (or a resonator ceramics in some models). To program this map, we use the **IDE** software Arduino. [44]

III. 3.2Applications:

The Arduino system allows us to achieve a lot of things, which have an application in all areas, we can give some examples:

- Control home appliances
- Make a set of lights
- Communicating with the computer
- Remote control of a mobile device (model) etc.
- Make your own robot.

With Arduino, we will make electronic systems such as an electronic candle, a simplified calculator, a synthesizer, etc. All of these systems will be designed with an Arduino card and a fairly wide range of electronic components.

III. 3.3Good reasons to choose Arduino:

However, there are a multitude of platforms in the trade that allow you to do the same thing. In particular, microcontrollers "PIC" from the manufacturer Micro chip. We'll see why choosing the Arduino

- **The price**

In terms of the performance they offer, Arduino cards are relatively inexpensive, which is a major criterion for beginners

- **Freedom**

It is a very big word, but it defines the spirit of the Arduino in a fairly concise way. It is in itself two things :

The software: free and open source, developed in Java, whose simplicity of use is a matter of knowing how to click on the mouse.

The material: electronic maps whose diagrams are freely circulated on the internet.

This freedom has one condition: the name "Arduino" should only be used for "official" cards. In short, you can't make your own map on the Arduino model and assign it the name "Arduino".

Unofficial maps can be found and purchased on the Internet and are almost entirely compatible with the official Arduino maps.

- **Compatibility**

The software, like the map, is compatible under the most common platforms (Windows, Linux and Mac), unlike other commercial programming tools that are generally only compatible with Windows.

- **The community**

The Arduino community is impressive and the number of resources about it is constantly evolving on the internet. In addition, there are references to the Arduino language as well as a full page of tutorials on the website **arduino.cc** (in English) and **arduino.cc** (in French).

III. 4-Arduino Tools

Now let's get closer to the "use" of the Arduino system and see how it presents itself. It consists of two main things, which are: hardware and software. These two tools combined, we will be able to make any achievement.

- **The material:** It is an electronic card based around a microcontroller A tmega from manufacturer Atmel, whose price is relatively low for the possible extent of applications.
- **The software:** The software will allow us to program the Arduino card. It offers us a multitude of features.

III. 5-Types of cards:

There are three types of cards:

The so-called « official » which are manufactured in Italy by the official manufacturer: Smart Projects.

The so-called « compatible »which are not manufactured by Smart Projects, but which are fully compatible with the official Arduino.

The « others » manufactured by various companies and marketed under a different name (Freeduino, Seeduino, Femtoduino, ...).

III. 6- Different cards:

Arduino cards there are many:

The Arduino system is an open source platform based on a microcontroller programmed card and a development environment (SDK) to write, compile and test a program.

Arduino cards and modules are equipped with inputs and exits that can receive signals from sensors or switches and can control motors, lighting, etc…

"Arduino" is not in itself a specific type of card or microcontroller. Arduino refers to an entire family. Choosing the right one for your project is no small task and you should think about which one you will use. In this article, we'll learn more about the different types of Arduino cards and their uses.

- Arduino ONE (UNO).
- Arduino Mega (2560).
- Arduino Nano.
- Arduino Due.
- Arduino Leonardo.

III. 7-Description of the material part:

III. 7.1 The Arduino ONE (UNO) card:

III. 7.1.1 Introducing the Card (UNO):

Arduino is a creative interactive object prototyping platform consisting of an electronic card and a programming environment. Without knowing or understanding everything about electronics, this hardware and software environment allows the user to formulate his projects through direct experimentation with the help of many resources available online.

Arduino is used in many applications such as industrial and on board electrical engineering; modeling, home automation but also in different fields such as contemporary art and robot control, control of engines and play light sets, communicate with the computer, order mobile devices (model) [45] [46].

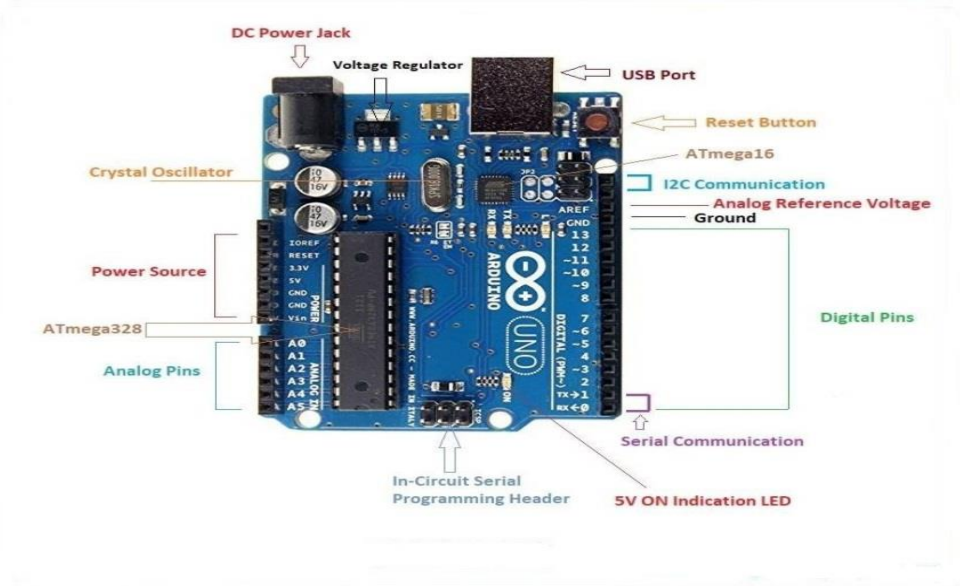
Figure III-1: The Arduino UNO Card

III. 7.1.2 Characteristics of the Arduino UNO Card :

Microcontroller	ATmega328
Operating voltage	5V
Input voltage (recommended)	7 to 12V,
Input Voltage (limits)	6 to 20 V
Digital I/O Pins	14 including 6 PWM releases
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB including 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Frequency	16 MHz

Table III-1 : Characteristics of the Arduino (UNO) Card

III. 7.1.3 General description of the Arduino UNO Card :



FigureIII-2:General description of the Arduino UNO Card

III. 7.2 The Arduino Mega card (2560) :

The Arduino Mega card is another card that offers all the features of previous ones, but with additional options.

These include a larger number of entries and exits, as well as several series links

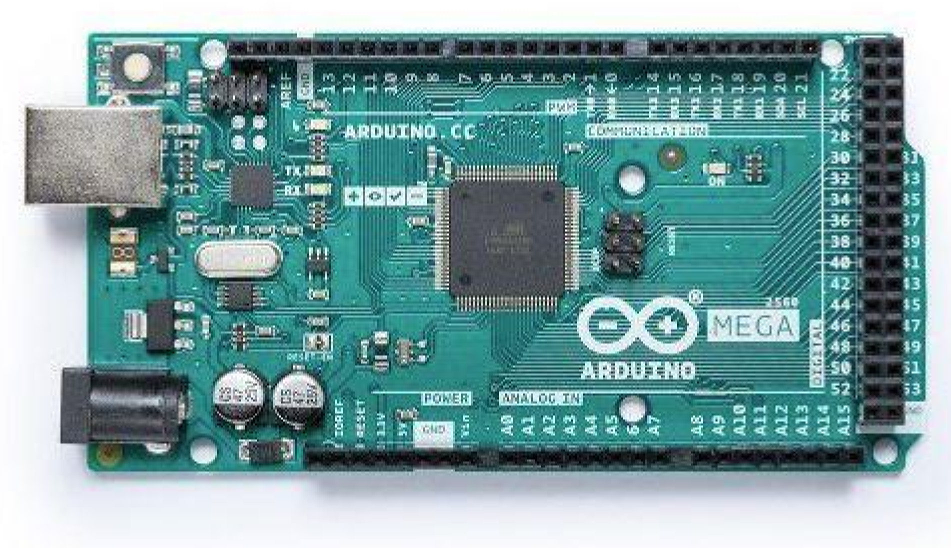


Figure III-3: Arduino Mega Card (2560)

III. 7.2.1 Introducing Arduino Mega 2560:

The Arduino card is based on an integrated circuit (a mini computer also called a microcontroller) combined with inputs and outputs that allow the user to connect different types of external elements [45]:

On the input side, sensors that collect information about their environment such as temperature change via a thermal probe, movement via a presence detector or accelerometer, contact via a push button, etc...

On the output side, actuators that act on the physical world like a small lamp that produces light, an engine that operates an articulated arm, etc. Like the Arduino software, the electronic circuit of this pad is free and its plans are available on the internet. So we can study them and create derivatives.

Several manufacturers offer different models of electronic circuits that can be programmed and can be used with The Arduino software. There are several varieties of Arduino cards. The figure below shows, for example; Arduino Mega card.

III. 7.2.2 Features of The Ardoino Mega 2560 : This card has:

- 54 digital input/exit pins (of which 14 can be used in outputs) PWM (modulated pulse width).
- 16 analog entries (which can also be used in digital input/exit pins).
- 4 UART (material series port).
- quartz 16Mhz.
- A USB connection.
- A jack power connector.
- An ICSP connector (in-circuit programming).
- A reset button (reset).

It contains everything that is necessary for the operation of the microcontroller; to be able to use and launch, simply connect it to a computer using a USB cable (or power it with an area adapter or battery, but this is not essential, the power being provided by the USB port).

III. 7.2.3 General description of the Arduino Mega(2560) :

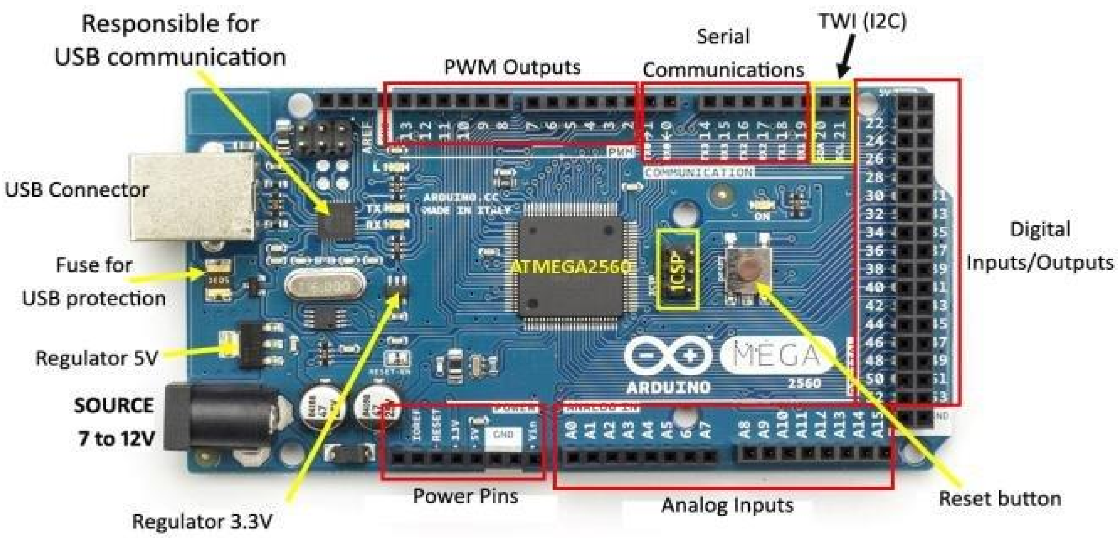


Figure III-4: General description of the Arduino Mega(2560)

III. 7.2.4 Characteristics of the Arduino Mega (2560) :

Microcontroller	AT Mega 2560
Operating voltage	5V
Input voltage (recommended)	7-12 V
Input Voltage (limits)	6-20V
Digital I/O Pins	54
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB
SRAM	8 KB
EEPROM	4 KB
Clock Frequency	16 KHz

Table III-2 : Characteristics of the Arduino Mega (2560)

III. 7.3 The Arduino Nano:

The Arduino Nano is essentially a reduced Arduino UNO, making it very convenient for tight spaces and projects that may require weight reduction whenever possible, such as modeling or portable DIY projects.

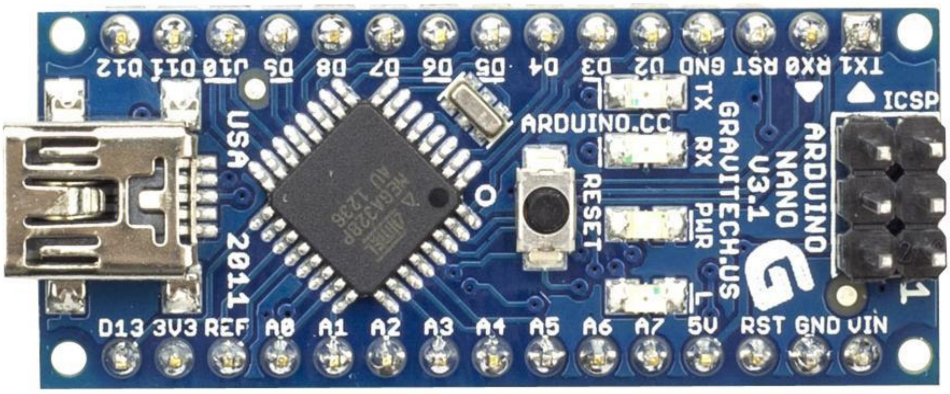


Figure III-5: The Arduino Nano Card

Like the UNO, the Nano is powered by an Atmega328 processor running at 16 MHz, includes 32KB of program memory, 1K of EEPROM, 2B of RAM, 14 digital inputs, 6 analog inputs and 5V and 3.3V power rails.

Note: (The Arduino Nano card prior to the V3.0 used the ATmega168, which essentially corresponds to half of the specifications).

On the contrary the UNO system, the Nano cannot connect to the prototyping decks. Arduino Nano cards are often the cheapest Arduino card option, making them profitable for large projects.

III. 7.3.1 General description of the Arduino Nano Card :

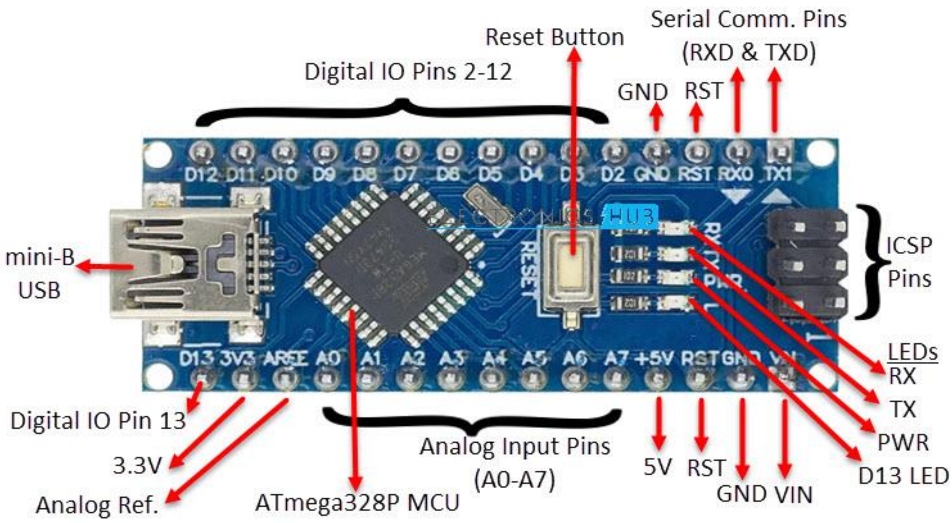


Figure III-6: General description of the Arduino Nano Card

III. 7.3.2 Characteristics of the Arduino Nano Card :

Microcontroller	Atmel ATmega 328
Operating voltage (logic level)	5V
Input voltage (recommended)	7V- 12V
Input Voltage (limits)	6V -20V
Digital I/O Pins	14(of Which 6 provide PMW output)
Analog Input Pins	8
DC Current per I/O Pin	40 mA
Flash Memory	32 KB of Which 2KB used by bootloader
SRAM	2KB
EEPROM	1KB
Clock Frequency	16 MHz
Dimensions	0.73 *1.7
Length	45 mm
Width	18 mm
Weight	5g

Table III-3 : Characteristics of the Arduino Nano Card

III. 7.4 The Arduino Due Card :

The Arduino Due is one of the largest cards and the first Arduino card to be powered by an ARM processor.

While the UNO and Nano operate at 5V, the DUO works in 3.3V - it's important to note that a surge would irreparably damage the card. Powered by a Cortex-M3 ATSAM3X8E clocked at 84 MHz, the Due has 512B of ROM and 96B of RAM, 54 digital E/S pins, 12 PWM channels, 12 analog inputs and 2 analog outputs.

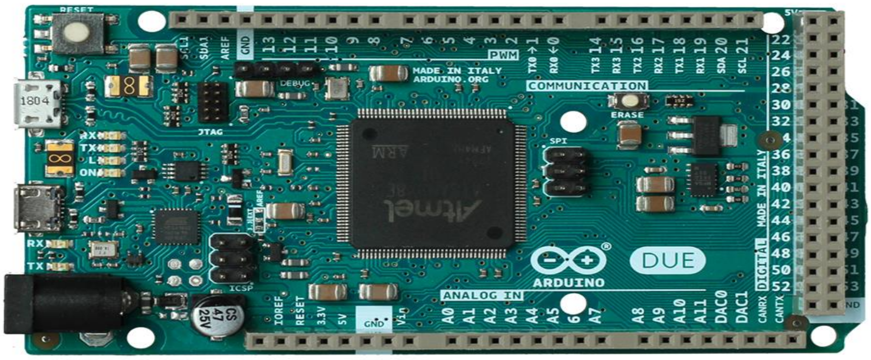


Figure III-7: The Arduino DUE

The DUE has no built-in EEPROM memory and is one of the most expensive Arduino cards. Although the Due has a large number of pin headers for connection to the many digital E/S, it is also compatible with standard Arduino pins.

III. 7.4.1 General description of the Arduino Due Card :

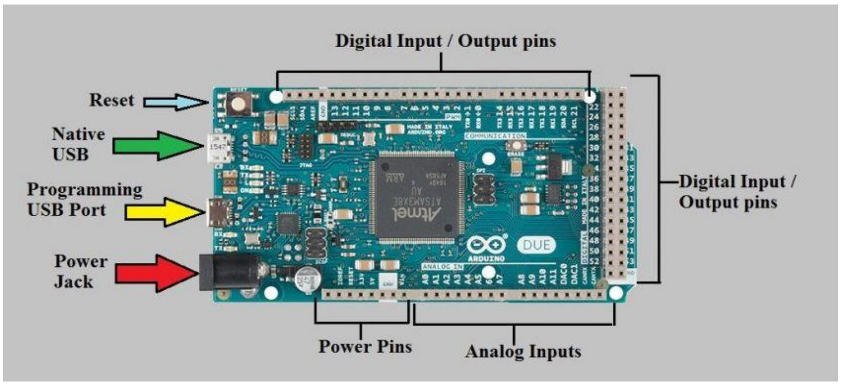


Figure III-8:General description of the Arduino Due Card

III. 7.4.2 Characteristics of the Arduino Due Card :

Microcontroller	AT91SAM3X8E
Operating voltage	3V
Input voltage (recommended)	7V- 12V
Input Voltage (limits)	6V-20V
Digital I/O Pins	54(of Which 12 provide PMW output)
Analog Input Pins	12
Analog output Pins	2 (DAC)
Total DC output Current on all I/O lines	130 mA
DC Current for 3.3 V Pin	800 mA
DC Current for 5 V Pin	800 mA
Flash Memory	512 KB all available for the user Applications
SRAM	96 KB (Two Banks : 64 KB and 32 KB)
Clock Frequency	84 MHz Back to up

Table III-4: Characteristics of the Arduino Due Card

III. 7.5 The Arduino Leonardo Card : The Arduino LEONARDO card is based on an ATMega32u4 clocked at 16 MHz allowing the management of the USB port by a single processor. Connectors located on the outer edges of the circuit board allow you to snap up a series of add-ons.

It can be programmed with The Arduino software. The ATMega32u4 controller allows port management, which increases flexibility in communication with the computer.

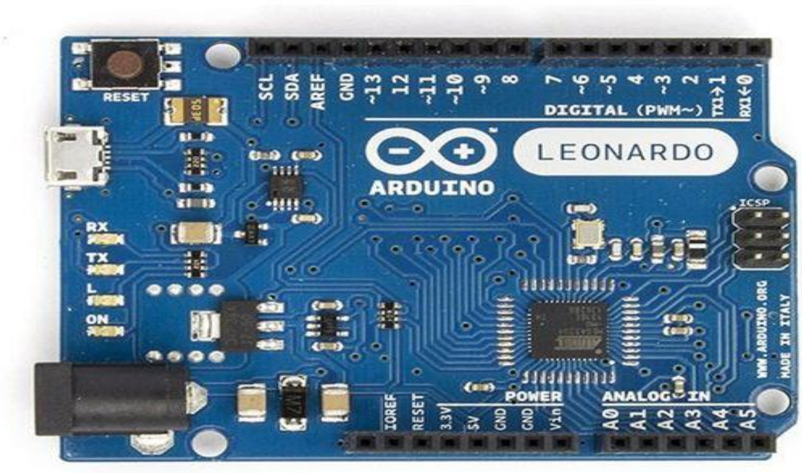


Figure III-9: The Arduino LEONARDO

III. 7.5.1 Characteristics of the Arduino Leonardo Card :

Microcontroller	ATmega 32u4
Operating voltage	5V
Input voltage (recommended)	7V-12V
Input Voltage (limits))	6V- 20V
Digital I/O Pins	20
PWM Channels	7
Analog Input Channels	12
DC Current for 3.3 V Pin	40 mA
DC Current for 5 V Pin	50Ma
Flash Memory	32 KB (ATmega32u4) of which 4 KB used by bootloader
SRAM	2.5 KB (ATmega32u4) 1 KB (ATmega32u4)

Clock Speed	16 MHz
Clock Speed	68.6 mm
Length	53.3 mm
Width	20 g
Weight	

Table III-5: Characteristics of the Arduino Leonardo Card.

III. 7.5.2 General description of the Arduino Leonardo Card:

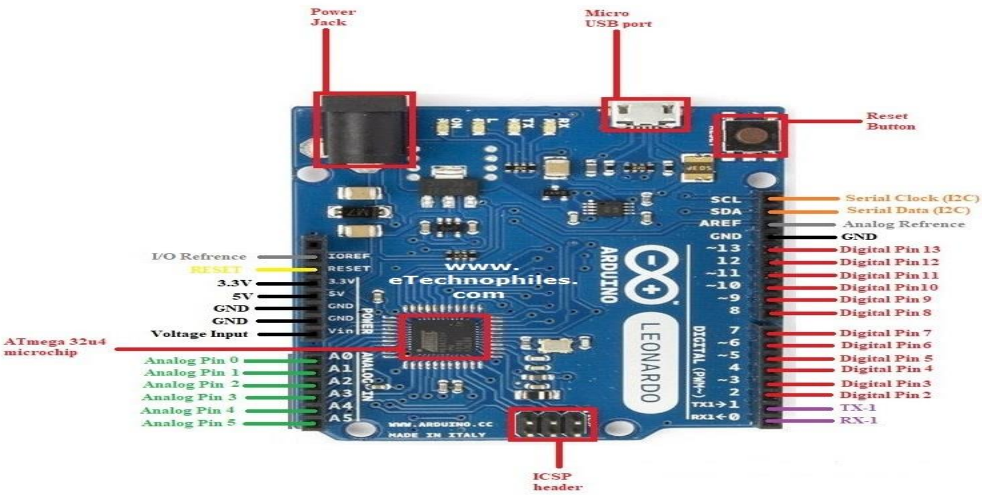


Figure III-10 General description of the Arduino Leonardo Card

III. 8. Plateforme de programmation Arduino :

III. 8.1 Description of the software part:

Our software realization needs two steps: the first is a program that will inject the microcontrollers of the Arduino card after being converted by IDE into HEX code and the second has a program that will be manipulated under «App Inventor »and installed under smart phone.

III. 8.2 The programming environment :

The Programming software of the Arduino card serves as a code editor (language Close to the C). Once the program typed or changed to the keyboard, it will be transferred and Stored in the card through the USB link. The USB cable powers both energy card and also carries information this program called **IDE Arduino**. [47]

III. 8.3 General program structure (IDE Arduino):

Like any programming language, a flexible and simple interface is executable on any Arduino operating system based on programming in C

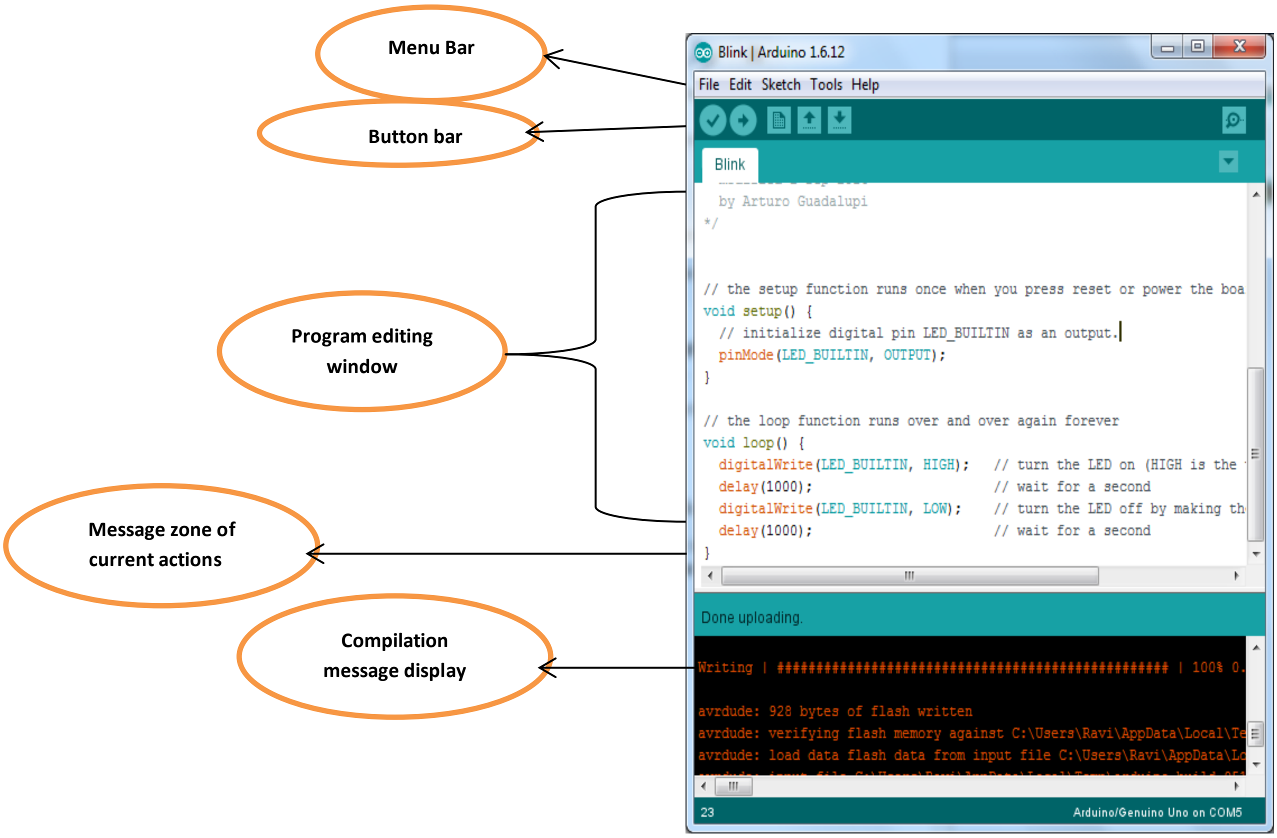


Figure III-11 : Interface IDE Arduino

1. Menu bar
2. Button bar
3. Program editing window
4. Message zone of current actions
5. Compilation message display console

Let's start with the structure. The structure of **IDE** consists of two main functions:

- Setup function( )

- Loop function ( )

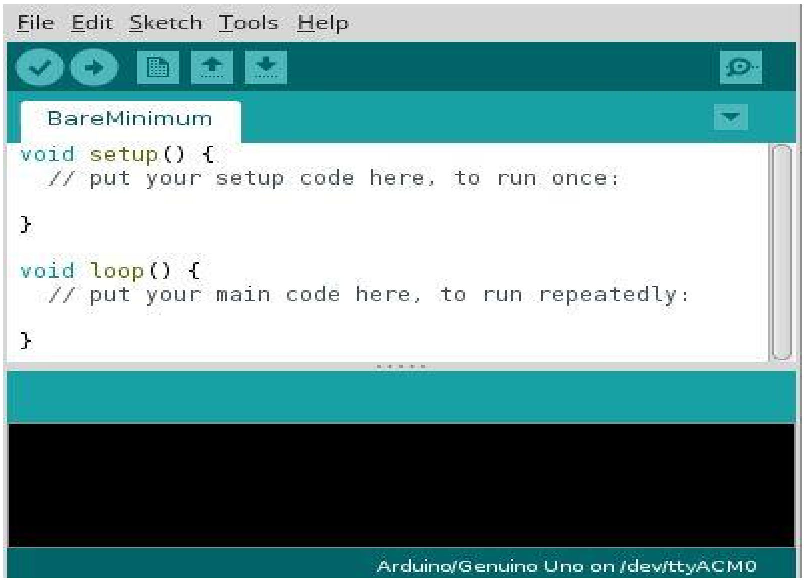


Figure III-12: Arduino programming structure

1- Setup function( ) :

```
void setup() {
  // put your setup code here, to executed once:
  Serial.begin(9600);
  Serial.println("This is setup code");
}
```

SETUP

The setup function is called when a sketch begins. Use it to start variables, pines, start using libraries, etc. The configuration function only runs once, after each powering or reset of the Arduino card.

2- Loop function ( ):

```
void loop() {
  // put your main code here, to run repeatedly:
  Serial.println("This is loop code");
  delay(1000);
}
```

LOOP

After creating a setup function that initiates and defines the initial values, the loop function () does exactly what its name says. It loops consecutively, allowing your program to change and respond. Use it to actively control the Arduino card.

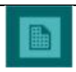
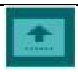
	"Verify" button; it allows you to compile your program and check if there are errors in it . this procedure takes some time to run and when it is finished, it displays a message like "Binary sketch size: ... indicating the size of the uploaded sketch.
	To transmit the successfully compiled sktche on the Arduino card in the microcontroller.
	"New" button (New) : This button allows you to create a new sketch.
	"Open" button; it shows a menu that allows you to open a sketch that appears in your work file or examples of sketches built into the software
	Save button; it saves your sketch.

Table III-6 : Actions Bar

III. 9. conclusion :

Summary this chapter we presented the different hardware " Arduino " (UNO, Mega, Nano, Due, Leonardo) and software " **IDE Arduino** " used in our project to achieve: the simulation, as well as the program.

CHAPTER IV

THE EXPRIMENTAL STUDY OF SOLAR DISTILLATION

IV. Introduction:

Water is essential for all human being, animals, plants and other living organisms. Since the industrial and other various sectors improves themselves by adopting the modern technologies, increase in population growth, deforestation and urbanisation, the availability of drinking water reduces currently thereby the water available must be treated to make it use for drinking purpose. The resources of ground water have been reduced due to increase in global temperature. Also, due to increase in sea water level, the readily available drinking water throughout the world is only about 1%. At the same time, the water from rivers, ponds and lakes cannot be directly used for drinking since they contain several impurities and micro-organisms. The above factors clearly state the scarcity/lack of potable water and hence we are in need of fresh water productivity in an effective way, Hence the water from available resources can be filtrated by various desalination techniques like reverse osmosis, electrolysis, etc. The energy efficiency reduces by adopting the conventional methods and so renewable energies like solar, wind, geothermal, etc.., Can be used as they are eco-friendly with free of cost. Solar energy is a non-seasonal one and available in plenty all over the world. Solar desalination/distillation is one of the oldest methods of desalination that uses solar radiation for productivity of potable water. It is majorly classified into two types. Passive type solar distillation system uses only the solar energy for producing drinking water and no augmentations are used in this type of distillation system. This leads to lesser yield of fresh water. Active type solar distillation system makes use of augmentation technologies like flat plate collectors, parabolic concentrators, evacuated tube collectors, heat pipes, etc. In this system, water to be treated is initially heated by using one of the above said augmentation systems working on solar energy and then it is used in solar still. This increases the amount of fresh water productivity.

IV. 2 Used materialsand manufacturing steps:

IV. 2.1 Used materials :

Dimensions	number	name	Images
L= 50 cm **Width = 50** **cmH_1 = 14 cm** **H_2 = 6 cm**	**4** slaps	Wood Box	
L = 50 cm **W =50 cm** **Thickness = 3 mm**	**4**	Glass	
L = 70 cm **Diameter=2.5 mm**	**4**	Tube	

L = 3.5 cm **Diam = 3.6 cm** **Diam = 2.6 cm**	**4**	Elbow at an angle of 90	
Diameter =2.7 cm	**4**	Plastic cover	

	8	Silicon Prosil black	
	1	Water Balance	
	1	Knives	

	4	Matte black paint	
	1	Water cone	
	1	Cup listed	

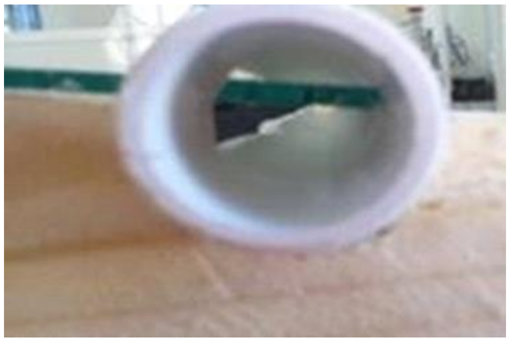
Length **Approximately 10 m**	**1**	Cable	
Iron 14We need (18 pieces) of length. Each piece 49.9 cm Also for iron 16 (18 piece)	**2**	Iron (14-16)	

Table IV-1 shows the starting materials for making a single slope solar distiller

IV. 2.2 Manufacturing steps:

Box installation: Designs 04 panels of 14, 6 cm x 2 cm cut into pieces then we do. Assemble it using special wood glue. And attached to the fifth board screws, so their size will be 50cm x 50 cm and be placed in the base as shown in the correspondingimage.	

We drill two holes on the sidepanels With a drill, the hole is in a semi-circle such that the tube can be fixed.	
inner coating of box: We paint the wooden box in matte black to absorb the most sunlight.	
Open the tube 1/3 of the top of the tube is cut to assemble Condensed water drops from the glass cap.	

Insulator (silicone) : We put the silicon on the sides and the base by the polisher so that we get a thin layer of insulator (silicon)	
Installation of elbow: We install the elbow at the end of the tube and then add a small tube at the other end to allow distilled water to transfer to the bottle.	
Positioning of the glass inside the tube: Insert the end of the glass cover into the plastic tube	

Finally ,we get Single slope solar distillers	

Table IV-2 shows the Manufacturing steps

IV. 3 Measuring devices and tools used in the experiment:

1. Pyranometer:

A pyranometer is a type of actinometer used for measuring solar irradiance on a planar surface and it is designed to measure the solar radiation flux density (W/m2) from the hemisphere above within a wavelength range 0.3 μm to 3 μm. The name pyranometer stems from the Greek words πῦρ (pyr), meaning "fire", and ἄνω (ano), meaning "above, sky."

A typical pyranometer does not require any power to operate. However, recent technical development includes use of electronics in pyranometers, which do require (low) external power.

Figure IV-1: pyranometer

2. Ph meter device:

A pH meter is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, and so the pH meter is sometimes referred to as a "potentiometric pH meter". The difference in electrical potential relates to the acidity or pH of the solution. The pH meter is used in many applications ranging from laboratory experimentation to quality control.

Figure IV-2 : pH meter device

3. Computer (laptop):

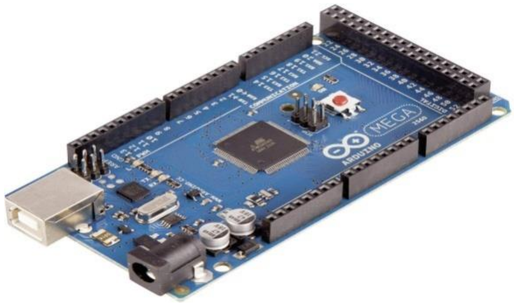
In order to connect all the devices and record the curve :

Figure IV-3: Computer(Laptop) for Recorde

4. Arduino Card (Mega 2560):

Connect all electronic devices to your computer.

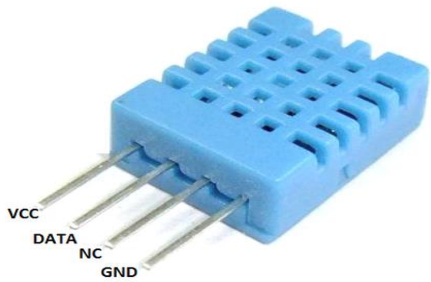
Figure IV-4 : Arduino mega 2560



5. DHT 11 Digital temperature and Humidity sensorArduino:

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). Its fairly simple to use, but requires careful timing to grab data.

Figure IV-5: DHT 11 Digital temperature and Humidity sensor



6. Cable usb for arduino :

Connectivitybetween a computer and an ardino card (Mega 2560):

Figure IV-6 : Cable usb for Arduino (Mega 2560)

7. Waterproof DS18B20 Temperature Sensor Adapter Module for Arduino Mega Card (2560):

Figure IV-7 : Waterproof DS18B20 Temperature Sensor

8. Iron fins (14-16) :

Figure IV-8 : Iron (14-16)

9. Network Cable :

Figure IV-9 : Network Cable

IV. 4 Methodology:

IV. 4.1 General description:

We use distillers with single slope of the same size 50 * 50 cm with a thickness of 2.5 cm. The Four distillers are tinted in a black color to maximize thermal absorption. The condenser of the system consists of a commercial glass 50* 50cm with a thickness of 3mm and an inclination of with respect to the horizontal whichisequal to the attitude of the place of the experiment. Figure 1 represents the shemas of the usedconventional distiller. The conventional distiller is named (CD).

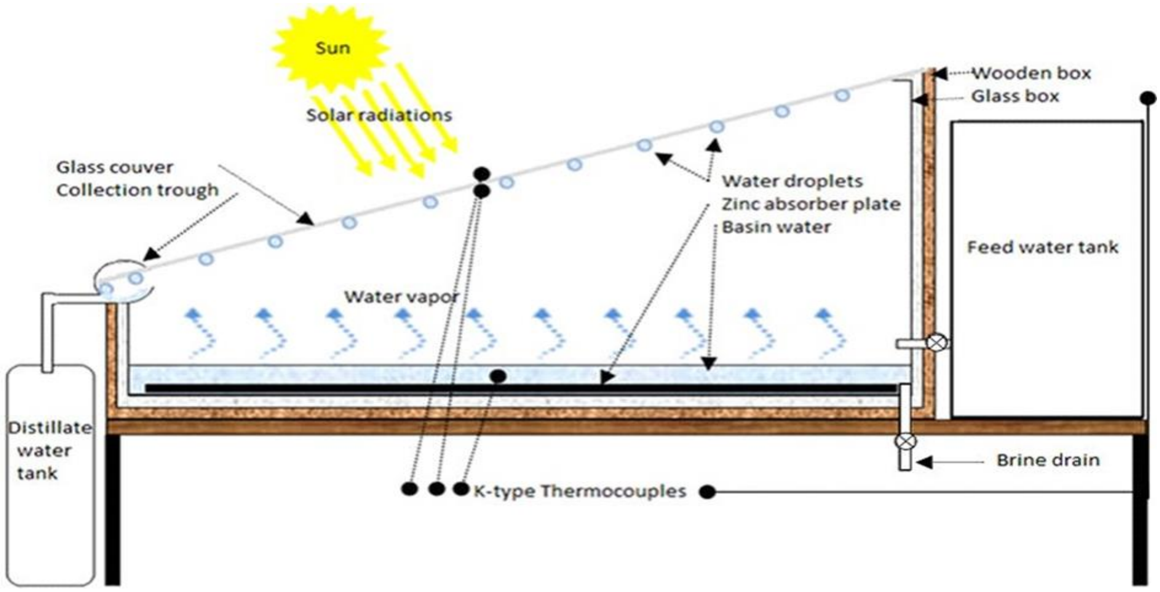


Figure IV-10.Diagrams of the experimental setup

The experiment is carried out in 3 days from 13/06/2021a from 8 am on the media library terrace of the University of Ghardaïa.

Ghardaïa is the capital city of Ghardaïa Province Algeria, It is located in northern-central Algeria in the Sahara Desert, Ghardaia's location is determined by Latitude: 32°29′27″ N and Longitude: 3°40′24″ E, Elevation above sea level: 503 m = 1650 ft

IV. 4.2Result and discussion:

IV. 4.2.1 the first day (13/06/2021): 4 distillers are used

The first is a conventional distiller, the second is a distiller that contains 3 bars of section 14, the third contains 6 bars of section 14 and the last contains 9 bars of section 14

IV. 4.2.1.1 Meteorological conditions of the experiment:

Sunrise	**5:38:49**
Sunset	**19:54:37**
Ambient temperature	**39 C°**
Atmospheric pressure	**1.014 bar**

Table IV-3: summarizes the meteorological conditions for the experiment

IV. 4.2.1.2 Quality of obtained distilled water:

Salty water (used water)	**Distilled water (produced water)**
pH =5.87	pH =6.95
σ = 4.72 ms/cm	σ = 230 us/cm

Table IV-4: Results of the analysis of the water used

IV. 4.2.1.3 solar radiation and ambient temperature:

Figure IV-12 shows the variation of solar radiation as a function of time during the day 13/06/2021 from 8 am to 7 pm, there is an increase in solar radiation from 328w/m^2 A 8h up to a maximum value of 963 W/m^2 A 12h30

A decrease in solar radiation is observed to wait according to a minimum value a 111w/m^2 at 19h

On the same figure (Figure IV.11) or shows the variation in the ambient temperature during the same day (13/06/2021). It is held that the variation in temperature has the same appearance as the variation in solar radiation

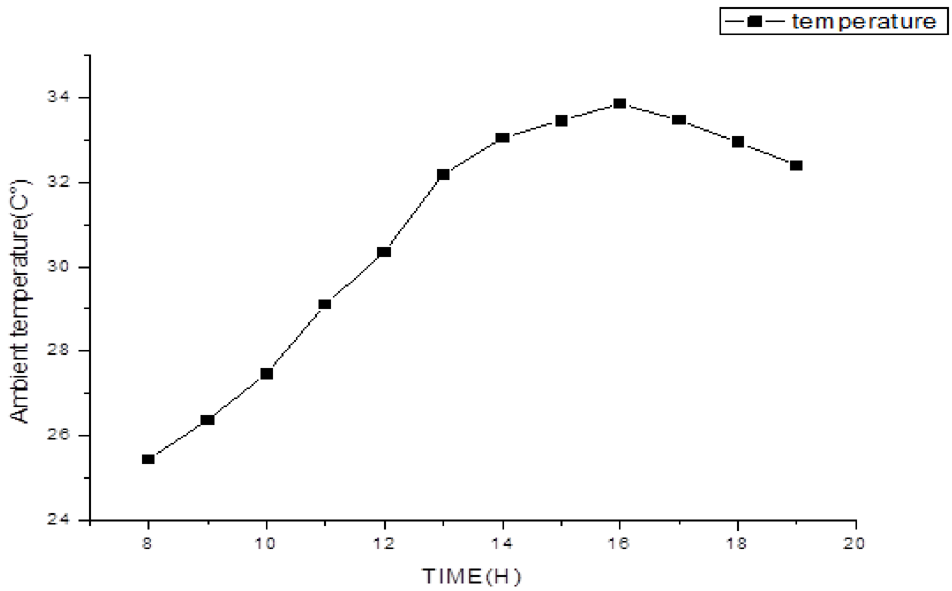


Figure IV-11. The variation of temperature as a function of time during the day 13/06/2021 from 8 am to 7 pm

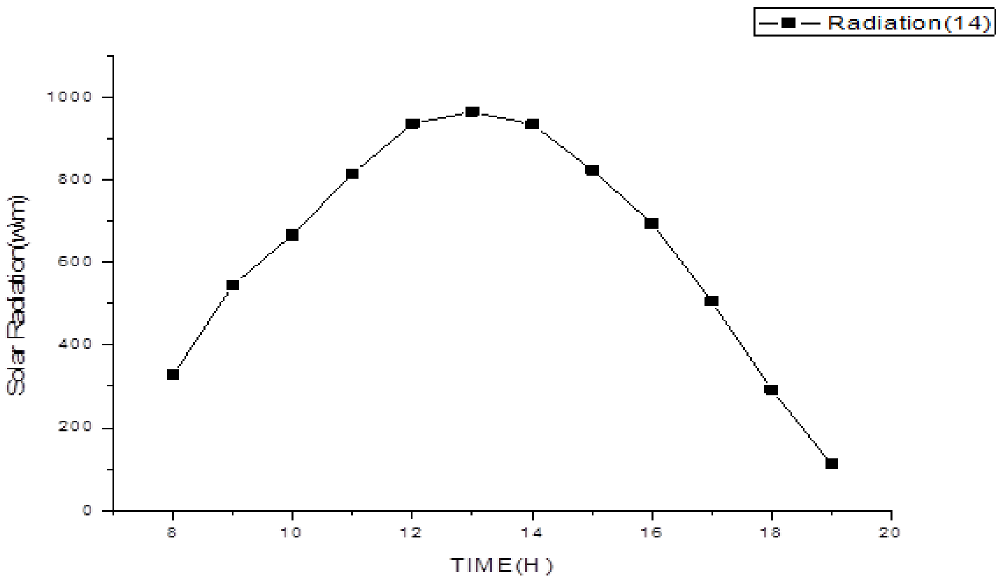


Figure IV-12. The variation of solar Radiation as a function of time during the day 13/06/2021 from 8 am to 7 pm

IV. 4.2.1.4 the variation of the basin salt-water temperatures:

Figure IV.13 shows the temporary variations in the water of the basin of the 4 distillers

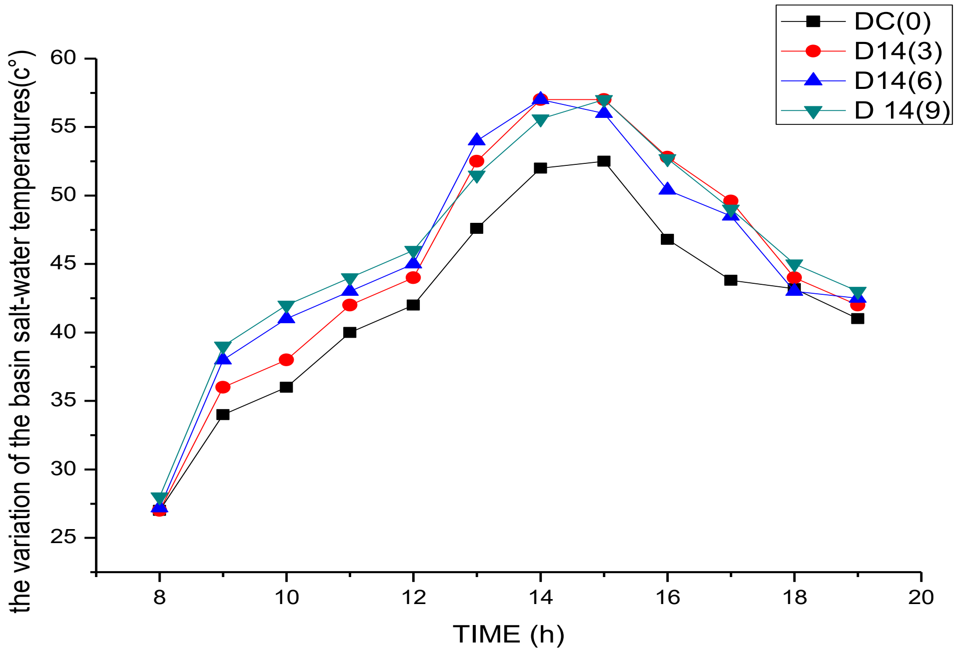


Figure IV- 13.the variation of the basin salt-water temperatures

IV. 4.2.1.5 temporary change in bar temperature:

The temporary variations in the temperature of the bars of the 4 distillers are illustrated in Figure IV-14

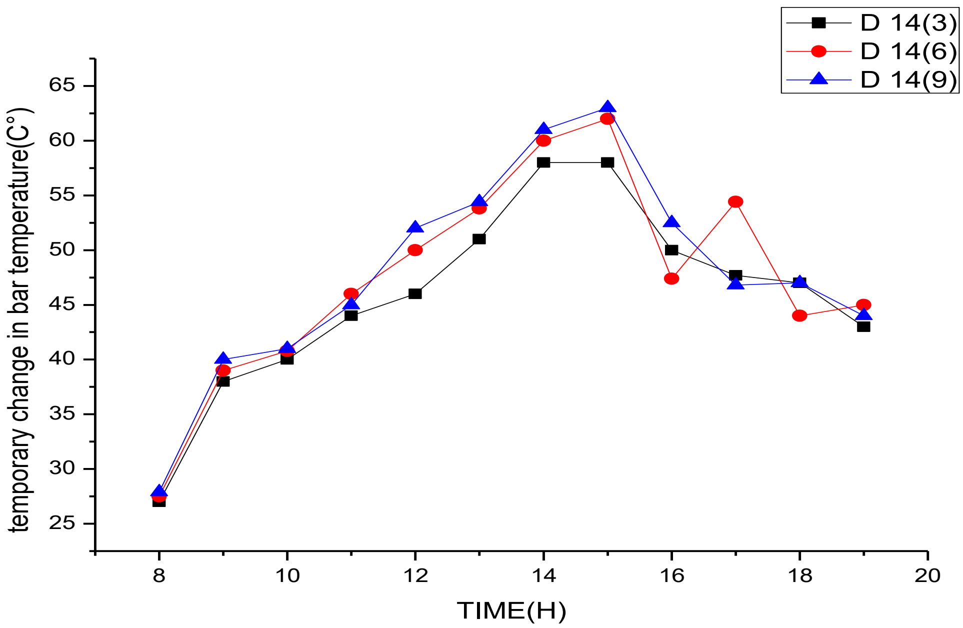


Figure IV- 14.temporary change in bar temperature

IV. 4.2.1.6 temporary variations in the external temperature of the pane:

Figure IV-15 shows the variations of the temporary temperature of the external temperature of the glass

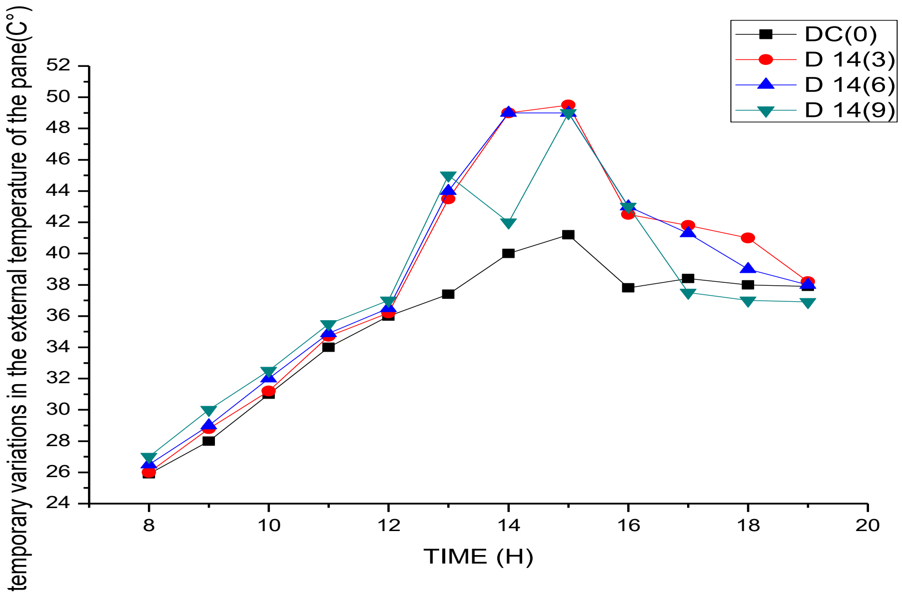


Figure IV- 15.temporary variations in the external temperature of the pane

IV. 4.2.1.7 temporary variation in the internal temperatures of the pane:

Figure IV-16 shows the temporary variations in the internal temperature of the glass

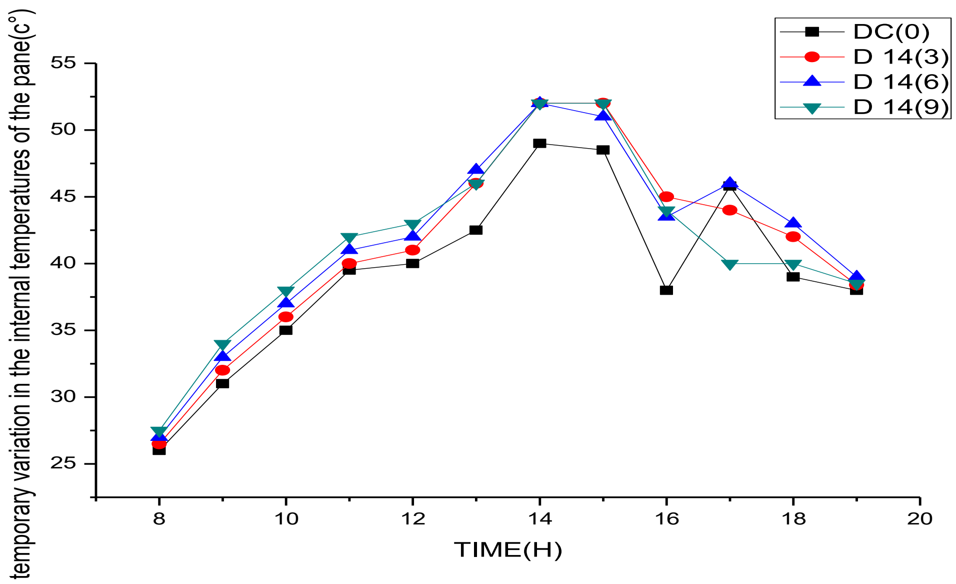


Figure IV-16.temporary variation in the internal temperatures of the pane

IV. 4.2.1.8 the variation of the hourly fresh water productivity:

The temporary variation in the productivity of distillate water is of the 4 distillers is illustrated in the figure IV-17

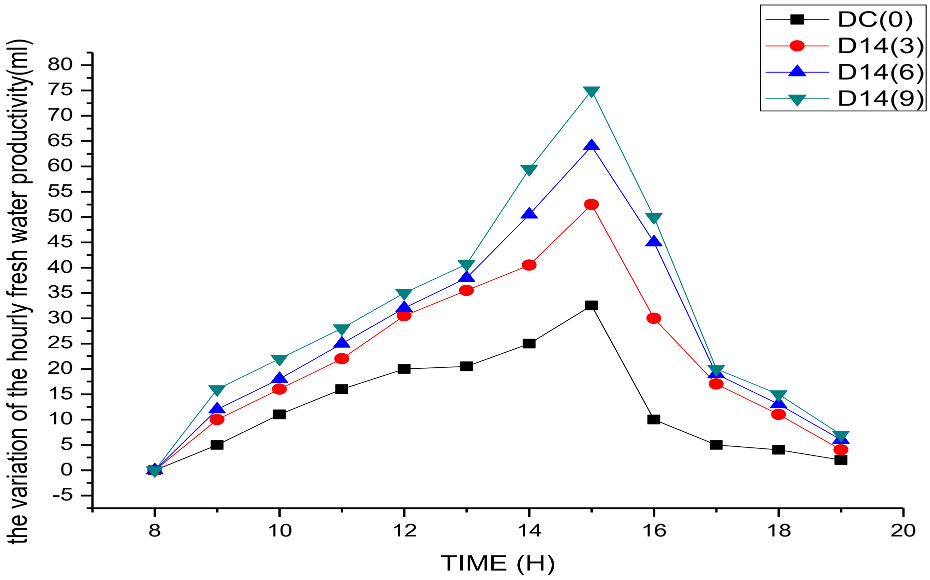


Figure IV- 17.the variation of the hourly fresh water productivity

IV. 4.2.1.9 CONCLUSION:

For the first day we concluded that the presense of the bars increase the temperature of the temperature of the water and the external,internal temperature of the cover glass of the distiller.

The increase of the number of the bar increase signeficatly the productivity of the distillation

IV.4.2.2 the second day (14/06/2021):

The first is a conventional distiller, the second is a distiller that contains 3 bars of section 16, the third contains 6 bars of section 16 and the last contains 9 bars of section 16

IV. 4.2.2.1 Meteorological conditions of the experiment:

Sunrise	**5:38:51**
Sunset	**19:54:59**
Ambient temperature	**38.5 C°**
Atmospheric pressure	**1.013 bar**

Table IV-5: summarizes the meteorological conditions for the experiment

IV. 4.2.2.2 Quality of obtained distilled water:

Salty water (used water)	**Distilled water (produced water)**
pH =5.85	pH =6.96
σ = 4.70 ms/cm	σ = 231 us/cm

Table IV-6: Results of the analysis of the water used

IV. 4.2.2.3 solar radiation and ambient temperature:

Figure IV-18 shows the variation of solar radiation as a function of time during the day 14/06/2021 from 8 am to 7 pm, there is an increase in solar radiation from418 w/m2 A 8h up to a maximum value of 1042w/m2 a13 H 10

A decrease in solar radiation is observed to wait according to a minimum value 118 w/m2 A19 h

On the same figure (Figure IV.19) or shows the variation in the ambient temperature during the same day (14/06/2021). It is held that the variation in temperature has the same appearance as the variation in solar radiation.

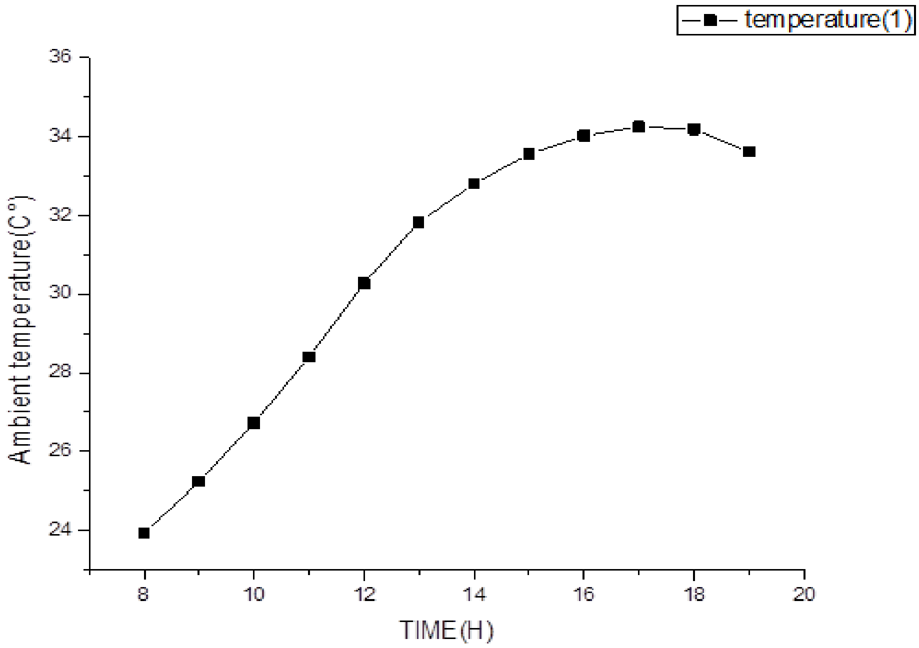


Figure IV-18.Ambient temperature (iron bar 16)

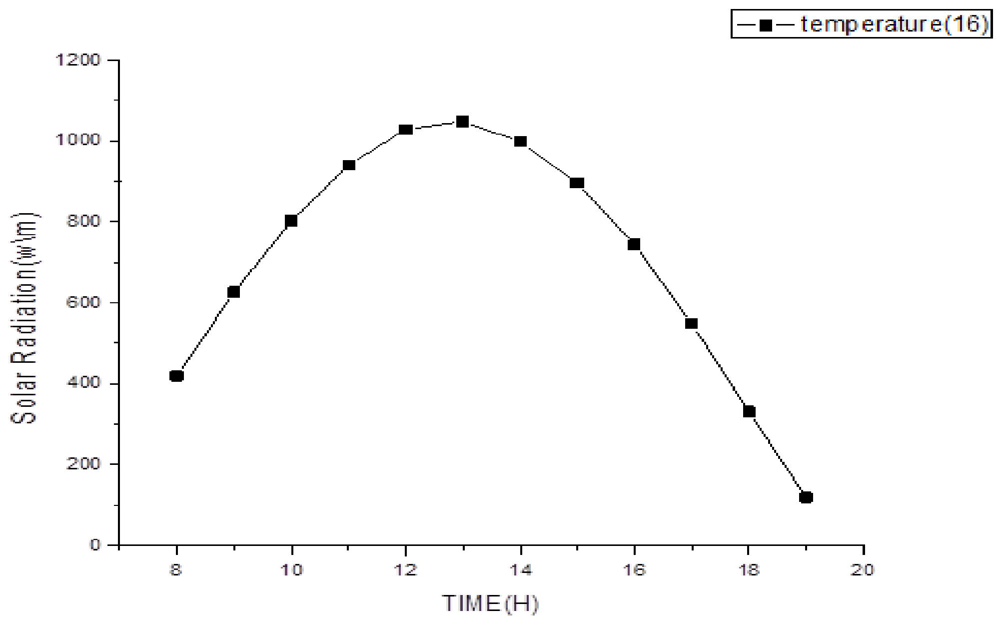


Figure IV-19.Solar Radiation (iron bar 16)

IV. 4.2.2.4 the variation of the basin salt-water temperatures:

Figure IV.20 shows the temporary variations in the water of the basin of the 4 distillers

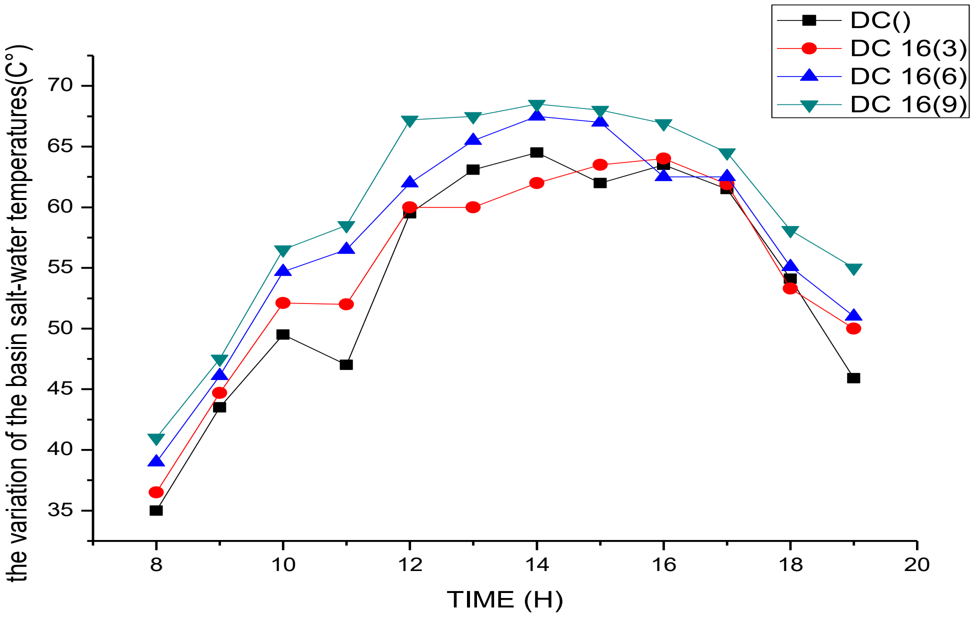


Figure IV- 20.the variation of the basin salt-water temperatures

We observe that the presence of the iron increase the temperature of the water but more significantly the maximum of the temperature in this day is 70 degres celsius

IV. 4.2.2.5 temporary variation in bar temperature:

The temporary variations in the temperature of the bars of the 4 distillers are illustrated in Figure IV-21

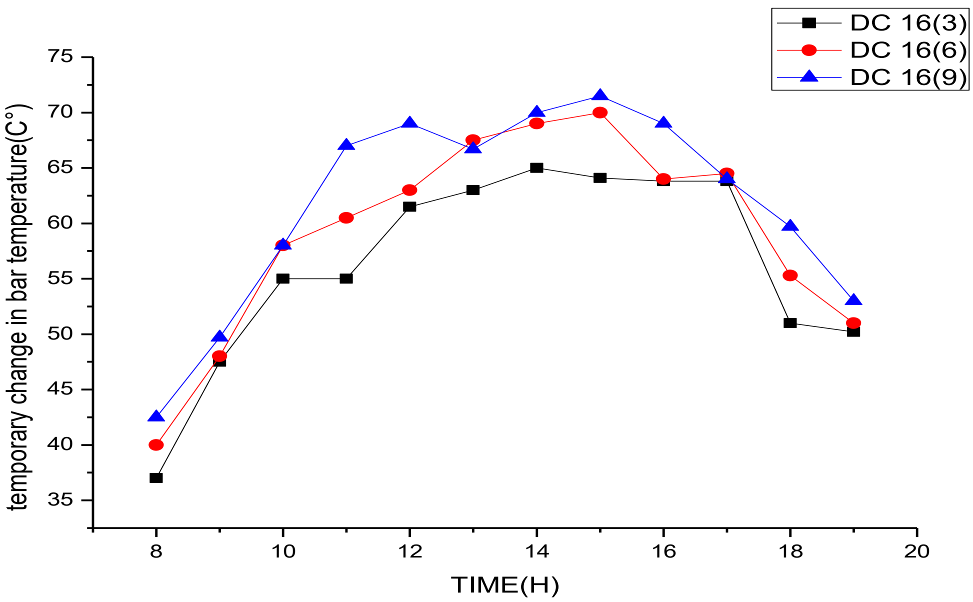


Figure IV-21.temporary in bar temperature

We conclude that the increase of number of the iron increase the temperature of the bars but more significantly the maximum of the temperature is 70 degres celsius

IV. 4.2.2.6 temporary variations in the external temperature of the glass:

Figure IV-22 shows the variations of the temporary temperature of the external temperature of the glass

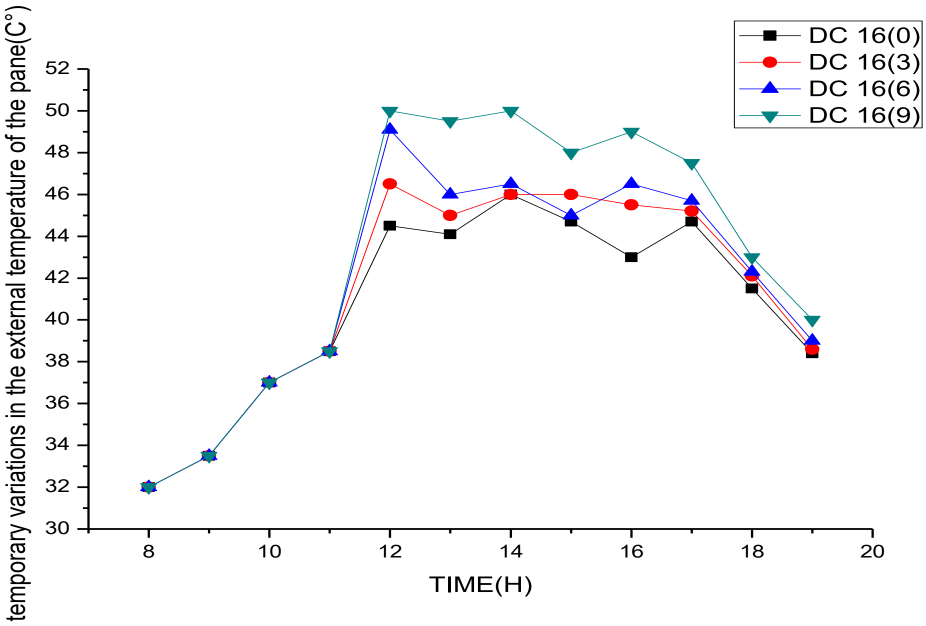


Figure IV-22.temporary variations in the external temperature of the glass

We observe that the presence of the bars increase the external temperature of the glass

IV. 4.2.2.7 temporary variation in the internal temperatures of the pane :

Figure IV-23 shows the temporary variations in the internal temperature of the glass

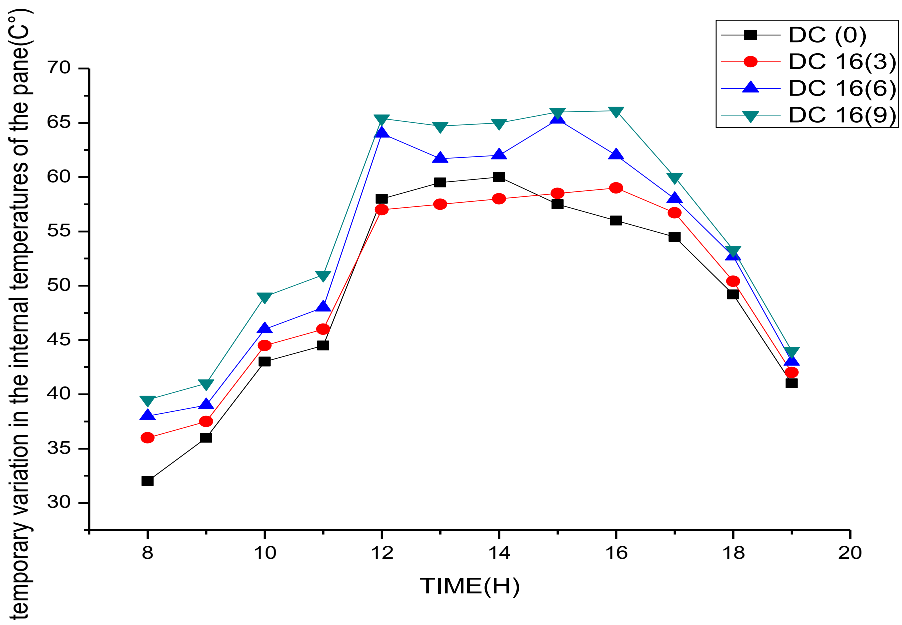


Figure IV- 23.temporary variation in the internal temperatures of the glass

We observe that the presence of the bars increase the external temperature of the glass but more significantly the maximum of the temperature is 66 degres celsius

IV. 4.2.2.8 the variation of the hourly distilled water productivity:

The temporary variation in the productivity of distillate water is of the 4 distillers is illustrated in the figure IV-24

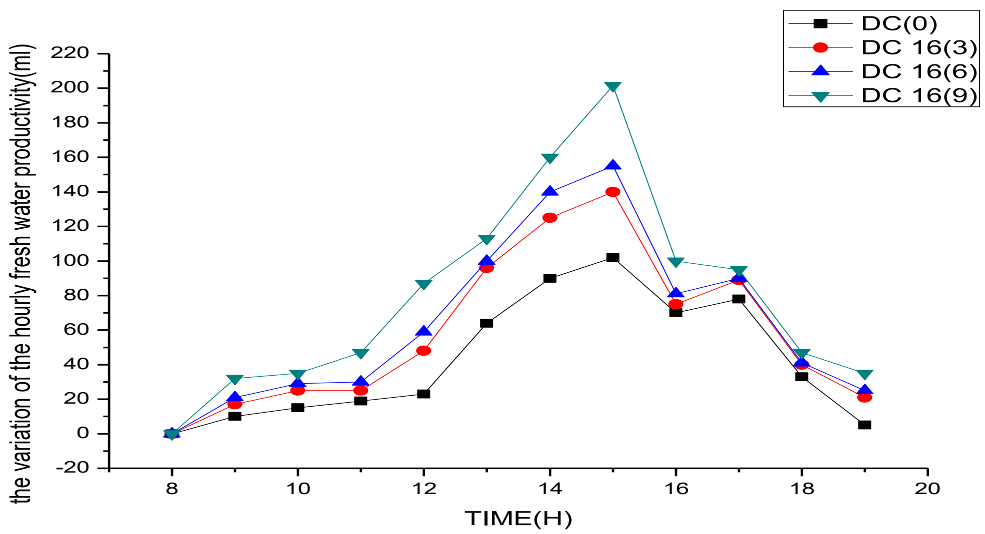


Figure IV-24.the variation of the hourly water productivity

We observe clearly that the increase of the number of the bar increase the productivity of the distilled water but more significantly the maximum is 220 ml

IV. 4.2.2.9 CONCLUSION:

For the second day we concluded the same observatino ; the presense of the bars increase the temperature of the temperature of the water and the external,internal temperature of the cover glass of the distiller The increase of the temperature is more significantly because the section of the bar is higher

The increase of the number of the bar increase signeficatly the productivity of the distillation because the section of the bar is higher

IV.4.2.3. The third day (15/06/2021): The first is a conventional distiller, the second is a distiller that contains 9 bars of section 14, and the third contains 9 bars of section 16

IV. 4.2.3.1 Meteorological conditions of the experiment:

Sunrise	**5:38:55**
Sunset	**19:55:20**
Ambient temperature	**38 C°**
Atmospheric pressure	**1.014 bar**

Table IV-7: summarizes the meteorological conditions for the experiment

IV. 4.2.3.2 Quality of obtained distilled water:

Salty water (used water)	**Distilled water (produced water)**
pH =5.82	pH =6.98
σ = 4.73 ms/cm	σ =232 us/cm

Table IV-8: Results of the analysis of the water used

IV. 4.2.3.3 solar radiation and ambient temperature:

Figure IV-25 shows the variation of solar radiation as a function of time during the day 15/06/2021 from 8 am to 7 pm, there is an increase in solar radiation from411w/mé A 8h up to a maximum value of 1041w/m2 a 12h50

A decrease in solar radiation is observed from to wait according to a minimum value 131w/m2 a 19h

On the same figure (Figure IV.25) or shows the variation in the ambient temperature during the same day (14/06/2021). It is held that the variation in temperature has the same appearance as the variation in solar radiation

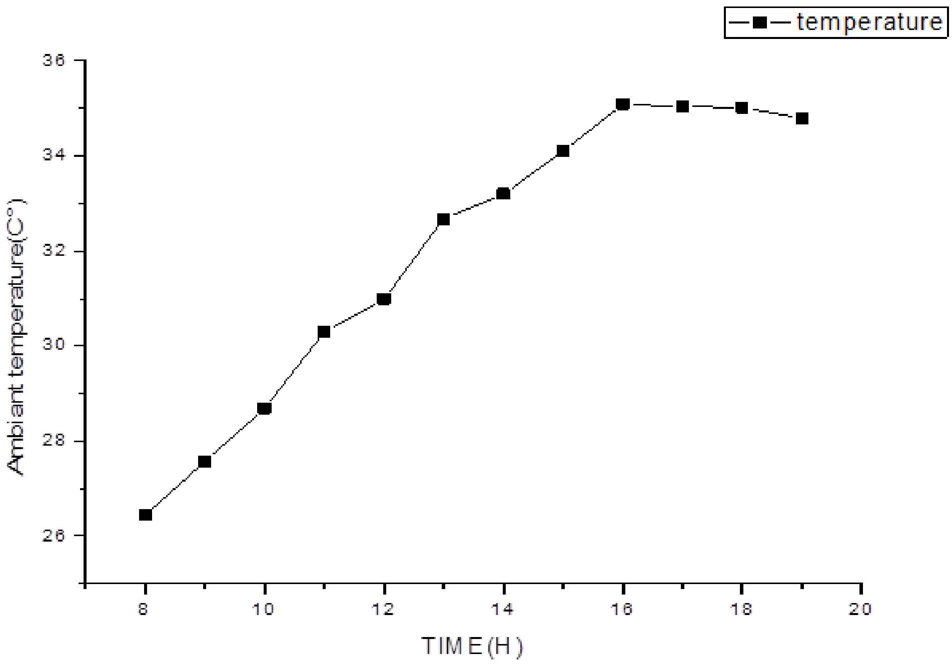


Figure IV-25. Ambient temperature

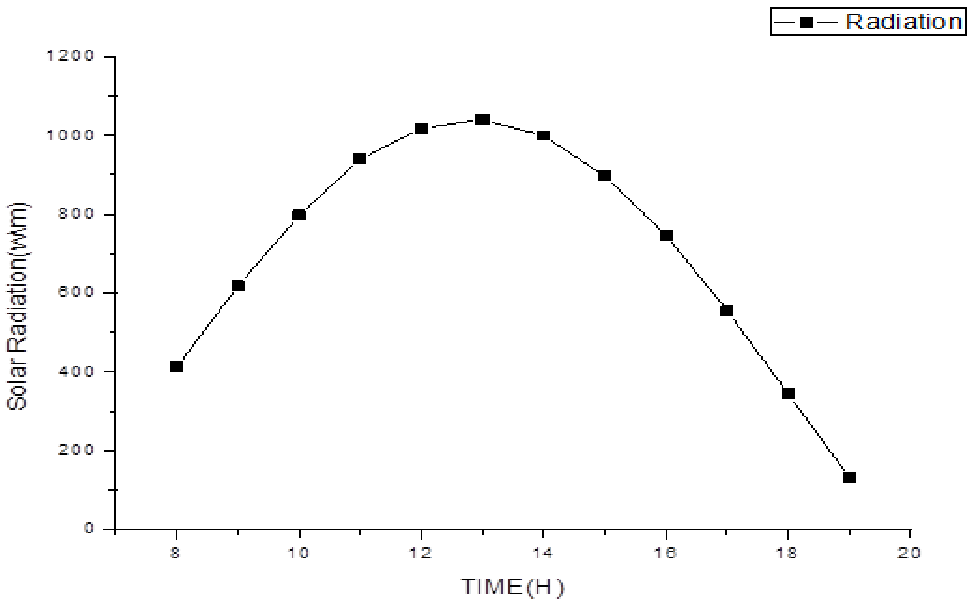


Figure IV-26. Solar Radiation

IV. 4.2.3.4 the variation of the basin salt-water temperatures:

Figure IV.24 shows the temporary variations in the water of the basin of the 3 distillers

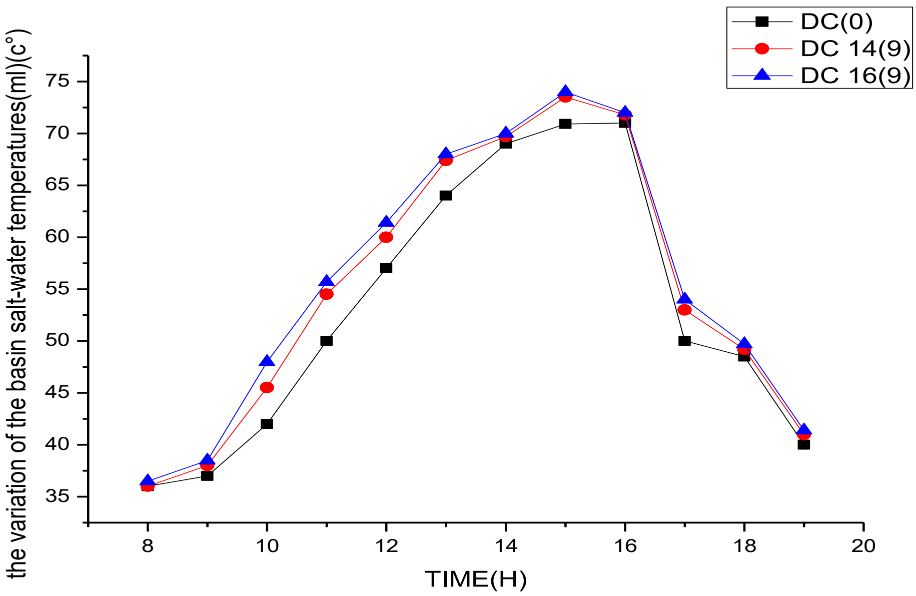


Figure IV- 27.the variation of the basin salt-water temperatures

We observe that the increase of the section of the bar increase the temperature of the water

IV. 4.2.3.5 temporary variation in bar temperature:

The temporary variations in the temperature of the bars of the 3 distillers are illustrated in Figure IV-28

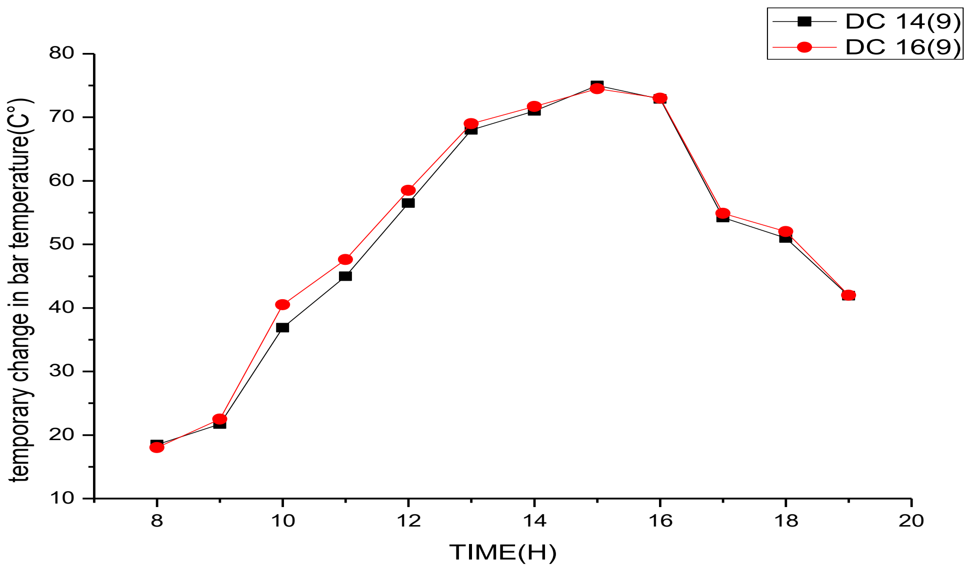


Figure IV-28.temporary variation in bar temperature.

We observe that the section of the bar don't influence on the temperature of the bar significantly

IV. 4.2.3.6 temporary variations in the external temperature of the glass :

Figure IV-29 shows the variations of the temporary temperature of the external temperature of the glass

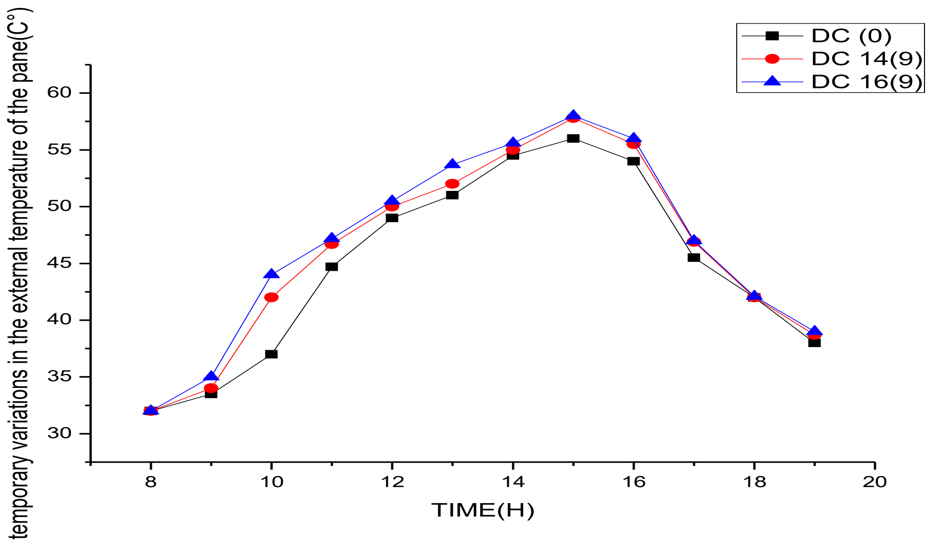


Figure IV- 29.temporary variations in the external temperature of the pane

We observe that the increase of the section of the bar increase the external temperature of the glass

IV. 4.2.3.7 temporary variation in the internal temperatures of the pane :

Figure IV-30 shows the temporary variations in the internal temperature of the glass

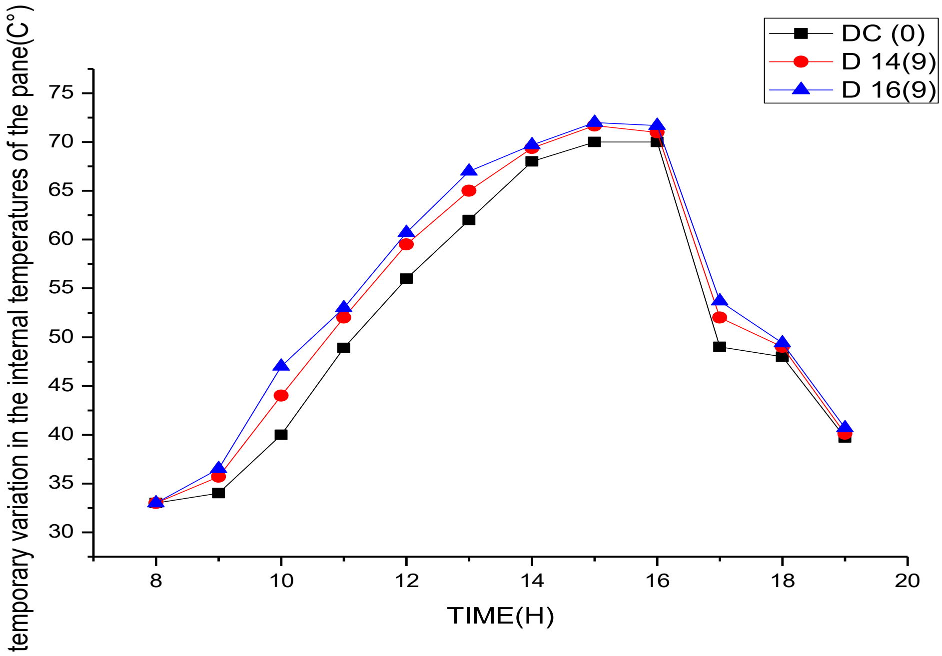


Figure IV-30.temporary variation in the internal temperatures of the pane

The same observation is observed for the internal temperature of the glass : the increase of the section of the bar increase the internal temperature of the glass

IV. 4.2.3.8 the variation of the hourly distilled water productivity:

The temporary variation in the productivity of distillate water is of the 3 distillers is illustrated in the figure IV-31

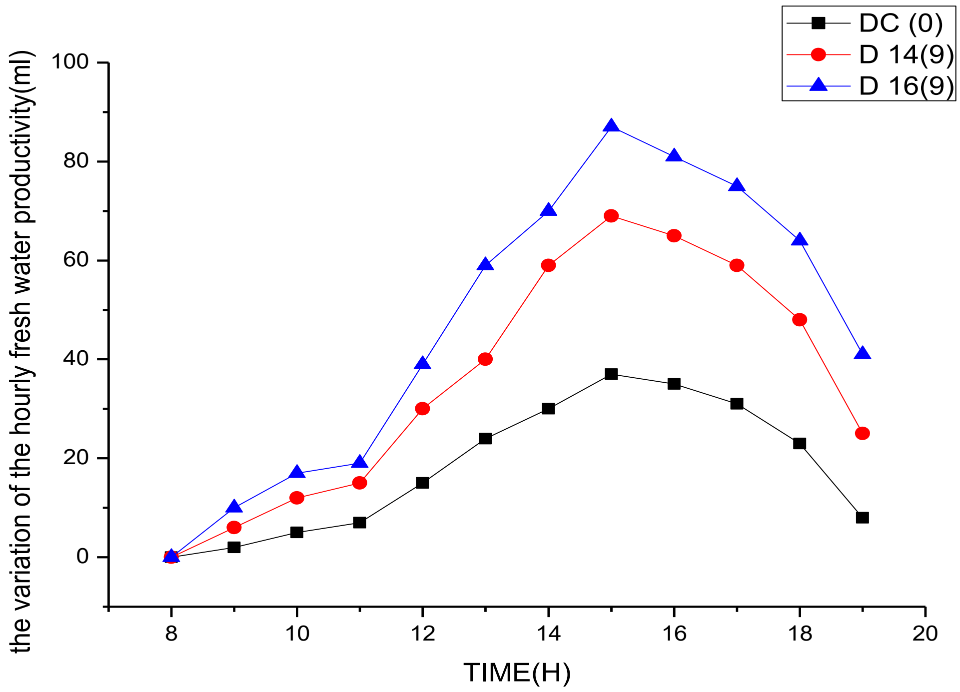


Figure IV-31.the variation of the hourly distilled water productivity

We observed that the increase of the section of the bar increase the productivity

IV. 4.2.3.9 CONCLUSION:

For this third day we concluded that the increase of the section of the bar increase the external and internal temperature of the glass but don't influence the temperature of the bar .

Also the increase of the section of the bar increase the temperature of the salty water and the productivity of the distilled water

GENERAL CONCLUSION

GENERAL CONCLUSION:

Lack of safe drinking water is a major global problem. Many researchers have tried to overcome this difficulty. A variety of techniques have been used but one problem is still present: the low productivity of the distilled water obtained and intended for obtaining drinking water.

The general methodology used to increase the productivity of stills is based on the idea of increasing the heat exchange surface between water and materials intended to store thermal energy from solar radiation , in this experimentaly study of the distillation we study the influence of the presence of the iron on the productivity of the distilled water

The experience is realised in three days, we conclude that the presence of the iron influenced significatly the productivity of the distilled water ,the section and the number of the iron influenced the productivity the increase of the section and the number of the iron increase the productivity of the distilled water because of the increase of the number and the section of the iron increase the echange surface of heat transfer

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