

UNIVERSITY OF KASDI MERBAH OUARGLA

FACULTY OF APPLIED SCIENCES

MECHANICAL ENGINEERING DEPARTMENT



Dissertation

Presented to obtain a diploma of

MASTER

Specialty: Mechanical Engineering

Option: Energetic

Presented by:

OUDDANE Omar

Theme

**Study on the integration of different
modes of thermal insulation and
passive cooling shelter**

Publicly supported on:

31/05/2017

In front of the jury:

Mr.BELIHIA Hocine	M.A.A. University KM Ouargla	President
Mr.CHARRADE Nourddine	M.A.A. University KM Ouargla	Examiner
Mr. DRID Mohamed .Mabrouk	M.A.B. University KM Ouargla	Reporter

ACADEMIC YEAR: 2016/2017



Remerciements

*I thank **ALLAH** who has given us the courage and willingness to continue our studies and for all his favor .*

Than ,I extend my sincere thanks to my family: My parents, my brothers, my wife and daughter who have accompanied, helped, supported and encouraged me always and throughout this work and alsoto my friends.

*would like to thank my encadror Mr **DRID M.Mebrouk** for his valuable help, his great availability , his valuable advice during the preparation of this study .*

We also thank the jury members who agreed to evaluate my work and honored us by their presence.

OUDDANE Omar





Dédicace

*I dedicate this modest
work first of all to my
dear parents that support
and encourage me during
my life and also for my
brothers my wife my
daughter all my friends*

OUDDANE Omar



Summary

Remerciements	I
Dedicate	II
Summary	III
Index of Figures	IV
Index of Tables	V
List of Symbols	VI
General Introduction	01

Chapter I: Different modes of cooling and litterateur review

I.1. Introduction.....	02
I.2. Active cooling system.....	02
I. 2.1. Air conditionner.....	02
I. 2.2. Vortexcooler.....	02
I. 3. Passive cooling systems.....	03
I. 3.1. Shading	03
I. 3.2. Reflection of Solar Heat	03
I. 3.3. Insulation	03
I. 3.4. Ground Cooling	04
I. 3.5. Wind Cooling	04
I. 4. Litterateur review.....	04
I. 5. Conclusion	06

Chapter II: Energetic Audit

II.1. Introduction to TRNSYS.....	07
II. 2. The TRNSYS Simulation Studio.....	07
II.3. The Building visual interface.....	08

II. 4. The TRNSYS Simulation software.....	08
II.5. TRNEdit and TRNSED applications.....	09
II. 6. Climate view	10
II.6.1. Ouargla climate	10
II.7. Project simulation.....	11
II.7.1. Validation of model.....	12
II. 7.2.Temperatures of walls.....	12
II. 8. Conclusion.....	14

Chapter III: Numerical approach

III.1.Introduction	15
III.2. Governing equations of fluid flow and heat transfer.....	15
III.2.1. Mass conservation	15
III.2.2. Momentum equation	15
III.2.3. Energy equation	16
III. 3. Boussinesq Approximation	16
III.4. Dimensionless number.....	16
III.4.1. Reynolds number.....	16
III.4.2. Prandtl number.....	17
III.4.3. Grashof number.....	17
III.4.4. Rayleigh number.....	17
III.4.5.Nusseltnumber	18
III.5.Generalitv of CDF.....	18
III.5.1.What is CDF?	18
III.5.2.How does a CDF code work?	19
III.6. Conclusion	19

Chapter IV: Results and discussion

IV.1 Introduction.....	20
IV.2.Simulation steps	20
IV.3. Air Physical parameters	21
IV.4. Shelter without gain.....	21
IV.4.1.Computational domain.....	21
IV.4.2.Mesh choice.....	22
IV.4.3. Convergence control.....	22
IV.4.4.Temperature profile.....	23
IV.4.4.Dynamic field.....	23
IV.5. Shelter with gain	24
IV.5.1. Computational domain.....	24
IV.5.2. Mesh choice.....	24
IV.5.3. Convergence control.....	24
IV.5.4. Temperature profile.....	25
IV.5.5. Dynamic field.....	25
IV.6. Shelter with roof shading	26
IV.6.1. Computational domain.....	26
IV.6.2. Mesh choice.....	27
IV.6.3. Convergence control.....	27
IV.6.4. Temperature profile.....	28
IV.6.5. Dynamic field.....	28
IV.7. Shelter with roof shading and natural ventilation Low-Low.....	29
IV.7.1. Computational domain.....	29

IV.7.2. Mesh choice.....	29
IV.7.3. Convergence control.....	29
IV.7.4. Temperature profile.....	30
IV.7.5. Dynamic field.....	31
IV.8. Shelter with roof shading and natural ventilation Low-Low	31
IV.8.1. Computational domain.....	31
IV.8.2. Mesh choice.....	32
IV.8.3. Convergence control.....	32
IV.8.4. Temperature profile.....	33
IV.8.5. Dynamic field.....	33
I. 9. Conclusion.....	34
GeneralConclusion.....	35

Bibliographical and References

Index of Figures

Figure I.1: Function system of air conditioner.....	2
Figure I.2: Vortex cooler.....	3
Figure I.3: model description.....	5
Figure I.4: Free convection passive cooling system during day and night.....	6
Figure II.1: TRNSYS simulation studio.....	7
Figure II.2: TRNSYS Build window.....	8
Figure II.3: TRNSYS simulation Engine	8
Figure II.4: TRNSYS TRNEdit.....	9
Figure II.5: Temperature variation of Ouargla in 2016.....	10
Figure II.6: Shelter characteristic.....	11
Figure II.7: Comparison between simulation and experimental values	12
Figure II.8: Temperature of the month June 2016 for Ouargla	12
Figure II.9: Simulation values of temperature for the roof and four walls of the shelter.....	13
Figure IV.1: Shelter without gain.....	21
Figure IV.2: Shelter Mesh.....	22
Figure IV.3: Residuals evolution in shelter without gain.....	22
Figure IV.4: Static temperature profile in shelter without gain.....	23
Figure IV.5: Velocity contours (Kg/s) in shelter without gain.....	23
Figure IV.6: Shelter with gain.....	24
Figure IV.7: Residuals evolutions Shelter with gain	25
Figure IV.8: Static temperature profile in shelter with gain.....	25
Figure IV.9: Velocity contours (Kg/s) in shelter with gain.....	26
Figure IV.10: Shelter with roof shading.....	26

Figure IV.11: Residuals evolution in shelter with roof shading.....	27
Figure IV.12: Static temperature profile in shelter with roof shading.....	28
Figure IV.13: Velocity contours (Kg/s) in shelter with roof shading.....	28
Figure IV.14: Shelter with roof shading and natural ventilation Low (Inlet)-low (Outlet)...	29
Figure IV.15: Residuals evolution in shelter with roof shading and natural ventilation Low-Low.....	30
Figure IV.16: Static temperature profile in shelter with roof shading and natural ventilation Low (inlet)-Low (outlet)	30
Figure IV.17: Velocity contours (Kg/s) in Shelter with roof shading and natural ventilation Low (Inlet)-low (Outlet).....	31
Figure IV.18: Shelter with roof shading and natural ventilation Low (Inlet)-High (Outlet)	31
Figure IV.19: Residuals evolutions Shelter with roof shading and natural ventilation Low (Inlet)-high (Outlet).....	32
Figure IV.20: Temperature profile in Shelter with roof shading and natural ventilation Low (Inlet)-high (Outlet)	33
Figure IV.21: Velocity contours (Kg/s) in Shelter with roof shading and natural ventilation Low (Inlet)-high (Outlet)	33

Index of Tables

Table II.1: Materials characteristics.....	11
Table II.2: Walls Max temperatures.....	14
Table IV.1: Air Physical parameter	21
Table IV.2: Gird information for shelter without gain.....	22
Table IV.3: Residues for different equations.....	22
Table IV.4: Gird information for shelter with gain.....	24
Table IV.5: Residues for different equations.....	24
Table IV.6: Gird information for shelter with roof shading.....	27
Table IV.7: Residues for different equations.....	27
Table IV.8: Gird information for shelter with roof shading and natural ventilation Low (Inlet)-low (Outlet).....	29
Table IV.9: Residues for different equations.....	30
Table IV.10: Gird information for shelter with roof shading and natural ventilation Low (Inlet)-High.....	32
Table IV.11: Residues for different equations.....	32

List of Symbols

L length	{m}
W Width	{m}
H Height	{m}
g Gravitational acceleration	{m/s ² }
T Temperature	{C ^o or K}
T ₀ Reference temperature	{C ^o or K}
ΔT Temperature difference	{C ^o or K}
Re Reynolds number	{ }
Pr Prandtl number	{ }
Gr Grashof number	{ }
Ra Rayleigh number	{ }
h Convection coefficient	{W/m ² K}
ρ Fluid density	{kg/m ³ }
V Velocity	{m/s}
D Diameter	{m}
μ Dynamic viscosity	{ Pa·s }
ν Kinematic viscosity	{ m ² /s }
ρ ₀ Density of fluid at some reference temperature T ₀	{kg/m ³ }
β Thermal expansion coefficient of air	{K ⁻¹ }
C _p Specific heat at constant pressure	{J/Kg.k-1}
k is the coefficient of thermal conduction	{W/m.K-1}

General Introduction

Nowadays the energy demand for the residential and commercial building increases rapidly due to the development of technology and other items, in hot climate where the uses of the air conditioning system is important element especially during summer seasons, also for cooling the enclosures of telecommunication the traditional cooling systems through air forced convection become inefficient for high power supply. For this reason, natural ventilation is introduced to help in cooling telecommunication equipment in the outdoor cabinet in order to keep equipment temperature below the operating temperature defined by European Telecommunication Standard Institute (ETSI) 55C.

In this study we integrate natural ventilation and roof shading and after simulation with fluent we choice the best system of cooling the shelter from all the cases that conserve the energy especially in the desert places where the electricity causes a big challenge.

This project is composed of four chapters, the first one shows the different types of cooling and a literatures review of the previous researches and studies realized about a several solutions of passive cooling.

The second chapter treated energy audit starting with introduction of the programmers used to carry this audit in the shelter and his types than simulation of our project

The third chapter is about a heat transfer equations and dimensiless number

The fourth chapter presents the result of simulation of all the cases

Numerical simulation were done using FLUENT software and the results show the impact of natural ventilation in cooling the inside space of the cabinet and that was shown by studying the internal temperature of the Telecom communication cabinet where the best case was by realising low inlet of air and high outlet of air .

I. Introduction:

In recent years several investigations and studies were performed to help individuals and groups to select and implement the appropriate technologies for cooling their building for this reason they developed many techniques of cooling, which they can divided into two types:

- ✓ Active system
- ✓ Passive system

I. 2. Active cooling system

It is the System that involves the use of energy to cool something this systems uses a coolant to transfer heat from one place to another.

The coolant is either a gas, or a liquid as in a car engine.

I. 2.1. Air conditioner

Air cooling is a method of dissipating heat. They have the Principe of heat pumps and refrigerators. It is the most common mean of cooling building, consist of evaporator and condenser between them a compressor and valve A fluid uses as a coolant circulate and transfer heat in aimed to cool or to heat from side to another side

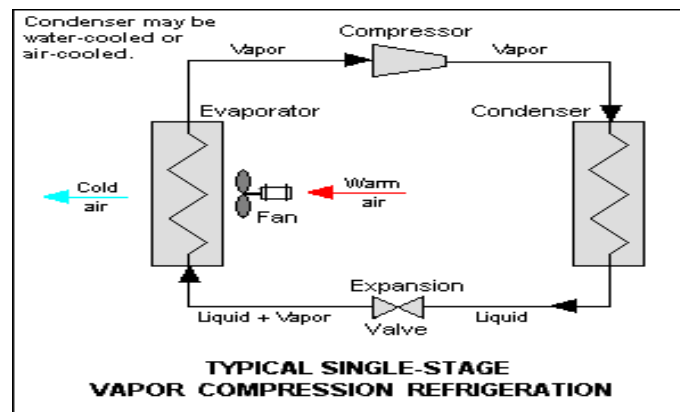


Figure I.1: System function of air conditioner

I. 2.2. Vortex cooler:

The vortex tube was invented in 1933 by French physicist Georges J. Ranque. German physicist Rudolf Hilsch as shown in Fig. 1

The system basically is consist of a tube, also known as the Ranque-Hilsch vortex tube that separates gas (usually compressed air) into hot and cold streams. Pressurized gas is injected into a swirl chamber and accelerates to a high rate of rotation (over 1,000,000 rpm). The gas is split into

two streams, one giving kinetic energy to the other, and resulting in separate flows of hot and cold gases [1].



Figure I.2: Vortex cooler

I. 3. Passive cooling systems

Passive cooling use free, renewable source of energy such as sun and wind to provide cooling and lighting needs for household, it is one of the innovative practice and technologies that provide building with the comfortable conditions

I. 3.1. Shading:

The simplest and most effective passive cooling technique is to keep the sun's heat from entering a building. This is accomplished primarily by shading, using:

- ❖ The building itself (roof, walls)
- ❖ Other buildings
- ❖ Supplemental shade (trees, vines, etc.) [2]

I. 3.2. Reflection of Solar Heat:

Light-colored roofs, walls, and other shading have the important advantage of reflecting much more heat than darker materials do .A white roof may absorb only 25 percent of solar heat, while 90 percent absorbed by a black one. This greatly reduces the amount of heat getting into the building. Reflective films can be applied to windows and other glass areas to keep out more heat while remaining transparent[2].

I. 3.3. Insulation:

Insulation usually is considered a means of keeping heat inside a building, but it can also keep heat out and thus provide cooling in summer.

Walls and ceilings may be filled with conventional insulation materials such as cellulose, vermiculite, rock wool, or glass fiber. Various kinds of rigid

foam board may be used either inside or outside of walls. A number of materials that have insulative properties may be available locally.

Also wood fiber, shredded sea weed, etc., can be used for insulation[2].

I.3.4. Ground Cooling:

When the surface temperature of soil rises during hot summer days, soil at a depth of several feet is much cooler and generally remains constant in this type underground passive cooling uses subsurface tunnels, or cool pipes, can provide summer comfort for buildings.

I.3.5. Wind Cooling:

By introducing natural wind indoor the building during daytime can decrease the temperature and removed the heat and discomfort inside.

I. 4. Litterateur review

Many researches and studies are done to develop the different passive cooling modes due to energy that use in active system, below we should discuss some of these studies .

B. Dokkar et al, [3] they investigate of using of solar chimney together with earth-air heat exchanger t, it includes shelter with solar chimney placed on the south side at an angle α and underground pipe connected to shelter from the north side .

Air with ambient temperature goes through underground pipe and cooled by earth absorption effect. Than this air goes into the shelter across its north side and push hot air toward shelter roof. solar chimney accelerates hot air to escape out. The results of this study have shows that by using this system the temperature in the middle of the shelter does not exceed 29 °C.

H. Ben Cheikh1 et al, [4] shows in his experimental study of passive cooling roof was carried out for a typical summer day of June for Laghouat in Algeria. He proposed roof design composed of concrete ceiling than a bed of rocks and a small quantity of water. Over this bed is an air gap separated from the external environment by an aluminum plate. The upper surface of this plate is painted with a white titanium-based pigment to increase the radiation reflection process during daytime.

An external treatment of the roof used to provide mass transfer to the outside (water vapor).At night, the temperature of the aluminum sheet falls below the temperature of the rocks water upper surface water vapour inside the roof condensates and falls by gravity

The results show that the air temperature can decrease with a range from 6 to 10 °C. This decrease can further be lowered by 2 to 3 °C if night natural ventilation of buildings is allowed.

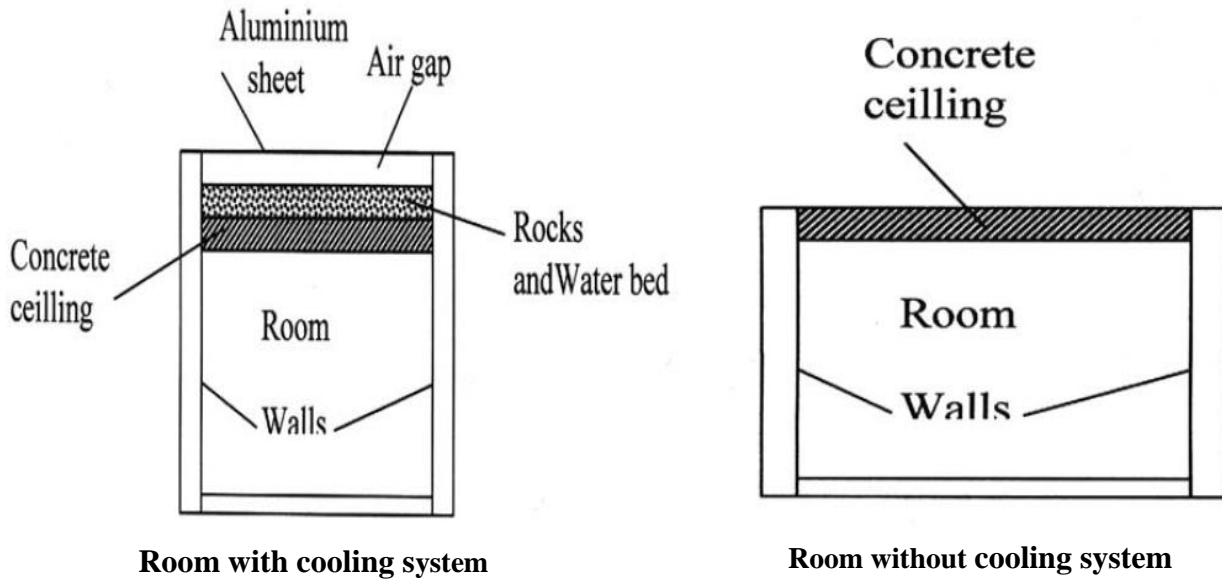
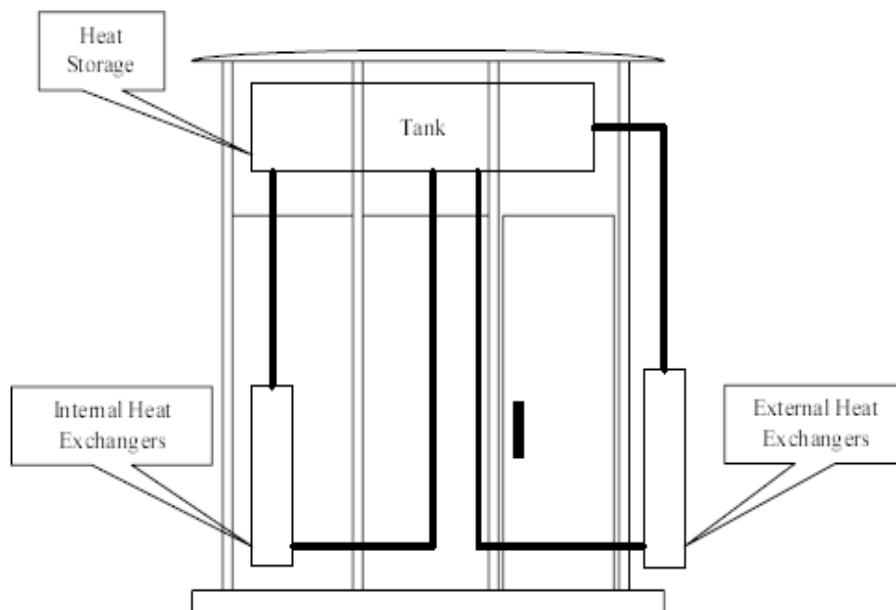


Figure I.3: model description

A. Darwiche et al, [1] in his study of natural convection which consists of housings with insulation, sun shade, external and internal heat exchangers, heat storage tank and conveyance of the medium (mainly water) Fig 1. The heat dissipated by the electronic equipment is absorbed by the internal heat exchanger and transferred to the water inside the tank by thermo siphon phenomenon. At night the water becomes cooled by using the external heat exchangers as illustrated in Fig2.



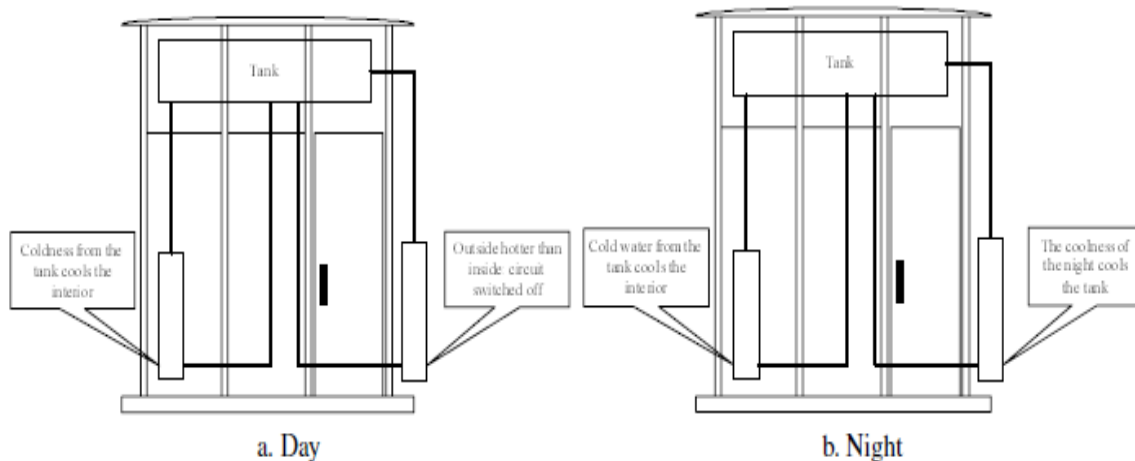


Figure I.3: Free convection passive cooling system during day and night

I. 5. Conclusion:

This chapter shows a general view about some types of cooling like active system that involved the using of power where the most common system is the air conditioner and the passive system that uses free, renewable source of energy, which consist of several methods as shading, insulation ..

Recently many researches were performed in passive cooling system due to his low cost and energy consumption in order to ensure a suitable condition in the building .In our case we have mentioned three studies:

The first it`s conducted by B. Dokkar about cooling telecommunication shelter using solar chimney together with earth-air heat exchanger the results indicate that the temperature in the middle of the shelter does not exceed 29 °C.

The second is the study of H. Ben Cheikh which was carried for a typical summer day of June for Laghouat region by using method of passive cooling roof, the results show that the air temperature can decrease with a range from 6 to 10 °C.

The third carried by A.Darwiche in his study uses the difference of temperature between the day and the night to cool the shelter.

II.1. Introduction to TRNSYS

Transient System Simulation is a complete and extensible simulation environment for the transient simulation of systems, including multi-zone buildings. It is used by engineers and researchers around the world to validate new energy concepts TRNSYS applications include:

- Solar systems (solar thermal)
- Low energy buildings and cooling systems with advanced design features (natural ventilation, slab heating/cooling, double façade, etc.)
- Renewable energy systems

The TRNSYS consist of:

II.2. The TRNSYS Simulation Studio

It used to create projects by drag-and-dropping components to the workspace, connecting them together and setting the global simulation parameters. the Studio also creates a TRNSYS input file (text file that contains all the information on the simulation but no graphical information and an output manager from where you control which variables are integrated)

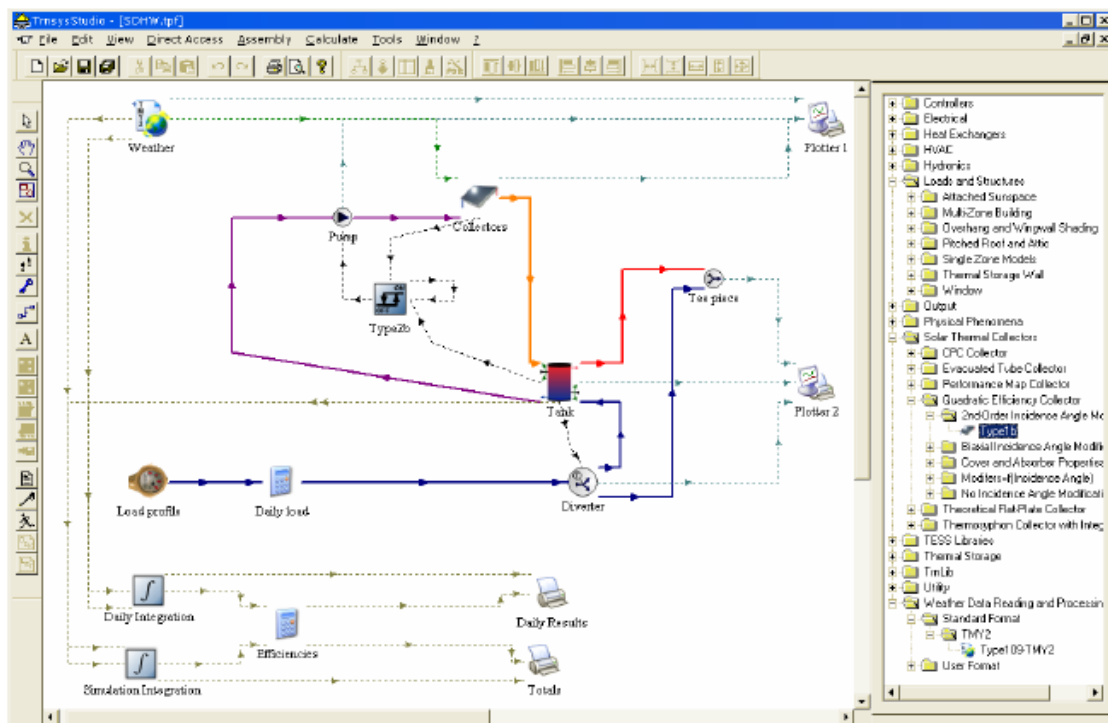


Figure II.1: TRNSYS simulation studio

II.3.The Building visual interface

Tool used to enter input data for multizone buildings. It allows you to specify all the building structure details to simulate the thermal behavior of the building, such as windows optical properties, heating and cooling schedules, etc.

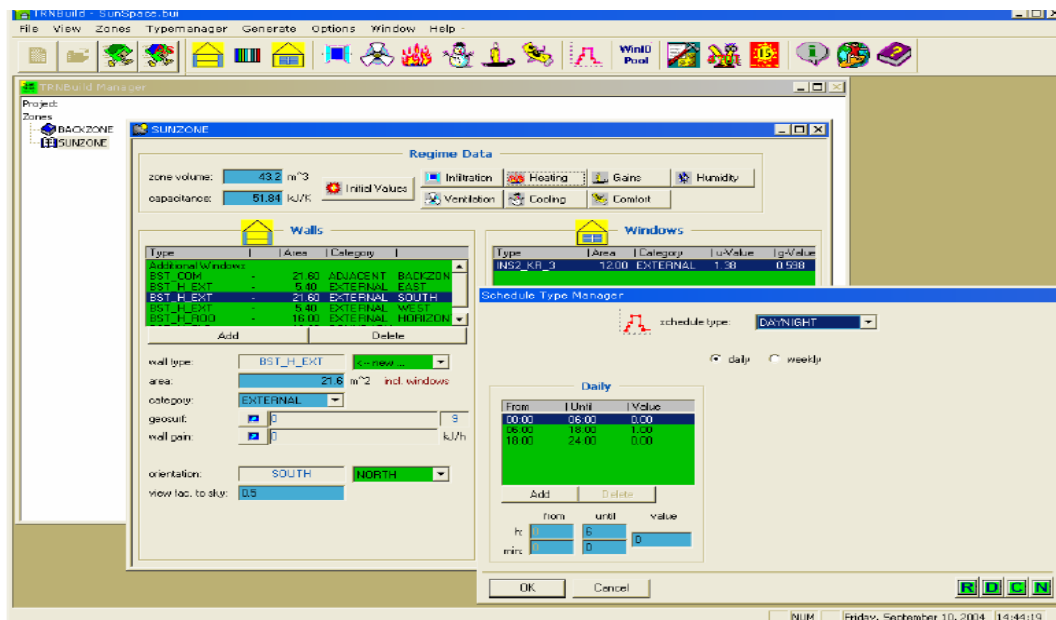


Figure II.2: TRN Build

II. 4. The TRNSYS Simulation software

Reads all the information on the simulation in the TRNSYS input file we opens other input file like weather data to creates output files

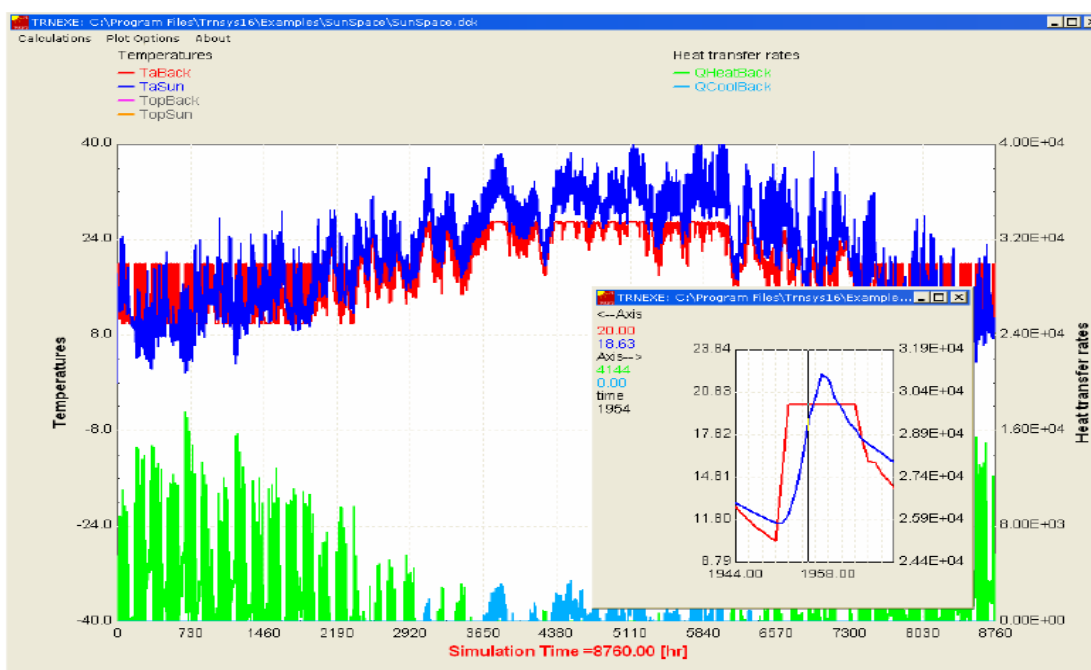


Figure II.3: TRNSYS Simulation engine

II. 5. TRNEdit and TRNSED applications

TRNEdit is a specialized editor that can be used to create or modify TRNSYS input files. Can be used to create redistributable applications. The distributable includes a dedicated visual interface designed by adding special commands to the TRNSYS input file [5]

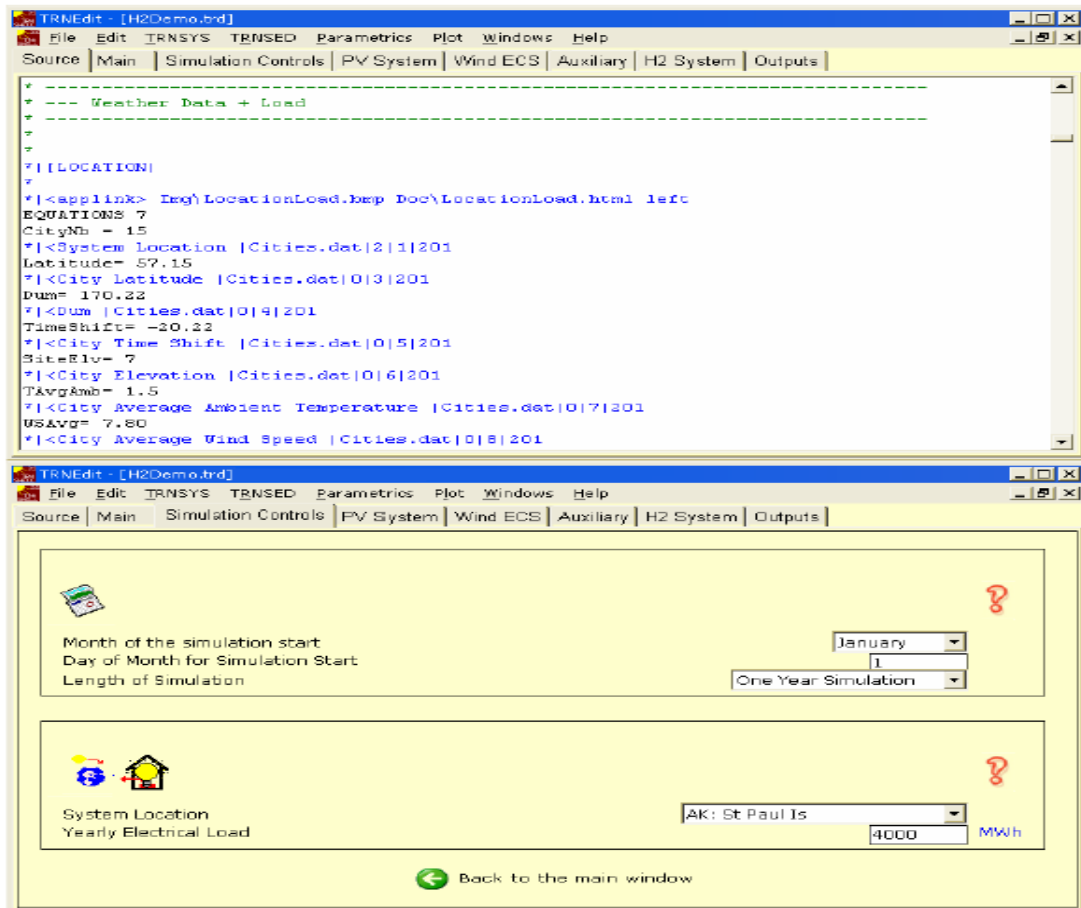


Figure II.4: TRNSYS TRNEdit

II. 6. Climate view

Weather data play an important role in the estimated energy savings, as they are important inputs required to simulate the thermal behavior of Shelters and can have a significant impact on the output of the simulation. Taking into account outdoor climatic and local conditions, as well as indoor climate requirements; Weather data can influence the Shelters performance in several way as follow :

- ❖ Temperature difference induced transmission through the envelope
- ❖ Air infiltration induced by pressure difference
- ❖ Convective surface heat transfer (wind, ΔT)
- ❖ Radioactive surface heat transfer (equivalent black body sky temperature);

II. 6.1. Ouargla climate

The province of Ouargla is located in the south-east of Algeria; it is distant 800 km from the capital and covers more than 163,233 km². The geographical coordinates of the region are: Average altitude: 134 m, Lat: 31 ° 58 'North Longitude: 5 ° 20 'East .

Ouargla has a hot desert climate with long, extremely hot summers and short warm winters. Averages high temperatures in summer are consistently over 40 °C during nearly 4 months (June, July, August and September). Average annual rainfall is around 45 mm and summers are especially dry.

The picture below shows Ouargla variation temperature for the year 2016 in which indicate -0.2 C for the lowest temperature at January in other hand the highest temperature indicated in June at the value 48 C [6] .

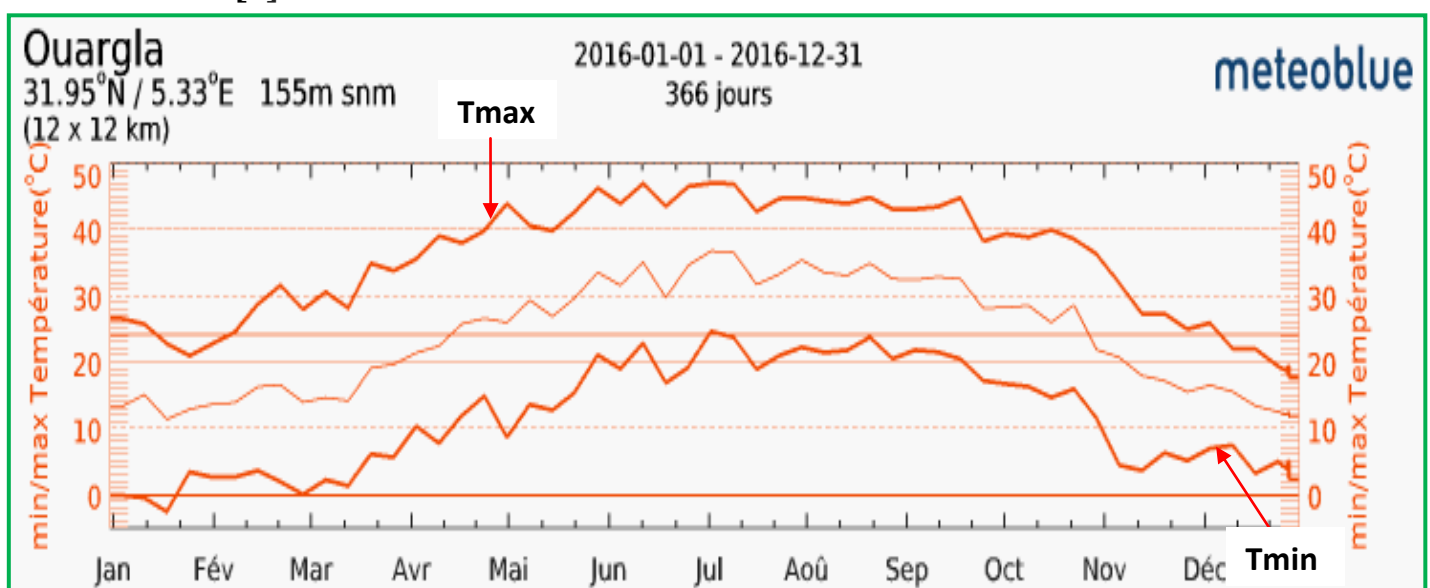


Figure II.5: Temperature variation of Ouargla in 2016

II. 7. Project simulation

In this paper we use a monozone buildings to simulate the temperature in the shelter of Algerian telecom which has the characteristics L x W x H (3.47x 2.47x3.8) [7].

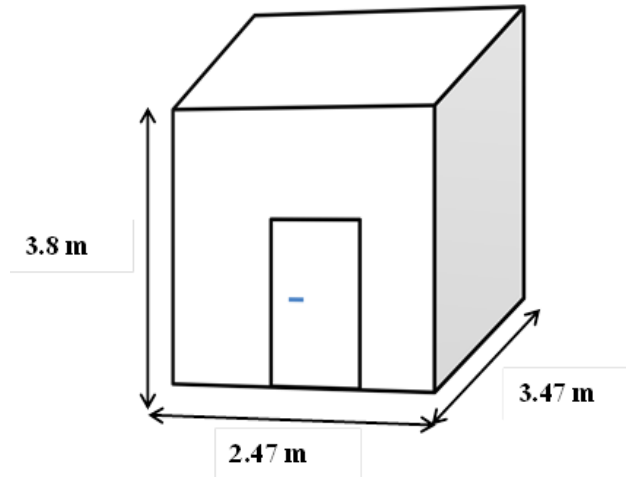


Figure II.6: Shelter characteristic

For the simulation we follow the steps below:

- 1) Select the multizone buildings model
- 2) Identify the zone dimension (project name, height, width and the depth).
- 3) Orientation and localization
- 4) Infiltration and Mechanical or natural ventilation
- 5) Heating and cooling
- 6) Gains and lighting
- 7) Fixed shading
- 8) After we chose the edit of building it appears the figure in which we can add more data condition like gains, initial values (temperature and humidity), infiltration, heating, gains, ventilation, air conditioning, humidity

After the first step, we click on the command "Edit building" and we enter the second step of the project where the wall materials are declared.

<i>Walls</i>	<i>Characteristics</i>	<i>Thickness</i>
North, south, east, west	Aluminum, polyurethane, Aluminum	0.02 m+0.08 m+0.02m
Ground	Floor, Stone, Aluminum, Plywood	0.1 m+0.12 m+0.02 m+0.1 m
Roof	Aluminum, polyurethane, Aluminum	0.02 m+0.08 m+0.02 m

Table II.1: Materials characteristics

II. 7.1. Validation of model

Simulations were performed for 9-hours periods with one hour time interval steps figure shows the sampling hours (9h00-17h00) of the first of March 2016.

The Figure II.7 below shows comparison between an experimental and simulation values for the experimental the temperature indicate 17 C and start increasing until achieve the highest point 24 C at 15h.00 than the decrease to the value 22 C at 17.00; in other hand the values of simulation start from the same point and achieve their highest value 27 C at the 15h00.

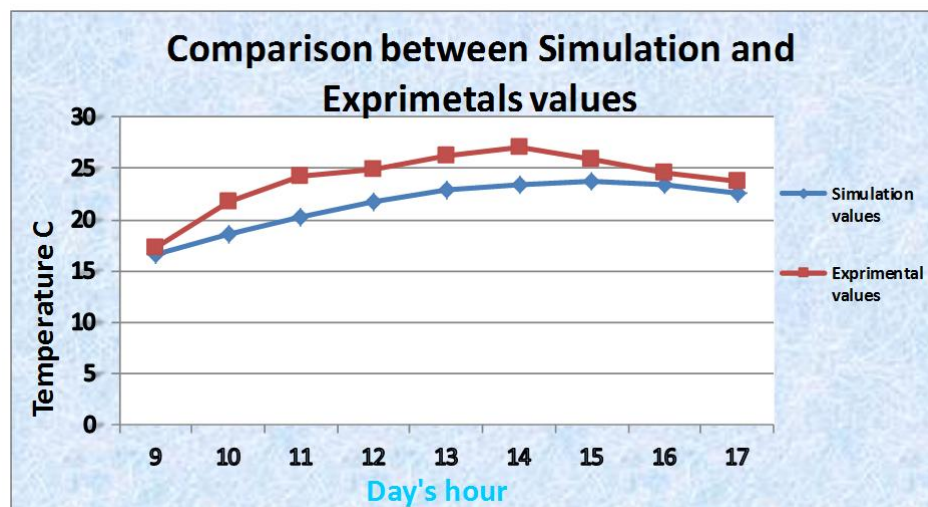


Figure II.7: Comparison between simulation and experimental values

II. 7.2. Temperatures of walls

According to picture taken from the site meteoblue we have here variation of the temperature for the month of June in which the values of temperatures are between 20 C and 48 C the highest value of the year 2016 in OUARGLA at the 15 June 2016 [6]

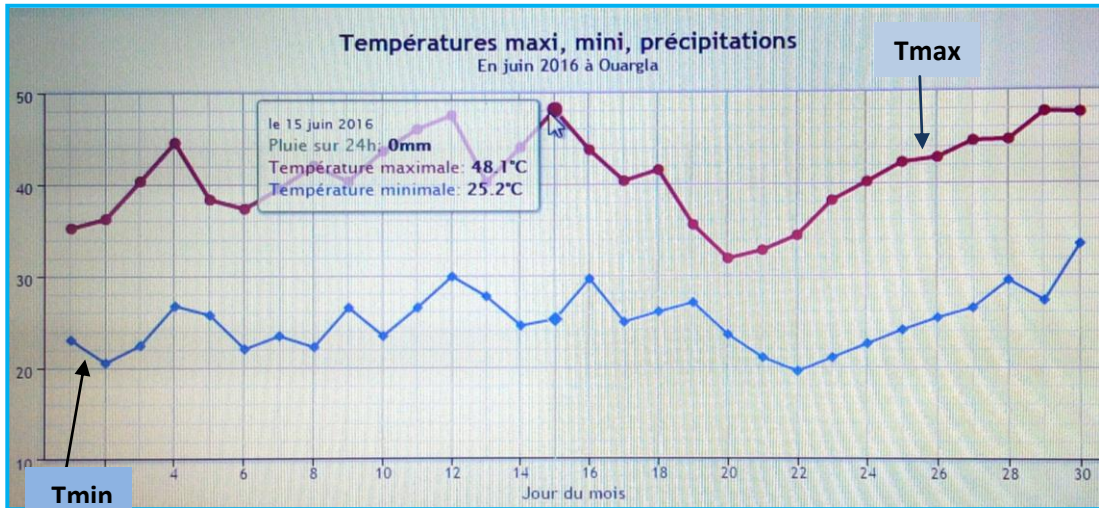


Figure II.8: Temperature of the month June 2016 at Ouargla

We chose this point in our simulation of the temperature in the shelter the results of simulation are in the next curb shows the variation of the temperature of the four walls and the ceiling. While the sun shine the temperature of the eastern wall at 8.00 because the most part of the shelter exposed to the sun rays start increasing till the value 50 C, for the ceiling is the element that's exposed for a long period of the day started at 10.00 till 19.00 to the sun rays due to changes of sun position the highest temperature are between 14.00 and 18.00 which indicate 62 C, afternoon the direction of the sun rays changed and the western wall is more exposed and the temperature indicate 52 C. in other hand we saw that the north and south wall are less exposed to the sun rays during the day and highest temperature are 45C and 48C respectively.

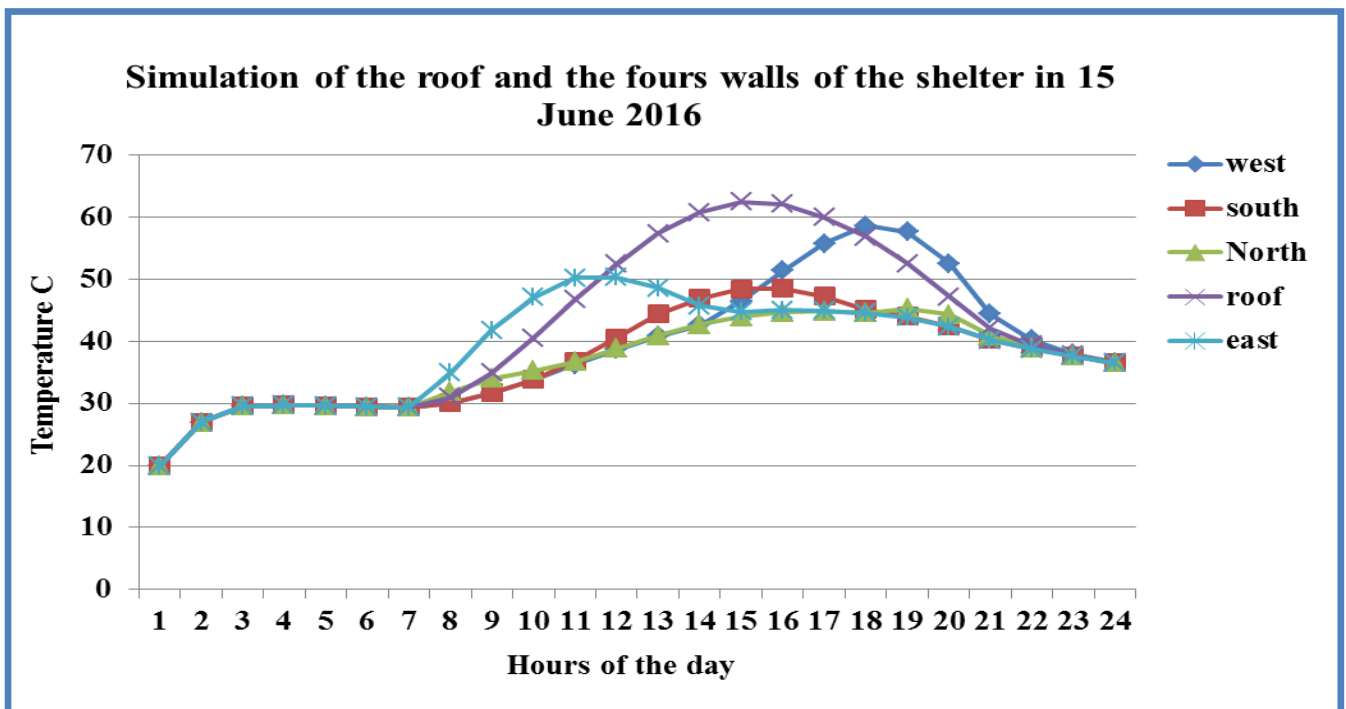


Figure II.9: Simulation values of temperature for the roof and four walls of the shelter

In the table after the max temperature

Elements of shelter	Max temperature C
Ceiling	62,5
East wall	50,31
West wall	58,69
North wall	45,33
South wall	48,51

Table II.2: Walls Max temperatures

II. 8.Conclusion:

We start in this part about energetic audit with a short glance about the program of TRNSYS than we utilizes one of his type monozone buildings to simulate the temperature of the walls and the roof of Algerian telecom shelter in the highest day of the year 2016 , simulation results shows that during the day the most element of the shelter exposed to external heat is the roof than the west and east walls at the end the south and north walls , the question here, is there a system used to avoid this type of heat ,especially for the roof as we conclude before that`s the part of the shelter more exposed to external heat ?

III.1. Introduction:

Nowadays with the development of the technology and equipment the study of heat transfer and flow allows for more understanding of several phenomena and suggestion other solution and improvement follow some of equation used to study the characteristic of flow and heat transfer

III.2. Governing equations of fluid flow and heat transfer

The governing equations of fluid flow represent mathematical statements of the conservation laws of physics:

- ❖ The mass of a fluid is conserved
- ❖ The rate of change of momentum equals the sum of the forces on a fluid particle (Newton's second law)
- ❖ The rate of change of energy is equal to sum of the rate of heat addition to and the rate of work done on a fluid particle (first law of thermodynamics)

III.2.1. Mass conservation

The first step in the derivation of the mass conservation equation is to write down a mass balance for the fluid element

Rate of increase of mass fluid element = Net rate of flow of mass into fluid element

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i} (\rho U_i) = 0$$

Equation is the unsteady, three-dimensional mass conservation or continuity equation at a point in a compressible fluid. The first term on the left hand is the rate of the change in time of the density (mass per unit volume).The second term describe the net flow of mass out of the element across its boundaries and called the convective term

III.2.2. Momentum equation

Newton's second law states that the rate of change of momentum of a fluid particle equals the sum of the forces on the particle

Rate of increase of momentum of fluid particle = sum of forces fluid particle

$$\rho \frac{\partial U_j}{\partial t} + U_j \rho \frac{\partial U_j}{\partial x_i} = -\frac{\partial p}{\partial x_j} + \mu \left[\frac{\partial^2 U_j}{\partial x_i^2} \right] + \rho g$$

III.2.3. Energy equation

The energy equation is derived from the first law of thermodynamics which states that the rate of change of energy of fluid particle is equal to the rate of heat addition to the fluid particle plus the rate of work done on the particle

Rate of increase of energy of fluid particle = Net rate of heat added to the fluid particle + Net rate of work done on the particle

$$\frac{\partial T}{\partial t} + U_i \rho \frac{\partial T}{\partial x_i} = \frac{1}{\rho c_p} \lambda \left[\frac{\partial^2 T}{\partial x_i^2} \right]$$

III.3. Boussinesq Approximation

Variations in the properties of the fluid, namely density and viscosity are caused by the variations in the temperature within a convective flow. Hence, to analyze these effects, we require some approximation methods. One such method is the famous Boussinesq approximation. For thermal convection to occur the density of the fluid must be a function of the temperature. Hence, we need an equation of state in addition to the equations of mass, momentum and energy.

The simplest equation of state is: $\rho = \rho_0 (1 - \beta (T - T_0))$

ρ_0 is the fluid density at some reference temperature T_0

β is the coefficient of thermal expansion.

The kinematic viscosity and thermal diffusivity are independent of temperature and hence constant except that the buoyancy term involving β which is retained in the momentum equation.

III.4. Dimensionless number

III.4.1. Reynolds number

The Reynolds number is dimensionless and describes the ratio of inertial forces to viscous forces in a flowing fluid. It is used to describe the boundaries of fluid flow regimes laminar, transition or turbulent.

- ❖ laminar flow occurs at low Reynolds numbers, where viscous forces are dominant
- ❖ turbulent flow occurs at high Reynolds numbers and is dominated by inertial forces

The Reynolds number is defined as

$$\mathbf{Re} = \rho V D / \mu = V D / \nu$$

Where:

- ρ = Density of the fluid (kg/m^3)
- V = Velocity (m/s)
- D = Diameter (m),
- μ = Dynamic viscosity ($\text{Pa}\cdot\text{s}$)
- ν = Kinematic viscosity (m^2/s)

The Reynolds number can be defined for several different situations where a fluid is in relative motion to a surface; these definitions generally include the fluid properties of density and viscosity, plus a velocity and a characteristic length or characteristic dimension (L in the above equation)

III.4.2. Prandtl number

The Prandtl number is the ratio of molecular diffusivity of momentum to the molecular diffusivity of heat. If a fluid is more viscous, the Prandtl number is greater and the heat transfer will be less convective. It may be calculated as follows:

$$\text{Pr} = \text{viscous diffusion rate} / \text{thermal diffusion rate} = \mu C_p / k$$

Where:

- μ is the dynamic viscosity coefficient ($\text{Pa}\cdot\text{s}$)
- C_p is the specific heat at constant pressure ($\text{J/Kg}\cdot\text{K}^{-1}$)
- k is the coefficient of thermal conduction ($\text{W/m}\cdot\text{K}^{-1}$)

III.4.3. Grashof number

Grashof number is a dimensionless number in fluid dynamics and heat transfer which approximates the ratio of the buoyancy force to viscous force acting on a fluid.

$$Gr = \frac{\text{buoyant force}}{\text{viscous force}} = \frac{g \Delta \rho V}{\rho v^2} = \frac{g \beta \Delta T V}{v^2}$$

- Where:

$\Delta \rho$ = Total change in density between regions of high temperature and low temperature (kg/m^3)

β = the inverse of the film (mean) temperature (K^{-1})

ρ = the density evaluated at the mean temperature (kg/m³)

g = the gravitational constant (m/s²)

ΔT = Temperature difference (C⁰ or K)

μ = Dynamic viscosity (Pl= Pa.s)

III.4.4. Rayleigh number

The ratio of the apparent conductivity to the true molecular conductivity is a function, which is the product of Grashoff and Prandtl numbers. This function is referred as the Rayleigh number.

$$Ra = Gr * Pr$$

III.4.5. Nusselt number

It is a dimensionless number and defined as ratio of convective heat transfer to conductive heat transfer across the boundary

$$Nu = \text{convective heat transfer} / \text{conductive heat transfer} = h L / K$$

Where

h = Convective heat transfer coefficient of the flow (W/m²K)

L = Length (m)

k = Thermal conductivity of the fluid (W/m.K-1)

III.5.Generalality of CDF

For our study we will use CDF to simulate the temperature of the shelter before and after the cooling solution

III.5.1.What is CDF?

Computational fluid Dynamics or CDF is the analysis of systems involving fluid flow, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation.

The technique is very powerful and spans a wide range of industrial and non-industrial applications areas some examples are:

- ❖ Aerodynamics of aircraft and vehicles: lift and drag
- ❖ Hydrodynamics of ships

- ❖ Power plant: combustion in IC engines and gas turbines
- ❖ Turbo machinery: flows inside rotating passages, diffusers etc.
- ❖ Electrical and electronic engineering: cooling of equipment including micro-circuits
- ❖ Chemical process engineering: mixing and separation, polymer moulding
- ❖ External and internal environment of buildings: wind loading and heating/ventilation
- ❖ Marine engineering: loads on off-shore structures
- ❖ Environmental engineering: distribution of pollutants and effluents
- ❖ Hydrology and oceanography: flows in rivers, estuaries, oceans
- ❖ Meteorology: weather prediction
- ❖ Biomedical engineering: blood flows through arteries and veins

III.5.2. How does a CDF code work?

CDF codes are structured around the numerical algorithms that can tackle fluid problems. In order to provide easy access to their solving power all commercial CDF package include sophisticated user interfaces to input problem parameters and to examine the results. Hence all codes contain three main elements [8]

- ❖ A pre-processor
- ❖ A solver
- ❖ A post processor

III.6. Conclusion:

Governing equations of fluid flow and heat transfer and the dimensionless number stated in this chapter give information about the variations of the parameters in the time to understand the phenomena is happening during the study after we have talked about CFD that is used to simulate many studies .

IV.1.Introduction

For study the shelter parameters ;Fluent will be used to all this simulation it is the most-powerful computational fluid dynamics (CFD) software tool available, empowering you to go further and faster as you optimize your product's performance. Fluent includes well-validated physical modeling capabilities

FLUENT CFD software simulation will show you how fluid flow, particle flow, heat transfer, chemical reactions, combustion, and other parameters evolve with time

IV.2. Simulation steps

In order to get start fluent it is necessary to began with creating and meshing geometry by Gambit programmer as follow:

- ❖ Start GAMBIT
- ❖ Use the Operation tool pad
- ❖ Create the geometry
- ❖ Mesh a volume
- ❖ Examine the quality of the mesh
- ❖ Identify the limits condition
- ❖ Save the file and exit GAMBIT

After this we start Fluent 6.3.26 than we read the model from the file saved and simulate all the cases of the problems

IV.3. Air Physical parameters [9]

Designation	Expression
Density	$\rho = [(1.1614 - 0.00353(T_m - 300))]$
dynamic viscosity	$\mu = [1.846 + 0.00472(T_m - 300)] \times 10^{-5}$
thermal expansion coefficient volumetric air	$\beta = 1/T_m$
Kinematic viscosity	$\nu = \mu / \rho$
thermal conductivity of air	$k = [0.0263 + 0.000074(T_m - 300)]$
Specific heat of the fluid	$C_p = [1.007 + 0.00004(T_m - 300)] \times 10^3$

Table IV.1: Air Physical parameters

$$T_{max} = 335.5 \text{ K}$$

$$\rho = 1.036 \text{ Kg/m}^3$$

$$\mu = 2.013 \times 10^{-5} \text{ Kg/m.s}^{-1}$$

$$\beta = 0.0029 \text{ k}^{-1}$$

$$\nu = 1.94 \times 10^{-5} \text{ m}^2/\text{s}$$

$$K = 0.0289 \text{ W/m.K}^{-1}$$

$$C_p = 1008.4 \text{ J/Kg.k}^{-1}$$

$$Pr = \mu C_p / K = 70.239 \times 10^{-5}$$

$$Ra = Gr * Pr = 4.8 \times 10^9 \quad \text{laminar regime}$$

IV.4. Shelter without gain

IV.4.1. Computational domain

The figure IV.1 shows a shelter in bidimensions consist of two panels of aluminum between them an insulate of polyurethane, the exteriors condition temperatures are as follow for the west wall $T = 331.69 \text{ K}$ and east wall $T = 323.31 \text{ K}$ and ceiling $T = 335.5 \text{ K}$

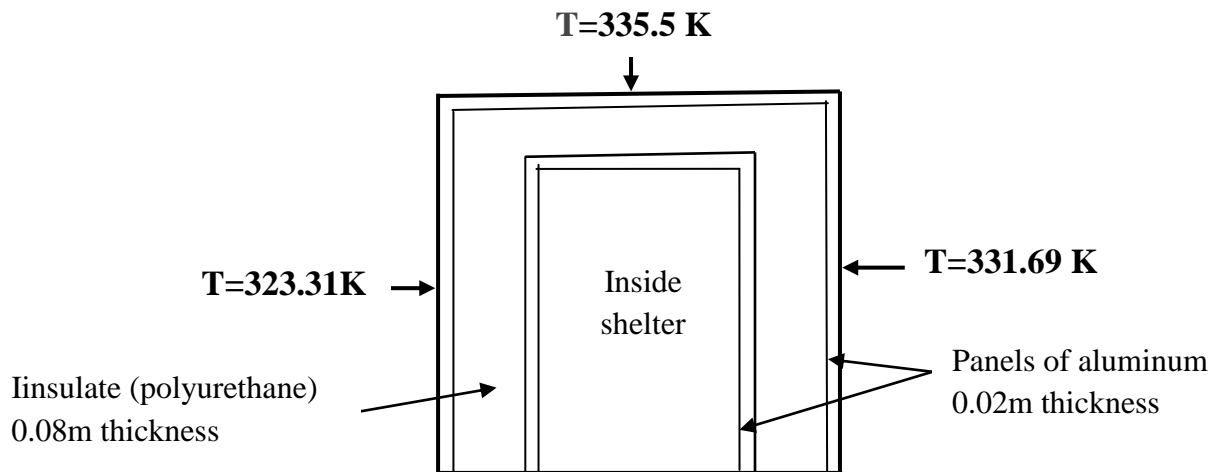


Figure IV.1: Shelter without gain

IV.4.2. Mesh choice

The table IV.2 below summary girds information after meshing for a shelter without gain

Gird information		
Cells	Faces	Nodes
49848	100800	50952

Table IV.2: Gird information for shelter without gain

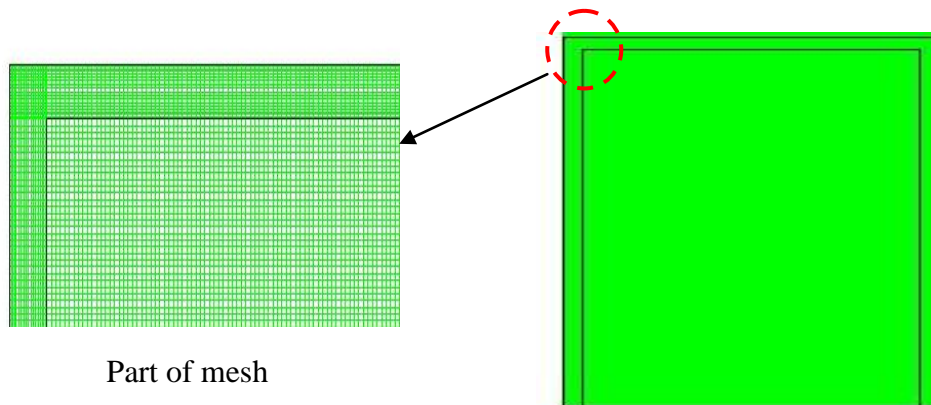


Figure IV.2: Shelter Mesh

IV.4.3. Convergence control

Table IV.3 presents the residues of the equations following by the curve of the evolution of these residues where the convergence achieved in fluent after 801 Iterations

Equation	Momentum along X	Momentum along Y	Continuity equation	Energy equation
Residues	10^{-3}	10^{-3}	10^{-3}	10^{-6}

Table IV.3: Residues for different equations

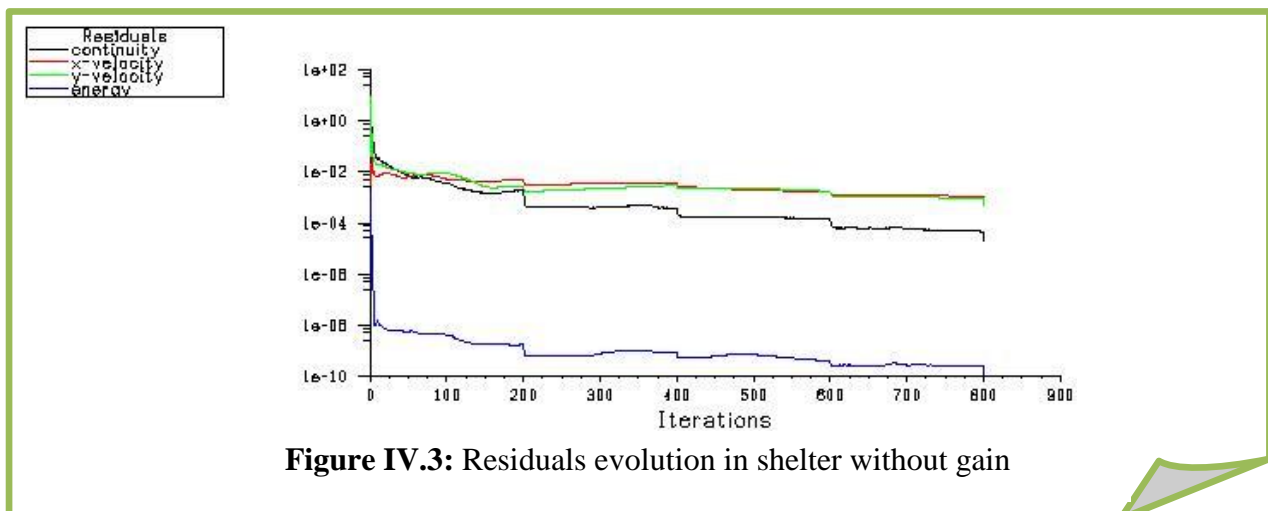


Figure IV.3: Residuals evolution in shelter without gain

IV.4.4. Temperature profile

The figure IV.4 represent the static temperature for a shelter without gain where we can see that the max $T=336$ K refer to the temperature of the ceiling and the min $T=324$ K refer also to the temperature east in other hand inside the shelter the temperature is about 330 k for this case it is affect by the exterior conditions

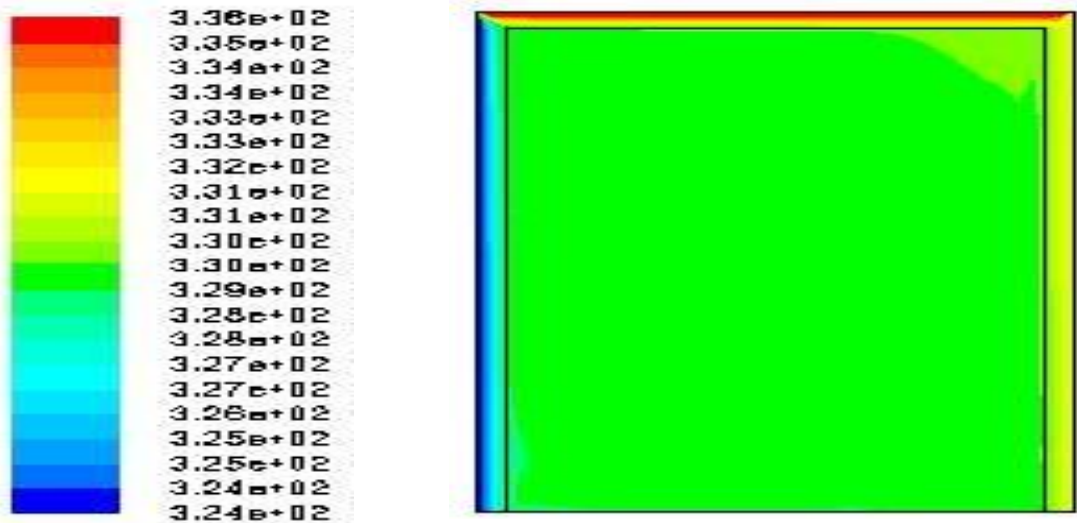


Figure IV.4: Static temperature profile in shelter without gain (K)

IV.4.5. Velocity

From the curve of the velocity contour we can see that the air flow is concentrate at the bottom of the shelter in opposite of the top it is very small

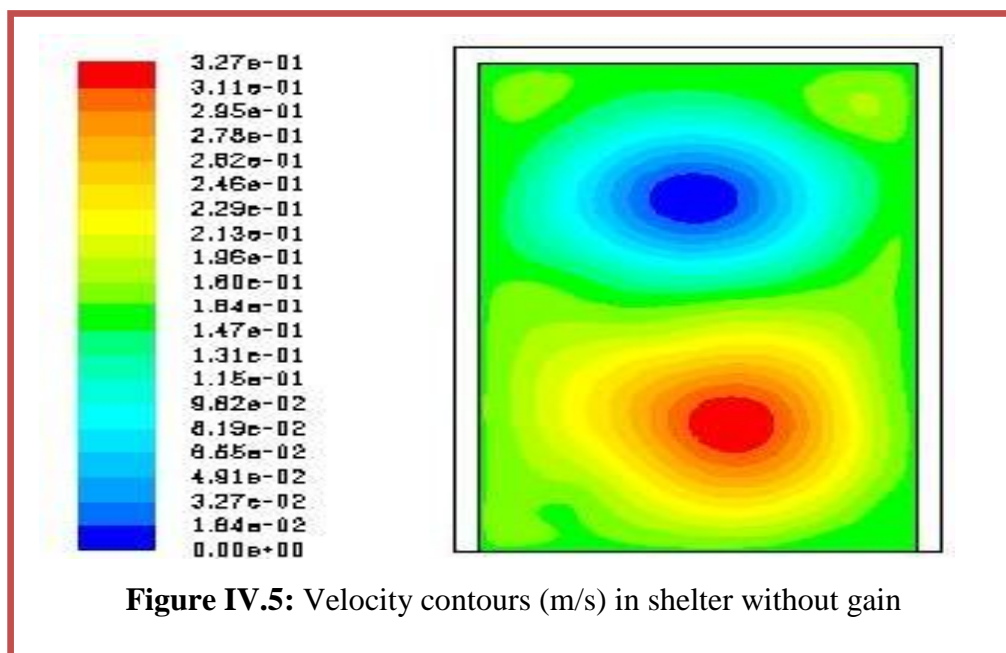


Figure IV.5: Velocity contours (m/s) in shelter without gain

IV.5. Shelter with gain

IV.5.1. Computational domain

Figure shows the same conditions first case and in we added a heat 720 w that comes from the electronic equipments inside the shelter.

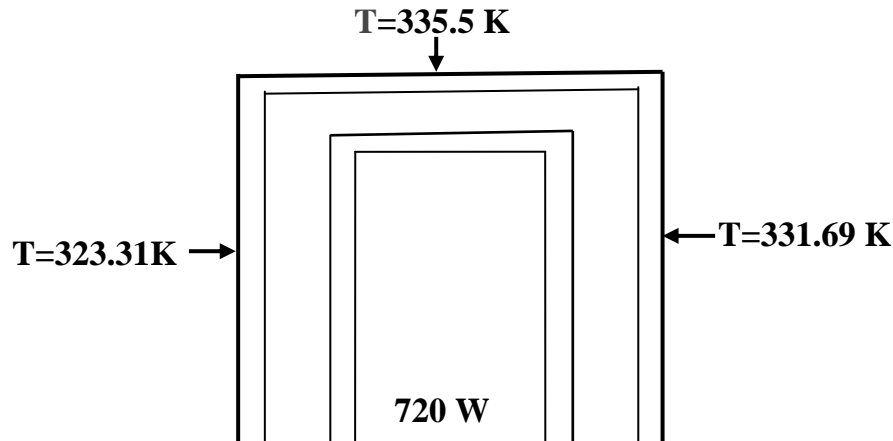


Figure IV.6: Shelter with gain

IV.5.2. Mesh choice

The table IV.4 below summary girds information after meshing for a shelter with gain

Gird information		
Cells	Faces	Nodes
49848	100800	50952

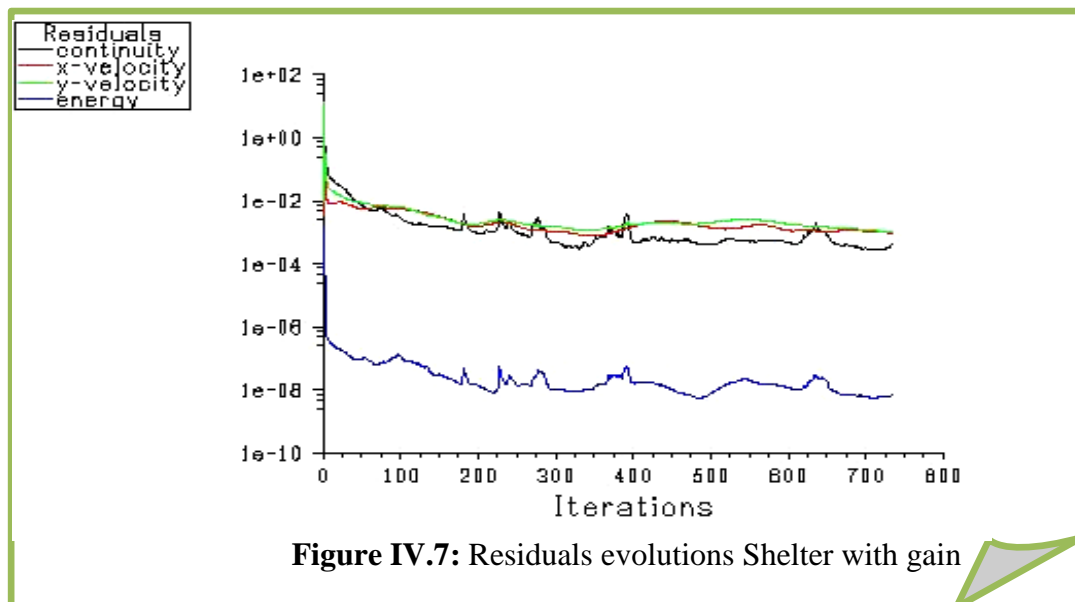
Table IV.4: Gird information for shelter with gain

IV.5.3. Convergence control

Table IV.5 presents the residues of the equations following by the curve of the evolution of these residues where the convergence achieved in fluent after 733 Iterations

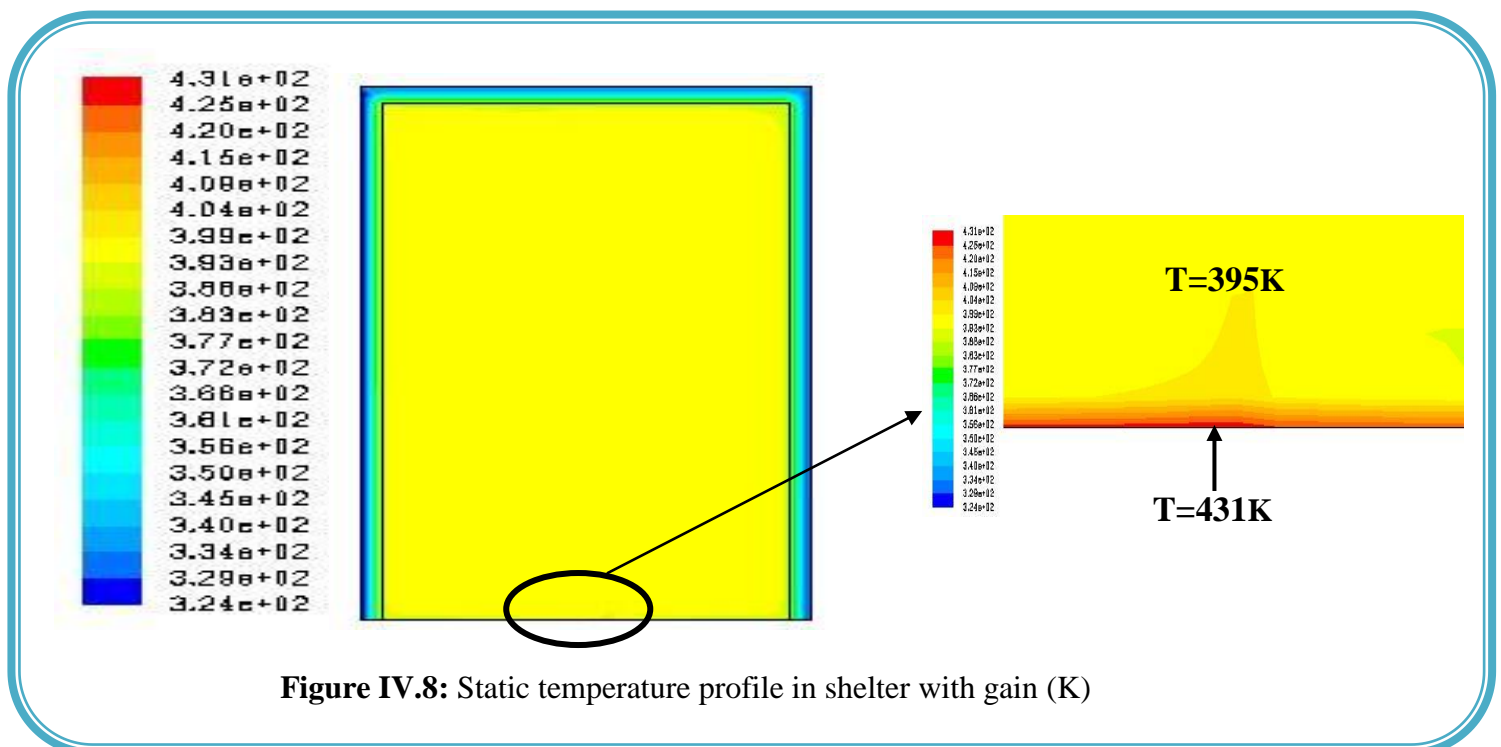
Equation	Momentum along X	Momentum along Y	Continuity equation	Energy equation
Residues	10^{-3}	10^{-3}	10^{-3}	10^{-6}

Table IV.5: Residues for different equations



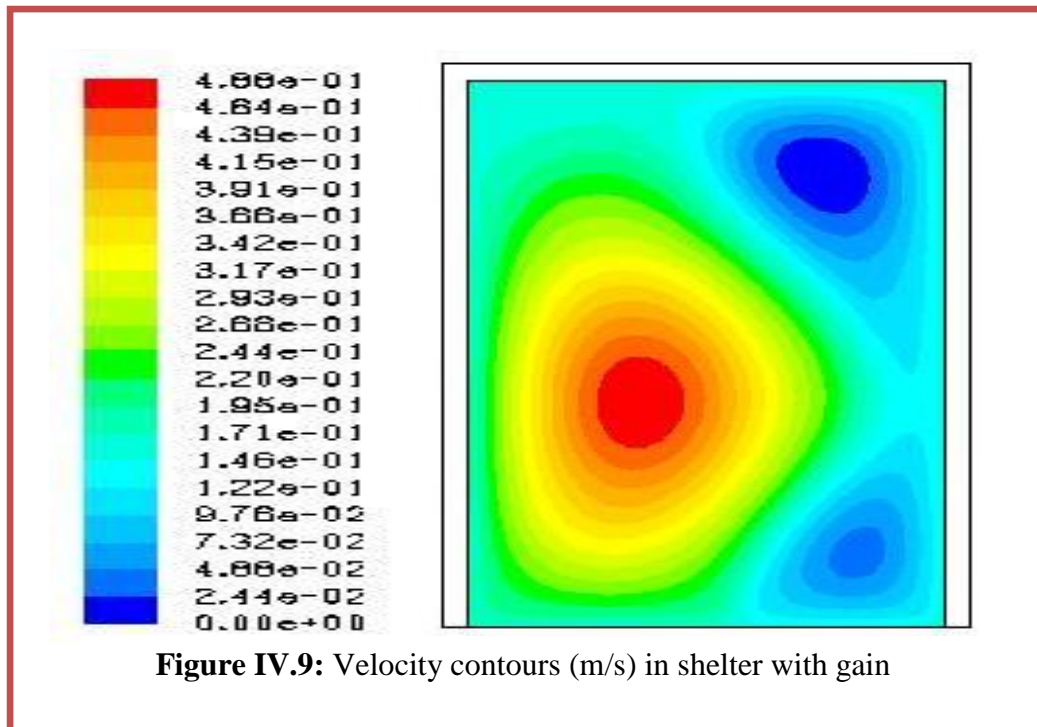
IV.5.4. Temperature profile

As we can see from the figure IV.8 which represent the static temperature of the shelter with gain where the inside temperature rises till 395 k due to the heat source the max $T=431$ k at the heat source and the lowest temperature is belong to east walls temperature



IV.5.5. Velocity

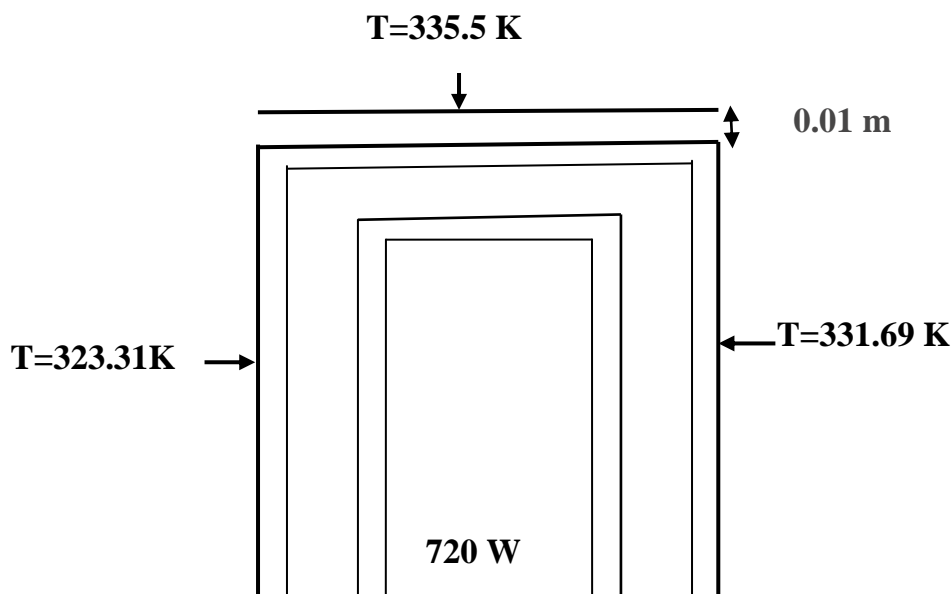
The air flow is in the bottom and at top of the shelter near the east wall where the gradient of temperature is less than the ceiling and the west wall



IV.6. Shelter with roof shading

IV.6.1. Computational domain

From the cases above we can note that the shelter is exposed to the inside heat dissipate from the electronic equipments and from outside heat comes from the exteriors condition especially weather condition where the roof is the important part exposed to this heat. In this case we propose shading in order to reduce a this part of heat



IV.6.2. Mesh choice

The table below summary grids information after meshing for a shelter with gain

Grid information		
Cells	Faces	Nodes
53568	108446	54877

Table IV.6: Grid information for shelter with roof shading

IV.6.3. Convergence control

Table IV.7 presents the residues of the equations following by the curve of the evolution of these residues where the convergence achieved in fluent after 900 Iterations

Equation	Momentum along X	Momentum along Y	Continuity equation	Energy equation
Residues	10^{-3}	10^{-3}	10^{-3}	10^{-6}

Table IV.7: Residues for different equations

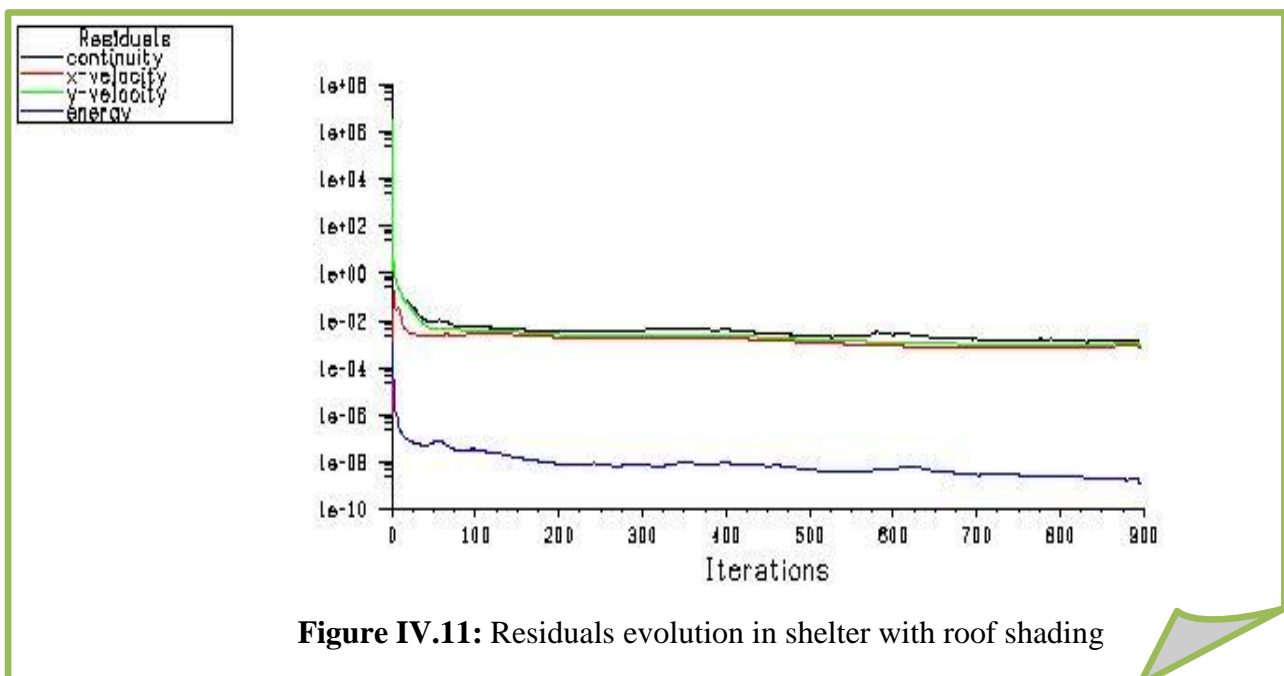


Figure IV.11: Residuals evolution in shelter with roof shading

IV.6.4. Temperature profile

The installations of the shading in the roof has Impact in the temperature of roof which is downed to the value 320 k comparing with the previous case when it was 360k and for the inside temperature of the shelter there is not a big change.

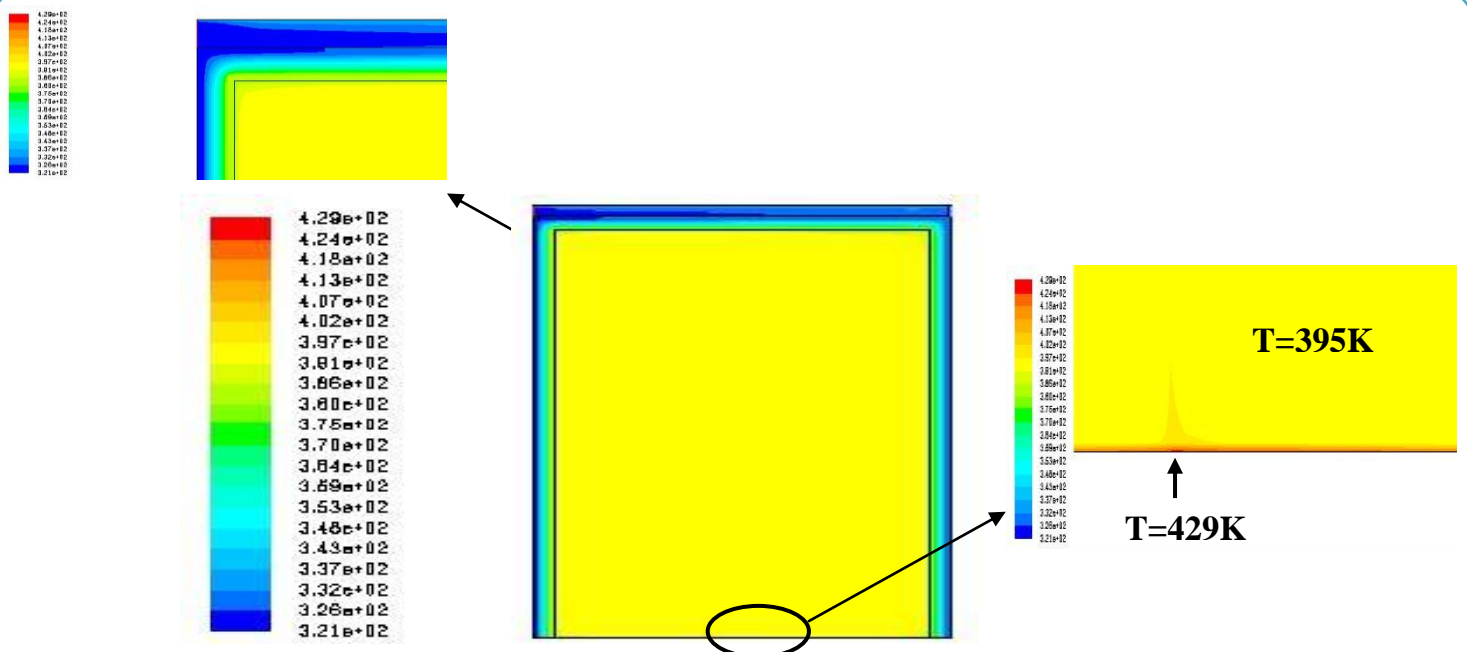


Figure IV.12: Static temperature profile in shelter with roof shading(K)

IV.6.5. Velocity

From the IV.13 the air flow located in the bottom and little at the top of the shelter near the east wall because of the gradients of temperature.

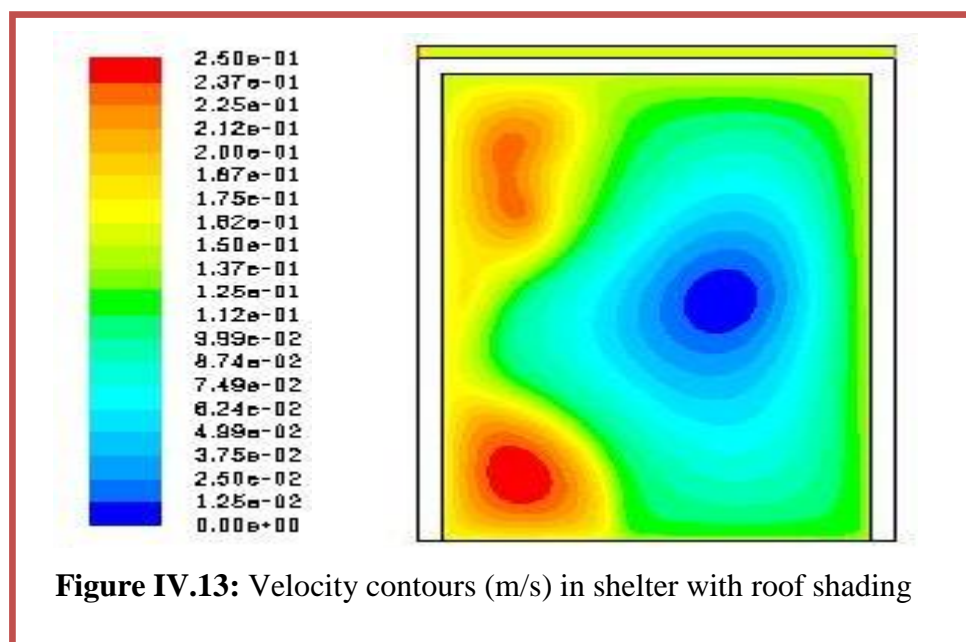


Figure IV.13: Velocity contours (m/s) in shelter with roof shading

IV.7. Shelter with roof shading and natural ventilation Low-Low

IV.7.1. Computational domain

We can note that we still have a hot temperature inside the shelter we suggest a natural ventilation by the mean of two opening at the bottom of the building

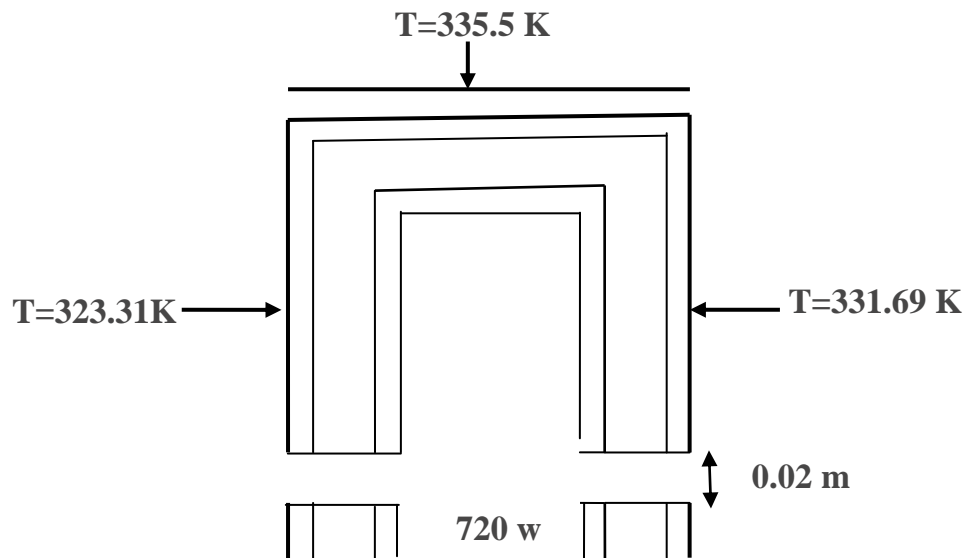


Figure IV.14: Shelter with roof shading and natural ventilation Low (Inlet)-low (Outlet)

IV.7.2. Mesh choice

The table below summary girds information after meshing for a shelter with gain and roof shading

Gird information		
Cells	Faces	Nodes
61008	123468	62449

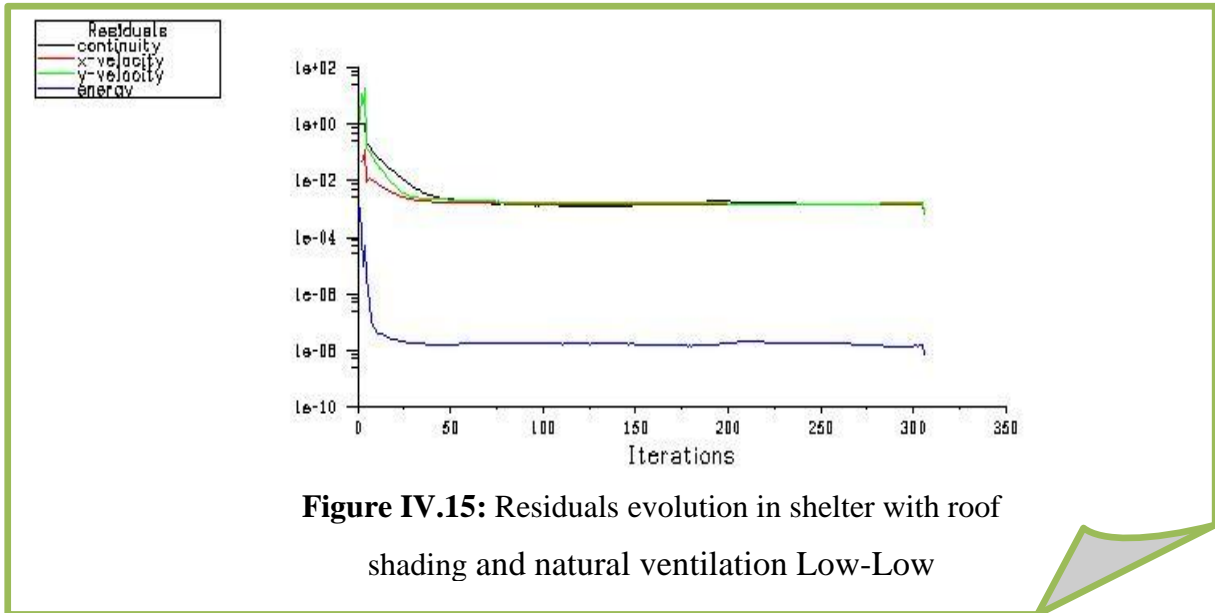
Table IV.8: Gird information for shelter with roof shading and natural ventilation Low (Inlet)-low (Outlet)

IV.7.3. Convergence control

Table IV.9 presents the residues of the equations following by the curve of the evolution of these residues where the convergence achieved in fluent after 301 Iterations

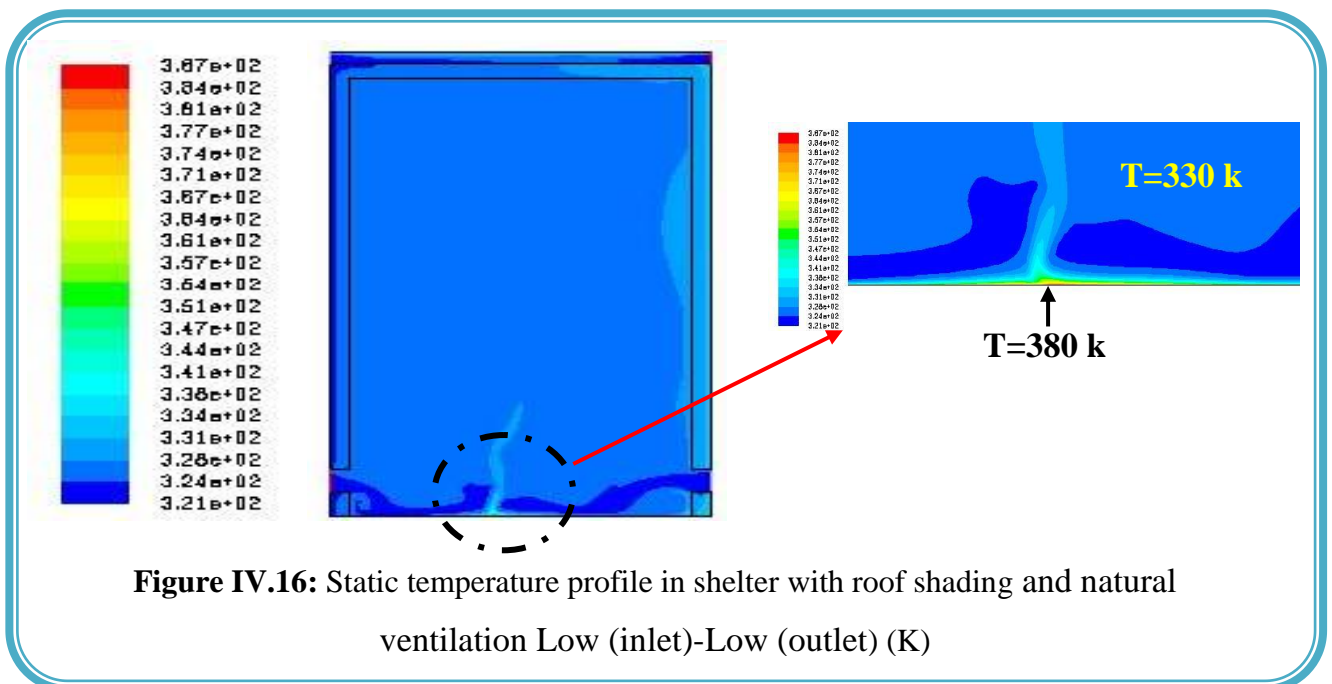
Equation	Momentum along X	Momentum along Y	Continuity equation	Energy equation
Residues	10^{-3}	10^{-3}	10^{-3}	10^{-6}

Table IV.9: Residues for different equations



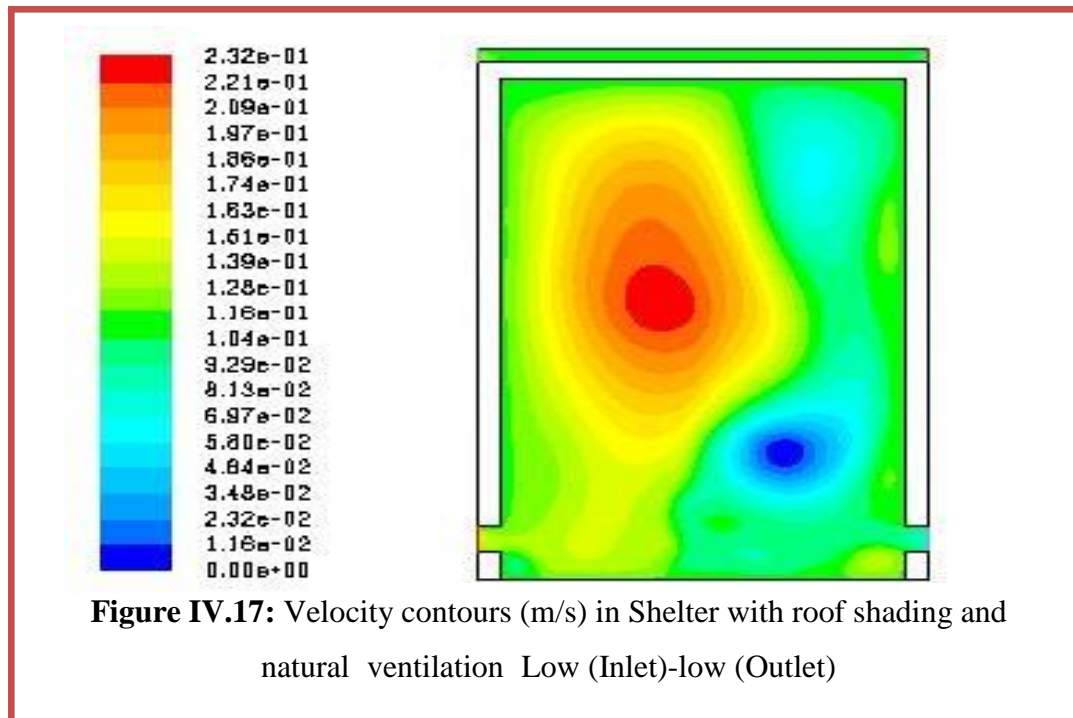
IV.7.4. Temperature profile

In this figure IV.16 we see that the temperature inside decreased from the value 390 k to 330 k that has a positive impact about the heat dissipate from the equipment where the temperature in this point is about 380 k.



IV.7.5. Velocity

When the air enter the shelter from the bottom bushing the hot air the hot circulate towards the top to and always is near the east wall where is the gradient of temperature



IV.8. Shelter with roof shading and natural ventilation Low-high

IV.8.1. Computational domain

For optimizing the best case of natural ventilation we propose for this time two opening one low at the bottom and the other high at the top of the shelter.

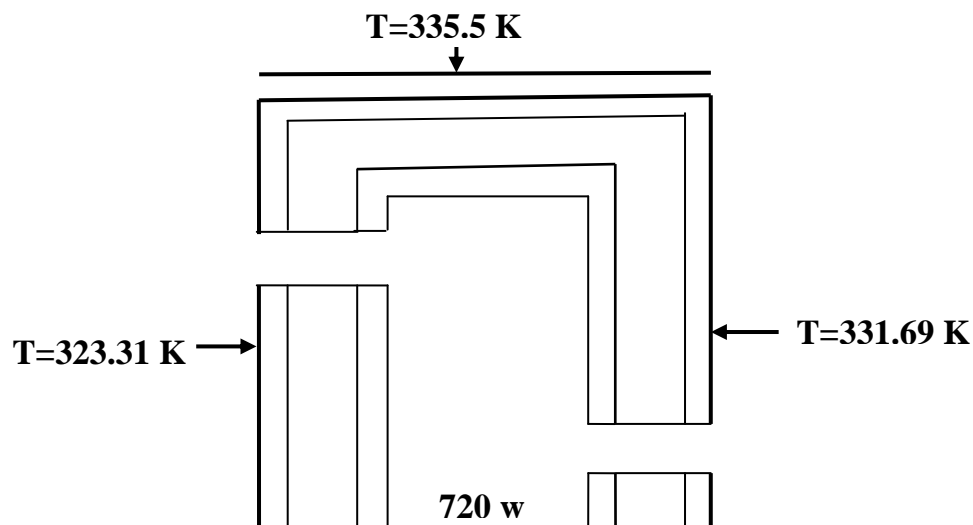


Figure IV.18: Shelter with roof shading and natural ventilation Low (Inlet)-High (Outlet)

IV.8.2. Mesh choice

The table below summary grids information after meshing for a shelter with gain and roof shading and natural ventilation Low-high

Grid information		
Cells	Faces	Nodes
60078	121603	61514

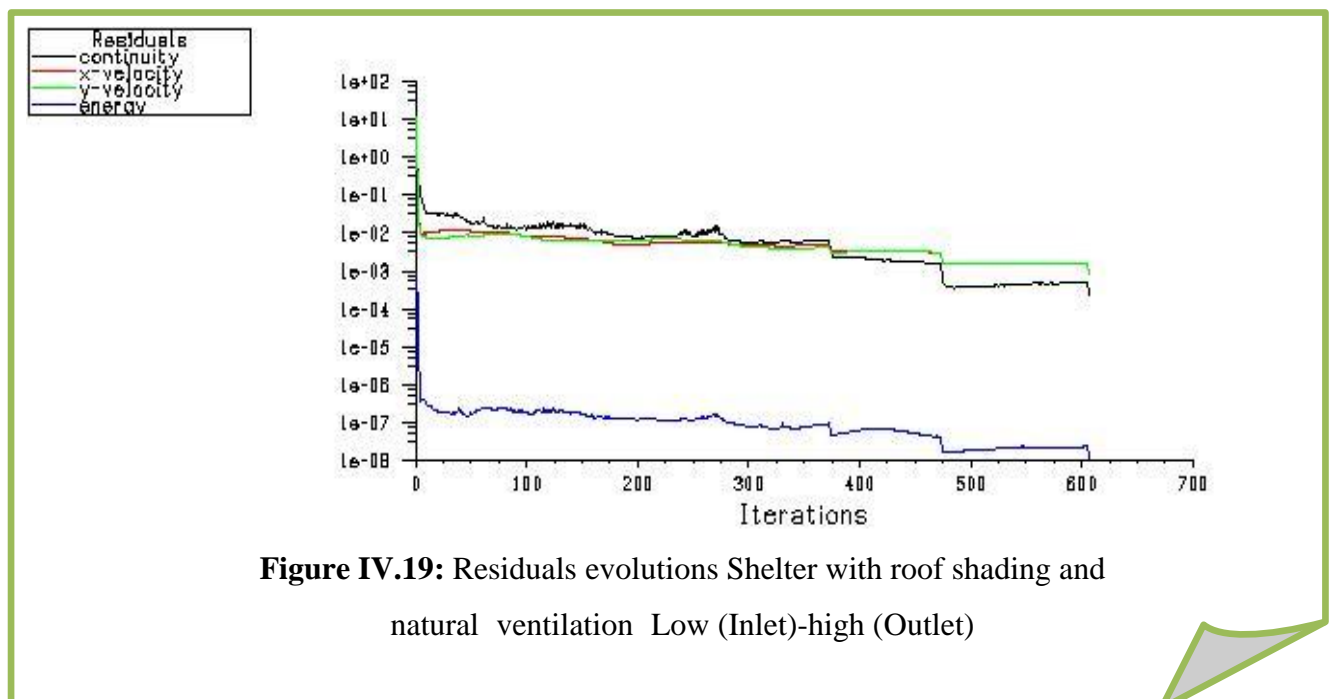
Table IV.10: Grid information for shelter with roof shading and natural ventilation Low (Inlet)-High

IV.8.3. Convergence control

Table IV.10 presents the residues of the equations following by the curve of the evolution of these residues where the convergence achieved in fluent after 602 Iterations

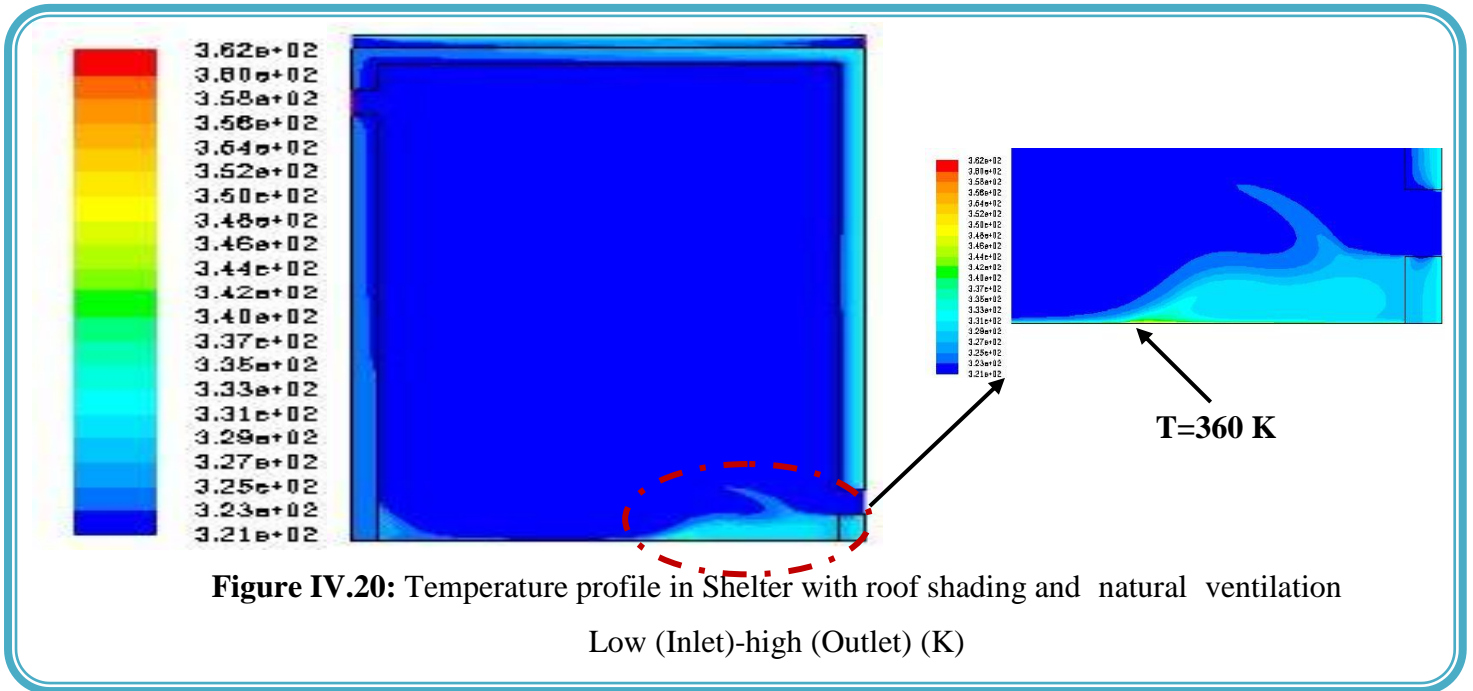
Equation	Momentum along X	Momentum along Y	Continuity equation	Energy equation
Residues	10^{-3}	10^{-3}	10^{-3}	10^{-6}

Table IV.11: Residues for different equations



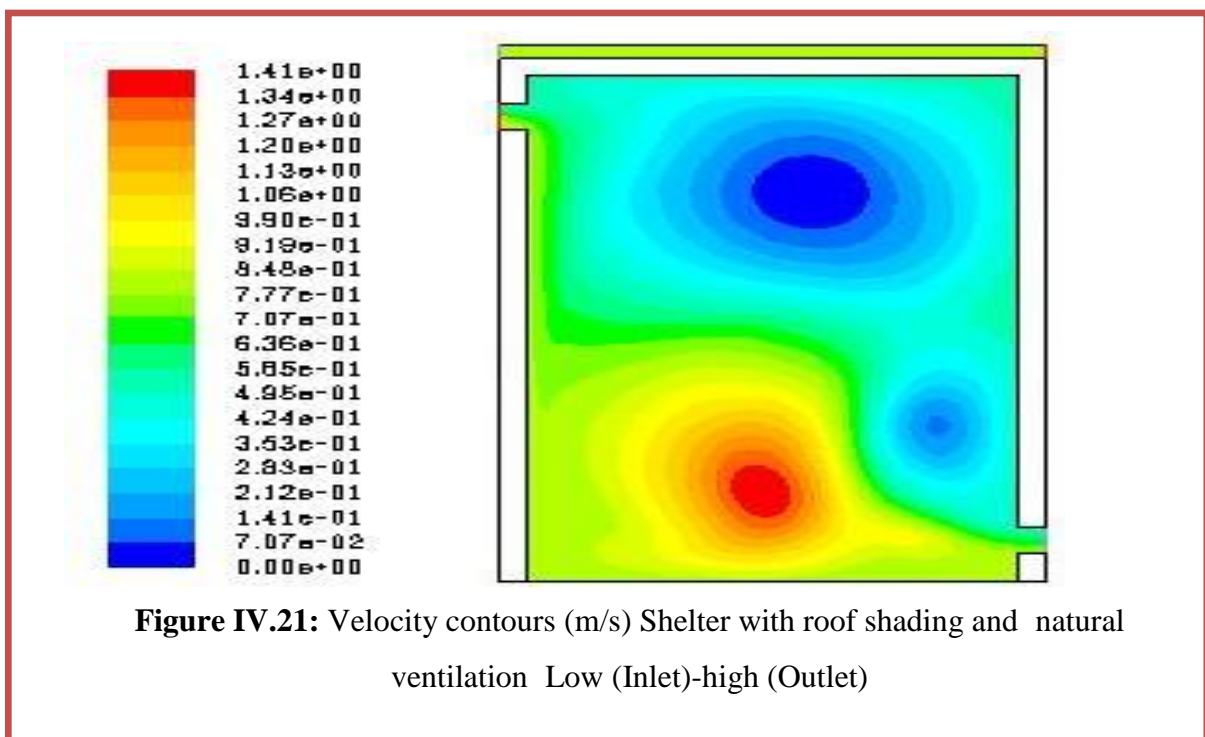
IV.8.4. Temperature profile

The figures IV.20 shows the temperature in the middle of shelter decreased at the value $T=320$ K , around the heat source and the west wall the temperature is about 335 k .



IV.8.5. Velocity

From the Figure IV.21 the air flow is concentrated at the bottom around the heat source and along the east wall goes towards the high opening



IV.9. Conclusion

For the first case shelter with outgain we can see that the max and min temperatures are the temperature of the roof and the east wall , inside the shelter temperature it was about 330 k than when we add in the second case gain the temperature inside increased till 395k

Than to prevent from the exterior heat we have proposed a shade for the roof and can see that`s can reduce the temperature with 10 k

For the fourth and the fifth case we suggest a natural ventilation one with low inlet –low outlet and the second low inlet –high outlet the results of simulation shows that the best case from the tow is the second where the temperature decrease to the value 321k .

:

General conclusion

Many studies were performed to select and implant the suitable systems of cooling in desert and aride regions for building, in our study about introducing a passive cooling system for telecommunication shelters located in OUARGLA, which is exposed external (weather conditions) and interior heat (despaired from electronic equipment) first of all we start with energetic audit using TRNSYS for the condition limit and using FLUNT we simulate SOME propositions for the two cases.

For the first case the suggestion was about making a shading for the roof which is the most part of shelter to the external heat the results of simulation indicate that the temperature of roof can decrease with 10 k and for the second case (interior heat) natural ventilation uses to push this heat outside the shelter.

We have optimized two cases from natural ventilation one is low inlet of air and high outlet the other low inlet of air and high outlet from simulation results we have conclude that the case of low inlet of air and high outlet gave conclusive results on the benefit of this system where the interior temperature of the shelter was about 48 C⁰ and another advantages such as : that`s viable , requires less power, easy to maintenance , low cost to implant and eco-friendly cooling system.

For future works, it recommended to install a system that allows cool air entre the shelter rather than ambient air in summer days in the case of natural ventilation that can uses in the other seasons

Bibliographical references

[1]-Cooling of Remote Sites Telecommunication Shelters –Abdelkader DARWICHE and Samivullah SHAIK November (2007)

[2]-Understanding passive cooling system by Daniel Halacy (1986)

[3]-Passive cooling of telecom shelter using solar chimney with Earth-air heat exchange –BOUBEKEUR DOKKAR BELKHIR NEGROU NASREDDINE CHENOUFF NOUREDDINE SETTOU ABDESSELEM BENMHIDI

[4]-Full scale experimental studies of passive cooling roof in hot arid areas – H.Bencheikh (2008)

[5]-TRNSYS 16 TRaNsient System Simulation program Volume 1 Getting Started (2004)

[6]- <https://www.meteoblue.com/fr/prevision/archive/Ouargla>

[7]- Document of Algeria telecom, manual about transport, installation, get starting and repairing a shelter, T.0011/C-Page no.3

[8]- An introduction to computational fluid dynamics the finite volume method – H.K.VERSTEEG and W.MALALASEKERA (1995)

[9]-AKCHICHE Zineb, Etude de comportement d'une cheminée Solar en vue de l'isolation thermique. Mémoire pour l'obtention du diplôme de magistère option Energétique et procédés (2011)

ملخص:

يظهر هذا العمل دراسة حول النموذج الحراري في محطات الارسال التابعة لاتصالات الجزائر الموجودة في ورقلة وبخاصة في المناطق الصحراوية البعيدة اين تشكل الطاقة عائق كبيرا، ونظرا للحرارة الناجمة عن المعدات وأشعة الشمس من جهة و ضرورة الحفاظ على درجة حرارة مناسبة من أجل الأداء السليم للمعدات الإلكترونية داخل غرفة المحطة يتطلب استخدام نظام تكييف مناسب، في هذه الدراسة تم استخدام TRNSYS 16 fluent 6.3 لمحاكاة درجة الحرارة والسرعة داخل المأوى لحلول التبريد المتمثلة في تظليل السقف حيث انها الجزء الاكثر عرضة للإشعة الشمس من بين مكونات المبنى ثم التبريد بواسطة التهوية الطبيعية عن طريق فتحات تهوية سفلية واخرى علوية لاختيار افضل الحالات.

البحث كلمات: النموذج الحراري، محطات الارسال، تظليل السقف، التهوية الطبيعية.

Abstract:

This work shows a study about thermal comfort for a telecommunication shelters located in ouargla especially in desert places where the energy causes a problem, and due to the heat sources comes from the equipment and sun radiation from side and the necessity to keep the operating temperature for correct functioning of the electronic equipment inside the shelter requires the uses of a suitable cooling system , in this study we have been used Transient Systems Simulation Software (TRNSYS 16) and fluent 6. 3 to simulation .the temperature and the velocity inside the shelter using the passive cooling solutions suggested such a roof shading where it`s the critical part that is highly susceptible to solar radiation Among the building envelope components than optimized a case from two cases of natural ventilation by the mean of low and other high opening to select the best case.

Key words: Telecommunication shelters, thermal comfort, roof shading, natural ventilation