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Senior Design Project Report

**Design of Desiccant Disk for use in Solar
Air Conditioners**

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

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Abstract

The majority of the energy consumed in a household is directed to heating and air conditioning. With increasing fuel prices and environmental concerns, renewable energy technologies are developing. However, the main focus of these technologies is the production of electricity. Using the electricity produced by renewable sources for heating and air conditioning creates inefficiency if the renewable source can be directly used for the purpose of heating and air conditioning. It is well known that the highest load on the electricity generation system is imposed by air conditioners during the warm season. Typically, the sun irradiance experiences a maximum during the warm season. There are several methods to harvest the solar energy for refrigeration purposes. Since the 1990s adsorption technology is used in dehumidification. The disadvantages of liquid–vapor adsorption systems are overcome by using solid–vapor cycles.

For this project, a solid-vapor system was developed. In particular, a water adsorption and emission disk was designed, manufactured and tested. Different types of silica were considered and investigated. Meteorological data for Saudi Arabia were retrieved to demonstrate the applicability of a solar dehumidifier and air conditioner. The application of the disk is in a simulated solar powered dehumidifier or air conditioner.

Acknowledgments

The project on the history of silica Gel was a heavy work that required an integration of many parties. In addition, it was the fruit of many sincere efforts and experiences. These efforts were crowned by the sincere directives of the project supervisor, Dr. Panos. It was great to receive his professional guidance that positively affected work a big deal. We address him the best hearty greetings for all his instructions, reviews and recommendations.

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1 Chapter 1: Introduction

1.1 Project definition

Because there is always a percentage of humidity in the climates all over the world, industrially, it is not good to process materials in a humid climate. That may affect the synthesis of materials and affect the functionality negatively. For example, handling sheets of steel in a humid climate may affect the quality of steel in a bad way. Iron also is corroded in a humid climate. Hence, there is a need to reduce humidity to the least limits available to be able to conduct chemical operations effectively. In fact, there are many triggers that can be used to reduce the high humid levels in the weather.

Desiccant dehumidifier is known for its ability to dry the atmosphere all around a chemical process. However, there must be a type of technology that supports a complete functionality of desiccant humidifiers. For example, there is the rotary desiccant air conditioning system. It integrates with other desiccant dehumidification technologies to enhance the process of evaporative cooling. This technology is great with the freeing the weather from all CFCs depending on low thermal energy grades. In addition, it is great with the controlling levels of general humidity and temperature as well. The Ongoing researches all over the world suggested new desiccant materials that can work better to improve desiccation process and to increase the reliability with dehumidification within air conditioning systems. Rotary desiccant air conditioning systems are good designed tools that help with dehumidification process.

This project is to design and manufacture a dehumidifier by using silica gel to absorb the moisture from the air. The design consists of a duct which is a cylindrical pipe used to dry the air in it. Inside the duct there is a disc that carries silica gel which is the material we used to dehumidify the air. There is also a shaft that makes the disc rotate. The duct is split into two parts from the inside and each part has its own enter and exit. The first part is for fresh air to do the operation on it and dehumidify it and the second part is for hot air to dry the silica gel.

1.2 Project Objectives

1. Improve the instrumentation and data acquisition (thermocouples, pitot tubes, RH sensors)
2. Add an indirect evaporative cooler and water sprayer
3. Manufacture a trolley to mount the disk and the motor on to be easier to move.
4. Design a gears box reduction mechanism to enhance the performance gears box.

1.3 Project Specifications

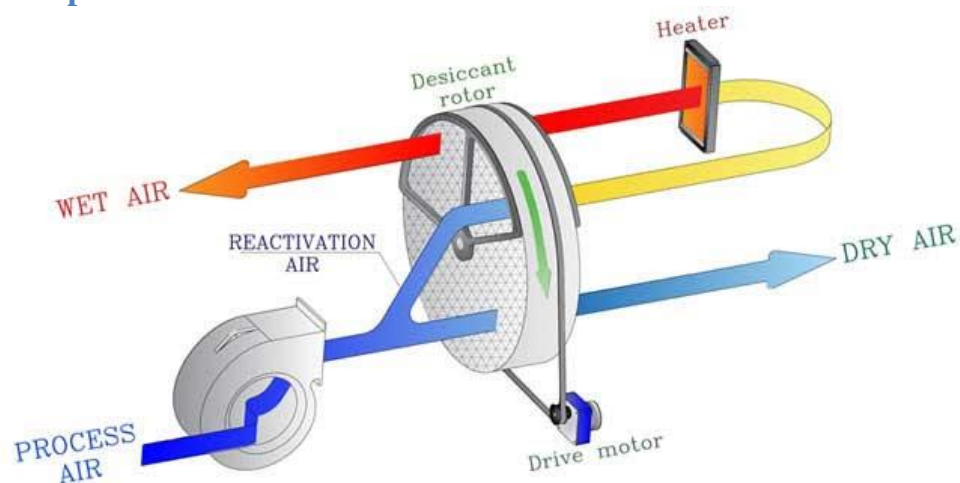


Figure 1 - Desiccant Disk

The project consists of different components in order to make this dehumidifier work properly. These components are motor, shaft, disc, duct, bearing, silica gel, dry air fan and hot air gun. The hot air gun will simulate the solar power system and the drying air fan. We will use Arduino Sensors, interactive objects that can sense and control objects. Gearbox, A transmission is a machine in a power transmission system, which provides controlled application of the power. Often the term transmission refers simply to the gearbox that uses gears and gear trains to provide speed and torque conversions from a rotating power source to another device. In addition, we will use an amplifier, uses electric power from a power supply to increase the amplitude of a signal. The amount of amplification provided by an amplifier is measured by its gain: the ratio of output voltage, current, or power to input. An amplifier is a circuit that has a power gains greater than one.

1.4 Applications

Dehumidifiers can be used in at places that are near shores like the eastern province of Kingdom of Saudi Arabia and places that have extreme humidity for example the tropical regions in Africa and South America. It also can be used in any place that could have moisture in the air like sport facilities. In addition, it can be used in households when the evaporative air conditioner added to the system. We want to manage this environment of a material sample not be corroded to be maintained at certain humidity percentage so, that it will not be corroding.

2 Chapter 2: Literature Review

This section describes the project background. Initially the meteorological conditions in Saudi Arabia are discussed, showing the practicality of this project. Then, the types of dehumidifiers and silica are discussed. The used experimental methods used in this work are reviewed. Finally, previous work is presented and a comparative study with the literature is performed.

2.1 Project background

The majority of the energy consumed in a household is directed to heating and air conditioning. With increasing fuel prices and environmental concerns, renewable energy technologies are developing. However, the main focus of these technologies is the production of electricity. Using the electricity produced by renewable sources for heating and air conditioning creates inefficiency if the renewable source can be directly used for the purpose of heating and air conditioning. It is well known that the highest load on the electricity generation system is imposed by air conditioners during the warm season. Typically, the sun irradiance experiences a maximum during the warm season. There are several methods to harvest the solar energy for refrigeration purposes. Since the 1990s adsorption technology is used in dehumidification. The disadvantages of liquid–vapor adsorption systems are overcome by using solid–vapor cycles.

The history of silica gel dates back to the 17th century. It was accidentally discovered in 1640 by a chemist looking for a substance with the ability to absorb moisture, vapor and gases. However, the first application of silica gel was during the First World War as it was used to absorb the gases that leaked into the gas masks of soldiers. In 1918, the silica gel was patented for the first time in by Professor Walter A. Patrick from Johns Hopkins University in 1918.

In the Second World War, silica gel was intensively used in military objectives. It was an important objective for doctors during the war to keep dryness of antibiotics like penicillin and others. In addition, it was important for the military people to think of the ways that safeguard the bodies of their equipment, tanks, and artilleries against from the

hazards of corrosion. Moreover, at that time, silica gel was used as a fluid catalyst, to produce gasoline with high octane number or as a catalyst to support the manufacturing of butadiene using ethanol.

2.2 Previous Work

Since Temperature is described as the amount of heat in air, it is well known that Saudi Arabia has a dry desert climate. The Kingdom is remarkable with very high degrees of temperature all over the country and nearly in most times of the year. However, scientifically, there is still some variation of temperature in different times of the year and also on different parts in the Kingdom [1]. That variation of temperature can sometimes reach the freezing points in different northern parts especially in winter. The following table 1 shows the averages of temperatures in different regions in the summer and winter [2].

Table 1 - Average temperature in some Saudi cities

| Region | Average temperature degrees (Celsius) | |
|--------------------------|---------------------------------------|---------|
| | Maximum | Minimum |
| Central (Riyadh) | 44°C | 7 °C |
| Central (Qasim) | 41°C | 5 °C |
| Eastern (Dammam) | 45°C | 11 °C |
| Western (Al-Wajh) | 23 °C | 21 °C |
| Southern (Jizan) | 38 °C | 22 °C |
| Northern (Hail) | 40 °C | 4 °C |
| Al-Madinah | 30 °C | 17 °C |
| Mecca | 44 °C | 30.5 |
| Jeddah | 39 °C | 23.5 °C |

Through the table 1, it is clear that climate in the Kingdom is highly variable across all regions. The northern parts experience the lowest temperature, especially in winter. Temperature may go to the lowest limits of freezing point. In winter, the lowest temperatures recorded range from 2 to 7 °C. Meanwhile, in the summer, the temperatures turn into the hottest to record between 40 and 44 °C.

Moving to the Mecca and Jeddah, they both record the highest degrees in the Kingdom. Sometimes, temperature in Mecca reaches up to 50 °C. The same extreme temperature can be found in Jeddah where recorded temperatures sometimes reach up to 47 °C. However, the recorded averages in the two cities (Jeddah and Mecca) show a difference. Jeddah experiences a milder winter with lower degrees that reach 23.5 °C while winter in Mecca is hotter with an average of 30 °C.

When comparing the eastern region to the western region, it can be found that the effect of the Arabian Gulf was higher than the effect of the red sea. While western region was warmer, eastern region varied between colder and hotter. In summer, the highest average recorded in Dammam in eastern region was 45 °C while it was 23°C in Wajh. Meanwhile, in winter, the highest averages recorded were 11°C and 21°C for Dammam and Wajh respectively.

Finally, the table showed great variation between the north and the south in Saudi Arabia. The two climates are different as if they are in different countries. That may be due to the vast distance between both north and south of the kingdom. The highest averages recorded for summer are 40°C and 38°C for Hail and Jizan respectively. On the other hand, winter in both regions is very different. The highest averages recorded in both are 4°C and 22°C for Jizan and Hail respectively.

2.2.1 **General Averages in Kingdom of Saudi Arabia**

The variation of temperature in the Kingdom is not only limited to the geographic regions. It is also more dependent on the periods of the year. The following figure shows the average of temperature in all regions in the kingdom across the year.

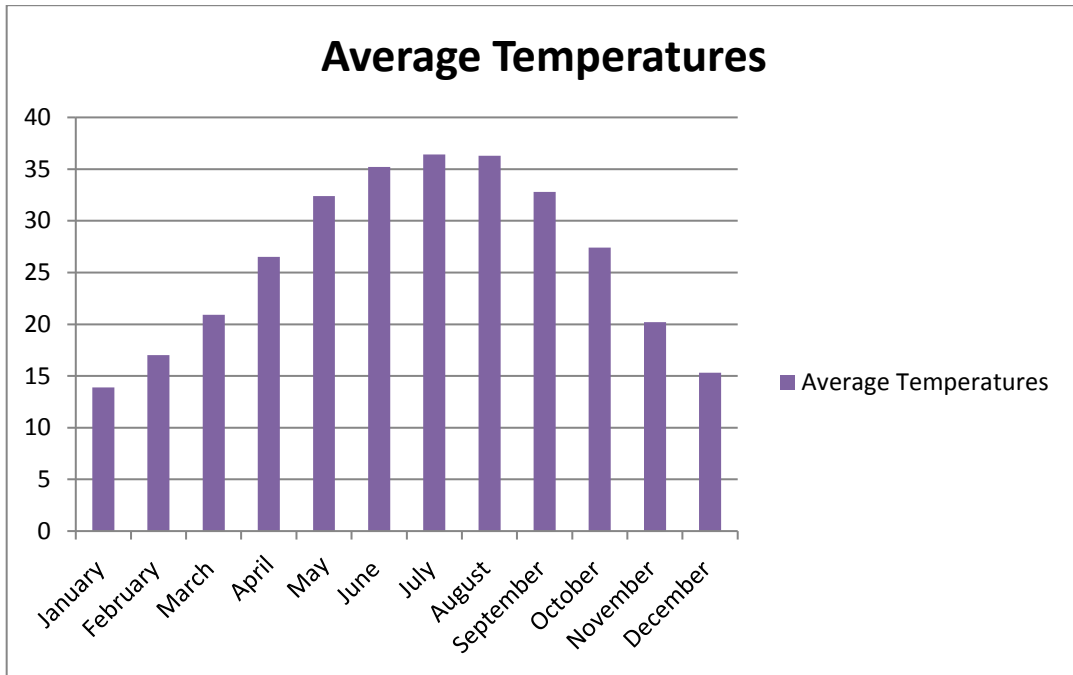


Figure2 - Average temperature in Saudi Arabia

According to the figure 2, July is the hottest month of the year in Saudi Arabia. In all regions, the average of temperature in July was recorded around 36.4°C. However, July is not the only hot month, as August is ranked the second hottest month of the year with an average of 36.3°C. On the other hand, January is the coldest month of the year in all regions of the Kingdom. The average of temperature in January is 13.9 °C. March and November are the mildest months of the year in all regions of the Kingdom. They recorded an average 20.9 °C and 20.2 °C respectively [3].

2.2.2 Sunshine Hours

The examination of temperatures in the Kingdom is strongly related to the examination of sunshine hours. Sunshine hour is meant to measure the time of having strong daylight. Sunshine affects the temperature in the Kingdom. It also affects people's perception of temperature. In addition, temperature differs according to the shining of the

sun. However, the effect of day light is not always in one direction, it means that having long daylight does not always mean to have a very high temperature in a region.

Taking Riyadh as an example, there is a simple variation of the sunshine hours along the year. This has affected the temperature of Riyadh especially in daylight. Looking at the figure 3, July is the highest sunshine month of the year in Riyadh with a number of 350 hours of sunshine. Meanwhile, January and December have the lowest sunshine hours all over the year with a number of 210 sunshine hours [1]. However, Riyadh also enjoys a long day light time. The longest daylight time all over the year in Riyadh is 13:32 hours long. Meanwhile, the shortest daylight time is 10:27 hours long.

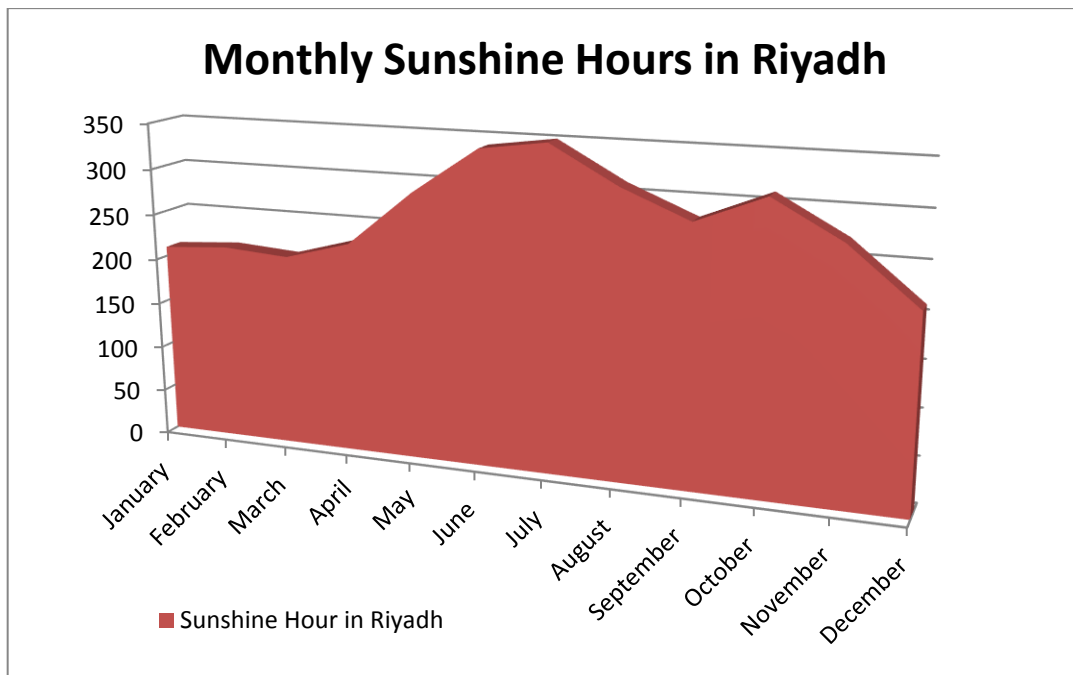


Figure3 - Monthly sunshine Hours in Riyadh

Moving to Hail in the north of Saudi Arabia, it was noticeable that it has a longer daylight time than Riyadh. However, the long daylight of hail did not affect the temperature significantly. Although it has longer daylight time, degrees of temperature in Hail are still underrated compared with degrees of temperature in Riyadh. The longest time for day light in hail is 13:44 hours while the shortest day light is 10:15 hours as shown in figure 3 [7].

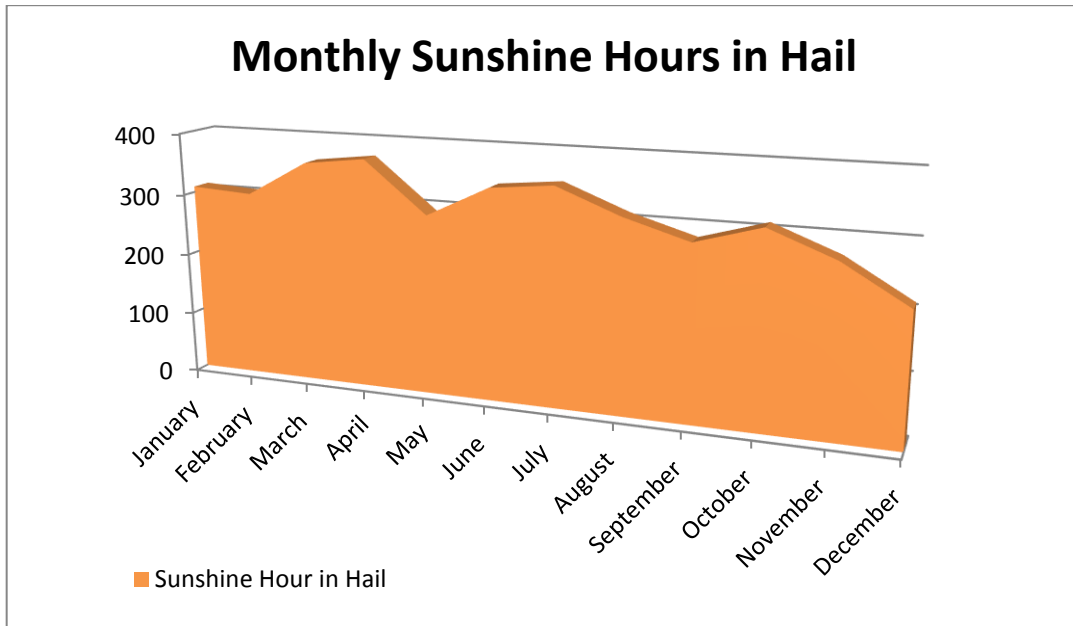


Figure 4 - Monthly sunshine hours in Hail city

Moving to the north west of the Kingdom, precisely in Al-Madinah city, it was also noticeable that climate in Al-Madinah has some differences concerning daylight and sunshine. Generally, Madinah enjoys a longer daylight time than Hail. The longest day in Madinah is 13:31 hours long and the shortest daylight is 10:28 hours long. The apex of daylight in Madinah is in June while the shortest daylight time is recorded in December as shown in figure 4.

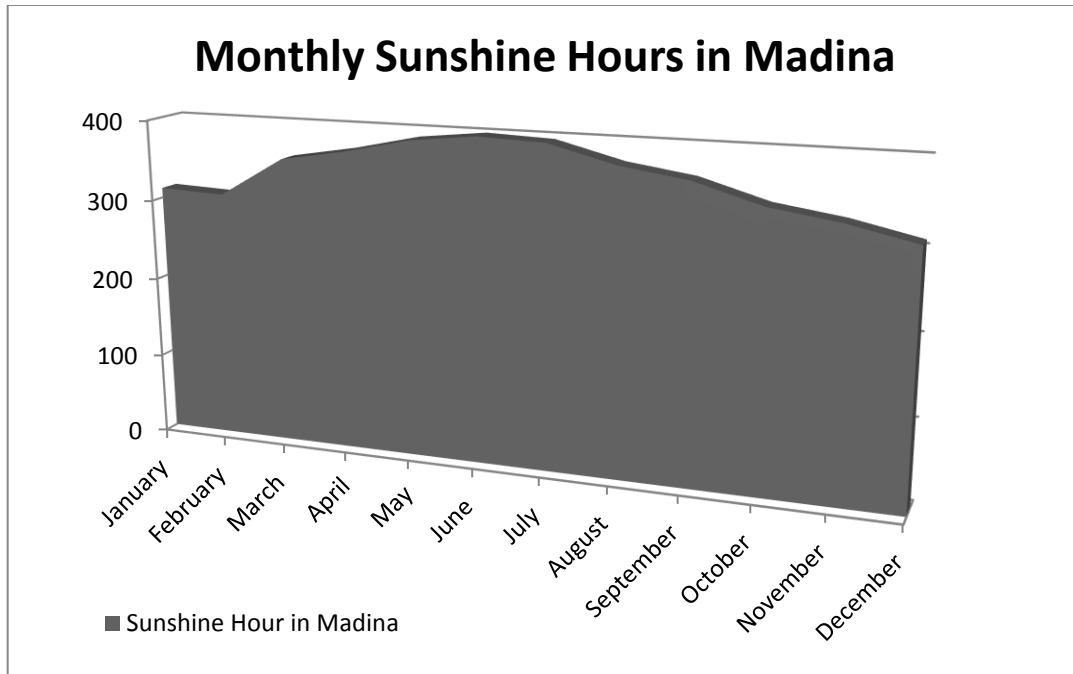


Figure 5 - Monthly sunshine hours in Madinah

2.2.3 Humidity

Humidity is considered by all climate experts as the second side of the coin of temperature. In other words, there is a strong relation between temperature and humidity. People's perception of temperature depends on the humidity records per a day. The more humid the weather is the higher temperature people will feel [5].

Humidity is defined as the amount of water vapor present in the air. It is generally known that the warmer the air, the more water vapor it can withhold. The opposite can be said on cold temperatures. The air can carry less water vapor so it gives a lower feeling of temperatures.

2.2.4 Humidity in Saudi Arabia

Climate in Saudi Arabia is generally described as very humid. This is due to the high temperatures of Saudi Arabia climate most of the year. In addition, there is a reason for the high humidity in Saudi Arabia which is represented in the effect of both the Red sea and the Arabian Gulf.

In Riyadh, January and November are the highest humidity months of the year. Humidity reaches the level of 50 and 46% respectively. Meanwhile in summer, June and July are the lowest two humid months of the year, the humidity reaches 14 and 15% for June and July respectively. It is noticeable that Riyadh is an inland city with dry climate so humidity in Riyadh does not take high records monthly. See figure 5.

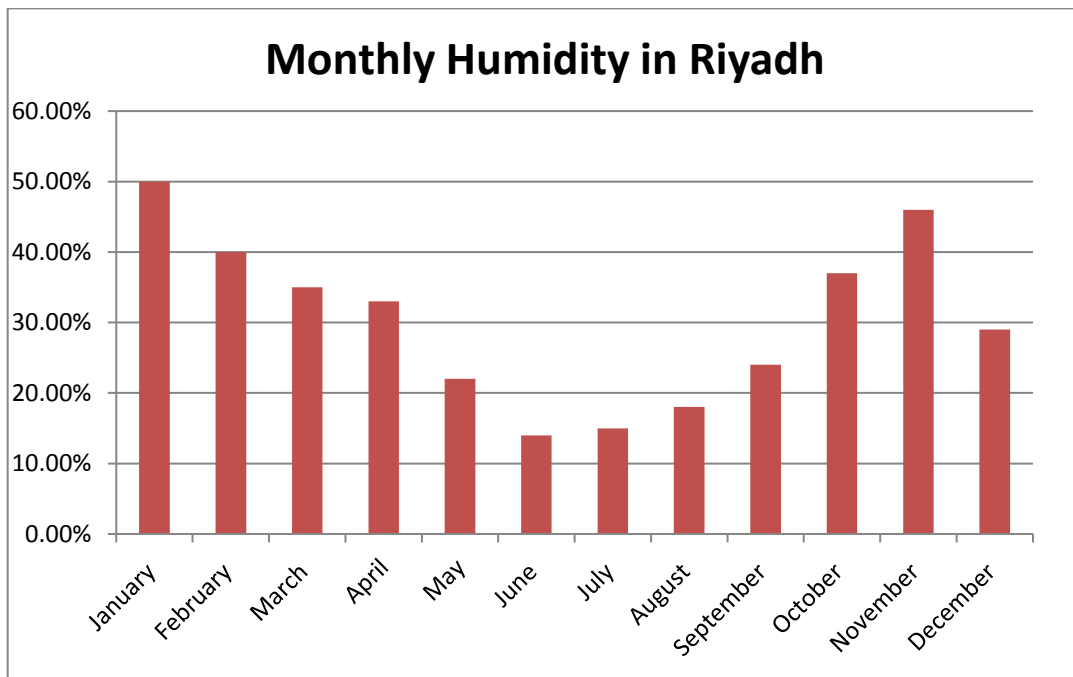


Figure 6 - Monthly humidity in Riyadh

In Jeddah, humidity takes a very different form with higher percentages. For example, for example, there are no higher differences of humidity among all then months of the year. All percentages are close and high. Generally, it can be said that January is the highest humid month in Jeddah with a percentage of 73% while July is the lowest humid month with a percentage of 59%. The effect of the red sea is very clear as it turns climate into very humid with high percentage of water vapor in the air as shown in figure 7.

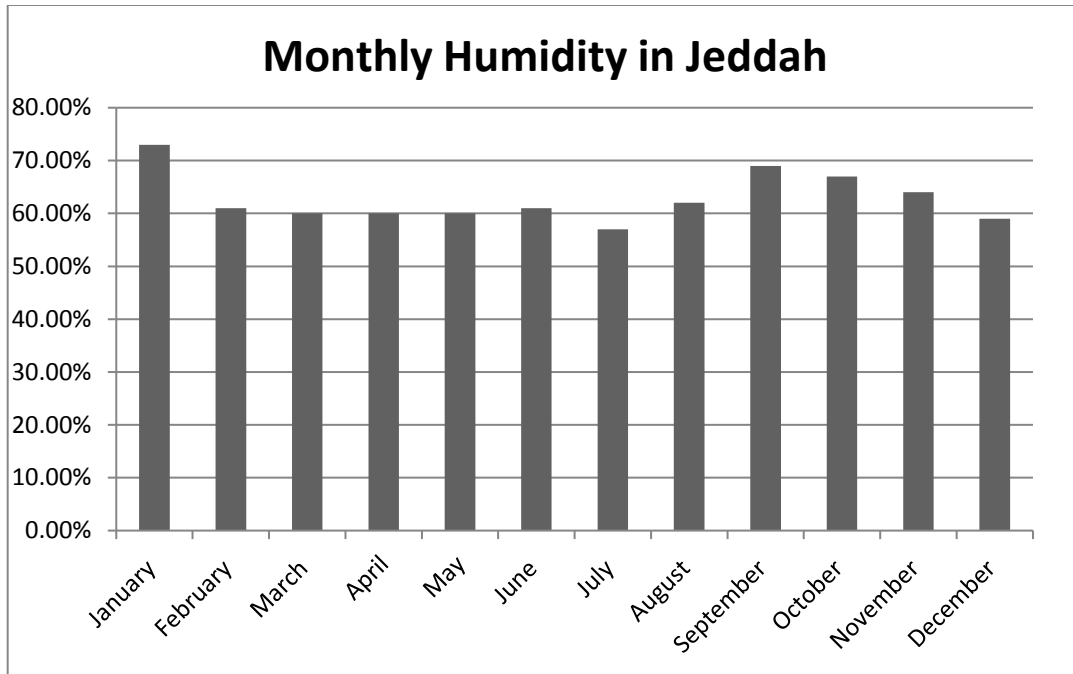


Figure 7 - Monthly humidity in Jeddah

In Hail humidity takes third different curves. Because hail is not a coastal city in addition that it is in the mild circle in the north of the kingdom, humidity was very low and variable across the year according to temperature. For example, December is the highest humid month in Hail with a percentage of 52% while July was the lowest and mildest humid month with a percentage of 15% as shown in figure 8.

In Dhahran in the eastern region, the effect of the Arabian Gulf was very large. The values of relative humidity in Dhahran were the largest in the kingdom. As usual, January recorded the highest humid percentage. It revolved around 73 % which is a very high percentage. Meanwhile, June was the lowest humid month with a percentage of 34% which is also considered a relatively high percentage see Figure 9 for more information.

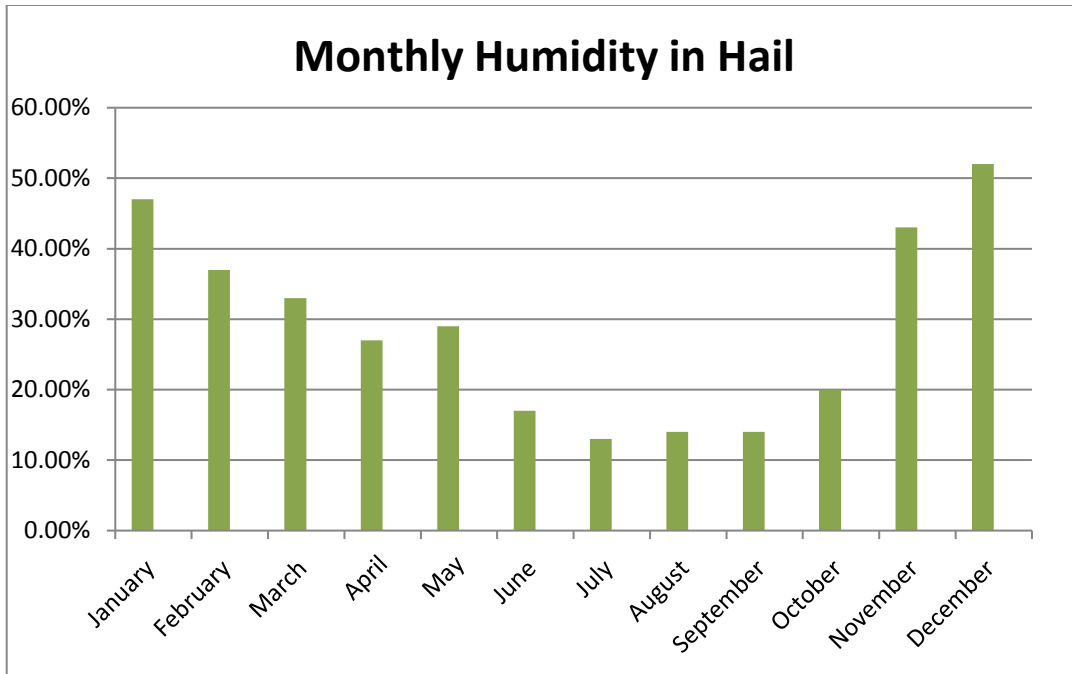


Figure 8 - Monthly humidity in Hail

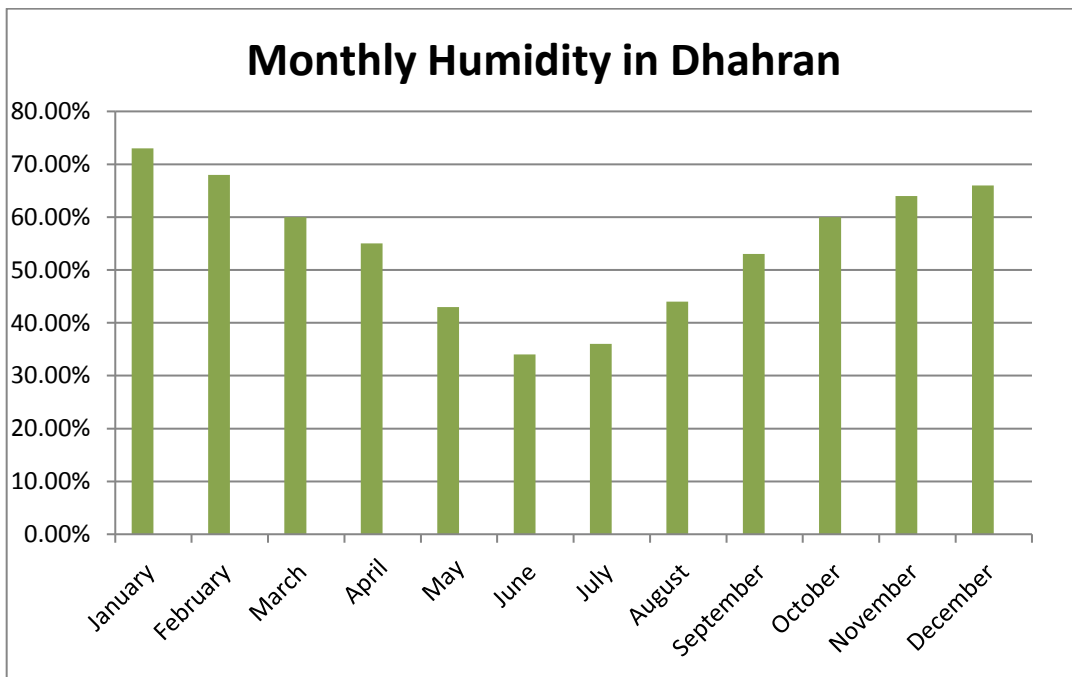


Figure 9 - Monthly humidity in Dhahran

2.2.5 Variation of humidity in the Kingdom

There are two main reasons for the variation of humidity in the Kingdom. The first reason is the effect of the coasts on both sides, the Red Sea and the Arabian Gulf.

The high temperature in the coastal cities like Dhahran, Dammam and Khobar on the Arabian Gulf, and Jeddah and Jizan on the Red sea has caused these cities to witness high rates of evaporation process that increased molecules of water vapor in the air. Therefore, these cities may be felt hotter than the real levels of temperature because of high humidity.

On the other hand, the inland cities like Riyadh, Qasim and Medina experience less humidity and milder temperatures. Hence, they are felt moderate in temperature. Even with high temperatures degrees, the low rate of relative humidity provides a gentle feeling of mild weather. The other cities like Hail, Kaka and Taluk do not show high humidity levels. They are located in the climate mild zone in the far north of the kingdom. In addition, they do not suffer high temperatures in summer. Moreover, they do not look over any waters. Consequently, they enjoy a very mild weather that is moderate in temperature and humidity.

Hence, both location and coasts of the red sea and Arabian Gulf determine significantly the variation of temperature and humidity in the Kingdom. On one side, cities like Jeddah, Dammam and Dhahran are high in temperature and humidity. On the other side, cities like Riyadh and Qasim are high only in temperatures but dry with low humidity. Other cities like Asir, Baha, Abha and Dheba are low in temperature and humidity because of inland mild location.

2.3 **Comparative Study**

In this section, we will talk about main part of our project which are a reduction mechanism and sensors of humidity and temperature, pulley and dc motor speed controller.

This literature review could help us in our project that can have two or more speed in design transmission parts. Assemblies of parts were made including the speed-changing gears and the propeller shaft by which will transmit the power from an engine to a live axle. Often transmission refers simply to the gearbox that uses gears and gears trains to provide speed and torque conversions from a rotating power source to another

device. The most common use is in motor vehicles, where the transmission adapts the output of the internal combustion engine to the drive wheels. Such engines need to operate at a relatively high rotational speed, which is inappropriate for starting, stopping, and slower travel. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process. Transmissions are also used on pedal bicycles, fixed machines, and where different rotational speeds and torques are adapted.

How system work:

1. System controlled by Arduino which programmed to maintain temperature at 25° by running the fan with variable speed to produce cooling and once temperature below 25° bulb will turn on to produce heat. Both temperature and fan speed will display on LCD screen.
2. A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a taut cable or belt, or transfer of power between the shaft and cable or belt. In the case of a pulley supported by a frame or shell that does not transfer power to a shaft, but is used to guide the cable or exert a force, the supporting shell is called a block, and the pulley may be called a sheave. A pulley may have a groove or grooves between flanges around its circumference to locate the cable or belt.
3. Speed control means intentional change of the drive speed to a value required for performing the specific work process. Speed control is a different concept from speed regulation where there is natural change in speed due change in load on the shaft. Speed control is either done manually by the operator or by means of some automatic control device. One of the important features of DC motor is that its speed can be controlled with relative ease.

3 Chapter 3: System Design

3.1 Design Constraints and Methodology

The constraints of each manufactured part are listed in table 2. The manufactured parts will contain the following parameters which are; size, geometry, weight, cost, and the effect of the environment on the design.

Table 2 - Contains the constraints and details of each manufactured part

| Item | Size | Geometry | Environment | Weight/materials | Cost |
|--------------------|--|--|---|--|---|
| Trolley | Surface area = 5.93 square meters | ASTM A123 Galvanized steel for the base sheet ASTM A217 cast alloy steel for bars | Mack our project easy to mobilization and helpful | Mass = 50.20 kilograms | The cost of the Trolley 1800 SR |
| Evaporative cooler | Dimensions: Height 78 cm, Width 91 cm, Depth 10 cm | Kraft Paper Pad | To cooling the Air from the Desiccant to the room | Weight: 3.65 kg Material: Kraft Paper Pad | The cost of the Evaporative cooler 450 SR |
| Torque wrench | Dimensions: 1.5 x 1.5 x 17 inches | Torque: 6 - 30 Nm Power: Lithium battery | LCD display to easily show measurements | Item Weight: 4 Pound | The cost of the Torque 230 SR |

| | | | | | |
|----------------------------------|--|---|--|---|--|
| pressure drop through an orifice | The width 1" and the orifice are 0.5" length the pipe 4" which is 100 mm | The material made from SS (Stanley steel) 304 | | To calculate the velocity of Air bases through the desiccant and duct | |
|----------------------------------|--|---|--|---|--|

The constraints and specifications of the motor are listed in table 3. The motor constraints and specifications have the following parameters, which are speed, power, efficiency, and cost of the design.

Table 3 - contains the constraints and specifications of the motor, AMP meter and tachometer

| Item | Type | Speed/Voltages | Power/torque | Efficiency | Cost |
|-----------|--|---|---|---|-----------------------------------|
| Motor | Car window motor for Chevrolet Caprice 1995 | The speed should be between 52 RPM - 12.V | The motor should have the appropriate torque to rotate the desiccant wheel 19 N.M | The efficiency should be high to reduce the power consumption of the system. and the watt are 103.46311 W | Should not exceed 100 SR. |
| Amp meter | Hitomall UNI-T digital clamp-on meter UT204A | Read up to 600V – 400 A | Its Tools we use to measure the electrical loads Voltage (V-AC) Voltage (V-DC) Ampere(A-AC) Ampere (A-DC) Resister (Ω) | Light and easy to hold and we need to cut the wire in to for + and – to tack the readings | The cost of the Amp meter 95 SR95 |

| | | | | | |
|------------|---|---|-----------------------------------|--|-----------------------------------|
| Tachometer | UNI-T's UT372 is a non-contact tachometer with ranges of 10RPM~99999RPM | Measurement Distance: 50mm ~ 200mm Dimensions: 184 x 56 x 34mm l Weight: 100g | Power: 4pcs x 1.5V batteries (AA) | A tachometer is a sensor device for measuring the rotation speed of an object. | The cost of the Tachometer 235 SR |
|------------|---|---|-----------------------------------|--|-----------------------------------|

The constraints and specifications of the Heat Gun are listed in table 4. The constraints and specifications have the following parameters, which are Air flow, power, working temperature, and cost of the design.

Table 4 - contains the constraints and specifications of the Heat Gun and Humidity and temperature sensors

| Item | Type | Airflow/power | Working temperature |
|----------------------------------|--|---|--|
| Heat Gun | <u>GHG 500-2</u> Professional | The Airflow between 240 - 450 l/min To have the ability to dry the silica gel. And it has 1600 W | The working temperature should be high to dry the silica. 300-500°C |
| Humidity and temperature sensors | DHT11 is a humidity and Temperature Sensor, which generates calibrated digital output. | Power supply 5K Ohm Resistor (1/4 W) Connecting wires | Humidity atmospheric wither |

3.1.1 Constraints

The desiccant air dehumidifier can be used in places all around the world as long as the humidity concentration is present. The constraints that can affect the overall design of the desiccant air dehumidifier are as follows:

- I. Environments
- II. Economical
- III. Manufacturability
- IV. Safety
- V. Sustainability

- VI. Geometrical constraints
- VII. Engineering standards

The design constraints above will be taken into consideration in more details. The final design of the Desiccant Air dehumidifier will have to take in consideration of the effect that any changes in dimensions will have as a result. The project will apply the engineering standards for future manufacturing to allocate the parts used in the Desiccant Air Dehumidifier.

3.1.1.1 Environments

The environment is a huge factor to take into consideration. The environment can affect the efficiency of the project as a whole. The environments that the project can work in are places near shores and in tropical regions where the humidity is concentrated. The desiccant air dehumidifier is not only limited to regions but it can also be used in closed places that have high occupancy levels where humidity can become very high for example, Gyms, enclosed swimming pools, changing rooms, etc. The Desiccant air dehumidifier will not be able to bring fresh air to reduce the humidity in cold regions where humidity is high but it can be used in enclosed places as a solution for the high humidity concentrations.

3.1.1.2 Economical

The main benefit of using the desiccant air dehumidifier is to reduce the amount of energy consumption that is needed to reduce the humidity of a space. This is due to the lack of air conditioning system where the consumption will be much higher. The constraint that we faced is the amount of power that the heater is consuming. The more heat we provide to the system the faster the rate of regeneration of the silica gel. The increase in power consumption will demean the concept of using a desiccant air dehumidifier.

3.1.1.3 Manufacturability

The system can be manufactured very easily due to the lack of fluids and seals where leaks can occur any moment and render the process. The main constraint that we

face during the manufacturing of the project is the assembly of the supports in the duct. The duct will use six supports for each bearing and the project will acquire three bearings. The supports will have to be welded to the duct, which will give us a bit of a challenge. The second challenge would be placing the silica gel inside of the desk without the mesh tearing apart. The mesh will have to be placed gently on the desk and it has to be multilayered.

3.1.1.4 Safety

Safety is always a main concern where the lives of people who are using the desiccant air dehumidifier have to take into consideration. The silica gel material is safe as long as it is not consumed. The main safety risk that we faced is the amount of moisture that is removed from the air. The silica gel will absorb as much moisture from the air as it can. This is prevented using a controlled airflow that can reduce the amount of airflow that goes through the silica gel. This will prevent the extreme dry air that can render the breathing of the people in the space.

3.1.1.5 Sustainability

The desiccant air dehumidifier will hopefully have a greater endurance compared to an air conditioning system where it lacks the gases (Refrigerant 134A or 22). That might leak through small openings or gaskets. The desiccant air dehumidifier will only need annual cleaning from the dust that might pile up and reduce the airflow.

3.1.1.6 Geometrical Constraints

The main geometrical constraints that prevent the reduction of the project's size would be the amount of silica gel that is used in the desiccant wheel. Theoretically, the desk needs at least 5.2Kgs of silica gel to remove the moisture of the air into an amount that is recommended for living situations. The amount of silica gel that is placed in the project that we are working with is 25Kgs. This will take into consideration the losses that might occur and air that might escape from the gaps on the sides of the desiccant wheel. The size increase of the desiccant wheel will reduce the amount of heat that passes through the silica gel, which will reduce the efficiency of regenerating the silica gel. Full drawings are available in Appendix 1.

3.1.1.7 *Engineering Standards*

The engineering standards will be applied on parts and materials that are being used on the project. The parts that will contain the standards are the motor, shaft, bearings and the galvanized metal sheets. The motor will be using the standard IEC 60034-1 from the international electro-technical commission. The shaft will be using the ASME standards codes to determine the calculations for the forces that are being applied on the shaft; this will consist of calculating the Torque and buckling effect. The bearings use the standard SAE 52100. The 6204RS is a rubber sealed bearing that can prevent dust from interfering with its ability as well as the static water from passing through the seal.

3.1.2 *Design Methodology*

Before starting to build our project and manufacture the parts we focused on some important points. The following are our important points that we focused on:

- Economical.
- Easy to manufacture.
- Practical.
- Applicable.

These points are important for us to build and manufacture our project in practical way. After we considered these points, we start build and manufacture the project's parts.

3.2 *Engineering Standards*

For all the components used in this project, engineering standards had to be followed. This section will briefly describe them. The engineering standards will be applied on parts and materials used on the project. The parts that will contain the standards are the motor, shaft, bearings and the galvanized metal sheets. The motor will be using the standard IEC 60034-1 from the international electro-technical commission. The shaft will be using the ASME standards codes to determine the calculations for the forces that are being applied on the shaft; this will consist of calculating the Torque and buckling effect. The bearings use the standard SAE 52100. The 6204RS is a rubber sealed bearing that can prevent dust from interfering with its ability as well as the static water from passing through the seal. Please see table 5 for the list of standards.

Table 5 - Engineering standards

| Component | Engineering Standard |
|-----------|---|
| Motor | Car window motor for Chevrolet Caprice 1995 |

3.2.1 Motor

The motor uses the Car window motor for Chevrolet Caprice 1995. The motor's type is Car window which works in horizontal and vertical positions; the motor is single-speed, the speed should be between 52 RPM - 12.V and the motor have the appropriate torque to rotate the desiccant wheel 19 N.M, the power output of the

Desiccant wheel

$$P_{out} = I \cdot W = g \cdot 2\pi \cdot (0.08333) \div 60 = 0.078539 \text{ Watt.}$$

Motor

$$P_{in} = I \cdot V = 12 \cdot 12 = 144 \text{ Watt.}$$

$$P_{out} = I \cdot W = 14 \cdot 52 \cdot 2\pi \div 60 = 103.46311 \text{ Watt.}$$

Torque (Disk) = 9 Nm

RPM = 52 rpm

Torque = 19 Nm

RPM (Disk) = 0.08 rpm



Figure 10 - the size specification of motor

3.3 Theory and Theoretical Calculation

In this project, there are five main objects that need to be calculated before starting to manufacture the prototype. One of these things is the velocity of air that moving through the desiccant wheel. Another thing is the mass of silica gel that should be used to absorb the water from the air. Then the shaft has three things that need to be calculated which are torque, axial stress, and buckling. All the calculations for the shaft are using the ASME standard.

3.4 Trolley

The trolley well makes our project easy to mobilize and use it in many places, as we wanted to be

Geometry and standard of the trolley:

ASTM A123 Galvanized steel for the base sheet, ASTM A217 cast alloy steel for bars and ASTM A27 Cast Carbon Steel for circular support it has Mass = 50.20 kilograms
Surface area = 5.93 square meters.

Table 6 - Specification

| Material Specification | A123 | A217 | A27 |
|------------------------|-------------------------|---------------------------|-------------------------|
| Density | 7870 kg/m ³ | 7300 kg/m ³ | 7800 kg/m ³ |
| Elastic Modulus | 2e+011 N/m ² | 1.9e+011 N/m ² | 2e+011 N/m ² |

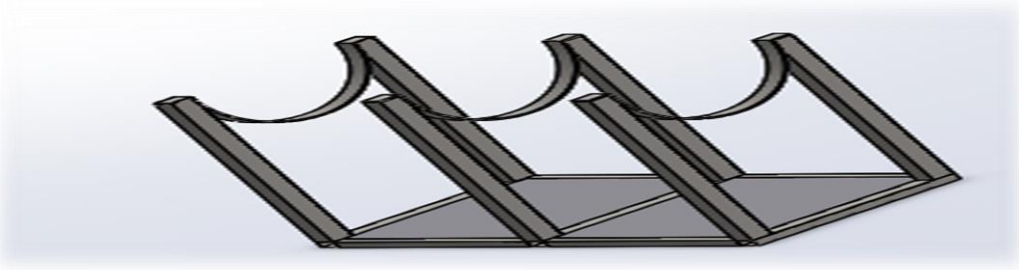


Figure 11 - trolley

3.5 Evaporative cooler

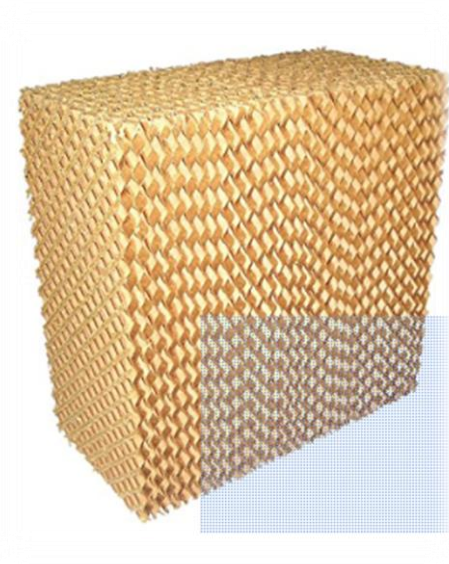


Figure 12 - evaporative cooler

The evaporative cooler to cooling the Air from the Desiccant to the room the martial made from Kraft Paper Pad the Dimensions are: Height 78 cm, Width 91 cm, Depth 10 cm the Weight is 3.65 kg.

3.6 Torque wrench



Figure 13 - LCD Torque Wrench

The torque we used it to tighten the shaft in the Desiccant with a torque between 6 - 30 Nm the modification and stander of the torque is weighted 4 Pound, The dimensions are 1.5 x 1.5 x 17 inches, the power lithium battery and LCD display to make it easily see measurements shows in the screem.

3.7 Pressure drop through an orifice

We had to fabricate the pressure drop through an orifice to calculate the velocity of Air bases through the desiccant and duct and there are tables we use to upload the figure to calculate the airflow. With dimeter width 1", orifice is 0.5" length the pipe 4" that is 100 mm and the material made from SS (Stanley steel) 304 this is the sample:

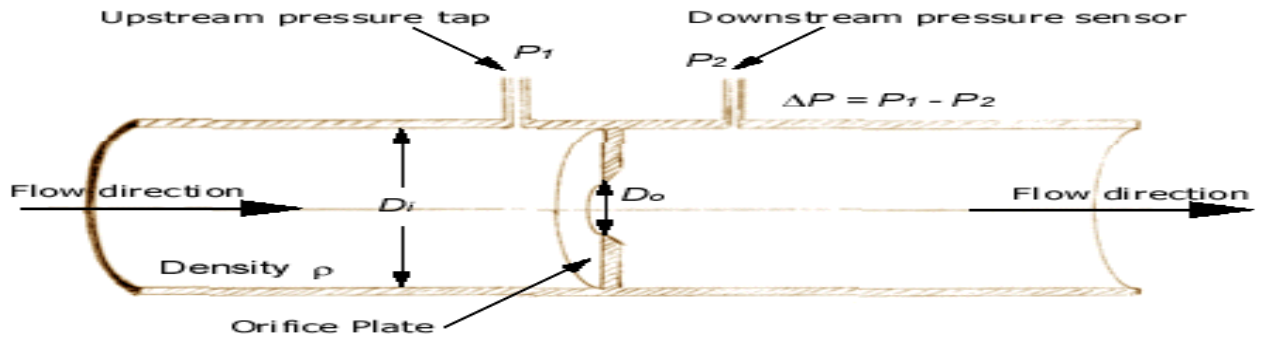


Figure 14 pressure drop through an orifice

Inputs

| | | |
|--|------|-------------------|
| Pipe (Inlet) diameter upstream of orifice, D_i : | 10 | cm |
| Orifice diameter (less than the inlet diameter), D_o : | 8 | cm |
| Pressure difference across the orifice, Δp : | 10 | Pa |
| Fluid density, ρ : | 1.29 | kg/m ³ |
| Flow Coefficient, C_f : | 0.7 | |

Answers

| | | |
|--------------------------------|--------|------|
| Velocity at the inlet, V_i : | 1.76 | m/s |
| Volumetric Flowrate, Q : | 13.9 | l/s |
| Mass Flowrate: | 0.0179 | kg/s |

Calculate Again Default Values

Figure 15 - the table we use to upload the figure to calculate the airflow

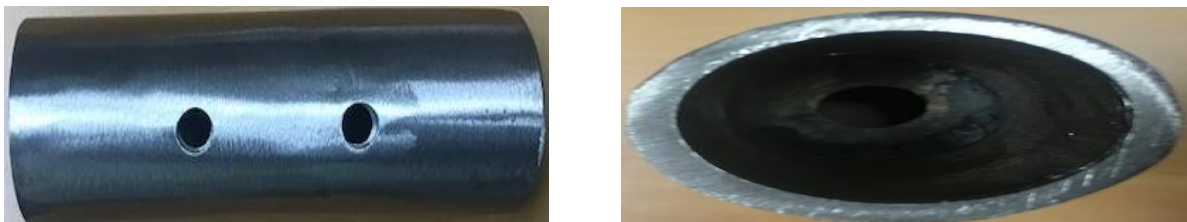


Figure 16 - the pressure drop through an orifice after fabrication

3.8 Heat Gun

The Heat Gun uses the standard GHG 500-2 Professional. The Heat Gun is produce heat around 300-500°C, three-phase, cage-inductor motor that has an output ranging from 0.75=750 W and 1Hp See table 3.1. Please see figure 3.5 for more size specifications on the model 90S-B3.

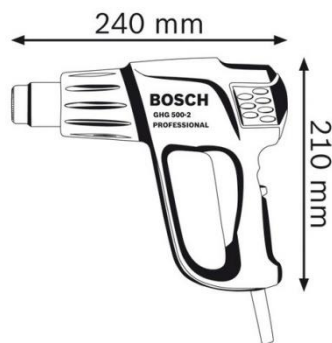


Figure 17 - heat gun

3.9 Amp meter

The AMP meter we use it to meager the Voltage and the resistant in our project electrical circuit, the type of the AMP meter is Hitomall UNI-T digital clamp-on meter UT204A. Read up to 600V – 400 A, also we use to measure the electrical loads Voltage (V- AC), Voltage (V-DC), Ampere(A- AC), Ampere (A-DC) and Resister (Ω). In addition, it is light and easy to holed and we need to cut the wire in to for + and – to tack the readings.



Figure 18 - AMP Meter

3.10 Tachometer

The tachometer is a sensor device for measuring the rotation speed of an object. Model or type UNI-T's UT372 is a non-contact tachometer with ranges of 10RPM~99999RPM. According to IEEE model DUT371.

Measurement Distance: 50mm ~ 200mm Dimensions: 184 x 56 x 34mm | Weight: 100g, and Power: 4pcs x 1.5V batteries (AA).



Figure 19 - tachometer

3.11 Humidity and temperature sensors

The humidity and temperature sensors we made it in house, the type is DHT11 is a humidity and Temperature Sensor, which generates calibrated digital output. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 16 MHz crystal oscillator and USB connection. The Arduino Uno can be power via the USB connection or with an external power supply. This breadboard is BPS Prototype Systems BPS830.the Power supply 5K Ohm, Resistor (1/4 W) is Connecting wires.

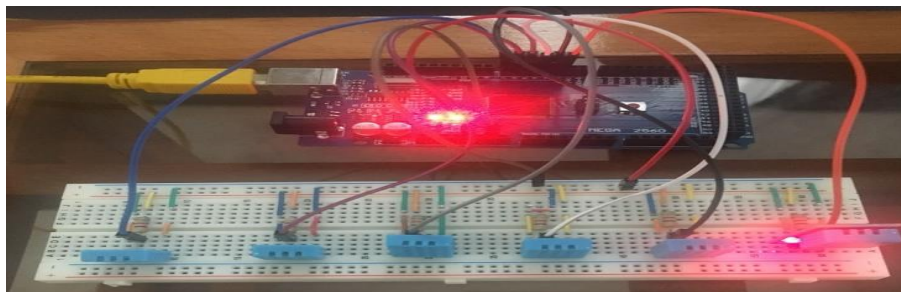


Figure 20 - Humidity & Temperature Arduino sensor

4 Chapter 4: System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

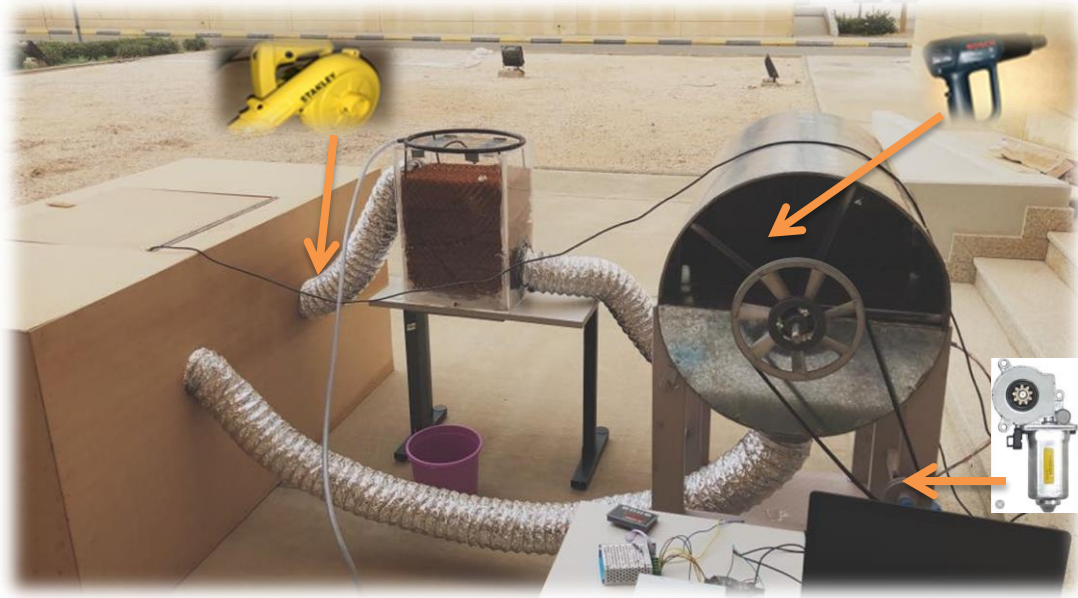


Figure 21 – System implementation & sensors places



Figure 22 - Arduino Uno connection



Figure 23 - Evaporative cooler



Figure 24 - Speed Controller & Amp Meter

4.1.1 Humidity and temperature sensors

The humidity and temperature sensors type is DHT11, which generates calibrated digital output. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 16 MHz crystal oscillator and USB connection. The

Arduino Uno can be powered via the USB connection or with an external power supply. This breadboard is BPS Prototype Systems BPS830.the Power supply 5K Ohm, Resistor (1/4 W) is Connecting wires. This provides a reading repeatedly after certain time for temperature and humidity.

4.2 Results, analysis and discussion

4.2.1 Goals

In this project, the major thing that needs to be considered is decreasing humidity. Another thing is the amount of temperature's degrees that will increase during the experiment due to the heating source. So, the goal of this experiment is to reduce the humidity with the least amount of temperature increasing by using evaporative cooling.

4.2.2 Experimental methodology

1. Humidity & Temperature sensor: it is the device that we used to measure the temperature and relevant humidity. We placed four sensors inside the cylinder and one to the ambient to collect data.
2. Air blower: it is used as a fan to take the humid air from the chamber to the desiccant wheel. We placed it inside the chamber near the duct that is used to bring the humid air.
3. Heat gun: to increase the amount of water vapor that can be absorbed by the silica gel, there should be a heating source to regenerate the silica gel. We placed it inside the pipe in front of the silica gel.
4. Motor: the motor is used to rotate the shaft so the heating source can reach all of the silica gel. We placed it beside the end of the shaft on the trolley.
5. Speed controller: it is used to control the speed of the shaft. We placed it beside the motor.

6. Evaporative cooler to decrease the temperature which will be held before the chamber and in the middle of the duct.

4.3 Testing

4.3.1 Procedure

First of all, the air blower is turned on at the same time with the motor and the heating source. After that, we start to take the data from sensors every minute for twenty minutes.

The connection of the system was decided after several tests which indicate the best outcome of the disk. For instant, the heat gun was placed on the side with the handle. After collecting data and analyzing them we found that we should do some modifications to make our system more efficient. The heat gun should be mounted on the opposite side of the handle of the trolley that near to the pulley and also the air blower should be switched too.

After modification and changing the direction of the system, the test was taken twice and the results shows that the evaporative cooler decreases the temperatures of the room but increases the humidity ratio which attacks the main objective of the system. So a two more tests were taken without the evaporative cooler.

4.4 Analysis

This table shows the places of sensors

Table 7 - sensors location

| #No. of sensor | Place of sensor |
|----------------|------------------------------------|
| Sensor 1 | after heat gun |
| Sensor 2 | before cooler |
| Sensor 3 | after heat gun after disk |
| Sensor 4 | from room after evaporative cooler |
| Sensor 5 | Ambient |

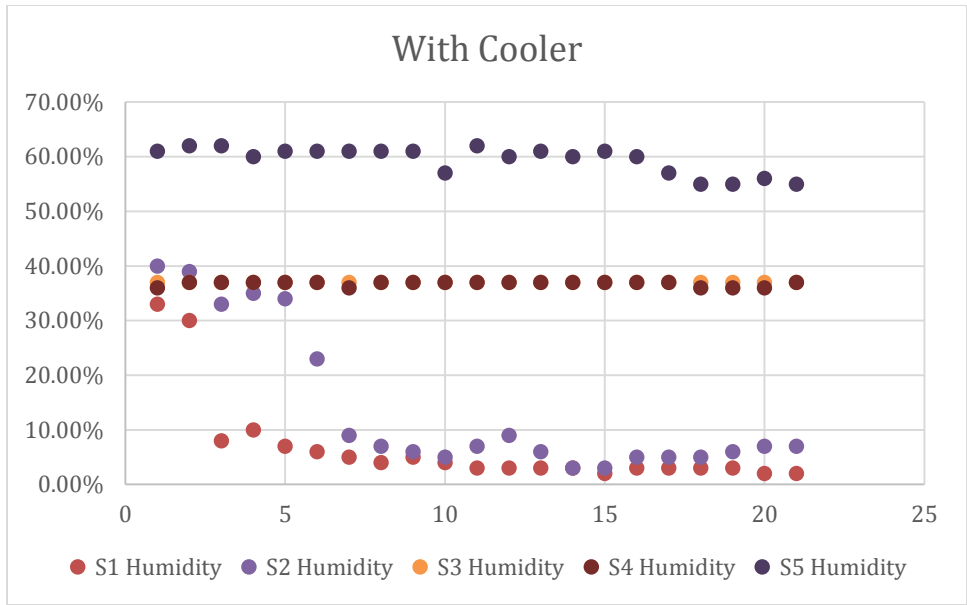


Figure 25 - Results for First trail with cooler of humidity sensor

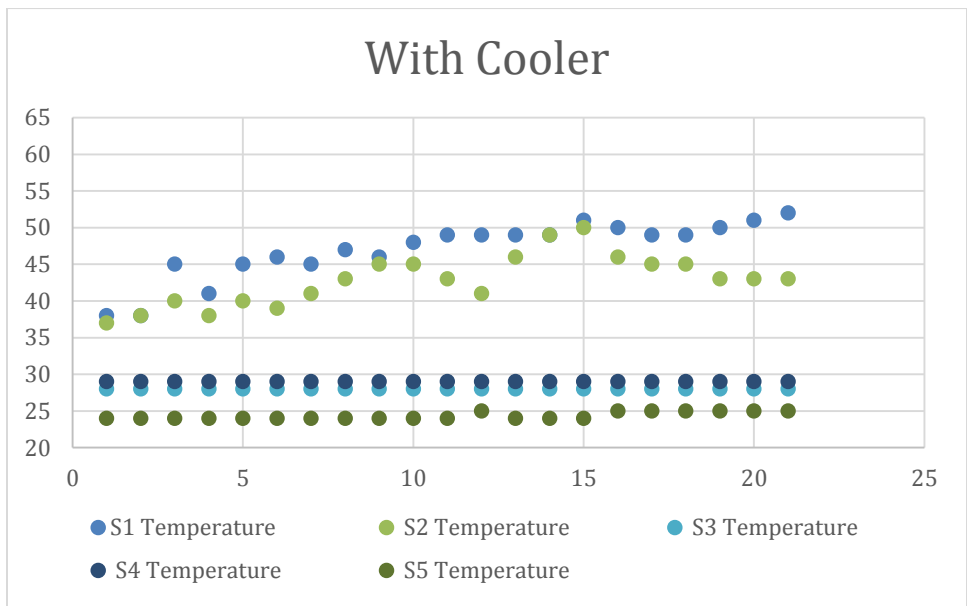


Figure 26 -Results for first trail with cooler temperature sensor

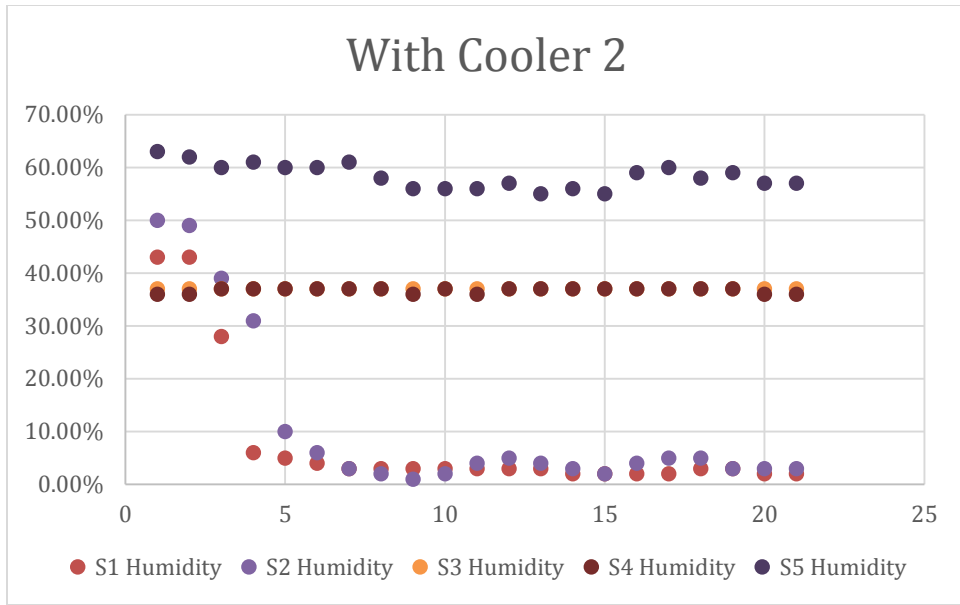


Figure 27 - Results for Second trail with cooler humidity sensor

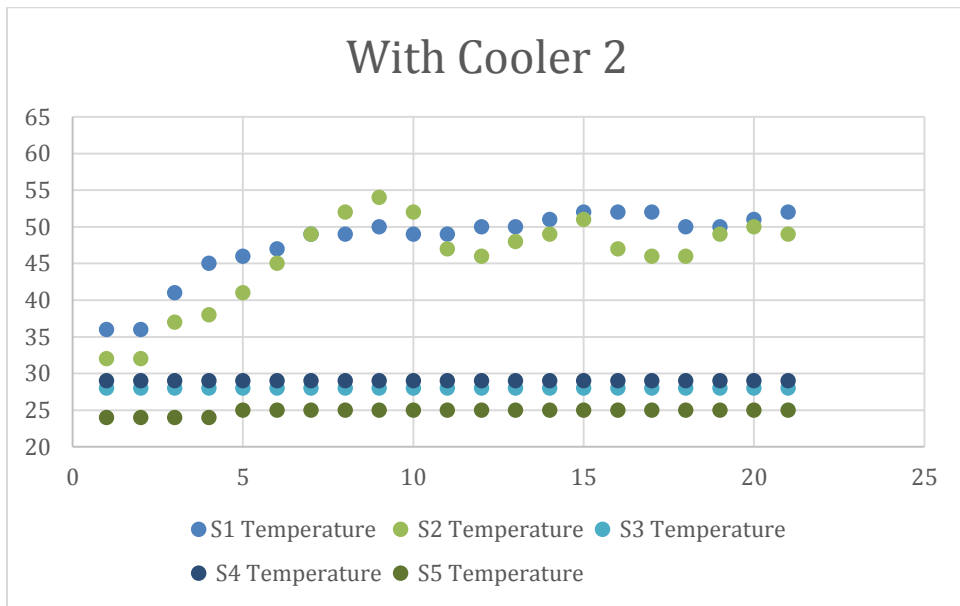


Figure 28 - Results for Second trail with cooler temperature sensor

These figures show the humidity and temperatures changes over time for the two trails with a period of recovery 10 minutes between the two trails to balance the chamber humidity and temperature.

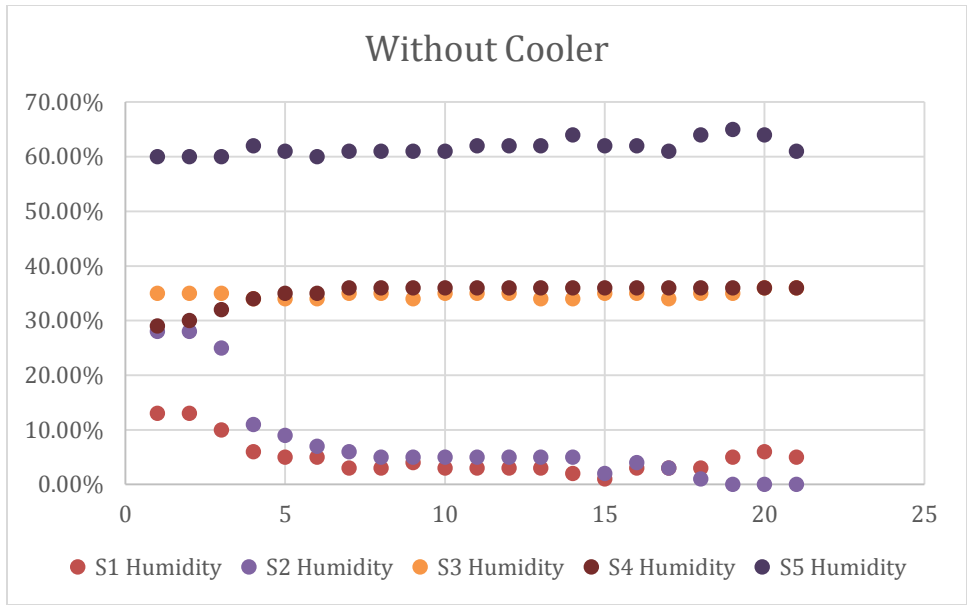


Figure 29 - Results for first trail without cooler humidity sensor

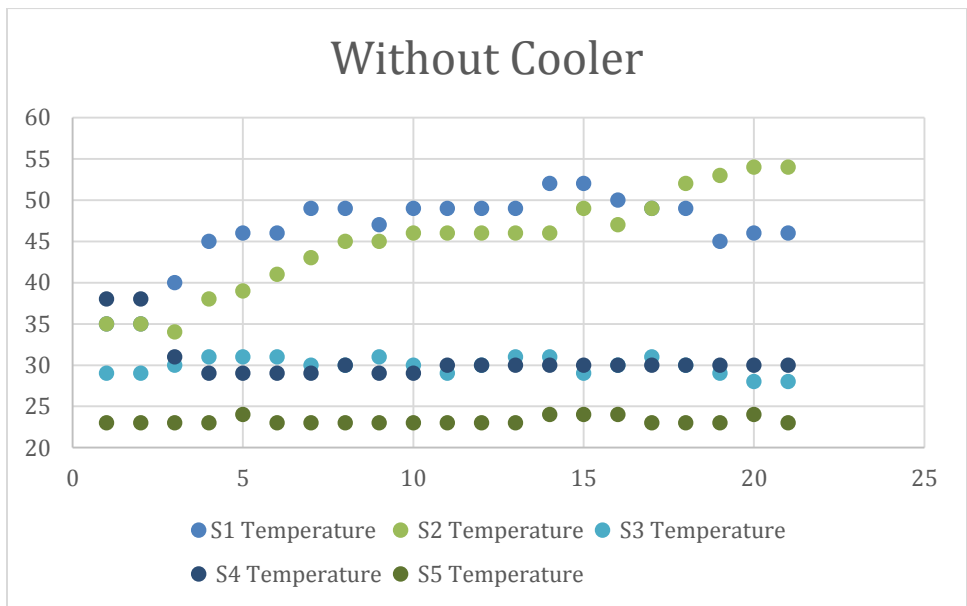


Figure 30 - Results for first trail without cooler temperature sensor

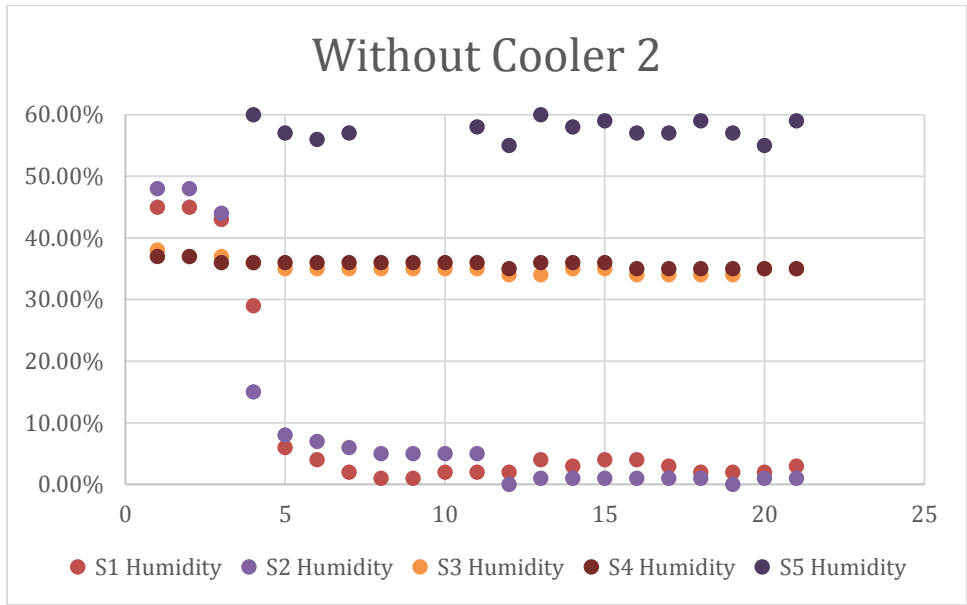


Figure 31- Results for second trail without cooler humidity sensor

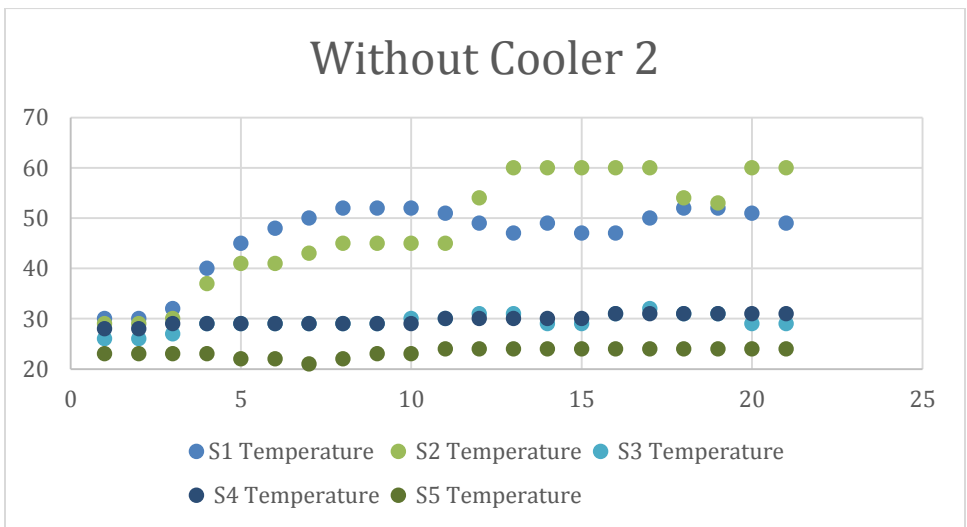


Figure 32- Results for second trail without cooler temperature sensor

These figures show the humidity and temperatures changes over time for the two trails with a period of recovery 10 minutes between the two trails to balance the chamber humidity and temperature without the evaporative cooler.

4.4.1 Discussion

As shown in the figures the relevant humidity decreased which is a great result because there is reduction in the relevant humidity. In addition, there is an increase in the temperature as expected due to the heating source.

5 Chapter 5: Project Management

5.1 Project Plan

Table 8 - project plan

| Task 1 | Start Date | Days to complete |
|--|------------|------------------|
| Identifying Project | 06/02/2018 | 10 |
| Determine objectives | | |
| subdividing small tasks to collect information | | |
| search and write small report about useful instruments | | |
| Task 2 | | |
| Workout a software shows collected data | 19/02/2018 | 5 |
| Writing chapter 1 and chapter 2 | 21/02/2018 | |
| Design trolley | 26/02/2018 | 10 |
| design a reduction mechanism | 26/02/2018 | 10 |
| Mention same projects | 28/02/2018 | 3 |
| prepare for midterm | 12/03/2018 | 5 |
| Task 3 | | |
| Taking the Calculations of : | 22/03/2018 | 10 |
| Rpm of the shaft | | |
| Air velocity | | |
| Stress on trolley | | |
| Required torque and voltage | | |
| Task 4 | | |
| Solidworks model | 24/03/2018 | 3 |
| Trolley | | 8 |
| Flow meter | | 5 |
| Air filter Cooling evaporator Water sprayer | | 7 |
| Motor selection | | 2 |
| Task 5 | | |
| Test the system | 08/04/2018 | 10 |
| Measure temperature | | |
| Measure humidity in and out | | |
| Task 6 | | |
| Writing | 18/04/2018 | 5 |
| corrections | | |
| presentation | 22/04/2018 | 11 |
| prepare for Final | 22/04/2018 | |
| Finalize final report | 02/05/2018 | 7 |

We worked on this project as a group and there was a very limited time to finish the project. So we provide limited time duration to each task. Table 8 provides a detailed presentation of the duration of the different tasks throughout the life of the project.

5.2 Contribution of Team

Table 9 - Members' contribution

| Task 1 | Assigned | Contribution |
|--|----------|--------------|
| Identifying Project | ALL | |
| Determine objectives | | |
| subdividing small tasks to collect information | | |
| search and write small report about useful instruments | | |
| Task 2 | | |
| Workout a software shows collected data | Mohammed | 23% |
| Writing chapter 1 and chapter 2 | Turki | 21% |
| Design trolley | Yasser | 19% |
| Mention same projects | Fahad | 19% |
| prepare for midterm | Sulaiman | 18% |
| Task 3 | | |
| Taking the Calculations of : | Suliman | 23% |
| Rpm of the shaft | Fahad | 21% |
| Air velocity | Yasser | 19% |
| Stress on trolley | Mohammed | 19% |
| Required torque and voltage | Turki | 18% |
| Task 4 | | |
| Solidworks model | Yasser | 23% |
| Trolley | Mohammed | 21% |
| Flow meter | Turki | 19% |
| Air Filter Cooling Evaporator Water Sprayer | suliman | 19% |
| Motor selection | Fahad | 18% |
| Task 5 | | |
| Test the system | Turki | 23% |
| Measure temperature | Fahad | 21% |
| Measure humidity in and out | Yasser | 19% |
| | Sulaiman | 19% |
| | Mohammed | 18% |

| Task 6 | | |
|-----------------------|----------|-----|
| Writing | Fahad | 23% |
| corrections | Mohammed | 21% |
| presentation | Turki | 19% |
| prepare for Final | Sulaiman | 19% |
| Finalize final report | Yasser | 18% |

Each task in this project assigned to one member and some tasks assigned to more than one member. The group leader and advisor are responsible to assign each task to the group members. Table 9 shows who assigned to each task and what the contribution for each member.

5.3 Project Execution Monitoring

We had many activities during our project period. Some of the activities are continuous and some of them are taking place only one time. Table 10 shows the time for each activity.

Table 10 - Table of activities

| Time | Activities |
|------------------|----------------------|
| Two times a week | Assessment class |
| Weekly meeting | With group members |
| Weekly meeting | With advisor |
| Tue, April 5 | Midterm presentation |
| Tue, April 10 | Preliminary test |
| Wed, April 18 | Test the system |
| The, May 3 | Final presentation |

5.4 Challenging and Decision Making

Throughout our senior project period, we faced many difficulties and challenges such as:

1. Material and equipment resourcing (purchasing).
2. Design problems.
3. Report writing and document.

5.4.1 **Material and equipment resourcing (purchasing)**

Our project needs many things to purchase either from local stores or international stores. We faced a variety of difficulties when we start purchasing the parts that we need. Some difficulties were:

- Local stores. A first thing that was important in our objective is to create our trolley, to make the disk move quickly. We made it, in local store with specific design. In addition, we purchase Torque wrench, Sensors DHT111, Tachometer, Motor, and Amp meter.
- International stores. The most important part of our project is cooling pad and Controller, so we looked for the local stores that cooling pad and Controller, but we did not find a local store that has this specific kind of them.
- Motor has specific speed.

The challenge that we faced is when we decided to buy a motor we started looking for a motor that has a specific speed based on our calculations. But we didn't find a motor that meets our requirements. The solution we found was a speed control that we can use it to control the speed. So we decided to buy this speed control to solve this problem.

5.4.2 **Design problems**

The main challenge that we faced in our designing is making the disk rotate with very low rpm. We solved this problem by doing three things. First, we searched about a motor that has a low rpm and suitable torque. Second, we designed a reduction mechanism using pulleys to decrease the rpm. Last thing, we used a speed controller to control how much percentage of the output rpm goes to the shaft that rotates the disk.

5.4.3 **Report writing and document**

While we were writing the report, we made many mistakes and weak sentences on the report. We worked hard to fix this problem. This problem will decrease the value of the report. So we decided before submit the final draft for each chapter, to go through some processes such as:

1. Make another member of the group read the part and correct it.
2. Give the first draft to the advisor to put his comments.
3. Give the second draft to the assessment's instructor to put his comments.

By going with the processes above, we decreased the mistakes as much as we could and we increased the value of the report.

5.5 Project Bill of Materials and Budget

Table11 - Bill of material

| Materials | Cost (SR) |
|---------------------------|-------------|
| Trolley | 1800 |
| Cooling pad with shipment | 1107 |
| Torque wrench | 270 |
| Sensors DHT111 | 262 |
| Tachometer | 235 |
| Cylinder holder | 200 |
| Controller with shipment | 178 |
| Welding a screw to shaft | 100 |
| Motor | 100 |
| Amp meter | 95 |
| Total | 4347 |

6 Chapter 6: Project Analysis

6.1 Life Long Learning

During our project's life we had learned and improve many skills, knowledge, and experiences. We had gained and taught all of these things from working in a group, limitation of time, and communications. Each one of these things taught us different skills, knowledge, and experiences. I will divide the most important learning that we had gained during our project's life into four parts and I will explain each of them.

6.1.1 Improve our Skills in Some Software Tools

We had to use many software tools during our project, such as Solidworks, Microsoft Word, and Microsoft PowerPoint. All of these software tools are not new for us, but we had used them in a more professional way. We learned many things in these software tools that we had not learned them before.

6.1.2 Time Management Skill

Time management skill is one of the important skills that we learned though our project's life. When we want to achieve some specific objective and goals at the specific time we have to manage our time and distribute the tasks for each member to end them at specific time. While we worked on the project we faced many tasks that assigned for us to do them at specific time. This challenge gave us a great skill and experience to manage our time. To manage our time, we built our GANTTS chart that includes all the tasks and the subtasks that we have to achieve them through the project's life. GANTTS chart is one of the most useful tools that help us to know when we should start and when we should end each task.

6.1.3 Problem Solving

While we worked on the project we faced many problems that we solved eventually. These problems gave us good knowledge, skills, and experience of how to solve the problems. We had faced many problems during our project's life that we solved them skillfully such as purchasing right materials and tools, finding a machinist, and

importing from abroad. Actually, this skill helped us to know how to solve the problem that we will face in the future skillfully.

6.2 **Impact of Engineering Solutions**

Our project achieved great impact on the society, environment, and economy. We will explain the impact of each of them in details.

6.2.1 **Society**

When we come to the society it is the most important source that we should care approximately it. Our target is to provide an excellent impact on the society to can present our project in exact manner. Our project may be utilized in homes to control the humidity in the living areas. Humidity is one of the factors that affect the comfort of the man or woman. If the humidity is simply too high or too low, the person will not feel comfortable. So our project can reduce the humidity into the comfort region. Also, we are able to use the project at places close to beaches and in tropical areas in which the humidity is excessive. Moreover, the other effect at the society is that we are able to use the project to reduce humidity within the closed recreation areas inclusive of gyms and swimming pools.

6.2.2 **Environment**

We can give an explanation for the affects that our project carried out on the environment. As we all recognize high humidity triggered plenty of troubles at living areas together with swelling timber, bad odor, and invisible spore. So our project will deliver exact effects on these issues to save you all of these troubles.

6.2.3 **Economy**

When it comes to the affects that our project carried out on the economy, our project is an easy instance of an efficient economic dehumidifier. Our project doesn't have a compressor, so it'll lessen the quantity of energy consumption compared to other traditional dehumidifiers. Additionally, our project needs less upkeep compared to other traditional dehumidifiers that used compressors.

6.3 Contemporary Issues Addressed

While start talk about the problems which are facing our GCC countries and Saudi Arabia, we are able to communicate about how high humidity effects human body. While the air has a high moisture content material, as is the case in humid weather, this sweat cannot evaporate, leaving our bodies feeling hot and sticky. To cool off, our bodies should work even harder. This result in excessive sweating, accelerated rate and intensity of blood circulate and increased respiration. Immoderate sweating can motive a lack of water and chemical compounds that the body wishes with a purpose to function well, probably placing our health in jeopardy.

7 Chapter 7: Conclusions and Future Recommendations

7.1 Conclusion

The project was designed, enhanced and modified to reach the best results that could be beneficial to the purpose that was designed for. The main objective of the project is to decrease the humidity ratio and temperature. After testing and analyzing data, humidity sharply decreased over time without using the evaporative cooler but the temperature increased. However, when the evaporative cooler was installed to the system, the temperature decreased.

There are other important aspects of the project. First, there was a difficulty in moving the system which was been overcome by designing a trolley. Designing the trolley need to consider the weight, size and motor of the cylinder. Also a reduction mechanism was designed to get the exact number of revolution needed to dry the silica inside the disk to improve the dehumidification. The designing contains pulleys to reduce the revolution by the ratio between them but it was not applicable because it will be considered as over designing due to the huge difference between them. So a DC speed controller was installed to reach the appropriate speed to function the system effectively. Finally, sensors were installed to proof that the system works in a right way, also to keep monitoring the system in getting data frequently to analyze the effectiveness of the system.

7.2 Recommendation

- A cross flow heat exchanger with a 134 refrigerant should be installed in the system between the cylinder and room to decrease the temperature of the room without increasing the humidity ratio which will replace the evaporative cooler.
- A gear box could be designed to reduce the energy wasted by the speed controller.

- Maintenance for the cylinder bearing and duct could be frequently done.
- Checking the performance of the silica after been used and heated for long time by replacing with new silica or searching for other material that could be better.
- Anemometer connected to Arduino.
- Improved design of evaporative cooler.

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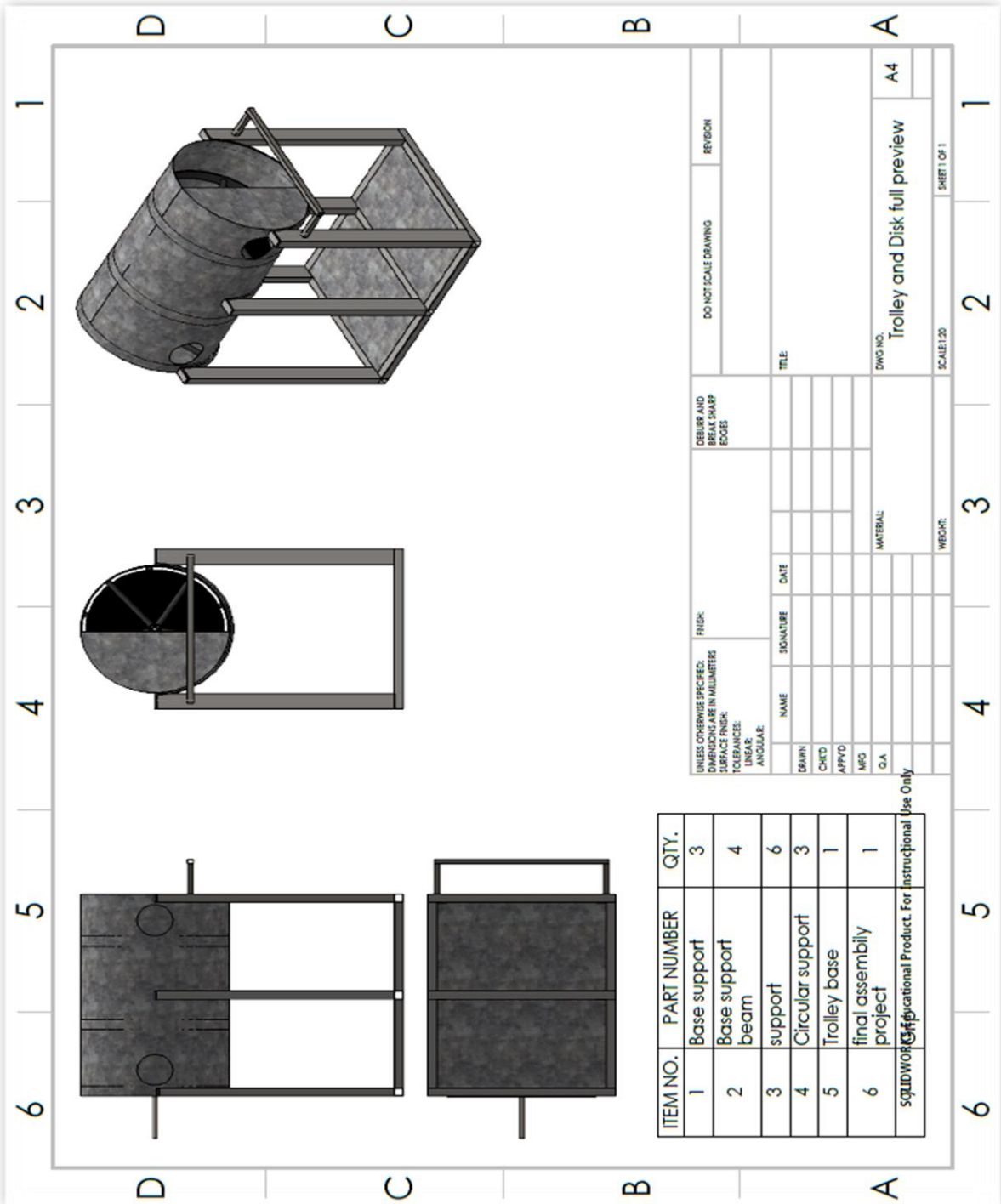
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| ITEM NO. | PART NUMBER | QTY. |
|----------|------------------------|------|
| 1 | Base support | 3 |
| 2 | Base support beam | 4 |
| 3 | support | 6 |
| 4 | Circular support | 3 |
| 5 | Trolley base | 1 |
| 6 | final assembly project | 1 |

UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH:
 TOLERANCES:
 LINEAR:
 ANGULAR:

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DEBUR AND REMOVE SHARP EDGES

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NAME

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DATE

TITLE

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APPROVED

MFG

Q.A.

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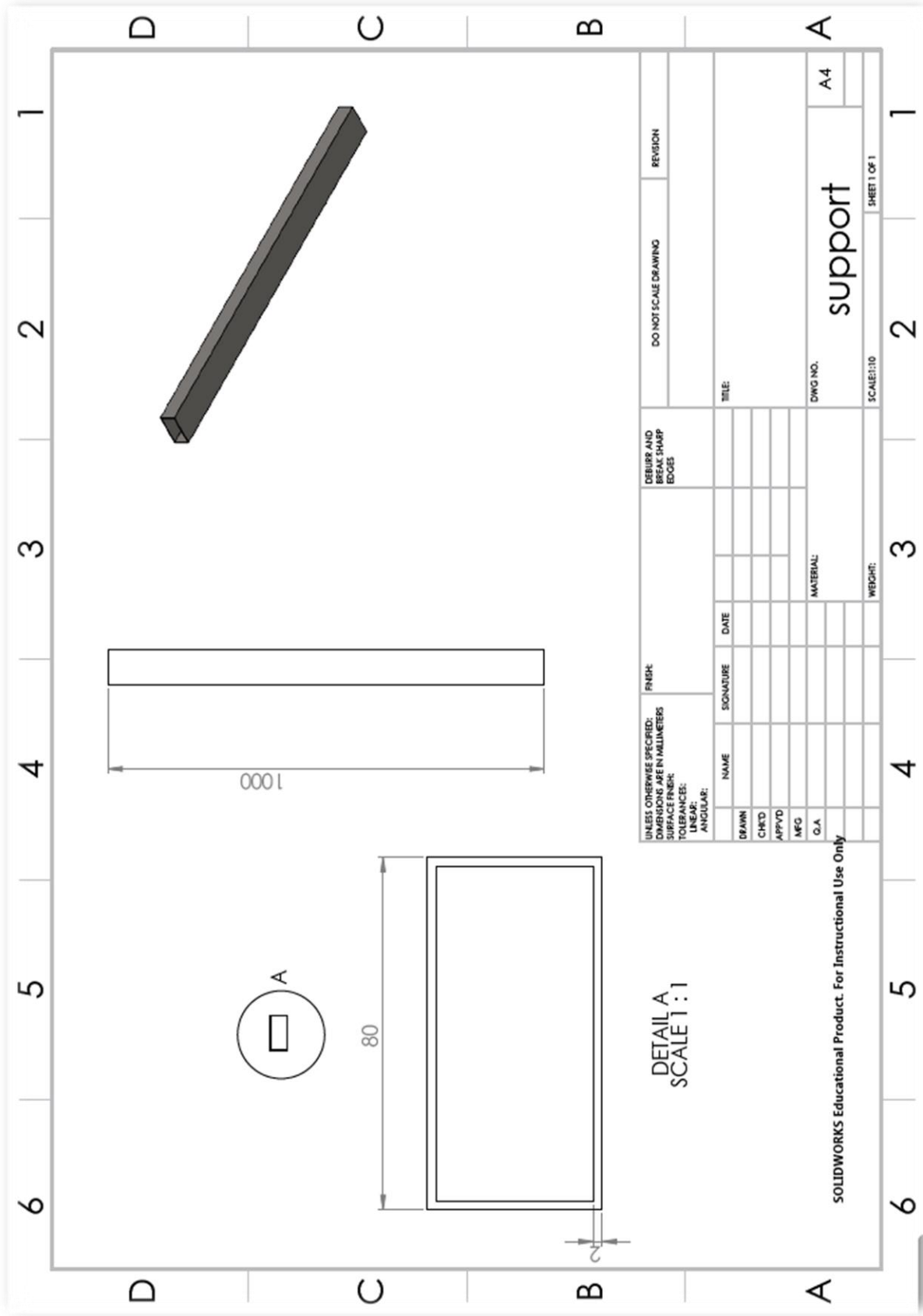
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Trolley and Disk full preview

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SHEET 1 OF 1

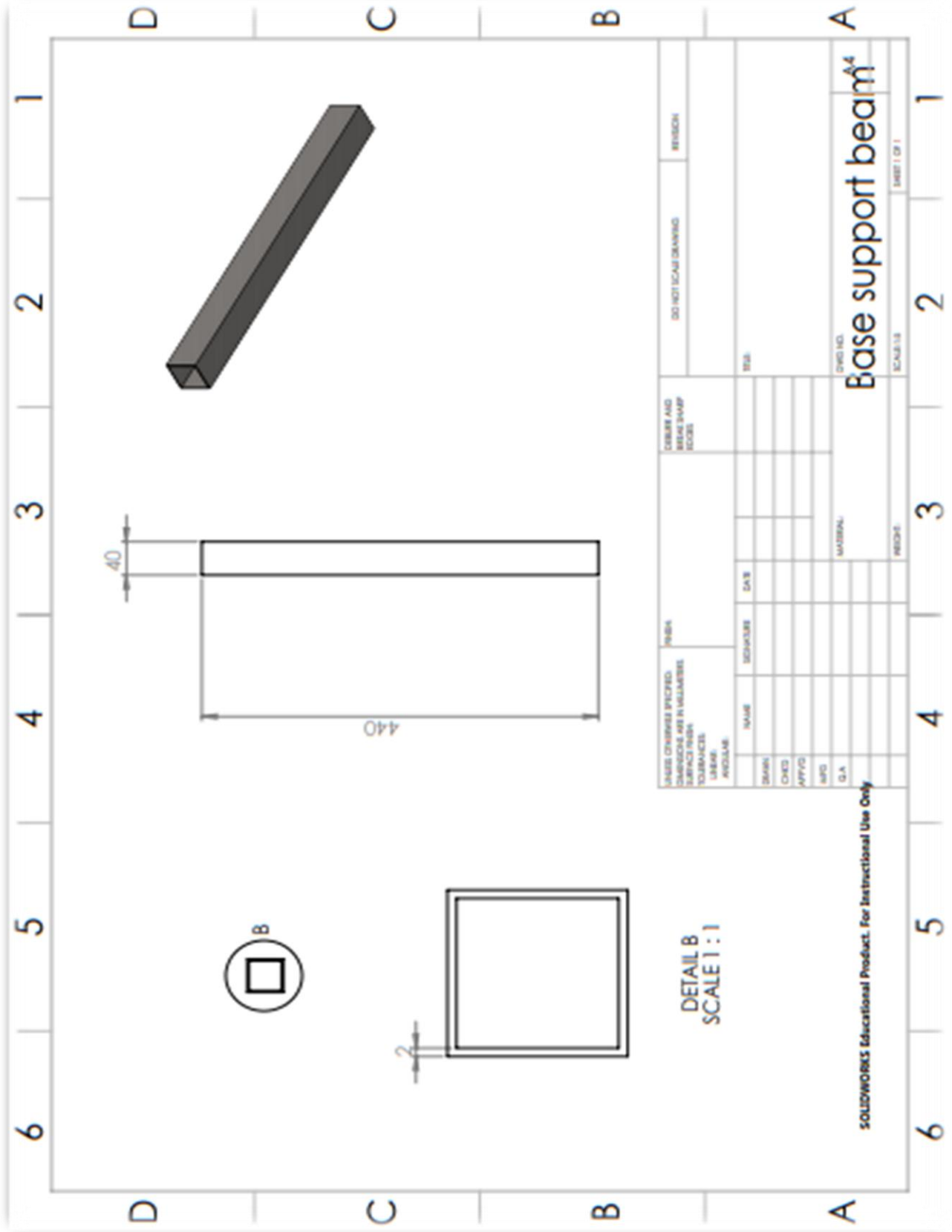
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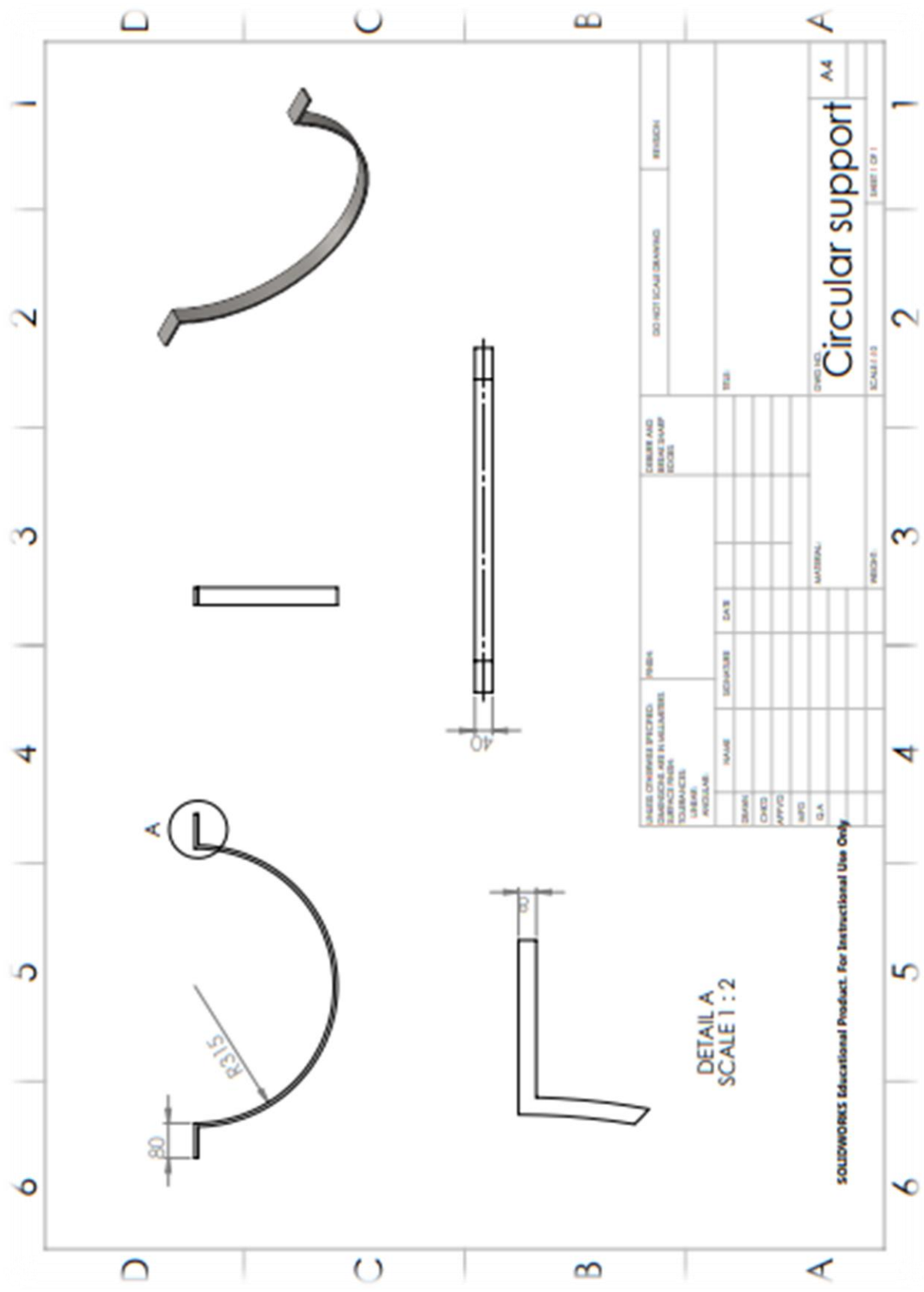


DETAIL A
SCALE 1:1

| | | | | | | | | | |
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| LINEAR: | | | | | | | | | |
| ANGULAR: | | | | | | | | | |
| DRAWN | NAME | SIGNATURE | DATE | TITLE: | | DWG NO. | | A4 | |
| CHK'D | | | | | | support | | | |
| APP'VD | | | | | | | | | |
| MFG | | | | | | | | | |
| Q.A. | | | | | | | | | |
| | | | | MATERIAL: | | SCALE: 1:1 | | SHEET 1 OF 1 | |
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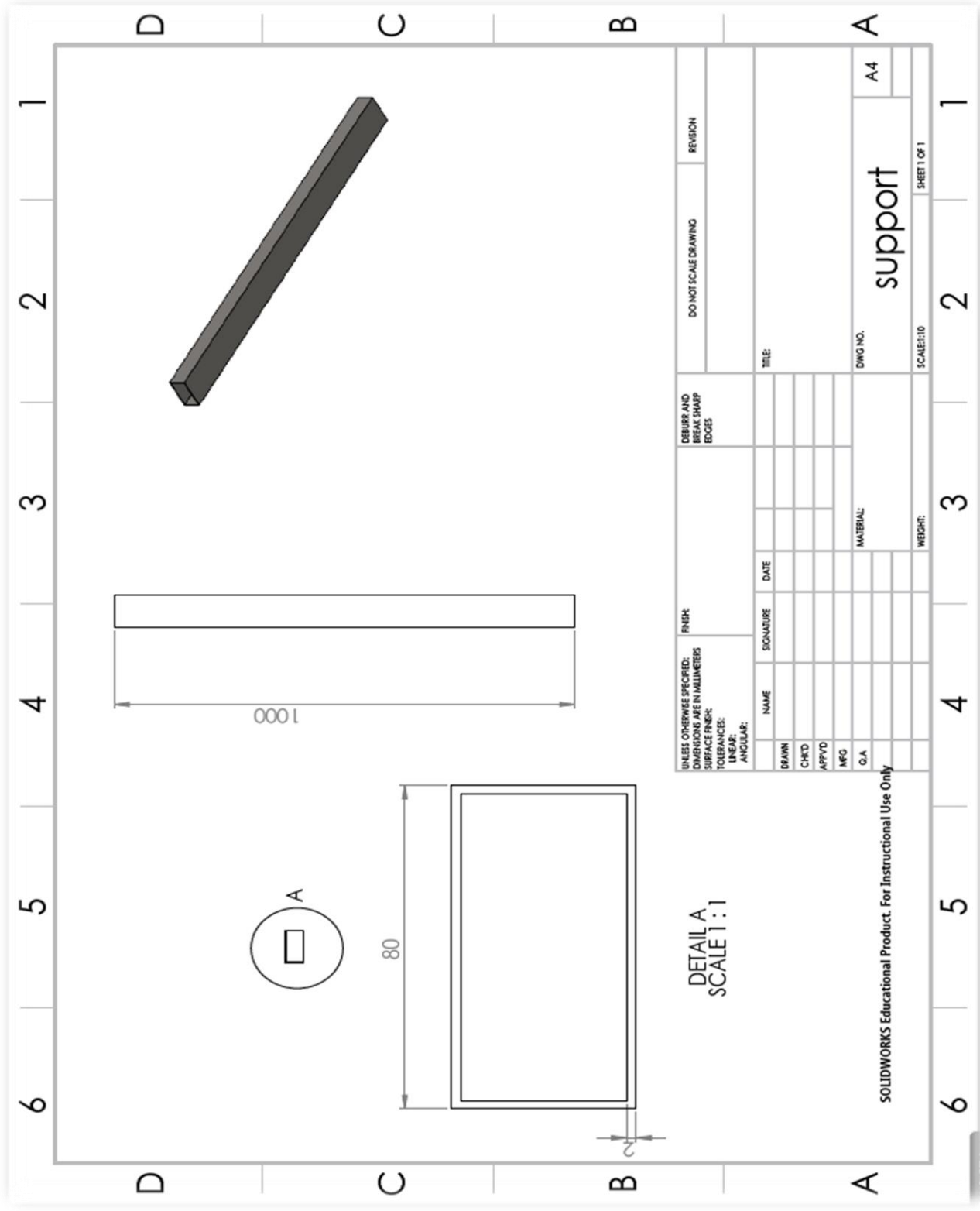




DETAIL A
SCALE 1:2

| | | | | | | | | | |
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| UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH TO BE UNLESS OTHERWISE SPECIFIED | | FINISH | | DIMENSIONS AND MAKE SHARP EDGES | | DO NOT SCALE DRAWING | | REVISION | |
| DATE | NAME | SECURITY | DATE | | | | | | |
| CHKD | | | | | | | | | |
| APP'D | | | | | | | | | |
| APP'D | | | | | | | | | |
| D.A. | | | | | | | | | |
| | | | | MATERIAL | | | | | |
| | | | | REWORK | | | | | |
| | | | | SCALE: 1:2 | | | | | |
| | | | | SHEET NO. | | | | | |
| | | | | Circular support | | | | | |
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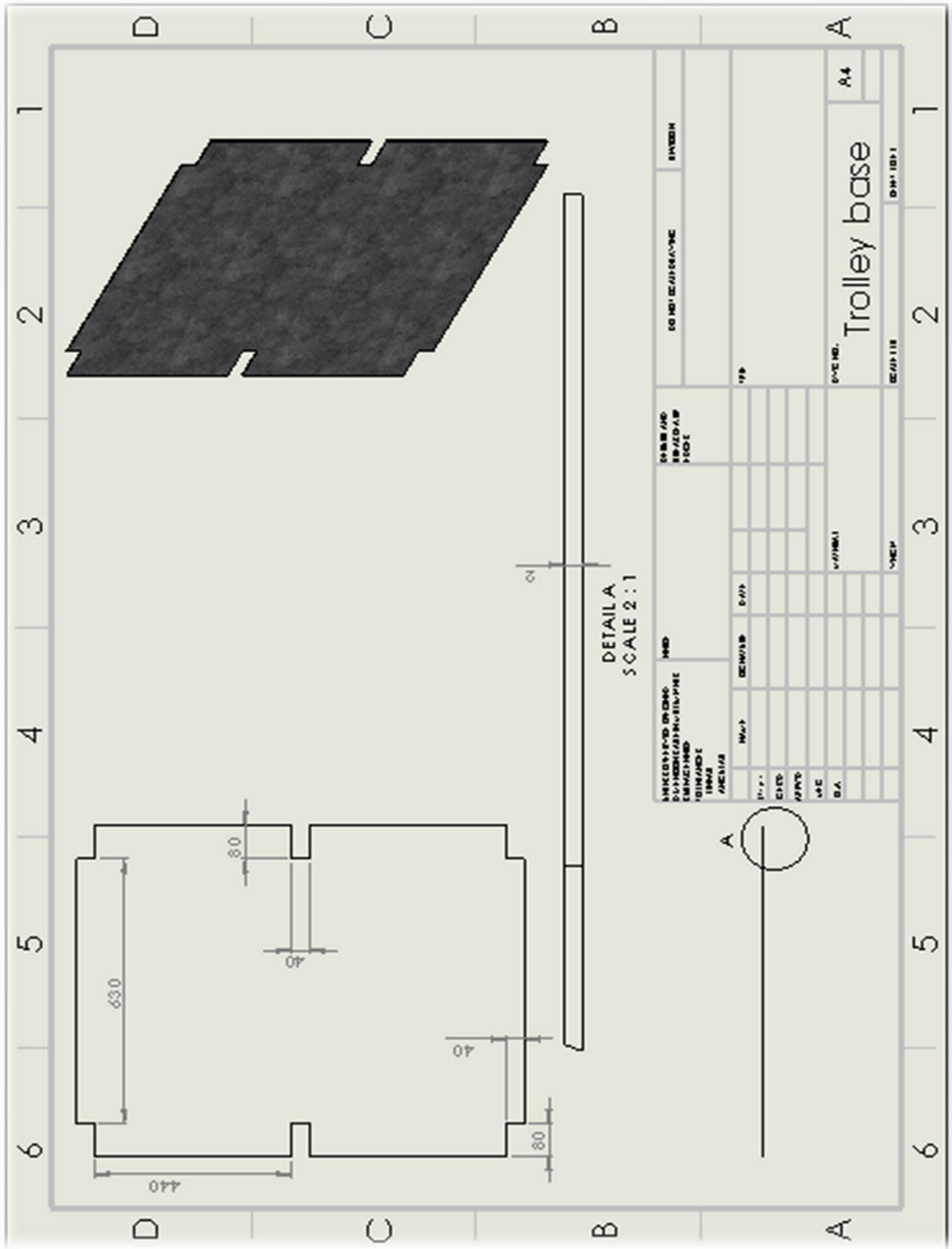
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| TOLERANCES: | | DRAWN | | CHK'D | | | | | |
| LINEAR: | | APP'D | | MFG | | | | DWG NO. A4 | |
| ANGULAR: | | QA | | MATERIAL: | | | | support | |
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| | | | | | | | | SHEET 1 OF 1 | |

DETAIL A
SCALE 1:1

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10 Appendix B: Data Sheet

| With Cooler | | | | | | | | | | | | | | | | | | | | | | |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | |
| S1 Temperature | 38 | 38 | 45 | 41 | 45 | 46 | 45 | 47 | 46 | 48 | 49 | 49 | 49 | 49 | 51 | 50 | 49 | 49 | 50 | 51 | 52 | 50 |
| S1 Humidity | 33.00% | 30.00% | 8.00% | 10.00% | 7.00% | 6.00% | 5.00% | 4.00% | 5.00% | 4.00% | 3.00% | 3.00% | 3.00% | 3.00% | 2.00% | 3.00% | 3.00% | 3.00% | 3.00% | 2.00% | 2.00% | 3.00% |
| S2 Temperature | 37 | 38 | 40 | 38 | 40 | 39 | 41 | 43 | 45 | 45 | 43 | 41 | 46 | 49 | 50 | 46 | 45 | 45 | 43 | 43 | 43 | 45 |
| S2 Humidity | 40.00% | 39.00% | 33.00% | 35.00% | 34.00% | 23.00% | 9.00% | 7.00% | 6.00% | 5.00% | 7.00% | 9.00% | 6.00% | 3.00% | 3.00% | 5.00% | 5.00% | 5.00% | 6.00% | 7.00% | 7.00% | 5.00% |
| S3 Temperature | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| S3 Humidity | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% |
| S4 Temperature | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| S4 Humidity | 36.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 36.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 36.00% | 36.00% | 36.00% | 37.00% | 37.00% |
| S5 Temperature | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 25 | 24 | 24 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| S5 Humidity | 61.00% | 62.00% | 62.00% | 60.00% | 61.00% | 61.00% | 61.00% | 61.00% | 61.00% | 57.00% | 62.00% | 60.00% | 61.00% | 60.00% | 61.00% | 60.00% | 57.00% | 55.00% | 55.00% | 56.00% | 55.00% | 60.00% |

| With Cooler 2 | | | | | | | | | | | | | | | | | | | | | |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| S1 Temperature | 36 | 36 | 41 | 45 | 46 | 47 | 49 | 49 | 50 | 49 | 49 | 50 | 50 | 51 | 52 | 52 | 52 | 50 | 50 | 51 | 52 |
| S1 Humidity | 43.00% | 43.00% | 28.00% | 6.00% | 5.00% | 4.00% | 3.00% | 3.00% | 3.00% | 3.00% | 3.00% | 3.00% | 3.00% | 2.00% | 2.00% | 2.00% | 2.00% | 3.00% | 3.00% | 2.00% | 2.00% |
| S2 Temperature | 32 | 32 | 37 | 38 | 41 | 45 | 49 | 52 | 54 | 52 | 47 | 46 | 48 | 49 | 51 | 47 | 46 | 46 | 49 | 50 | 49 |
| S2 Humidity | 50.00% | 49.00% | 39.00% | 31.00% | 10.00% | 6.00% | 3.00% | 2.00% | 1.00% | 2.00% | 4.00% | 5.00% | 4.00% | 3.00% | 2.00% | 4.00% | 5.00% | 5.00% | 3.00% | 3.00% | 3.00% |
| S3 Temperature | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| S3 Humidity | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% |
| S4 Temperature | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| S4 Humidity | 36.00% | 36.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 36.00% | 37.00% | 36.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 37.00% | 36.00% | 36.00% |
| S5 Temperature | 24 | 24 | 24 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| S5 Humidity | 63.00% | 62.00% | 60.00% | 61.00% | 60.00% | 60.00% | 61.00% | 58.00% | 56.00% | 56.00% | 56.00% | 57.00% | 55.00% | 56.00% | 55.00% | 59.00% | 60.00% | 58.00% | 59.00% | 57.00% | 57.00% |

| Without Cooler | | | | | | | | | | | | | | | | | | | | | |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| S1 Temperature | 35 | 35 | 40 | 45 | 46 | 46 | 49 | 49 | 47 | 49 | 49 | 49 | 49 | 52 | 52 | 50 | 49 | 49 | 45 | 46 | 46 |
| S1 Humidity | 13.00% | 13.00% | 10.00% | 6.00% | 5.00% | 5.00% | 3.00% | 3.00% | 4.00% | 3.00% | 3.00% | 3.00% | 3.00% | 2.00% | 1.00% | 3.00% | 3.00% | 3.00% | 5.00% | 6.00% | 5.00% |
| S2 Temperature | 35 | 35 | 34 | 38 | 39 | 41 | 43 | 45 | 45 | 46 | 46 | 46 | 46 | 46 | 49 | 47 | 49 | 52 | 53 | 54 | 54 |
| S2 Humidity | 28.00% | 28.00% | 25.00% | 11.00% | 9.00% | 7.00% | 6.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 2.00% | 4.00% | 3.00% | 1.00% | 0.00% | 0.00% | 0.00% |
| S3 Temperature | 29 | 29 | 30 | 31 | 31 | 31 | 30 | 30 | 31 | 30 | 29 | 30 | 31 | 31 | 29 | 30 | 31 | 30 | 29 | 28 | 28 |
| S3 Humidity | 35.00% | 35.00% | 35.00% | 34.00% | 34.00% | 34.00% | 35.00% | 35.00% | 34.00% | 35.00% | 35.00% | 35.00% | 34.00% | 34.00% | 35.00% | 35.00% | 34.00% | 35.00% | 35.00% | 36.00% | 36.00% |
| S4 Temperature | 38 | 38 | 31 | 29 | 29 | 29 | 29 | 30 | 29 | 29 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| S4 Humidity | 29.00% | 30.00% | 32.00% | 34.00% | 35.00% | 35.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% |
| S5 Temperature | 23 | 23 | 23 | 23 | 24 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 24 | 24 | 24 | 23 | 23 | 23 | 24 | 23 |
| S5 Humidity | 60.00% | 60.00% | 60.00% | 62.00% | 61.00% | 60.00% | 61.00% | 61.00% | 61.00% | 61.00% | 62.00% | 62.00% | 62.00% | 64.00% | 62.00% | 62.00% | 61.00% | 64.00% | 65.00% | 64.00% | 61.00% |

| Without Cooler 2 | | | | | | | | | | | | | | | | | | | | | |
|------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| S1 Temperature | 30 | 30 | 32 | 40 | 45 | 48 | 50 | 52 | 52 | 52 | 51 | 49 | 47 | 49 | 47 | 47 | 50 | 52 | 52 | 51 | 49 |
| S1 Humidity | 45.00% | 45.00% | 43.00% | 29.00% | 6.00% | 4.00% | 2.00% | 1.00% | 1.00% | 2.00% | 2.00% | 2.00% | 4.00% | 3.00% | 4.00% | 4.00% | 3.00% | 2.00% | 2.00% | 2.00% | 3.00% |
| S2 Temperature | 29 | 29 | 30 | 37 | 41 | 41 | 43 | 45 | 45 | 45 | 45 | 54 | 60 | 60 | 60 | 60 | 60 | 54 | 53 | 60 | 60 |
| S2 Humidity | 48.00% | 48.00% | 44.00% | 15.00% | 8.00% | 7.00% | 6.00% | 5.00% | 5.00% | 5.00% | 5.00% | 0.00% | 1.00% | 1.00% | 1.00% | 1.00% | 1.00% | 1.00% | 0.00% | 1.00% | 1.00% |
| S3 Temperature | 26 | 26 | 27 | 29 | 29 | 29 | 29 | 29 | 29 | 30 | 30 | 31 | 31 | 29 | 29 | 31 | 32 | 31 | 31 | 29 | 29 |
| S3 Humidity | 38.00% | 37.00% | 37.00% | 36.00% | 35.00% | 35.00% | 35.00% | 35.00% | 35.00% | 35.00% | 35.00% | 34.00% | 34.00% | 35.00% | 35.00% | 34.00% | 34.00% | 34.00% | 34.00% | 35.00% | 35.00% |
| S4 Temperature | 28 | 28 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 30 | 30 | 30 | 30 | 30 | 31 | 31 | 31 | 31 | 31 | 31 |
| S4 Humidity | 37.00% | 37.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 36.00% | 35.00% | 36.00% | 36.00% | 36.00% | 35.00% | 35.00% | 35.00% | 35.00% | 35.00% | 35.00% |
| S5 Temperature | 23 | 23 | 23 | 23 | 22 | 22 | 21 | 22 | 23 | 23 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| S5 Humidity | 61.00% | 61.00% | 61.00% | 60.00% | 57.00% | 56.00% | 57.00% | 62.00% | 61.00% | 61.00% | 58.00% | 55.00% | 60.00% | 58.00% | 59.00% | 57.00% | 57.00% | 59.00% | 57.00% | 55.00% | 59.00% |

11 Appendix C: Humidity and Temperature Sensor on

Arduino code

```
#include <LiquidCrystal.h> // load lib
#include <dht.h> // load lib

LiquidCrystal mlcd(12,11,5,4,3,2); // make a lcd object
#define dht_apin 7
dht DHT; // sensor pin S to pin11

void setup() {
  Serial.begin(9600);
  mlcd.begin(16,2); // to tell arduino there are 16 columns and 2 rows
}

void loop(){
  DHT.read11(dht_apin);
  mlcd.setCursor(0,0); // row 1
  mlcd.print(" Humidity = "); // print on the lcd Humidity =
  mlcd.print(DHT.humidity); // to print the humidity
  Serial.print("Humidity");
  Serial.println(DHT.humidity);
  Serial.print("Tempreture");
  Serial.println(DHT.temperature);
  Serial.println("-----");

  mlcd.setCursor(0,1);
  mlcd.print(" Temp = "); // print on the lcd temp =
  mlcd.print(DHT.temperature); // print on the lcd temperture
  mlcd.println(" C ");
  delay (2500); // delay
```

12 Appendix E : Operation Manual

This is the procedure to start the Desiccant disk project; you have the room box, two air nozzle, cooling box with water nozzle distributor inside it cooling pads, cylinder disk with silica, shaft and pulley all on trolley, motor with pulley connected to with trolley, circuit board, Audrina Uno, heat gun, air blower and laptop to select the data from the cylinder inlet and outlet through the humidification sensor.

1. First of all you have to connect the room box with two air nozzle from the inlet and outlet holes, for more details:
 - The inlet for the room box will connected with the cooling box that connected to the water source.
 - After that connect the inlet nozzle from the cooling box to the outlet of the cylinder.
 - Furthermore, the outlets you have to passes through it the air blower which is connected to electrical source and connected to the inlet of the desiccant disk cylinder.
2. Secondly loss the motor blots which is fixed on the trolley, to redressing the belt thru the motor pulley and connected to the cylinder pulley and tight the bolts to have the belt tighten and aligned.
3. Connect the heat gun thru the electrical connecting source; fix it on the pulley side to dry the silica.
4. After that you have to connect the motor to the circuit board and then to Arduino Uno
5. Furthermore, you connect the Arduino Uno to the laptop to collect the data and result.
6. Finally start the main electrical source for the motor to rotate, heat gun, air blower, circuit board, Arduino Uno and the laptop.

The result should be same as the bellow figures, with cooler and without cooler:

