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Senior Design Project Report

Design of Free Cooling Ventilator

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

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Abstract

A global issue surrounding people all around the world is saving money and electricity, this problem could cause a lot of losses. Now talking in Saudi Arabia according to Alhyat paper "The Kingdom ranks among the top five energy-consuming countries in the country, with an average household electricity consumption of 24,400 kWh in the Kingdom, more than five times that of France and Germany, and nearly twice that of Norway, Canada and the United States.

This project will help in minimizing the consumption of electricity in Saudi Arabia, our project is designed to use the ambient air to cool off the room temperature using three windows with fans. The air will go inside, and the room will start to cool with time.

Acknowledgment

First of all, we would like to thank our university for this great opportunity working as a team to apply our knowledge and experience in our final project and use all the university facilities that help us in our research. Also, we would like to thank all the instructors in Prince Mohammed bin Fahad University for supporting us during our final project.

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Chapter 1: Introduction

HVAC system is a function of controlling the temperatures and controlling the humidity. The main reason of the project is to save money without using AC. As we, all know Saudi vision 2030 is focusing on economy. We think that this project will help many people in order to save money in off sure areas.

Our idea is to use the outside air when it becomes at good temperature spicily in evening. For that, we will do a prototype. We will do a box made from glass, and we will install four fans in the box. Moreover, there will be a thermostat beside each window to measure the temperature inside the box. We will divide the box into two parts. The first part will a heat source (lamp) to increase the temperature and while it is heating; it will reach to the desire temperature that we want. For example: if the lamp is on, the temperature inside the box reached to 27 Celsius, and the ambient air temperature was 21 Celsius. The fans will start to run by using programing hardware to cool the box at a certain temperature. This is the idea of the project.

Example in real life: Some cities in KSA have a beautiful weather in the spring. So, instead of using AC and consume a lot of money, our idea will be applicable for them to save money.

In General, we would like eliminate the cost of A/C as we all know the heavy amount of the cost is coming from the A/C. with small creativity we can make something different.

1.1 Project Objectives

- ❖ Management of energy consumption by HVAC system.
- ❖ optimize the air quality in the comfort zone.
- ❖ Measure the effect of shell coat on the total energy consumption.

1.2 Project Specifications

1- Four Fans 3=1330 RPM inlet 1=3390 outlet
2- Arduino MEGA 2650
3- 200 Watt bulb
4- Aluminum foil flexible duct

Chapter 2: Literature Review

2.1 Project background

- Monitoring and evaluation of a low energy office building with passive cooling by night ventilation. In some environments, passive cooling by night ventilation is one promising strategy to decreasing the energy demand of office structures for air conditioning without decreasing convenience. [1]

- A support system for natural ventilation design of greenhouses has been developed, based on computational aerodynamics. This system can predict the distribution of airflow, temperature, humidity and gas concentration under different greenhouse structure circumstances, including fan opening environments and arrangements, plants and weather. The expected environmental variables are described in graphic displays in a user-friendly manner. [2]

- Free-cooling by ventilation is one of the most energy efficient techniques for cooling. To attain pleasant room temperatures and minimize the energy demand for mechanical ventilation, varying airflow rates should be used when ventilation is used for cooling. [3]

2.2 Previous Work

- Nowadays the world is subjecting from basic industrial to Eco-friendly transition in order to save, use, and conserve energy. That can be confirmed by noticing the societies demands around the world and governmental orientations. Economies has advanced to reconfirmed the previous statement, Funny to know that the first car invented use to run on electricity. However, due to low efficiency and technology back then they've shifted their approach to combustion engines cars. World has turned around from back then, more Eco-friendly technology in a higher efficiency and that all been connected to sustainability. [4]

- Saudi vision consists in reconstructing society members to contribute in the coming change of ideologies in many aspects. And big corporations are included under the roof of society in terms of sustainability. Therefore, many companies are now heading towards energy conserving and consumption in order to save money, time, environment and the world. Students are important part of society due to their intellectual capacity, the hunger for innovation and imagination. As a students of this great community this document hopefully will become an additional knowledge to success of this great nation and vision. [5]

- There is a huge demand of cooling system in any place but the problem is cooling systems consume a lots of energy. A free cooling system is the best solution for cost saving, and Its environment friendly. “The cooling energy consumption takes up around 30–50% of the total consumption of data centers due to the inefficient cooling system. Free cooling is an effective solution for reducing the power consumption of cooling systems” [6]

2.3 Comparative Study

- Most computers and laptops have fan for cooling. In fact, you can use the fans for any free cooling system by using temperature sensors to control the temperature. “A method and system of controlling a cooling fan of a computer system including a power supply unit. The method includes sensing a power load of the power supply unit. A reference air temperature of the computer system is also sensed. Finally, a fan setting is determined based upon the sensed power load and the sensed reference air temperature” [7]
- In this article It was approved that the efficiency of free cooling using latent heat storage integrated into the ventilation system of a low energy will be reduction in the size of the mechanical ventilation system and more favorable temperatures. “It was found that the free cooling technique enables a reduction in the size of the mechanical ventilation system, provides more favorable temperatures and therefore enables better thermal comfort conditions, and in our studied case also fresh air for the occupants” [8]
- In this research the flow rate of cooling air increased by 80% compared with that of conventional machines. “The actual motor with both the low-ventilation-resistance structure and fans with forward-swept and inclined blades showed that the flow rate of cooling air increased by 80% compared with that of conventional machines and the average temperature rise of the stator windings decreased by 30%.” [9]

Chapter 3: System Design

3.1 Design Constraints and Design Methodology

Ventilation is one of the most important things in any place to be consider. Likewise Warehouses, as we know the size are usually huge and strongly need to Heat Ventilator Air Conditioner. Moreover Engineering is an indispensable to create and design with in engineering standers. There is design constraints in Ventilation system should be consider. The design constraints of free ventilation for warehouse include, Box size which is present the room that we need to create the ventilation system on , fans size and location, heat source, and controlling system. We are designing of the two sides are based on specific sizes, one of them include three inlet fans and outlet fan, the other one include the heat source.

The material chosen for the Box is Cast Acrylic which has a lot of features, Cast Acrylic has low thermal conductivity so it’s one of the best choice in teat the theoretical and experimental in project, in our case we use Cast Acrylic because is easy to see through and easy to carry on. Mechanical fans derive the air for ventilation in to the box. We installed the fans in walls or windows, installed in air ducts on the top side of the box.

3.1.1. Constraints

- The hole box will be 60*40*40cm
- Room one will be 40*40*40cm
- Room two will be 20*40*40cm

Design of free cooling ventilator, there are many different constraints, and varying result types. These constraints are.

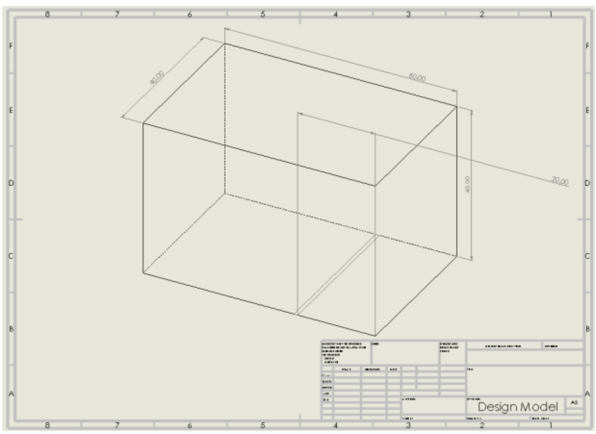

Figure 1 : Pre Design Model

3.1.2. Environmental

Design of free cooling ventilator is deepening on fresh air which is a natural source of ventilation. Three fans make the fresh air enter into to the room by three windows to cooling up the room, then the air comes out of the duct at the top. Air conditioning cooling consumes so much electricity and therefore releases pollution. Unlike, cooling by free ventilation system consumes very low electricity and no environment pollution.

3.1.3. Economic

- One of the most important aspect that our project focused on is save the energy. In the economic point of view, our Kingdom of Saudi Arabia vision 2030 is trying to reduce the amount of energy. Design of free cooling ventilator one of the economic HVAC system because it's depends on the fans instead of air conditioning for ventilations.
- Budget

The entire budget should not exceed 3500 SAR

Figure 5 : Base Lamp Socket

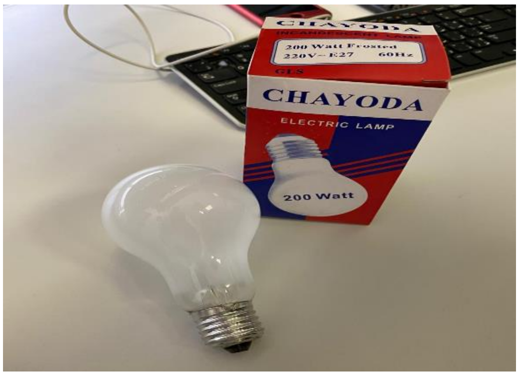

Figure 2: 200-Watt Lamp

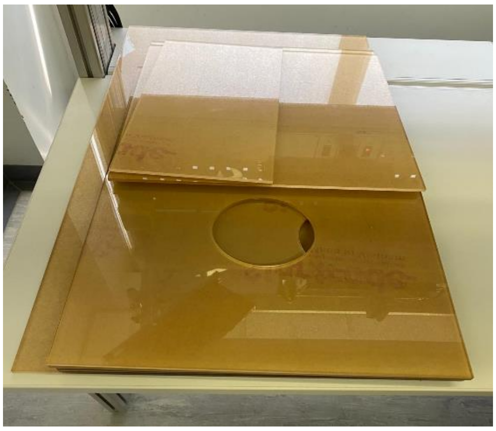

Figure 4 : Cast Acrylic

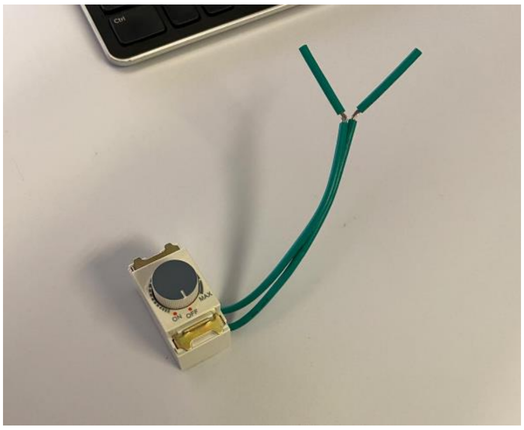

Figure 3 : Dimmer Switch

Figure 6 : Fan PWM

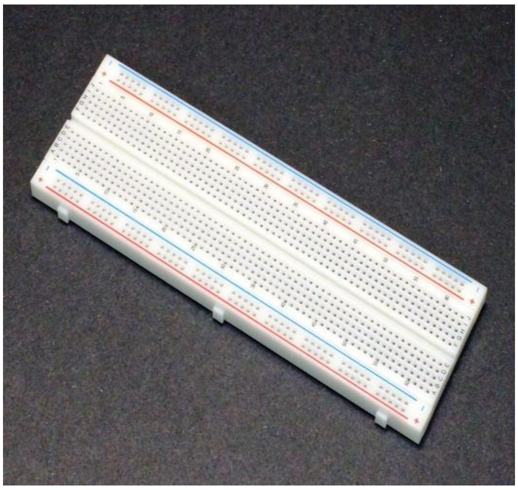

Figure 7: Solderless Breadboard

Figure 9 : Temperature Sensor

Figure 8 : Wires

Item Figure.	Part Descripition	Quantity	Total Price
3	Base Lamp Socket	1	9 SR
2	200-Watt Lamp	2	6 SR
5	Cast Acrylic Glass	8	400 SR
6	Dimmer Switch	1	35 SR
7	Fan	4	300 R
7	Solderless Breadboard	1	61 SR
8	Temperature Sensor	N\A	N\A
9	wires	N\A	N\A
	Sum		811

Table 1 : Estimated price

3.1.4. Manufacturability

To create a free ventilation for warehouse many mechanical parts is needed. The two rooms are made of fiberglass, heat source is 200-watt electric lamp with power control system, four Nidec Betav DEL cooling Fans, temperature sponsors and controlling system. All these parts are available.

3.1.5. Design Methodology

The cooling ventilation system is to reduce and limit the usage of air condition and power. Commonly used techniques in cooling buildings uses a high energy in order to achieve the desired efficiency. Variety of techniques are used to reduce temperature due to heat sources like the sun, machines, or even people inside buildings without the need of using air conditioner. For example, using trombic walls, solar chimneys, and operable windows. Controlling the windows and using the ambient air flow to be used to cool up the room can be considered as a technique. Climate is always the main factor of designing and implementing a cooling system.

3.2 Engineering Design standards

This is one of the initial decisions to be taken in a ventilation for the occupants is if the system will be active or inactive in nature and power consumption. This is one of the fundamental concerns that participate in design decision making; the main structure orientation, internal occupation, type of materials, and main usage of the structure. Thus, in a system concerned with the ventilation and air-cooling illustration by simulating. The Cast Acrylic ASTM D4802-15 is shown in the Table 2 is the candidate to be used in the system due to availability, cost and properties.

Specific Heat Capacity	1.46 - 2.16 J/g-°C	Average value: 1.50 J/g-°C
Thermal conductivity	0.187 - 0.209 W/m-K	Average value: 0.189 W/m-K
Maximum Service Temperature, Air	70.0 - 200 °C	Average value: 97.6 °C
Deflection Temperature at 0.46MPa (66psi)	110 - 115 °C	Average value: 111 °C
Deflection Temperature at 1.8 MPa (264 psi)	86.0 - 115 °C	Average value: 102 °C
Minimum Service Temperature, Air	-40.0 - -32.2 °C	Average value: -34.2 °C

Table 2 : Cast Acrylic properties

3.3 Theory and Theoretical Calculations

In this part we calculate the cooling load when it comes to the constriction of the building material used in this apartment, we will have a few options which is described in the table below:

Type of Material	R (K/W)	Comment
Outside Convection and Radiation	0.12	For still air
Cast Acrylic wall of thickness 6 mm	0.03158	K=0.19 W/mK
Inside Convection and Radiation	0.29	For moving air in Winter (V= 6.7 m/s)
R_{tot} =	0.44158 K/W	
U_{tot} =	2.2646 W/K	

Table 3 : Theoretical constants

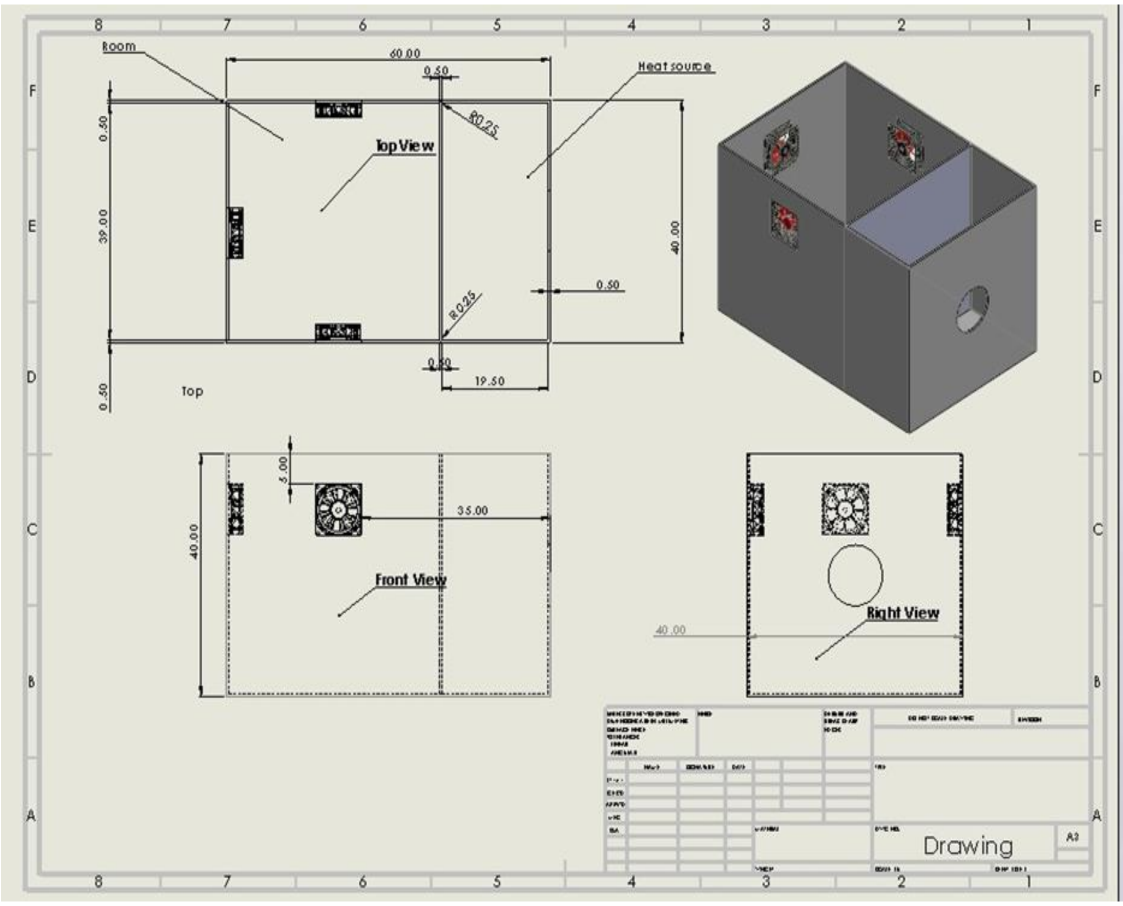

Figure 10 : Pre Drawing with measurements

- **Calculations:**

*3.3.1. **Transmission through Structure***

Equation 1

Component	Area (m^2)	U	ΔT (ΔT= 30-23= 7 ^{o} C)	Q_t=UA ΔT (W)
Wall: Right	0.4*0.4 = 0.16	2.2646	7	2.54
Wall: Left	0.39*0.4 = 0.156	2.2646	7	2.47
Wall: Front	0.6*0.4 = 0.24	2.2646	7	3.80
Wall: Back	0.6*0.4 = 0.24	2.2646	7	3.80
Celling	0.6*0.4 = 0.24	2.2646	7	3.80
Floor	0.6*0.4 = 0.24	2.2646	0	0
Sum				16.41

3.3.2. Lighting

Equation 2

Component	P (W)	DF	Q_l = DF*P (W)
lamb	200	1	200
Sum			200

3.3.3. Equipment

Equation 3

Component	P $_{fan}$ (W)	Efficiency $_{fan}$	Q_e = n*P $_{fan}$ /efficiency $_{fan}$ (W)
4 fans	16.8	0.6	112
SUM			112

3.3.4. Ventilation

Equation 4

Q_v= H_v * ΔT

$H_v = C_p$*Q_v / v_2

Where

H_v is ventilation heat loss coefficient,

C_p is specific heat of air.

Q_v = The outgoing airflow is (0.5 per hour times the volume of the room):

Q_v = (0.5/3600 s) * (0.6*0.4*0.4 m^3) = 0.0000133 m^3/s.

H_v = (1005) *(0.0000133) / (0.852) = 0.0157 W/K

Q_v= (0.0157) * (4) = 0.063 W

Cooling load = $Q_t + Q_L + Q_e + Q_v$ = 16.41+ 200 + 112 + 0.063 = 328.473 W

3.4 Product Subsystems and selection of Components

Based on the size of the fans, we will make the dimension of the box as 60 x 40 x 40 cm. Moreover, the box will have two main section. The first section will be for the heat source 20 x 40 x 40cm. The other section will be for cooling by using fans 40 x 40 x40 cm. The box will be made of fiberglass. The main parts of our project is listed as the following:

3.4.1. Microcontroller:

The function of the microcontroller is to control the devices. For our project, we will use the microcontroller to control the speed of the fans so we can run the fans according to the desired speed flow.

Figure 11 : Arduino mega

3.4.2. Thermocouple sensor:

It is a temperature sensor device. The function of it is to measure the amount of heat energy or even coldness that is generated by an object or system. We will install it beside the fans inside the box so when the temperature increase inside the box, the sensors will read the temperature.

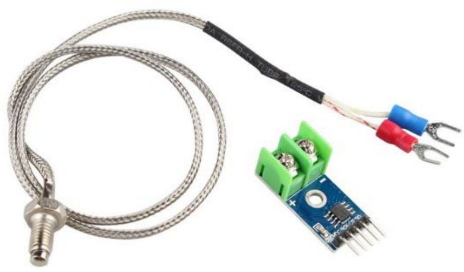

Figure 12 : Temperature sensor

3.4.3. Heat source (lamp):

The main purpose of choosing the lamp in our project is to make heat inside the box. This lamp will heat the box by convection, conduction and radiation.

Figure 13 : Lamp

3.4.4. Fans:

Figure 14 : Fan PWM

The role of the fans is to cool the box from the ambient air. There will be 4 fans and one of them will be on the top of the box as a duct.

The three fans will cool the box and the summation of airflow of these three fans will be equal to the duct airflow.

The specification of the fans as the following:

Fan features	Specifcation
Size	120 * 120 * 38mm
Voltage	12V
Current	1.40A
Power	16.8W
Maximum Speed	4000 RPM
Air volume	160 CFM
Wind pressure	0.883in H2O

Table 4 specification of the fans

3.5 Manufacturing and assembly (Implementation)

In terms of selection of materials, the box will be made of fiber glass. The box will have two rooms inside separated by a shielded wall. In speaking of parts First of all, 4 fans will be attached to the box three will be for air inlet, and one will be a duct for hot air extraction(outlet). Second, a lamb will be in the other room to produce heat that will come throw the shaded wall into the room which has the fans and the duct. Third part will be the ceiling from this part we can open our box for editing and other things. For system controlling, still under process

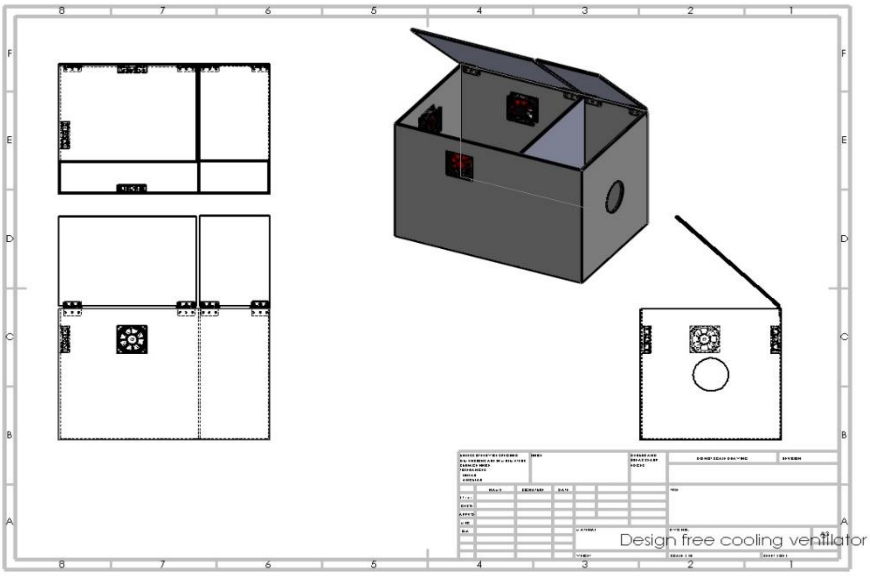

Figure 15 : Expected final design

Chapter 4: System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

As shown in the figure below is the main setup of the system. The setup consists of a hot and cold chamber where the heat exchange will takes place. A heat s, in this study, we are using a 200 watts incandescent bulb. Cooling fans are then used to remove the transferred heat from the cold chamber. Temperature sensors are placed on the 3 corners of the cold chamber and the readings are then interpreted and analyzed by the Atmel Mega 2560 Microcontroller. The results are displayed in an lcd located on the lower portion of the system. The heater is controlled by a triac to increase or decrease the heating intensity of the system.

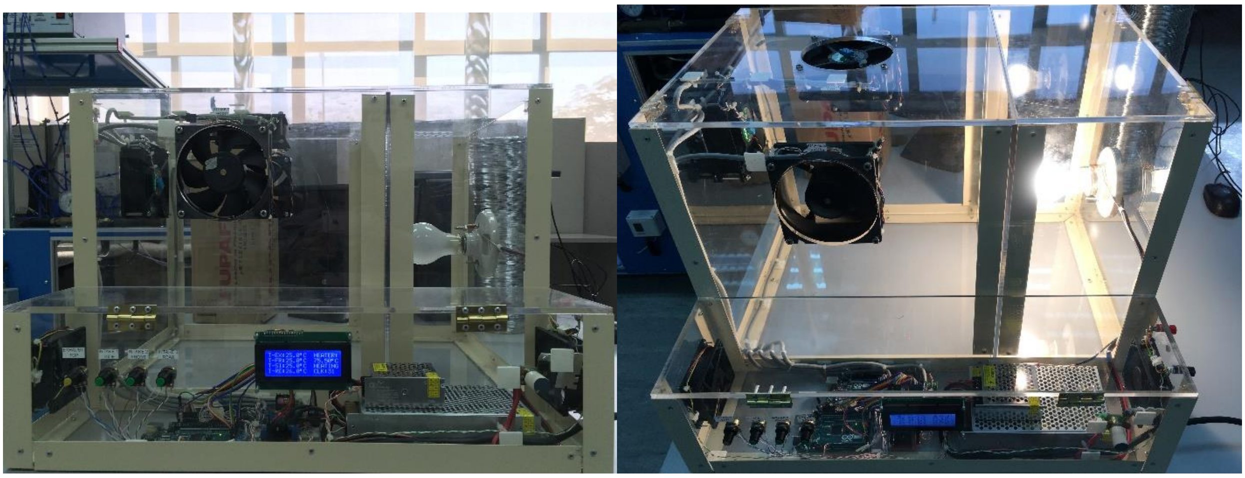

Figure 16 the Setup of the HVAC System

Cooling Fans

The main cooling system of the HVAC setup are the cooling fans. The setup consists of 3 intake fans from the sides and 1 exhaust fan on top. The fans are controlled by the microcontroller. When the temperature reached to 26 degrees on the T-SI sensor, these fans will start working. The speed of the three intake fans is equal to that of the exhaust fan on top of the cold chamber.

<u>Specifications:</u>

Size: 120 * 120 * 38mm
Lead: the 5Pin plug +4 line
Voltage: DC 12V
Current: 1.4A
Power: 16.8W
Speed: 4000RPM
Air Volume: 160 CFM
Wind pressure: 0.883 in H2O
Noise: 56.5 d-BA
Bearings: precision double ball bearing

Figure 17 Cooling Fans

DHT11 Temperature Sensor
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). The reading interval of the sensor is every 2 seconds. The setup has 4 DHT11 sensors located on the 4 cooling fans

<u>Specifications:</u>
3 to 5V power and I/O
2.5mA max current use during conversion (while requesting data)
Good for 20-80% humidity readings with 5% accuracy
Good for 0-50°C temperature readings ±2°C accuracy
No more than 1 Hz sampling rate (once every second)
Body size 15.5mm x 12mm x 5.5mm
4 pins with 0.1" spacing

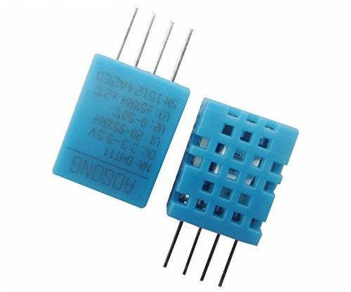

Figure 18 DHT11 Air Temperature Sensor

MAX6675 Thermocouple
It is impossible to use the DHT11 sensor on the hot chamber. In this, we used the maxx6675 thermocouple that is able to detect temperature up to 1024 degrees Celsius.
The max6675 K-Type Thermocouple Temperature Sensor performs cold-junction compensation and digitizes the signal from a type-K thermocouple. The data is output in a 12-bit resolution, SPI™-compatible,read-only format.
MAX6675 converter resolves temperatures to 0.25°C, allows readings as high as +1024°C, and exhibits thermocouple accuracy of 8 LSBs for temperatures ranging from 0°C to +700°C.

<u>Specifications:</u>
Working Voltage: DC 5V
Operating Current: 50mA
Test Temperature Range: 0°C – 1024°C, the converter temperature resolution is 0.25°C
The Temperature Measurement Accuracy: +/-1.5C
The Temperature Resolution : 0.25C
The Output mode: SPI digital signal

Figure 19 MAX6675

L298N Dual DC Motor Driver

The 4 cooling fans are driven by 2 L298N motor driver. It has a maximum output capacity of 2 amperes per channel of which is sufficient for each cooling fans. The command pins of the L298N are connected to Arduino that outputs PWM signals.

<u>Specifications:</u>

Double H Bridge Drive Chip: **L298N**.
Logical Voltage: 5V.
Drive Voltage: 5V-35V.
Logical Current: 0-36mA.
Drive current: 2A (MAX single bridge)
Max Power: 25W.
Dimensions: 43 x 43 x 26mm.
Weight: 26g.

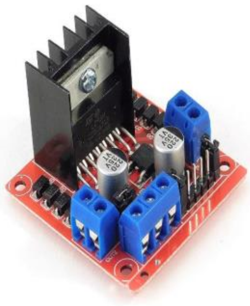

Figure 20 Figure 4.5 DC Motor Driver

Arduino Mega 2560 Microcontroller

Basically, this device processes all the data gathered by the DHT11 and MAX6675 sensors and then signals the fans to be on and off respectively once the setpoint is reached. The cooling setpoint is 26 degrees Celsius and the heating setpoint is 24 degrees Celsius. It is a 10 bit microcontroller.

Specifications	Values
Microcontroller	ATmega 2560
Operating voltage	5 V
Digital I/O pins	54 (of which 15 provide PWM output)
Analog input pins	16
Clock speed	16 MHz
Flash memory	256 kB
SRAM	8 kB
EEPROM	4 kB
Communication interfaces	UART, SPI, I^2C

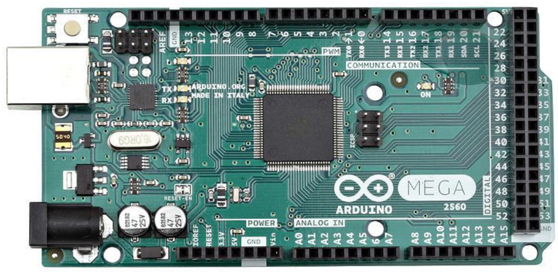

Figure 21 Arduino Mega 2560 MCU

Liquid Crystal Display

All the necessary information of the system is displayed on the screen. On the left side of the screen the temperature for the rear, front, side and top DHT11 sensor reading are displayed. The right side has the heater temperature, the heating and cooling indication and the timer that indicates the operational minutes of the HVAC system.

Figure 22 LCD

<u>Specifications:</u>
Operating Voltage is 4.7V to 5.3V.
Current consumption is 1mA without backlight.
Alphanumeric **LCD** display module, meaning can display alphabets and numbers.
Consists of two rows and each row can print 16 characters.
Each character is build by a 5×8 pixel box.
Can work on both 8-bit and 4-bit mode.
4 Rows 20 Columns

The Heat Source

The heat source of the system is a 200 watts, 220V incandescent bulb controlled by a lamp dimmer switch. The lamp is plugged in a 220V AC outlet.

Figure 23 200-watt bulb

The Power Supply of the System

The electronics and sensors of the system including the fans and control boards are powered using a DC power supply. The Capacity of the power source is 12 Volts at 10 Amperes.

Figure 24 The Power Supply of the

4.2 Results and Analysis

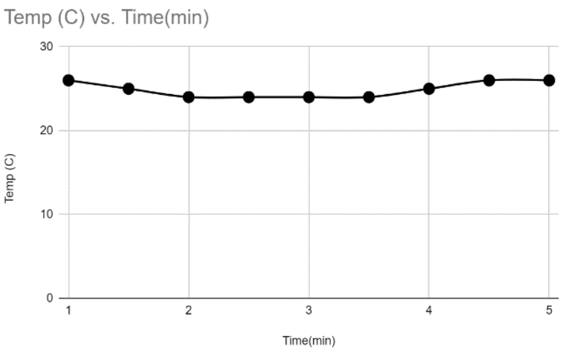

Figure 25 Temp vs Time for TE

Time(min)	Temp (C)
1	26
1.5	25
2	24
2.5	24
3	24
3.5	24
4	25
4.5	26
5	26

Table 5 Temp vs Time for TE

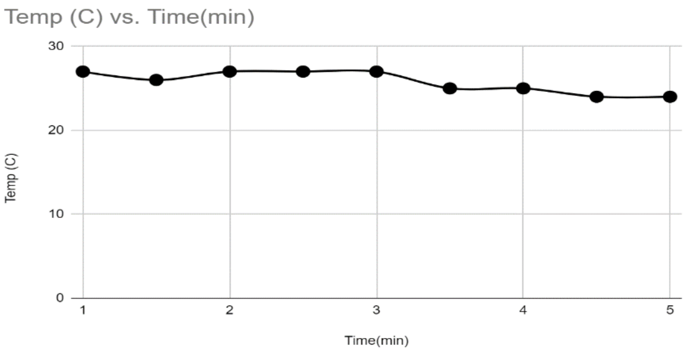

Figure 26 Temp vs Time for TS

Time(min)	Temp (C)
1	27
1.5	26
2	27
2.5	27
3	27
3.5	25
4	25
4.5	24
5	24

Table 6 Temp vs Time for TS

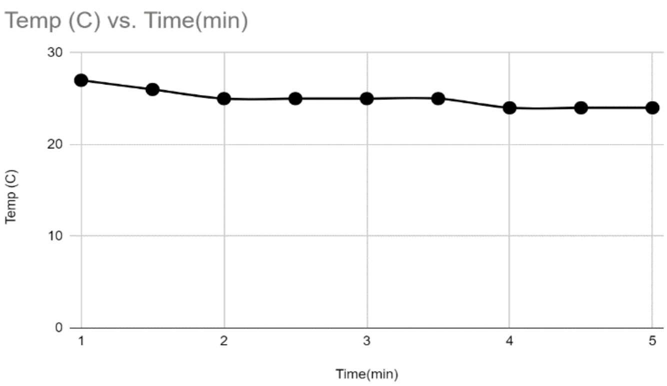

Figure 27 Temp vs Time for TR

Time(min)	Temp (C)
1	27
1.5	26
2	25
2.5	25
3	25
3.5	25
4	24
4.5	24
5	24

Table 7 Temp vs Time for TR

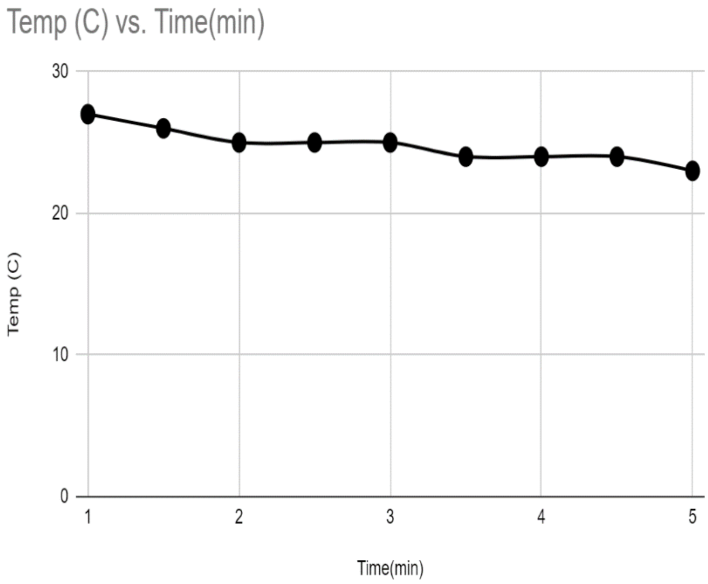

Figure 28 Temp vs Time for TF

Time (min)	Temp(C)
1	27
1.5	26
2	25
2.5	25
3	25
3.5	24
4	24
4.5	24
5	23

Table 8 Temp vs Time for TF

Chapter 5: Project Management

5.1 Project Plan

Each project's strategy was structured in a detailed way to cover the required work function and to execute the solid specific work. Until implementing it, it was very important to address the objectives and priorities of this campaign. This includes the responsibilities and action of the plan as well. The schedule below "Table: 5.1" kept the number of stages, the mission in full detail, and main description and achieved time.

Number of stages	Task	Description	Time
Stage one	Design and component	Provide all the materials	Week 1 to 3
Stage two	Literature Review	This stage includes researching for information using different places with different ideas.	Week 3 to 4
Stage three	Modules storage	Provided in one unit which loads for this purpose containers of the stored materials with various components.	Week 4 to 6
Stage four	Test the project	Recording the tests and treating with unexpected troubleshooting for successful conclusions.	Week 7 to 11
Stage five	Calculation	Calculate the time and the different amounts that help in successful process Stage	Week 11 to12
Week six	Data analysis	All data collected from experiments and reported observations will be used in processes of analysis and assessment to conduct modifications and modify the necessary stages for mechanical and electronic evaluation in the final	Week 13:16

Table 9 Project Plan

Week Plan	Description Progress’s	Percent
One	In the first step, the chamber is loosely constructed with the first product bill, description and choice of the necessary parts and specifications.	100%
two	In the second stage, the second draft of the design resulting from the review of the literature, and the final design.	100%
Three	When we visited the laboratory, it was important to look at what is available on the market, what component, if any, needs to be ordered or made.	100%
Four	There was concern with the apparatus in solid works in the digital development portion.	100%
Five	The procurement of parts relied on all the necessary parts and components being produced in compliance with the device requirements where some parts were being manufactured.	100%
Six	Both pieces are put in and securely assembled during the manufacture of the frame that is considered the key component.	
Seven	In the assembly stage of the manufacturing components, all related parts in the main frame should be finished.	100%
Eight	Fans purchasing order	100 %

Table 10 Project Plan

5.2 Contribution of Team Members

We have worked on this project like a one person. All of the team members. No one did the task by himself. In each milestone and in each task of this project all of us were involve to share the ideas to improve the project. The table below 5.3 shows the contribution of team members.

Task	Member 1 Awab	Member 2 Fahad	Member 3 Marwan	Member 4 Massaad	Member 5 Saud
Chapter 1 Introduction	All Members				
Chapter 2 Literature review	100%	95%	93%	90%	100%
Chapter 3 System Design	100%	100%	100%	100%	100%
Chapter 4 System Testing	100%	100%	95%	97%	94%
Chapter 5 Project Management	97%	97%	96%	92%	96%
Chapter 6 Project Analysis	97%	95%	96%	93%	95%
Prototype, Manufacturing, Parts Purchase	All Members				

Table 11 Contribution of Team Members

5.3 Project Execution Monitoring

There are many activities which relates to improve our project. These activities consisting of the vital meeting and activities that related to our project. In below table, it shows the list of meeting and other activities for our undertaking at some point of Fall semester 2019.

Time/Date	**Activities/Events**
Week one	Assessment III first lecture
Two times a week	Meeting with group
Once a week	Meeting with the advisor
27 Oct 2019	Finishing first prototype
14 Nov 2019	Midterm presentation
24 Nov 2019	First test of the system
4 Dec 2019	Finishing final prototype
4 Dec 2019	Test the system
12 Dec 2019	Final Submission of the report
19 Dec 2019	Final presentation

Table 12 Project Execution Monitoring

5.4 Challenges and Decision Making

Its normal to face some challenges during the project phase. some of those challenges that has an impact will be listed as follows:

1) Lack of equipment and time

2) Testing and safety issues/ Selecting materials

5.5 Project Bill of Materials and Budget

In this table below it shows the parts we purchased and the cost in SR

Item Figure.	Part Description	Quantity	Total Price
3	Base Lamp Socket	1	9 SR
2	200-Watt Lamp	2	6 SR
5	Cast Acrylic Glass	8	800 SR
6	Dimmer Switch	1	35 SR
7	Fan	4	1200 SR
7	Solderless Breadboard	1	61 SR
8	Temperature Sensor	5	180 SR
8	wires	30	100 SR
	Sum	52	2,391 SR

Table 13 Bill of Materials

Chapter 6: Project Analysis

6.1 Life-long Learning

As senior students of our institution, we had to make sure to utilize all our knowledge and to challenge ourselves of how much have we learnt over the past few years. This also includes, that we had to undergo some of the difficulties we weren't ready to encounter but that is how we would be able to fight back strong and accomplish the goals we managed to set for over these three months of pure dedication and hard-work. Furthermore, it has and will refine us as a person because we gained the knowledge of how to lead as a team and completely abide by the timelines set for each task and with all due respect, it has been extremely helpful for us now and in our future.

6.1.1 Software Skills

As senior year students in the department of mechanical engineering, we have been extremely privileged to make use of our acquired skills over the past 3-4 years of study in designing and execution of project. Since, we have used SolidWorks software to design a 3D CAD model upon which we started working as we had a benchmark to follow. Moreover, software like Arduino was also helpful in programming our microcontroller which would be controlling the fans based on the thermostats fitted to each section of the compartment. Finally, Microsoft Word has been the priority in our project since we were to record and report our project and its status on a timely basis to the department and for our own portfolio.

6.1.2: Hardware Skills

As far as hardware skills are concerned, there was nothing out of the ordinary to work upon since we were able to assemble the acrylic compartment and fans just the by the help of standard fasteners. Moreover, the electrical connections and its proper joints were handled by the assistance of lab technicians who were extremely helpful in providing us knowledge as they performed the work.

6.1.3: Time Management

We had about three months of total time to complete the project, we really needed to manage our time in an efficient manner in order to be ahead of time for unpredicted difficulties and obstacles we might face. Thankfully, all group members were in close contact and everyone was on the same page when making decisions, which really helped with cutting time and utilizing it effectively.

6.1.4: Project Management

In achieving something of this big task as our project, we needed a proper plan and time management so every task can be accomplished in a timely fashion. It also shows us the properly managed teamwork among us all as a group because without proper communication, understanding, dedication and commitment with responsibility it was not possible to achieve the amount of goals set for our group and us.

6.2 Impact of Engineering Solutions

6.2.1 Society

Since the beginning of this project's idea we were aiming towards the facilitation of the Saudi Society in regards to Vision 2030 as we have to ensure that the people are getting more and benefit of new projects which they can apply in their lives. Therefore, when talking about the social benefit, this project can really help people in rectifying the problems especially related to HVAC concerns where air conditioning is not always the best option.

6.2.2 Economy

In terms of economical aspect, there was not a lot to be spent on this project since the project already kicked off with the aim of saving cost in the HVAC sector where Air Conditioning Units can be quite expensive. Therefore, using such a system and technology in ventilating systems, there is a proper assurance of cost savings since the temperature can be maintained and there will not be any worry related to the operational costs in HVAC units where ventilation is a prime concern.

6.2.3 Environment

Environmentally looking towards our prototype, there is no threat towards the environment as the prototype does not produce any harmful by-products upon usage except of consuming a very little amount of electric power via batteries which are actually charged. Moreover, the whole material the unit is made of is degradable in a safe manner which has little to no effect on the environmental scale. Also, as we are working towards the betterment of the global environmental concerns in usage of unnecessary electricity, we can safely claim that by following such a method and project mindset, it can be very environmentally friendly.

6.3 Contemporary Issues Addressed

Any project when started is not always in its peak form or condition as the idea which is executed is still in its young form. This is why, we can address the issues that we have faced over the span of our project in properly performing it and successfully finishing it to accomplish the objectives we set forth in fixing the problems. Our project has one minor concern and that is related to the humidity factor arising inside the chamber. This humidity may not be very prominent in dry weathers but in humid conditions especially coastal regions, it can be a bit problematic. However, for our project, since the heat source (bulb) is of a significant size compared to the chamber, the water content could be evaporated easily and also because of fans placed at each face of the chamber. In the end, these little problems could be resolved as it further proceeds the development stages for a much more refined usage on an industrial scale.

Chapter 7: Conclusions and Future Recommendations

7.1 Conclusions

In every project, people learn many things that assist them in the normal life. From this project, we gained the experiences, we improved our communication skills, and we learned new things. Also, we achieved important results from this project that will encourage us in terms of working in different projects in future. In engineering science, our project is consisting various areas of engineering including; Mechanical Design, solid mechanics, and thermodynamics which help us to improve our background on these areas. In this project, we learned how to use various manufacturing processes that are essential in our lives such as finishing. Moreover, we improved our skills regarding to engineering software such as solidworks. This project as any other project has some challenges. We faced a problem regrading to finding the workshops that have HVAC system.

7.2 Future Recommendations

For improvements

1- Adding filtration system

2- Make the fan run in variable speed

3- Reduce the noise of the fans

4- Use Green energy (Solar panels .. Etc)

8.References

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Appendix A: Progress Reports

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering Prince Mohammad bin Fahd University

SEMESTER:	Fall Semester	ACADEMIC YEAR:	2019\2020
PROJECT TITLE	Design of Free Cooling Ventilator		
SUPERVISORS	Dr. Esam Jassim		

Month : October

ID Number	Member Name
201501353	Awab L. Jambi
201401611	Fahad A. Alkhan
201401159	Marwan A. Alghamdi
201402886	Mussaad M. Alyahya
201402877	Saud N. Alodah

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Create the Drawing and Conducting Calculation	Awab		
2	Analytical Result , Analysis	Saud		
3	Subsystem and selection components	Fahad		
4	Order Major Parts (Fans)	Marwan		
5	Material Selection and Design Methodology	Mussaad		

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Manufacturing process	Awab
2	Assemble and shakedown system	Awab
3	Control and program	Saud
4	Testing and analyzing the system	Fahad and Marwan
5	Check the quality	Mussaad

- **To be Filled by Project Supervisor and team leader:**

- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	**Awab L. Jambi**	4	4	4	4
2	**Fahad A. Alkhan**	4	4	4	4
3	**Marwan A. Alghamdi**	4	4	4	4
4	**Mussaad M. Alyahya**	4	4	4	4
5	**Saud N. Alodah**	4	4	4	4

Comments on individual members

Name	Comments
Awab L. Jambi	No comment
Fahad A. Alkhan	No comment
Marwan A. Alghamdi	No comment
Mussaad M. Alyahya	No comment
Saud N. Alodah	No comment

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering Prince Mohammad bin Fahd University

SEMESTER:	Fall Semester	ACADEMIC YEAR:	2019\2020
PROJECT TITLE	Design of Free Cooling Ventilator		
SUPERVISORS	Dr. Esam Jassim		

Month : November

ID Number	Member Name
201501353	Awab L. Jambi
201401611	Fahad A. Alkhan
201401159	Marwan A. Alghamdi
201402886	Mussaad M. Alyahya
201402877	Saud N. Alodah

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Manufacturing process	Awab	100%	
2	Assemble and shakedown system	Awab	95%	
3	Control and program	Saud	90%	
4	Testing and analyzing the system	Fahad and Marwan	70%	
5	Check the quality	Mussaad	80%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Prepare for Final presentation	Awab
2	Finalize the data need to developed	Saud
3	Poster	Fahad and Marwan
4	Writing the report	Mussaad

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Awab L. Jambi	4	4	4	4
2	Fahad A. Alkhan	4	4	4	4
3	Marwan A. Alghamdi	4	4	4	4
4	Mussaad M. Alyahya	4	4	4	4
5	Saud N. Alodah	4	4	4	4

Comments on individual members

Name	Comments
Awab L. Jambi	No comment
Fahad A. Alkhan	No comment
Marwan A. Alghamdi	No comment
Mussaad M. Alyahya	No comment
Saud N. Alodah	No comment

Appendix B: Engineering standards (Local and International)

Base on ANSI/ASHREA Standard 62.1-2019 Requirements All Requirements has been fulfilled

K5. SECTION 6 NATURAL VENTILATION PROCEDURE

Natural ventilation systems shall follow either the prescriptive or the engineered system compliance path.

For the prescriptive compliance path:

- ❑ Is a mechanical system compliant with either Section 6.2 or 6.3 included?
  - ❑ If no, does design comply with Exceptions 1 or 2 of Section 6.4.1?
- ❑ Do maximum distances from openings comply with Sections 6.4.1.2, 6.4.1.3, or 6.4.1.4?
- ❑ Do opening sizes comply with the requirements of Section 6.4.2?
  - ❑ Is net free area of openings specified?
  - ❑ Are sill-to-head heights specified?
  - ❑ Are aggregate widths specified?
- ❑ Are controls readily accessible?

For the engineered compliance path:

- ❑ Do the design documents provide evaluation of the following:
  - ❑ Hourly environmental conditions, including, but not limited to, outdoor air dry-bulb temperature; dew-point temperature; outdoor concentration of contaminants of concern (including but not limited to PM2.5, PM10, and ozone), where data are available; wind speed and direction; and internal heat gains during expected hours of natural ventilation operation.
  - ❑ The effect of pressure losses along airflow paths of natural ventilation airflow on the resulting flow rates, including, but not limited to, inlet vents, air transfer grills, ventilation stacks, and outlet vents.
  - ❑ Qualification of natural ventilation airflow rates of identified airflow paths accounting for wind and thermally induced driving pressures.
  - ❑ Outdoor air is provided in sufficient quantities to ensure pollutants and odors of indoor origin do not result in unacceptable IAQ as established under Section 6.2.1.1 and/or 6.3.
  - ❑ Outdoor air introduced into the space through natural ventilation system openings does not result in unacceptable IAQ according to Sections 6.1.4.1 through 6.1.4.4.
  - ❑ Effective interior air barriers and insulation are provided that separate naturally ventilated spaces from mechanically cooled spaces, ensuring that high-dew-point outdoor air does not come into contact with mechanically cooled surfaces.
- ❑ Are controls readily accessible?

Appendix C: CAD drawings

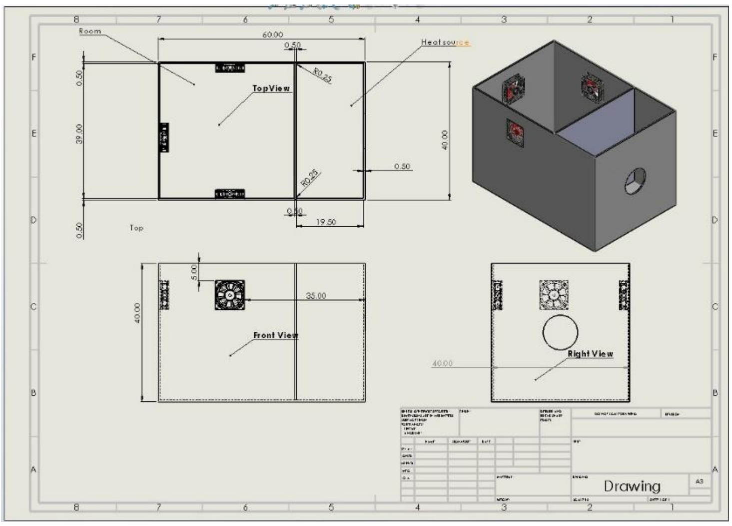

Figure 29 The dimensions

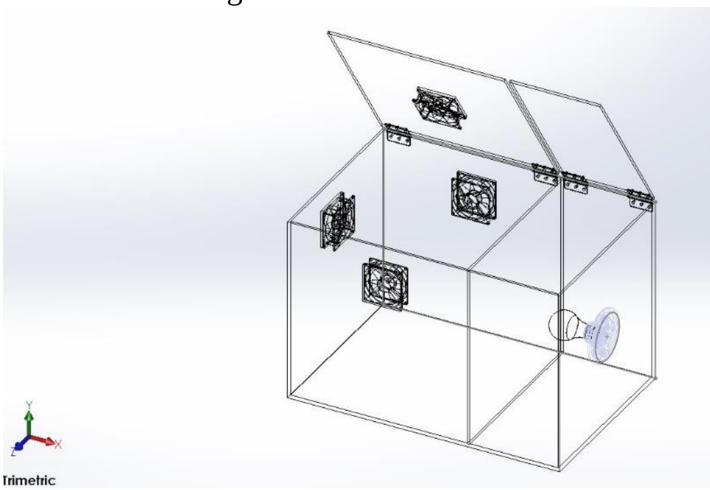

Figure 30 Isometric View

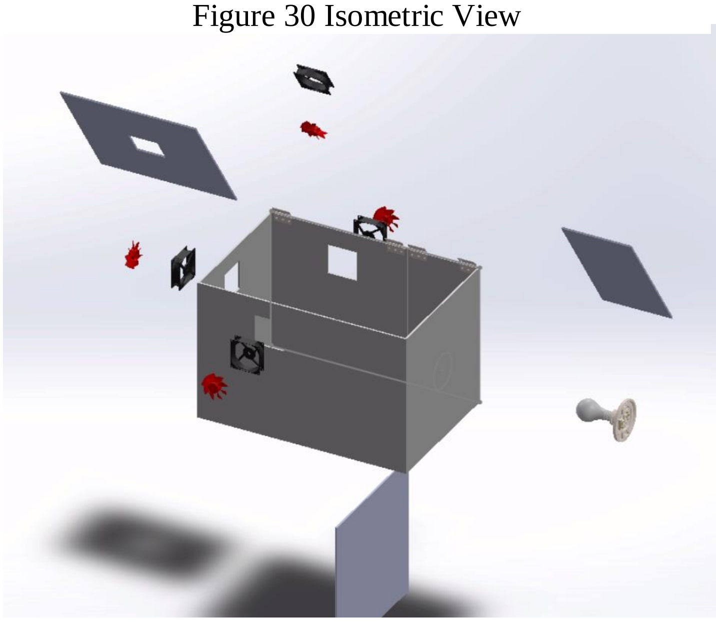

Figure 31 Exploded view

Appendix D: Program Codes

```
#include<dht.h>
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 10, 9, 8, 4);

#define dht_dpin 13
dht DHT;

#define pwm 9
#define pwm 44
#define pwm 45
#define pwm 46
#define pwm 52

byte degree[8] =
              {
                0b00011,
                0b00011,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000
              };

void setup()
{
 lcd.begin(16, 2);
 lcd.createChar(1, degree);
 lcd.clear();
 lcd.print("   T-EX:  ");
 lcd.setCursor(0,1);
 lcd.print("  T-FR: ");
 delay(2000);
 analogWrite(pwm, 255);
 lcd.clear();
 lcd.print("T-RE: ");
 delay(2000);
}

void loop()
{
  DHT.read11(dht_dpin);
  int temp=DHT.temperature;
  lcd.setCursor(0,0);
  lcd.print("T-SI:");
  lcd.print(temp);
  lcd.write(1);
  lcd.print("C");
  lcd.setCursor(0,1);
  if(temp <24 )
    {
     analogWrite(9,0);
     lcd.print("HEATING             ");
     delay(100);
```

```
    }

    else if(temp==26)
    {
      analogWrite(pwm, 51);
      lcd.print("COOLING   ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 102);
      lcd.print("COOLING  ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 153);
      lcd.print("COOLING   ");
      delay(100);
    }

    else if(temp==26)
    {
      analogWrite(pwm, 204);
      lcd.print("COOLING    ");
      delay(100);
    }
     else if(temp>26)
    {
      analogWrite(pwm, 255);
      lcd.print("COOLING   ");
      delay(100);
    }
  delay(3000);
}
```

```
#include<dht.h>
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 10, 9, 8, 4);

#define dht_dpin 13
dht DHT;

#define pwm 9
#define pwm 44
#define pwm 45
#define pwm 46
#define pwm 52
```

```
byte degree[8] =
              {
                0b00011,
                0b00011,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000
              };

void setup()
{
 lcd.begin(16, 2);
 lcd.createChar(1, degree);
 lcd.clear();
 lcd.print("   T-EX:  ");
 lcd.setCursor(0,1);
 lcd.print("  T-FR: ");
 delay(2000);
 analogWrite(pwm, 255);
 lcd.clear();
 lcd.print("T-RE: ");
 delay(2000);
}

void loop()
{
  DHT.read11(dht_dpin);
  int temp=DHT.temperature;
  lcd.setCursor(0,0);
  lcd.print("T-SI:");
  lcd.print(temp);
  lcd.write(1);
  lcd.print("C");
  lcd.setCursor(0,1);
  if(temp <24 )
    {
      analogWrite(9,0);
      lcd.print("HEATING            ");
      delay(100);
    }

    else if(temp==26)
    {
      analogWrite(pwm, 51);
      lcd.print("COOLING   ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 102);
      lcd.print("COOLING  ");
      delay(100);
    }
```

```
     else if(temp==26)
    {
      analogWrite(pwm, 153);
      lcd.print("COOLING   ");
      delay(100);
    }

    else if(temp==26)
    {
      analogWrite(pwm, 204);
      lcd.print("COOLING    ");
      delay(100);
    }
     else if(temp>26)
    {
      analogWrite(pwm, 255);
      lcd.print("COOLING   ");
      delay(100);
    }
  delay(3000);
}
```

```
#include<dht.h>
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 10, 9, 8, 4);

#define dht_dpin 13
dht DHT;

#define pwm 9
#define pwm 44
#define pwm 45
#define pwm 46
#define pwm 52

byte degree[8] =
              {
                0b00011,
                0b00011,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000
              };

void setup()
{
 lcd.begin(16, 2);
```

```
 lcd.createChar(1, degree);
 lcd.clear();
 lcd.print("   T-EX:  ");
 lcd.setCursor(0,1);
 lcd.print("  T-FR: ");
 delay(2000);
 analogWrite(pwm, 255);
 lcd.clear();
 lcd.print("T-RE: ");
 delay(2000);
}

void loop()
{
  DHT.read11(dht_dpin);
  int temp=DHT.temperature;
  lcd.setCursor(0,0);
  lcd.print("T-SI:");
  lcd.print(temp);
  lcd.write(1);
  lcd.print("C");
  lcd.setCursor(0,1);
  if(temp <24 )
    {
      analogWrite(9,0);
      lcd.print("HEATING            ");
      delay(100);
    }

    else if(temp==26)
    {
      analogWrite(pwm, 51);
      lcd.print("COOLING   ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 102);
      lcd.print("COOLING  ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 153);
      lcd.print("COOLING   ");
      delay(100);
    }

    else if(temp==26)
    {
      analogWrite(pwm, 204);
      lcd.print("COOLING    ");
      delay(100);
    }
     else if(temp>26)
```

```
    {
      analogWrite(pwm, 255);
      lcd.print("COOLING   ");
      delay(100);
    }
  delay(3000);
}
```

```
#include<dht.h>
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 10, 9, 8, 4);

#define dht_dpin 13
dht DHT;

#define pwm 9
#define pwm 44
#define pwm 45
#define pwm 46
#define pwm 52

byte degree[8] =
              {
                0b00011,
                0b00011,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000
              };

void setup()
{
 lcd.begin(16, 2);
 lcd.createChar(1, degree);
 lcd.clear();
 lcd.print("   T-EX:  ");
 lcd.setCursor(0,1);
 lcd.print("  T-FR: ");
 delay(2000);
 analogWrite(pwm, 255);
 lcd.clear();
 lcd.print("T-RE: ");
 delay(2000);
}

void loop()
{
  DHT.read11(dht_dpin);
```

```
 int temp=DHT.temperature;
 lcd.setCursor(0,0);
 lcd.print("T-SI:");
 lcd.print(temp);
 lcd.write(1);
 lcd.print("C");
 lcd.setCursor(0,1);
 if(temp <24 )
   {
    analogWrite(9,0);
    lcd.print("HEATING           ");
    delay(100);
   }

   else if(temp==26)
   {
    analogWrite(pwm, 51);
    lcd.print("COOLING   ");
    delay(100);
   }

    else if(temp==26)
   {
    analogWrite(pwm, 102);
    lcd.print("COOLING  ");
    delay(100);
   }

    else if(temp==26)
   {
    analogWrite(pwm, 153);
    lcd.print("COOLING   ");
    delay(100);
   }

   else if(temp==26)
   {
    analogWrite(pwm, 204);
    lcd.print("COOLING    ");
    delay(100);
   }
    else if(temp>26)
   {
    analogWrite(pwm, 255);
    lcd.print("COOLING   ");
    delay(100);
   }
 delay(3000);
}
```

```
#include<dht.h>
```

```
#include<LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 10, 9, 8, 4);

#define dht_dpin 13
dht DHT;

#define pwm 9
#define pwm 44
#define pwm 45
#define pwm 46
#define pwm 52

byte degree[8] =
              {
                0b00011,
                0b00011,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000,
                0b00000
              };

void setup()
{
 lcd.begin(16, 2);
 lcd.createChar(1, degree);
 lcd.clear();
 lcd.print("   T-EX:  ");
 lcd.setCursor(0,1);
 lcd.print("  T-FR: ");
 delay(2000);
 analogWrite(pwm, 255);
 lcd.clear();
 lcd.print("T-RE: ");
 delay(2000);
}

void loop()
{
  DHT.read11(dht_dpin);
  int temp=DHT.temperature;
  lcd.setCursor(0,0);
  lcd.print("T-SI:");
  lcd.print(temp);
  lcd.write(1);
  lcd.print("C");
  lcd.setCursor(0,1);
  if(temp <24 )
    {
      analogWrite(9,0);
      lcd.print("HEATING            ");
      delay(100);
    }

    else if(temp==26)
```

```
    {
      analogWrite(pwm, 51);
      lcd.print("COOLING   ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 102);
      lcd.print("COOLING  ");
      delay(100);
    }

     else if(temp==26)
    {
      analogWrite(pwm, 153);
      lcd.print("COOLING   ");
      delay(100);
    }

    else if(temp==26)
    {
      analogWrite(pwm, 204);
      lcd.print("COOLING    ");
      delay(100);
    }
     else if(temp>26)
    {
      analogWrite(pwm, 255);
      lcd.print("COOLING   ");
      delay(100);
    }
  delay(3000);
}
```

Appendix E: Adviser, Co - Adviser and team members

Figure 32 Final prototype