NUST COLLEGE OF

ELECTRICAL AND MECHANICAL ENGINEERING

DEVELOPMENT AND TESTING OF NOVEL WATER PURIFICATION AND REFRIGERATION SYSTEM

THESIS REPORT

DE-41 (DME)

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2023

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ACKNOWLEDGEMENTS

We are grateful to Allah Almighty who guided us throughout the whole project. Due to His Blessings, we were able to accomplish our project. With our deep gratitude and Appreciation, we would like to thank our project supervisor Dr. Abdur Rehman Mazhar, whose continuous guidance and tireless efforts made this project possible. This project would not have been possible without his support and encouragement. We would also like to thank a few other people who helped us throughout our project with their valuable suggestions and time such as our colleagues and Research Assistant Usman Zia. We are entirely thanks to all those who supported us in any way possible.

ABSTRACT

Water is an essential part of our lives. With the rapid increase in population and industrialization, the need for water has also increased, leading to an incremental increase in water pollution. Consumption of such polluted water may lead to improved health problems. Our project aims to prevent such situations by providing clean and safe water. We aim to accomplish this by using an activated carbon filter which has been proven effective in removing dust, sediment particles, as well as chlorine, and different chemicals and reagents from water. Moreover, also checking the pH of the water at the end of the process to ensure that it is safe for drinking.

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CHAPTER NO.1 BACKGROUND

1.1. Introduction:

Water is a clear, transparent, colorless, odorless liquid used for drinking, cleaning, and other various purposes. Water is essential for life on Earth and is vital to all its forms. Our dependence on water is not limited to drinking and cleaning purposes as it is also used in almost every industry for the manufacturing of different products. However, due to its high demand, this natural resource is being used up at a very rapid rate resulting in the supply of fresh water being reduced every year [1]. Moreover, due to the dumping of industrial waste in water bodies, the already available resources of fresh water are being contaminated.

Due to the above-mentioned reasons water purification systems, especially solar-powered ones are becoming more popular in recent years. Solar-powered water purification systems run on solar energy which is a clean and free source of energy. Purification systems don't only remove the sedimented particles from the water but also remove different chemicals, reagents, and dissolved ions while also killing different micro-organisms and pathogens in water that may prove detrimental to human health. Our water purification system is based on such standards as we are using an activated carbon filter which uses the process of adsorption to remove different chemicals, reagents, dissolved ions as well as different micro-organisms, odor, and pathogens from water. Moreover, our setup also uses a pH measurement device that checks the pH of the water and deems whether it is suitable for use or not.

1.2 Executive Summary:

The filtration process will start by first removing large particles using different dishes. Then the water will be transferred to a storage tank from which the water will then be passed through an activated carbon filter. The purpose of an activated carbon filter is to remove all the different chemicals, reagents, bacteria, dissolved ions as well as different micro-organisms and pathogens from the water [2]. The activated carbon filter will not only remove the unwanted odor from water but also add a pleasant fragrance to it. After the filtration process, the pH of the water will be evaluated to check whether it is suitable for use or not. The pH of the filtered water will lie between 6.5 to 8.5 so it can be used for drinking purposes. After that, the water will be stored in another compartment from where it can be extracted for different purposes.

1.2.1. Water storage tank:

For the first stage, the water is first stored in a water storage tank which can store about 1.5 liters of water. There are multiple water tanks. The first tank holds unfiltered water which is to be filtered. The second tank contains filtered drinkable water. The pH is evaluated by taking a water sample from the second water tank. Then the water is transferred to the last tank from where water can be extracted. The tanks are placed at an elevated height such that water can easily move downwards to different compartments by the action of gravity.

1.2.2. Activated Carbon Filter:

A water filtration system with an activated carbon filter will help make sure that your most valuable resource, clean water, is free from impurities. The activated carbon absorption removes not just taste and smell but also standard contaminants such as lead, pharmaceuticals, and other harmful chemicals [2]. The activated carbon filter is used to separate all the contaminants (different sedimented particles, ions, chemicals, and their reagents) via the method of adsorption. Activated carbon has a large number of microscopic pores in its structure which allow it to have a large surface area thus allowing it to adsorb different particles on its surface thus making the water clean. The quality filtration materials in this water purification system remove chemicals, pharmaceuticals, and other harmful contaminants from water to help keep its quality high.

1.3. Design Requirement Summary:

The following table shows the design requirements of our project as set out by the team and supervisor:

Table 1-1: Design Requirements

Category	Requirements
Power	• Electrically powered system
Flow rate	• Must at least produce 2 liters per minute of clean water
Water Quality	• Contamination, bacteria, virus free clean, and drinkable water as per standards
Product specifications	• Endure strength and portability • Efort-less operation • Weight limit under 30 kg
Economy	• Must not exceed 30000 PKR

CHAPTER NO.2 LITERATURE REVIEW

2.1 **Overview**

Filtration is the process of removing different particles, such as dust and pollutants, from a liquid or gas. Filtration is used in a variety of ways including air purification, drinking water purification, and food processing. For our current project, we will only limit ourselves to water filtration methods.

2.2 **Filtration methods**

The various Water purification methods used generally are as follows:

- Boiling
- Distillation
- Chemical treatment
- Micro Filtration
- Ultra Filtration
- Reverse Osmosis
- Solar Disinfection
- Activated Carbon Filters
- Cartridge Filters

2.2.1. Boiling:

Boiling is one of the most common and effective methods of making the water suitable for drinking. For this process, the water should be brought to its boiling point and then left for 2 to 3 minutes. In areas with higher altitudes, it is advisable to boil water for a greater time as compared to the areas with low altitudes [4]. This is due to the reason that water boils at a lower temperature at higher altitudes due to a reduction in atmospheric pressure which increases the risk of germs in it as all the germs are not killed.

2.2.2. Distillation:

Distillation of water is a simple method that removes contaminants. It involves boiling the water to create steam. This steam turns back into a liquid, minus all the contaminants and impurities [5]. It involves boiling water and capturing the pure steam to be collected at the top of the container. This steam can then be led into another container, including containers of drinking water.

2.2.3. Chemical treatment:

Chemical treatment is another way of purifying water. In this process, a chemical is added to water which kills the germs. The chemical is then removed from the water which makes the water safe to use [6]. The addition of chemicals in water is an overly sensitive process and should be monitored cautiously if the chemical that is added to water is less than the required amount then it becomes ineffective while if it is more than the required amount it becomes dangerous for the user. The chemicals that are added to water are

1. Chlorine Bleach
2. Iodine
3. Calcium Hypochlorite
4. Chlorine Dioxide Tablets
5. Hydrogen peroxide
6. Lime

2.2.4. Micro Filtration:

In this process, a special pore-sized membrane of 0.1-10 µm is used which can filter out micro-organisms in the range of 0.05-5 Microns diameter. However, this method of filtration is not completely effective as it does not trap viruses and bacteria but only a limited type of micro-organisms [7].

2.2.5. Ultra-filtration:

It is used to separate microorganism particles up to 0.0001-0.1 µm. this type of filtration can remove almost every type of bacteria and virus from water, but it is ineffective against ions such as arsenic and lead that cause cancer [8].

2.2.6. Reverse Osmosis:

This process uses a high-pressure pump (usually ranging from 150-1500 psi) to force water through a semi-permeable RO membrane [9]. The membrane rejects all the contaminants and only allows water to pass through it thus making the water safe for use.

2.2.7. Solar disinfection:

Solar disinfection is a process for water purification using solar energy and ultraviolet rays [10]. Water becomes disinfected when ultraviolet light is absorbed by the water and then converted to UV radiation, which destroys bacteria through photolysis or fragmentation.

2.2.8. Activated Carbon filter:

Activated carbon filters are capable of removing more than 99 percent of bacteria, viruses, and cysts from filtered water [2]. They take any residual impurities in the water and trap them to improve their taste and smell. Activated carbon filters are used when working with highly polluted water to remove as many chemicals, heavy metals, and pathogens as possible.

2.2.9. Cartridge Filters:

There are two types of cartridge filters, surface type, and depth type. Depth-type filters remove contaminants through the total depth of the medium whereas surface-type filters use surface membranes to separate contaminants and other hazardous materials from water.

2.3 Advantages and Disadvantages

Table 2-1: Filtration Process Comparison

Filtration Method	Advantages	Disadvantages
Boiling	• Boiling kills all the bacteria and germs in water thus making it drinkable • The process is easy to use for a commoner [4].	• Unable to kill all chemical pollutants. • Unable to remove unpleasant smell.
Distillation	• It helps in killing harmful microbes. • Improves water quality [5].	• Large energy is needed. • Inflated cost.
Chemical Treatment	• Eliminates harmful bacteria. • Can be safely recycled back into a water source [6].	• Using more than the required amount of chemicals may prove detrimental to a person
Micro Filtration	• Remove particles up to 0.05-5 µm. • Used as a pre-filtration stage [7].	• Not effective to remove viruses and bacteria.
Ultra Filtration	• Remove particles up to 0.0001-0.1 µm. • Can remove virus and bacteria [8].	• Not effective to remove ions from water. • High pressure is required.
Reverse Osmosis	• Remove all contaminants and ions from the water like arsenic etc [9].	• Require high pressure up to 150-1500 psi. • It does not convert all contaminated water to pure water.
Solar Disinfection	• Used to remove different micro-organisms [10]. • Uses renewable energy sources.	• Effective for clear water only since UV rays are used to remove viruses and bacteria.
Cartridge Filter	• Used to remove odors, chlorine, micro-organisms and objectionable taste [11].	• The buildup of organic material and concentration of bacteria combine to foster the growth and shedding of bacteria into the water. • Again, water is passed from the filter to make it drinkable after passing from the activated carbon filter.
Activated Carbon filter	• Convert all the contaminated water to pure water, no water is wasted [12]. • Can filter small particles.	• The cartridge needs to be replaced after 1.5-2 years depending on use.

2.4 Activated Carbon Filter

The active carbon filter is used for water filtration. In a simple system, active carbon filter media is material that can be in the form of granules or powder and is packed into most common housings to make a water filter cartridge. There are many types of active carbon water filters [12]. They come in varied sizes and media pore sizes, micron ratings, and flow rates. To stop dirt, debris, and chemicals from getting into your drinking water, you need an effective filter. The active carbon filter is an excellent choice for removing a wide range of contaminants.

2.4.1 Construction

It consists of a cylindrical vessel, made from concrete or glass. A copper screen is placed at one end of the cylinder for laying out the filter layer. Then a layer of activated carbon is produced on now screen, several filter layers are produced from now onwards and layers are successively added [13]. These layers may be periodically agitated by paddles to help with the process of oxidation thereby increasing the rate within the filter. Once this process is completed several layers will have been produced with an apparent thickness ranging from 2 inches to 9 inches depending upon the amount required by manufacturer and user requirements.

2.4.2 Working

Activated carbon is a filter element that exists in the pores of diamonds, graphite, and other materials. This material has a high pore volume, so it attracts impurities in water very easily. Filtration is done by adsorption. The filter removes impurities from water, such as chlorine and fluoride, which are harmful to humans [13]. One of the main advantages of this filter is that it does not remove dissolved minerals like other household filters.

Due to the high surface area and porous structure, it can remove many diverse types of contaminants and chemicals through biological means by passing them through several stages of filtration [13]. Because activated carbon has a high surface area relative to its weight, it creates a microscopic pore space that allows small particles suspended in water to attach to its surface. This allows the water to be filtered by simply reverse osmosis or filtration, removing salt or other large particles automatically.

2.4.3 Types of Activated Carbon Filters

In general, the active carbon prefilter used in the wastewater treatment process is divided into two main categories, i.e., granular activated carbon (GAC) and non-woven material like powdered activated carbon [13]. These types of activated carbon filters are categorized due to their construction, material properties, and usage. The construction and working of GAC filters and powdered filters are discussed in detail in the following paper.

Granule Activated Carbon Filter

In the case of granule-activated carbon, the carbon is in the form of individual microscopic particles or nanosized granules. These are usually coated with a rutile titanium dioxide catalyst layer that accelerates the reaction between the water and the carbon, thus ensuring very complete adsorption [13]. GAC works by physically removing contaminants from water by adsorption. Adsorption occurs when impurities become trapped between the granule's outer surface and inner pore structure. Water flows through the hole structure of the activated carbon, where it encounters the adsorbent material. Any non-adsorbed impurities remain in the water and are removed.

Powdered Activated Carbon Filter

The powdered carbon filter is a kind of carbon-based water filter that uses powdered activated carbon. Powdered activated carbon has excellent adsorption ability. It is widely used in drinking water purification and odor removal treatment. As it has a large surface area, it can adsorb most harmful impurities in water quickly, thus making the water taste good [13]. When water passes through the state, it can remove dissolved substances from the oxygen, and it effectively blocks organic compounds from attaching to the surface of the membrane material by employing adsorption and oxidation reaction. The product mainly matches the general-purpose reverse osmosis purification system for urban water treatment for domestic use.

2.4.4 Advantages of Active Carbon Filter

An activated carbon filter removes organic impurities from water and is more powerful than its non-activated counterparts. There are numerous amounts of pores in activated carbon which causes it to have an exceptionally large surface area as compared to the size of the specimen [14]. The filter reduces health hazards as the filter removes dirt, dissolved organic pollutants, unwanted minerals, and other impurities from water. Activated carbon, can remove chlorine, chlorinated organic contaminants, volatile organic compounds (VOCs), taste and odor particles, and heavy metals such as aluminum, iron, mercury, and lead.

Activated carbon filters absorb most chemical pollutants in water. They remove many contaminants, including pesticides and disinfectants, and are typically colorless, odorless, and tasteless. The activated carbon adsorbs chlorinated solvents, pesticides, herbicides (such as DDT), suspended solids, nitrogen compounds, and some other chemicals as they pass through the media [14]. The activated carbon also acts as a support for beneficial microbial growth during water purification, which helps keep your pipes clean while adding beneficial microbes to your environment.

2.4.5 Disadvantages of Active Carbon Filter

Since an activated carbon filter performs filtration via the method of adsorption it needs to be changed periodically [15].

2.4.6 Applications of Active Carbon Filter

In the water treatment industry, activated carbon is used to purify water so that it meets or exceeds regulatory guidelines and standards. Activated carbon is a material that has many uses. Some of them are in the purification of water, wastewater treatment, and oil well. Activated carbon filters are used in continuous-flow systems, reverse osmosis, electrocoagulation and recovery, distillation, RO purification, and other applications that produce high-quality drinkable water [16]. Suitable for aquariums with elevated levels of dissolved organic compounds and other contaminants, the filter will effectively eliminate these pollutants from water. This filter is a highly effective method of removing harmful contaminants, including chemicals, pesticides, and heavy metals. It is also used to remove foul odor and sediment. Industrial strength activated carbon filters are used to inactivate contaminants and freshen the air for good, healthy breathing. Designed to meet all industrial needs, continuous flow indoor and outdoor models regenerate after 90 minutes in use for the best results.

An activated carbon filter is also used in filtration methods for swimming pools, and aquariums. Granular activated carbon and powdered activated carbon is widely used for row purification of gas and liquid, especially for the separation and purification of crude oil to remove a wide range of contaminant respectively including phenol, hexane, sulfur compounds, and dissolved inorganic salts [16]. The activated carbon filter is an effective and efficient water purification method. It can be used to purify the contaminated water through a combination of granular activated carbon, oxide powder, and a double membrane inside.

2.4.7 Why do we use activated carbon?

Activated carbon boasts exceedingly high porosity and the most vital physical adsorption forces of any material known to mankind. It can have a surface area greater than $1000m^2/g$ meaning that 3g of activated carbon can have a surface area like that of a football field [12]. Because of these properties, activated carbon is considered one of the most suitable materials for the water filtration process.

What is adsorption?

Adsorption is the process of adhesion of different atoms, ions, or molecules from a liquid or a gas onto the surface of a solid. Due to this process, a film of adsorbate is created on the adsorbent [17].

Lifespan:

It is advisable to replace carbon filters after 18-24 months of continuous usage. While the lifespan may vary depending upon the quality of the product the most a carbon filter can last is up to 4 years [18]. The lifespan of a carbon filter is largely dependent on its carbon quality, use, humidity, and plant type.

How to wash?

Carbon filters have an important anti-odor action and immersing them in water will likely damage it resulting in the loss of their purifying properties, so it is advisable to replace carbon filters or immerse them in 10% hydrogen peroxide solution for the purpose of washing them [19].

How to recharge?

Reactivating carbon filters to extend their life requires keeping them at a temperature of more than 900 degrees Celsius. This can be done, but it does not retain the activated carbon. If you heat your filter back up to the temperature used to create it and then reactivate it, any impurities that have managed to escape will be released [20]. These impurities are potentially toxic at higher temperatures, so it is recommended to store your filter within its container or other inert media to prevent them from escaping into the environment.

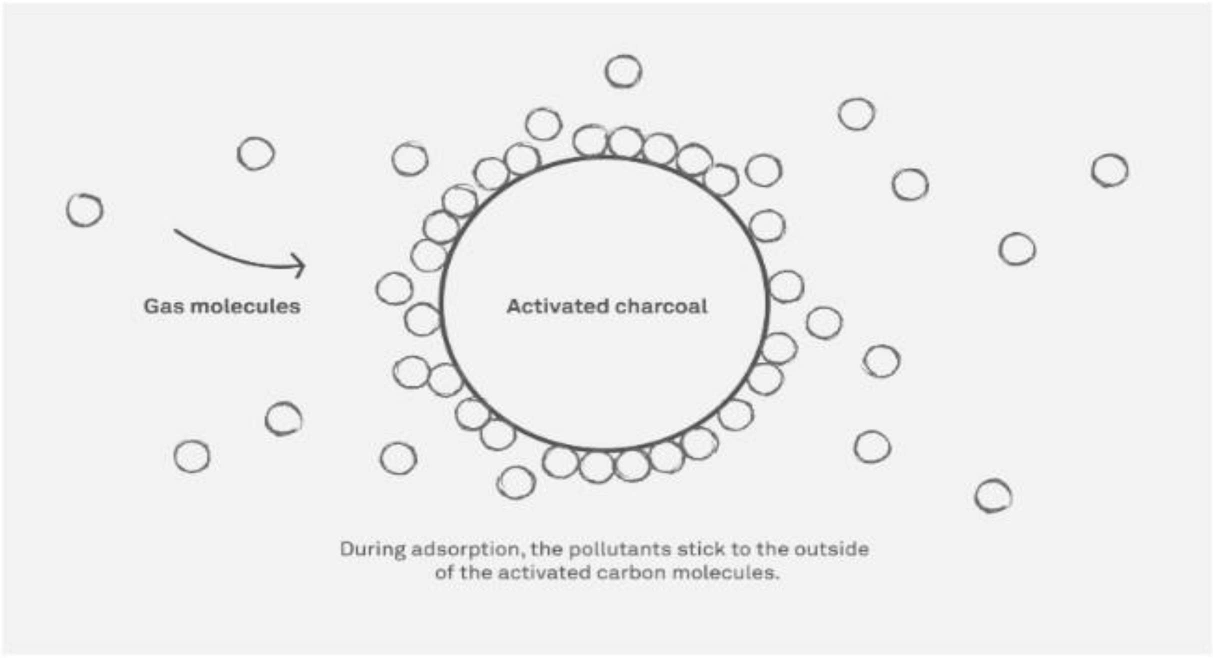

How do carbon air filters trap gaseous pollutants?

DIAGRAM: ADSORPTION IS VERY DIFFERENT FROM ABSORPTION. AIRBORNE GASEOUS CHEMICALS (SPECIFICALLY VOLATILE ORGANIC CHEMICALS, OR VOCS) STICK THE SURFACE OF CARBON AIR FILTERS UNTIL THE FILTER SURFACE IS FULLY SATURATED.

2.4.8 How to effectively use an activated carbon air filter

Make sure it uses enough carbon, some filters that claim to be activated carbon filters have only a trace amount of carbon which causes the pores in the activated carbon to fill up very quickly thus rendering them incapable of use**.**

2.4.9 Flow rate vital

Flow rate is an essential part of effective filtration. The slower the flow rate the more time the contaminants get to react with the activated carbon thus effectively making the water cleaner. The suggested flow rate should be 0.5 gallons per minute [21].

2.5 Conclusion:

We conclude that an Activated carbon filter is the most effective filter due to the following reasons

- It is safe and easy to use.
- It can remove chemicals, micro-organisms as well as odor from water.
- It does not require any manpower for operation.
- The activated carbon used in this filter has a large surface area making it suitable for filtration.
- The activated carbon can be recharged thus making it a reusable filter.

CHAPTER NO.3 MATHEMATICAL MODEL

3.1 Overview:

A thermoelectric Peltier is used for purpose of cooling and heating filtered water. The thermoelectric Peltier is supplied with the current which causes electrons to flow across the P-N junctions of the Peltier causing a temperature rise at one end and a temperature drop at the other end. A generalized thermoelectric Peltier can reach temperatures as high as 115 °C and as low as -15 °C.

3.2 Thermoelectric Peltier:

The thermoelectric Peltier is also called the thermal generator, a device for generating heat from an electric current. When an electric current is applied, it creates hot and cold junctions between its two ends, which cause one end to become hot while the other end becomes cold. This can be turned on or off by connecting or disconnecting wires to one of the ends of the device [22].

3.2.1 History:

In 1834 Jean Charles Athanase Peltier, a French watchmaker and a part-time physicist found out that an electrical current would produce a heating or cooling effect at the junction of two dissimilar metals [22].

3.2.2 Construction:

Thermoelectric (Peltier) coolers are typically made of thermocouples and may consist of hundreds of elements. Copper commutation tabs interconnect the pellets, which are traditionally made of bismuth telluride-based alloy [23]. A typical TEC consists of a pair of Alumina plates sandwiched between a pair of semiconductors connected electrically in series and separated by a film of dielectric material such as Teflon. This allows for construction with a desirable cooling capacity ranging from fractions of Watts to hundreds of Watts.

A Peltier cooler works by using one side of the device to absorb heat from its environment and the other side to release it into the surrounding area. As DC moves across the Peltier cooler, it causes a temperature differential between TEC sides. The alternate side is called hot and the opposite side is called cold [23]. If the heat generated on the TEC hot side is effectively dissipated into heat sinks and the surrounding environment, then the temperature on one side of the thermoelectric cooler will be much lower than that of the ambient by dozens of degrees. The thermoelectric cooler's cooling capacity is proportional to the current passing through it; therefore when polarity changes, so do its cooling capacity.

3.2.3 Working principle:

The thermoelectric Peltier is a heat pump that uses the See-beck effect. The See-beck effect is the phenomenon in which two different junctions of a perfect conductor are made to be at different temperatures when an electric current is applied [24]. The See-beck effect is observed in materials that exhibit both electrical conductivity and thermal conductivity, such as perfect conductors. Pressure changes created by the See-beck effect cause heat to move from one junction to another [24]. This creates a temperature difference between the two junctions that can create a measurable amount of power. The Thermoelectric Peltier extensively cools the hot side and heats the cold side of a thermocouple, converting thermal energy into electricity.

3.2.4 See-back effect:

The See-beck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances [25]. The See-beck coefficient $\propto_m$ (also known as thermopower, thermoelectric power, and thermoelectric sensitivity) of a material is a measure of the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material, as induced by the Seebeck effect.

3.3 Electricity generation:

A device that changes heat into electrical energy and vice versa. The Peltier-tube thermoelectric (Peltier) converter uses the rolling friction between the hot and cold ends of an electrically conductive Peltier element to generate electricity from one form of energy, using a reciprocal process to extract waste heat from another form of energy [26].

3.3.1 Explanation:

Using two junction thermocouples embedded within a heat dissipation material. As an electric current flows through a Peltier device, Joule heating causes the thermal expansion of the two junctions to vary. The temperature difference is measured and this can be used to generate electricity [26].

3.3.2 Reasoning behind the process:

When the junction between p-type and n-type is heated, electrons flow in one direction (cathode) from metal to glass, creating a region where electrons are transported easily. When the junction between metal and n-type is cooled, it becomes an electrical barrier that reduces the movement of electrons through it (anode), creating a region where electron flow is reduced and electrical energy cannot be generated [26].

3.3.3 Different semiconductors used:

Common thermoelectric materials used as semiconductors include bismuth telluride, lead telluride, silicon–germanium, and bismuth antimonite alloys. Of these, bismuth telluride is the most used in thermoelectric Peltier [26].

3.3.4 What is a thermogenerator?

Thermoelectricity is also known as the thermogenerator. It's a device that converts electrical power into thermal energy and vice versa [26]. The device creates hot and cold zones between its two ends, which causes one end to become hot while the other end becomes cold. Two thermocouples are used to convert the heat energy into electrical energy or vice versa.

3.3.5 Applications:

Technologically advanced, the Peltier is a solid-state heat pump. It's often used to circulate liquid coolant in refrigeration and air conditioning applications.Used in a wide variety of applications, Peltier modules are great for producing cold water or for heating elements. The Peltier cools by creating a temperature difference when it passes the current. It's been used to cool computer chips and other high-performance electronics [27]. Although most used as a cooling system, this refrigeration device can also be used to heat a liquid. Is used in dehumidifiers for the extraction of water from the air. It is used to balance the effects of sunlight on both sides of the spacecraft by dissipating the heat (due to direct sunlight) on one side of the spacecraft to the other side (which doesn’t receive sunlight) which is much cooler [27].

Its other applications include

- Black box cooling
- Cold plates
- Compact heat exchangers
- Constant temperature baths
- Integrated circuit cooling
- Inertial guidance systems
- Laser diode coolers
- Microprocessor cooling
- Microtome stage coolers
- NEMA enclosure
- Thermal cycling devices (DNA and blood analyzers)
- Thermostat calibrating baths
- Water and beverage coolers
- Wet process temperature controller
- Wine cabinets

3.4 **Advantages:**

It allows us to build cooling/heating devices that do not have any mobile parts, and therefore, have a lower chance of failure as compared to conventional coolers and heaters. They also require almost no maintenance. Peltier devices make no noise and can theoretically achieve temperatures as low as -80ºC (-176ºF). The Peltier effect can also be used at the microscopic level, where conventional cooling methods are inefficient [28].

3.5 **Disadvantages:**

The major disadvantage of the Thermoelectric Peltier is its inefficiency. Heat is generated by the electric current which gets added to the overall heat dissipation. In large applications, this is troublesome because it results in an excessive amount of heat, due to which additional fans must be used in the system [28]. This effect also uses a lot of electricity, which can make it expensive to use for large-scale applications. Condensation may occur if the components of Peltier devices are cooled too much resulting in a short circuit.

3.6 **Module Details:**

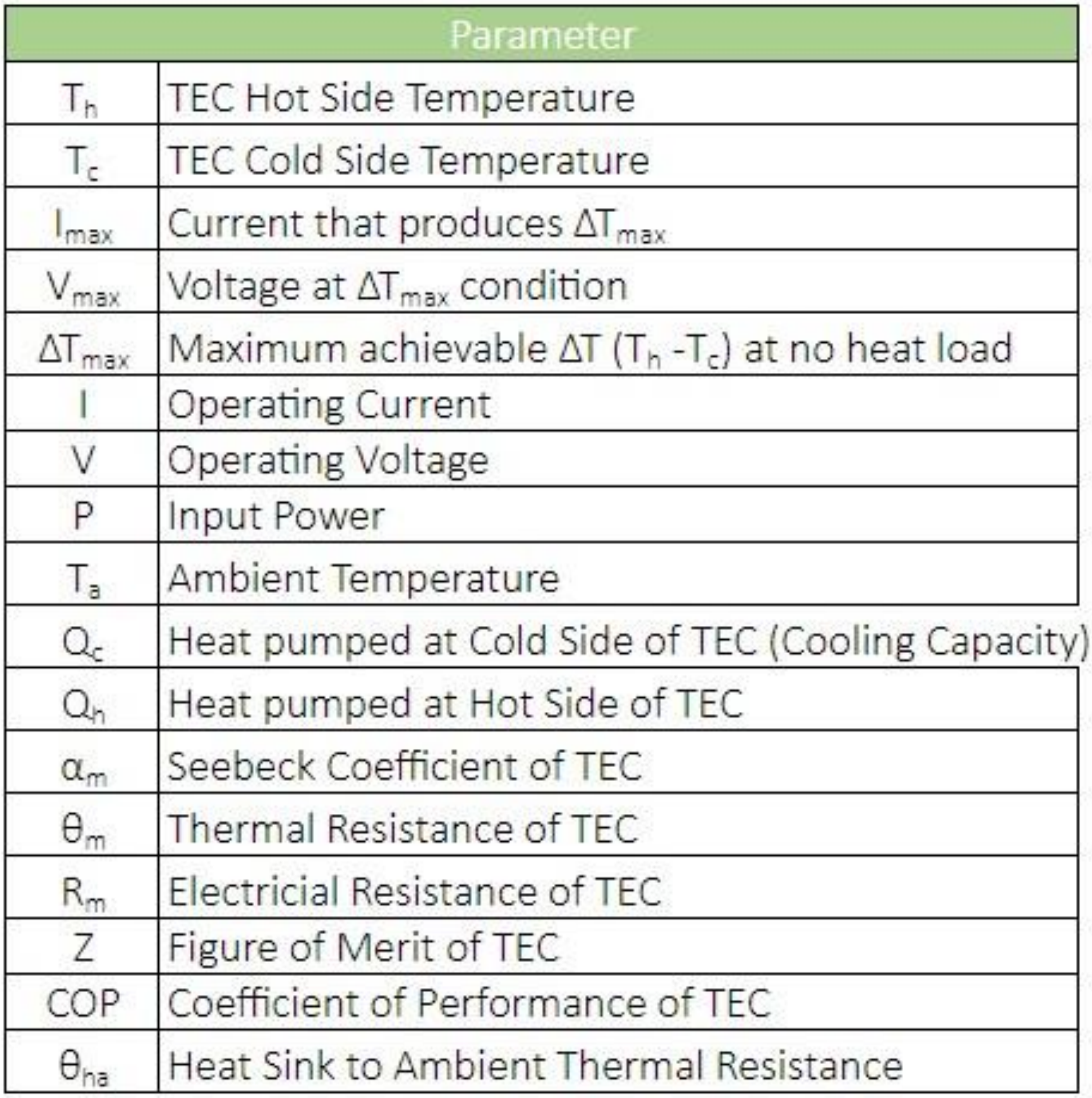
Model number: TEC1-12706

Dimensions: 40mm x 40mm x 4mm

Model: TEC1-12706
Voltage: 12V
Umax (V): 15V
Max Current (A): 4-4.6A
Cooling Power: Qcmax 50-60W
Resistance: 2.1-2.4Ω
△Tmax(Qc=0): up to 67°C
Operates Temperature: -55°C to 83°C
Power Cord: 29cm
Dimensions : 40mm x 40mm x 3.75mm (L*W*T)

3.7 Mathematical Calculations:

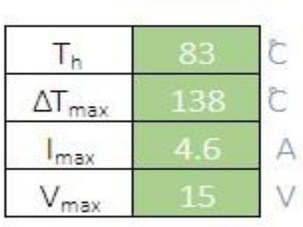
For mathematical calculations, the desired hot side temperature of the thermoelectric Peltier was designated to be 115 degrees Celsius while the cold side temperature was designated to be -60 degrees Celsius. The calculation parameters along with their designated symbols are expressed and explained in the table below:



Parameter	
T_h	TEC Hot Side Temperature
T_c	TEC Cold Side Temperature
I_{max}	Current that produces ΔT_{max}
V_{max}	Voltage at ΔT_{max} condition
ΔT_{max}	Maximum achievable ΔT (T_h -T_c) at no heat load
I	Operating Current
V	Operating Voltage
P	Input Power
T_a	Ambient Temperature
Q_c	Heat pumped at Cold Side of TEC (Cooling Capacity)
Q_h	Heat pumped at Hot Side of TEC
α_m	Seebeck Coefficient of TEC
θ_m	Thermal Resistance of TEC
R_m	Electricial Resistance of TEC
Z	Figure of Merit of TEC
COP	Coefficient of Performance of TEC
θ_{ha}	Heat Sink to Ambient Thermal Resistance

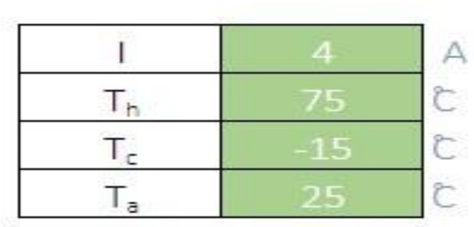
3.7.1 Input parameters:

The input technical specifications refer to the theoretical values that encompass the base values and are specific to the model being used. The input operating conditions refer to the actual values of the products obtained after experimentation. Note that these values may differ from the theoretical base values [29].



T_h	83	℃
ΔT_{max}	138	℃
I_{max}	4.6	A
V_{max}	15	V

Table 3-1: Technical specifications

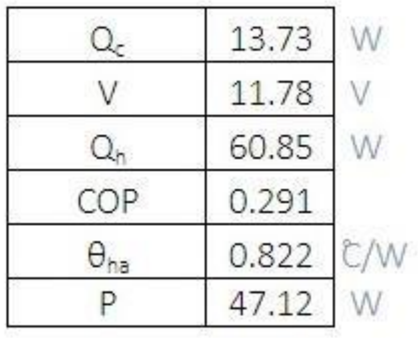


I	4	A
T_h	75	℃
T_c	-15	℃
T_a	25	℃

Table 3-2: Operating conditions

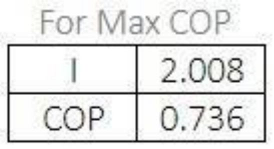
Output parameters:

Output operating parameters are calculated from different mathematical formulas under the designated operating conditions. Under the input operating conditions, COP obtained is about 0.29. The low value of COP of refrigeration is because the current being supplied to the thermoelectric Peltier is about 4 Amperes. To obtain a COP of 0.736 a current of 2 Amperes must be supplied [29].



Q_c	13.73	W
V	11.78	V
Q_h	60.85	W
COP	0.291	
θ_{ha}	0.822	℃/W
P	47.12	W

Table 3-3: Output parameters



For Max COP

I	2.008
COP	0.736

Table 3-4: Max COP

3.8 Mathematical Prediction:

Calculations were carried out for cooling capacity and COP of the system. The cooling capacity of the cold side of the Thermoelectric Peltier was calculated which was further used to estimate the COP of the system. Calculations for the flow rate of the water through the Activated Carbon filter were also carried out. The calculations are as follows,

Given Data:

- Volume of water, V = 2 L
- Mass of water, m = V * ρ = 2 kg (assuming the density of water is 1000 kg/m^3)
- Initial temperature of water, Ti = 40°C
- Final temperature of water, Tf = 17°C
- Time taken for cooling, t = 1 hour = 3600 seconds
- Power consumed, P = 40.32 W

The amount of heat removed, Q, is still given by:

Q’= m * c * ΔT

where c is the specific heat capacity of water and ΔT is the change in temperature.

Substituting the values, we get:

Q’ = 2 kg * 4182 J/kg·K * (-23°C) = -192828 J

The cooling load in watts, Q, is given by:

Q = Q’ / t

Substituting the values, we get:

Q = (-192828 J) / (3600 s) = -53.5633 W

The coefficient of performance (COP) is given by:

COP = Q / P

Substituting the values, we get:

COP = (-53.5633 W) / (40.32 W) = -1.3296

Note that the COP is negative in this case, which indicates that the system is a cooling system (i.e., it removes heat from the water).

Therefore, the cooling load is approximately -53.5633 W, and the COP is approximately -1.3296.

3.8 <u>Graphical data:</u>

The graphical data represents the dependence of COP on various operating parameters. The generalized chart of COP vs current ratio for a single-stage thermoelectric module shows that for maximum COP the ratio of $\frac{\Delta T}{\Delta T_{max}}$ should be kept the smallest possible. For COP of refrigeration to be greater than 1 the value of $\frac{I}{I_{max}}$ should be around 0.2 and the value of $\frac{\Delta T}{\Delta T_{max}}$ should be around 0.2 [29].

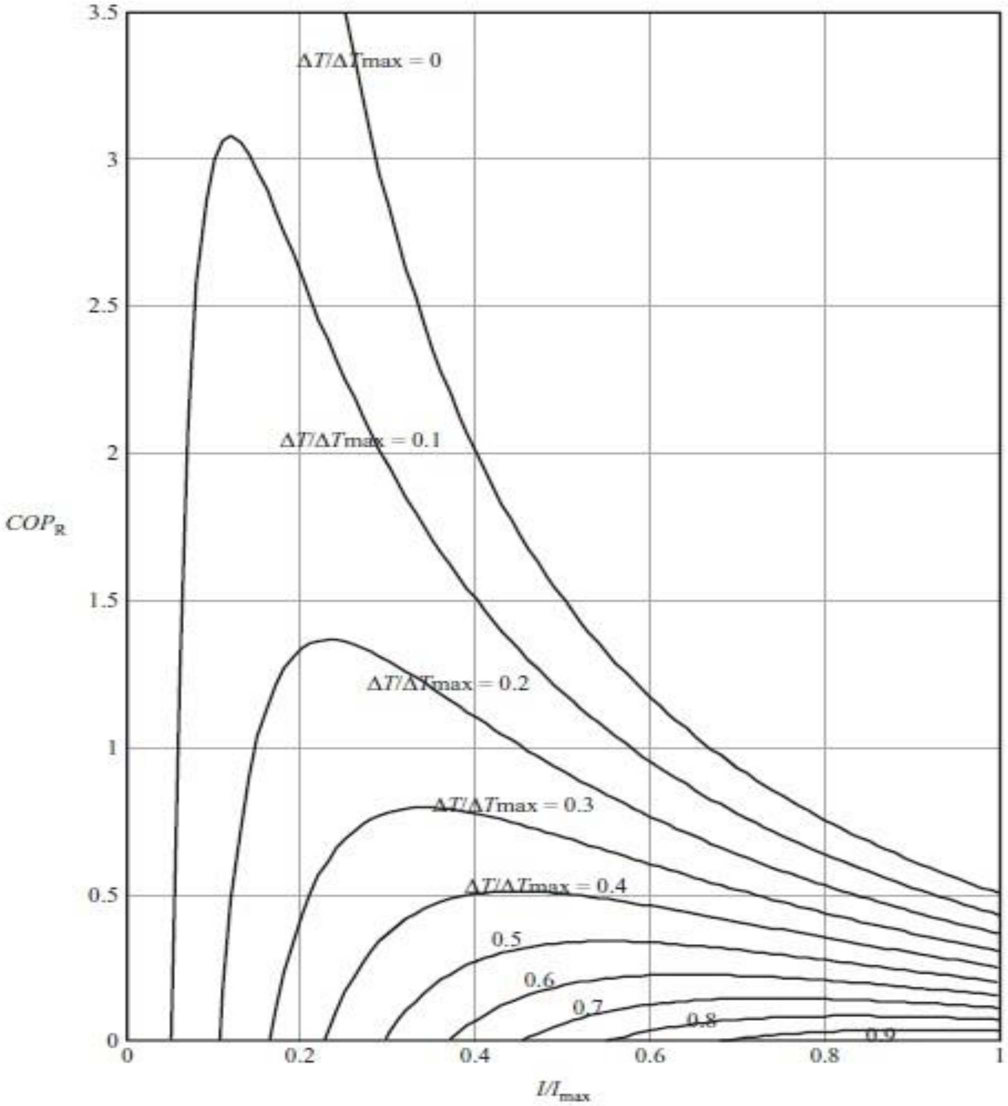


Figure 3.3 COP versus $\frac{I}{I_{max}}$

The generalized chart shows that the relationship between the cooling capacity ratio and the current ratio for a single-stage thermoelectric module is of direct proportion. The colling capacity ratio increases or decreases with the increase or decrease of the current ratio with subtle dependence on $\frac{\Delta T}{\Delta T_{max}}$ values [29].

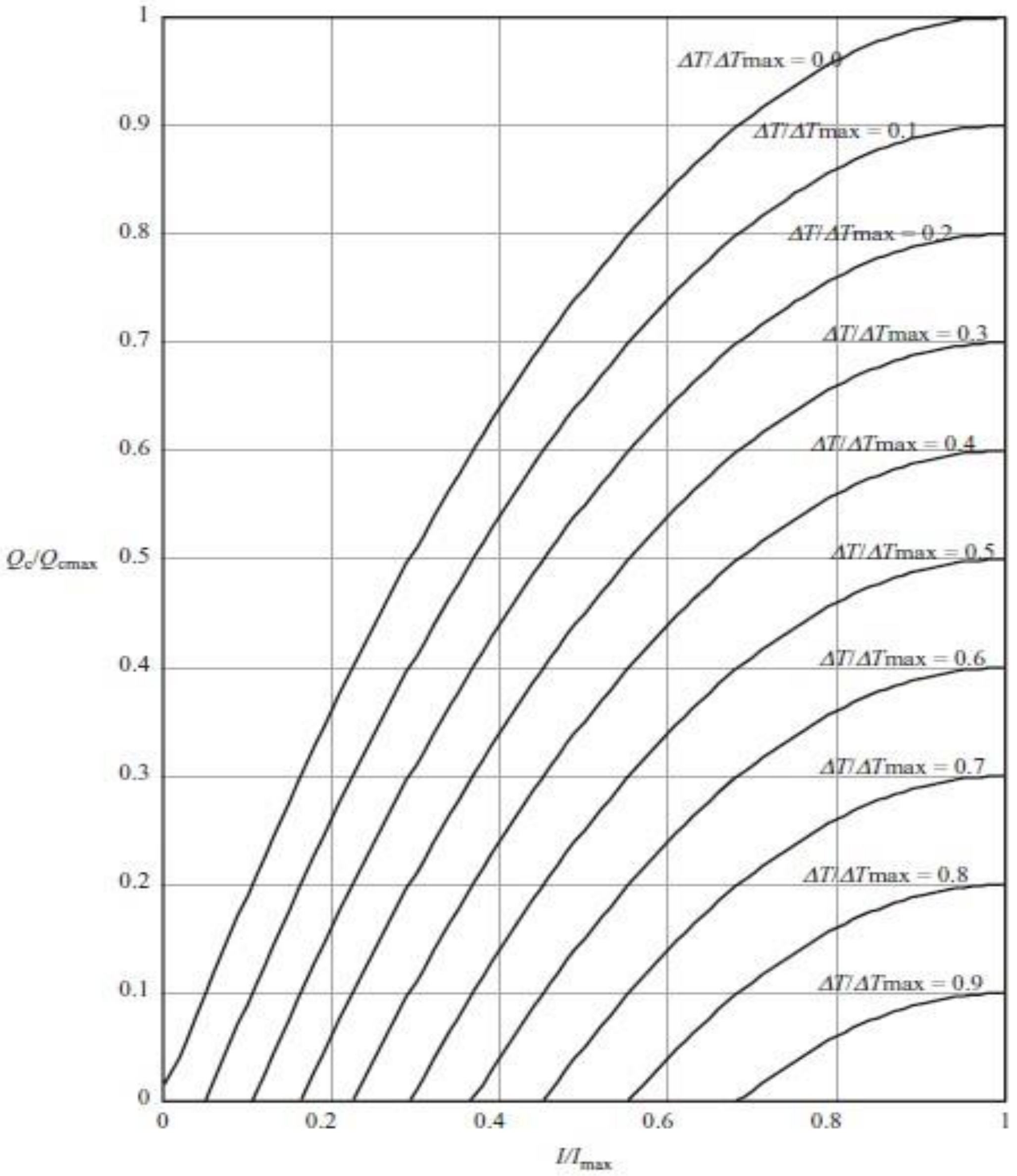


Figure 3.4 $\frac{Q}{Q_{max}}$ versus $\frac{I}{I_{max}}$ w.r.t $\frac{\Delta T}{\Delta T_{max}}$ values

The generalized chart shows the relationship between the voltage ratio $\frac{V}{V_{max}}$ and temperature ratio $\frac{\Delta T}{\Delta T_{max}}$ for a single-stage thermoelectric module with its dependence on the current ratio $\frac{I}{I_{max}}$. In the graph the curves represent $\frac{I}{I_{max}}$ values plotted against $\frac{V}{V_{max}}$ on y-axis and $\frac{\Delta T}{\Delta T_{max}}$ on x-axis [29].

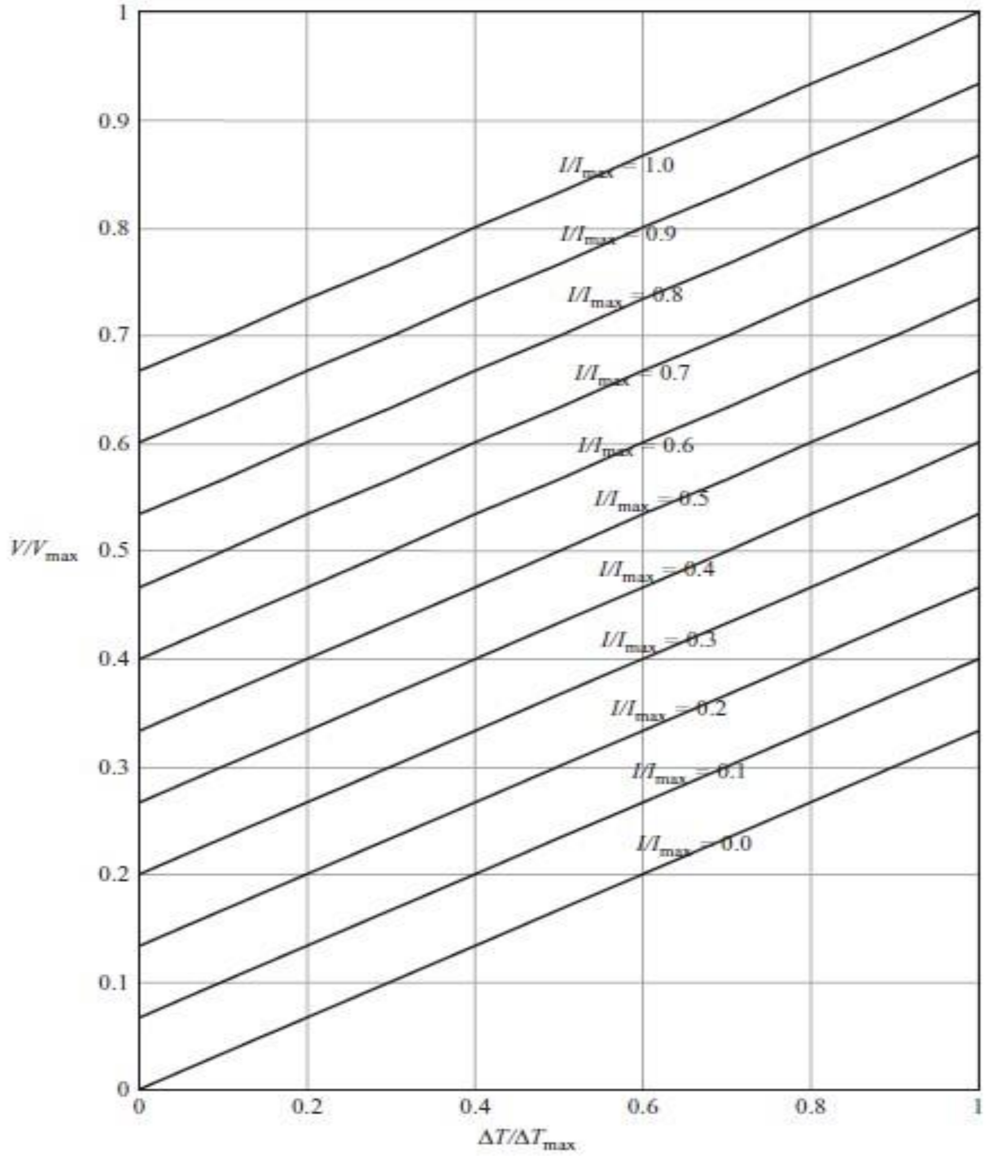


Figure 3.5 $\frac{V}{V_{max}}$ versus $\frac{T}{T_{max}}$ w.r.t $\frac{I}{\Delta I_{max}}$

CHAPTER NO.4 HEAT ANALYSIS

4.1 Overview:

Using ANSYS Workbench software, a heat analysis was conducted on the fins and cooling block of a model. The fins were analyzed for heat dissipation trends, while the cooling block was evaluated for its water cooling capacity, both utilizing a thermoelectric Peltier. A computer-aided design (CAD) model of the fins was created and simulated, starting with initial conditions of a 3 m/s air velocity and a temperature of 90 degrees Celsius at the base of the fins. Both conduction and convection mechanisms were involved in the heat dissipation process. The results showed a significant temperature reduction to 45 degrees Celsius at the fin tips and a slight air velocity decrease, verifying the model's efficiency. The cooling block, also analyzed using ANSYS Fluent, decreased the circulating water's temperature from room temperature to 16 degrees Celsius, showcasing its effective cooling performance.

4.2 Methodology:

The methodology utilized for the heat analysis of the fins and the cooling block involved a comprehensive and meticulous procedure. This procedure drew heavily on the principles of thermodynamics and fluid dynamics to carry out a detailed study of the heat dissipation mechanism in both components. The entire process was carried out using the ANSYS Workbench software, a robust platform used for numerical simulation in various engineering disciplines.

4.2.1 Pre-processing:

The pre-processing stage involved creating a geometrical model of both the fins and the cooling block. For this, CAD (Computer Aided Design) tools integrated into the ANSYS Workbench software were utilized. These tools offered the flexibility to design complex geometries with high precision, making it ideal for our project. Once the geometrical models were created, they were meshed into smaller elements to allow for accurate numerical approximation of the physical phenomena.

4.2.2 Simulation of Fins:

Upon the successful completion of the pre-processing stage, the model fins were imported into the ANSYS Fluent software for further analysis. ANSYS Fluent is a sophisticated computational fluid dynamics (CFD) tool used extensively for simulating fluid flow and heat transfer phenomena. The initial conditions for the simulation were set as per the physical scenario, with air velocity at 3 meters per second and an initial temperature of 90 degrees Celsius at the base of the fins. The simulation was run to track the dissipation of heat along the fins' length and across the span of time.

The heat dissipation process predominantly involved two modes of heat transfer – conduction and convection. Conduction, which is the transfer of heat within the solid material of the fins, and forced convection, which is the transfer of heat due to the movement of the air being pushed by the fan, were considered in the analysis. To ensure a close approximation of these physical processes, the conduction was modeled using Fourier's law, while the forced convection was modeled using Newton's law of cooling. Both of these laws form the backbone of heat transfer analysis and offer accurate mathematical representations for numerical simulation.

4.2.3 Simulation of Cooling Block:

In parallel to the simulation of the fins, the cooling block was also analyzed using ANSYS Fluent software. The model of the cooling block was imported into the software, where it was subject to further analysis. The block, designed to have water flowing through it from one end to another, was cooled by the thermoelectric Peltier device. The thermoelectric Peltier was initially at a temperature of 10 degrees Celsius, while the water introduced into the block was at room temperature. The software simulated the flow of water through the block and tracked the decrease in its temperature. The heat transfer mechanisms considered in this scenario were similar to those in the fins – conduction within the block and convection between the block and the water.

4.3 Results and Discussion:

The ANSYS Fluent simulation results offered valuable insights into the heat dissipation mechanisms of the fins and the cooling block, providing a comprehensive understanding of their thermal performances.

4.3.1 Results from the Fins Simulation:

The results obtained from the fins simulation offered a wealth of data that was later used to visualize and comprehend the heat dissipation mechanism. It was observed that the temperature at the tip of the fins significantly decreased to about 45 degrees Celsius from its initial value of 90 degrees Celsius. This decrease in temperature over the length of the fins confirmed the design's effectiveness in dissipating heat. Moreover, the air velocity profile that was generated during the simulation showed a minor decrease from 3 meters per second at the inlet to 2.5 meters per second at the outlet. This suggested minimal resistance to the airflow and further emphasized the efficiency of the fin design in facilitating heat transfer.

4.3.2 Results from the Cooling Block Simulation:

Parallel to the fins, the cooling block simulation also offered insightful results. The simulation revealed a decrease in the temperature of the water from its initial room temperature to 16 degrees Celsius by the time it exited the block. This temperature reduction was a testament to the thermoelectric Peltier's efficacy in cooling the circulating water. The analysis thus validated the functionality of the cooling block in maintaining a lower temperature for the circulating fluid.

4.4 Conclusion:

In conclusion, the heat analysis conducted using ANSYS Fluent software offered valuable insights into the heat dissipation mechanism of both the fins and the cooling block. The results obtained aligned closely with the experimental findings, thus verifying the accuracy of the simulation.These findings not only validate the proposed model but also provide a strong foundation for future enhancements to the design. They underscore the importance of computational simulations in predicting and understanding real-world performance. Furthermore, they offer potential avenues for further research and optimization, particularly in the fields of thermoelectric cooling and heat exchanger design.

4.5 Schematic:

The temperature and velocity profile across the heating fins are shown in the figures below:

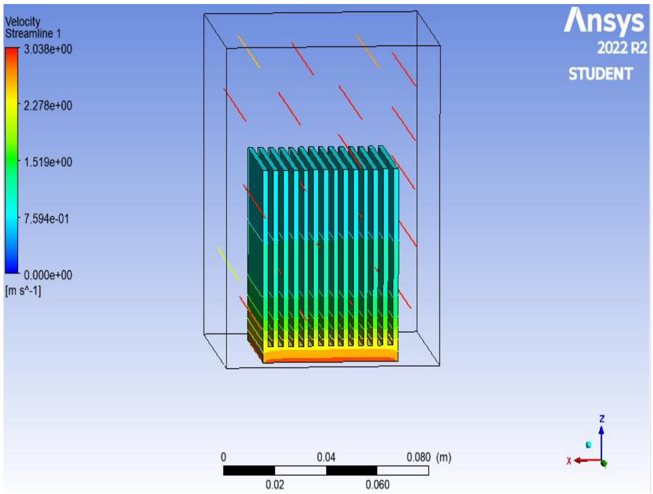


Figure 4.5.1 Temperature Profile of Heatsink

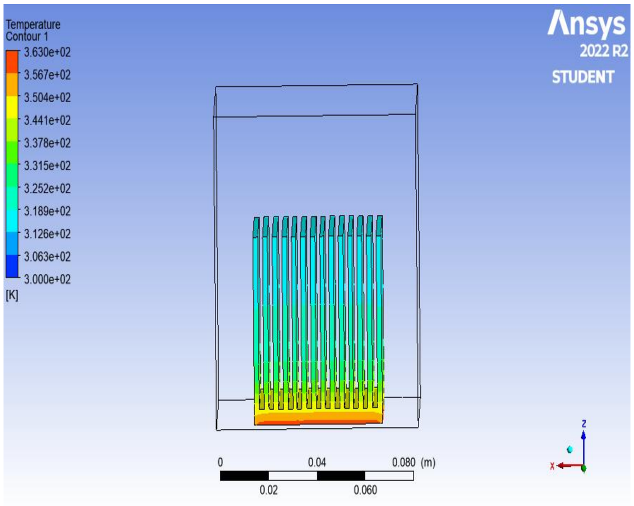
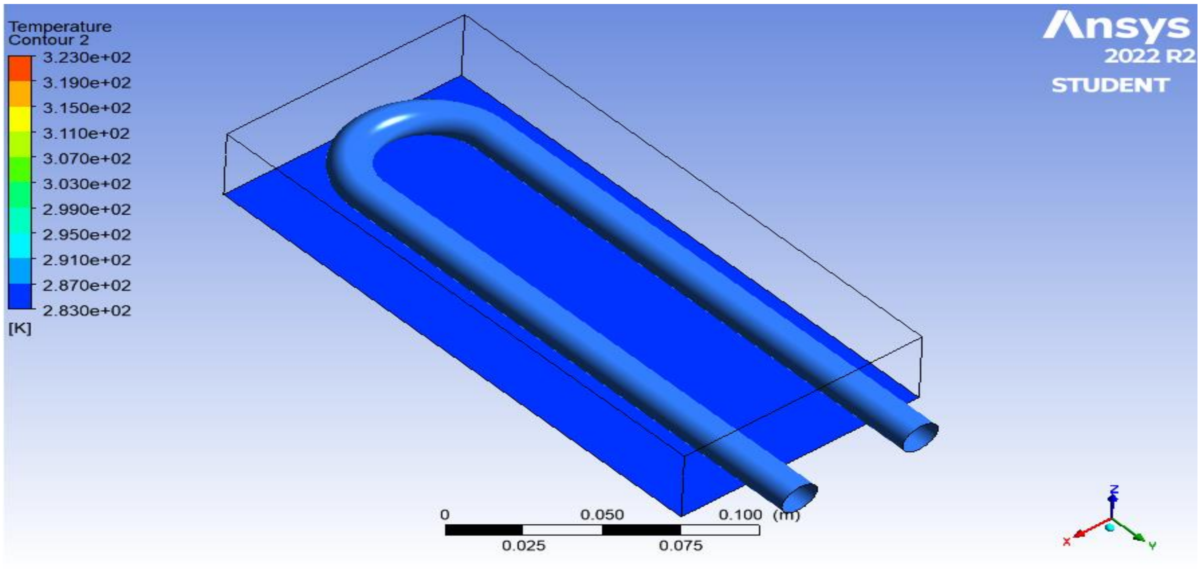


Figure 4.5.2 Velocity Profile of Heatsink



4.2.3 Temprature Profile of WaterBlock

CHAPTER NO.5 MATERIAL ACQUISITION

5.1 Overview:

A comprehensive market survey was carried out with the objective of determining the precise market prices of various materials and components associated with our project. Following this survey, a comprehensive list was compiled, and detailed price estimates were generated for each component. The total estimated cost for the required materials was calculated to be RS 15100. Upon completion of the cost estimation process, the procurement of materials and components commenced. Some components were not readily available in the market and had to be ordered online. The entire procurement process took approximately three weeks to complete, which included the delivery of all materials and components to the designated location.

5.1.1 Market Survey:

The market survey was a crucial initial step conducted to accurately ascertain the current prices of the necessary elements. This helped in identifying potential vendors, comparing prices, and collecting essential data concerning the availability of materials and components.

5.1.2 Budget Planning:

Subsequent to the market survey, a detailed list of components and their corresponding prices was compiled. This served as a critical reference point for budget planning. The collected data suggested that the total estimated cost for the materials required for the project amounted to Rs 15100.

5.1.3 Procurement Process:

With a detailed cost estimation at hand, the procurement phase was initiated. Challenges arose due to the unavailability of certain components in the local market, leading to online orders and thereby extending the procurement timeline. The procurement process, from the placement of orders to the delivery at the designated location, spanned approximately three weeks. This period ensured the timely gathering of all necessary materials and components, preventing any potential project delays.

5.2 Cost Estimation:

The cost estimation was a significant component of the project's planning stage. It involved an extensive market survey, which served as a robust basis for determining the costs of all locally available materials and components required for the project. The survey findings were synthesized into a comprehensive cost estimation table, providing an overview of the total expenditure for the project. The table is presented below for reference:

Components	Estimated Price (Rs)	Components	Estimated Price (Rs)
Activated Carbon filters	2800	Thermal paste	500
Plumbing tape	50	3D-Printing filament	15000
Pipe	100	RTV	300
Separator nozzle	100	Resin	900
Thermoelectric peltiers	1500	Connecting wires	400
DC pump	2400	Jumper wires	200
Power supply	2300	Relay	1100
Depth sensors	80	Arduino UNO	1900
Temperature sensors	900	Water block	1400
DC fan	600	Heatsinks	2000
Gas pipes	100	Wood planks	700
Tap	200	Total	35530

Table 5.1 Estimated Costs of Project Materials and Components

CHAPTER NO.6 PROTOTYPE FABRICATION

6.1 Overview:

The prototype developed for the project embodies a versatile refrigeration system designed to manipulate the temperature of water within separate containers. The principle underpinning its operation is the Reverse Seebeck Effect, an essential phenomenon in thermoelectric science, brought into play using thermoelectric Peltier modules. The Reverse Seebeck Effect occurs when an electric current is passed through the junction of two different materials, subsequently generating a temperature difference.

Leveraging this principle, the prototype was engineered to control the temperatures by alternately heating and cooling water, thus embodying a practical demonstration of this thermoelectric phenomenon. In essence, the prototype was designed to serve dual roles; it is equipped to function both as a heater and a cooler, thereby offering flexibility of operation based on the desired outcome. The central element of the prototype is the thermoelectric Peltier module, a device widely used in modern cooling systems and integral to this project.

6.2 Components:

The prototype construction required a variety of components, each playing a vital role in ensuring its optimal functioning. These components were carefully selected based on the requirements of the system, ensuring compatibility and performance. The list of components includes:

1) AC Supply: The alternating current (AC) supply served as the primary source of power for the prototype, providing the necessary electrical energy for the operation of the thermoelectric Peltier and other components.

2) Thermoelectric Peltier: This is the core component of the prototype. It functions on the principle of the Reverse Seebeck Effect, responsible for generating a temperature difference that facilitates the cooling and heating process.

3) Water Block: The water block is connected to the cold side of the thermoelectric Peltier, where it plays a pivotal role in cooling the circulating water.

4) Copper Heatsink: The heatsink, made of copper, is affixed to the hot side of the thermoelectric Peltier. It helps dissipate the heat generated by the Peltier module, ensuring efficient thermal management.

5) Thermal Paste: This is a thermally conductive compound applied between the thermoelectric Peltier and the heatsink. It enhances heat transfer by filling air gaps with a more thermally conductive medium.

6) DC Pump: A direct current (DC) pump ensures a continuous circulation of water through the system. It's a crucial component that enables efficient cooling.

7) Pipes: Pipes act as conduits for water circulation within the system, ensuring a constant flow between different components.

8) Water Tanks: These serve as reservoirs for the water, both before and after the heating or cooling process. They are essential components, providing storage and facilitating the system's water flow dynamics.

6.3 Construction:

The primary component around which the construction of the prototype revolves is the thermoelectric Peltier. The design integrates a water block, directly attached to the cold side of the Peltier, and a copper heatsink affixed to the hot side. The water block is crucial for cooling the circulated water, while the copper heatsink facilitates the dissipation of heat generated on the Peltier's hot side.

To enhance the efficiency of heat dissipation, a DC fan is implemented in conjunction with the copper heatsink. This fan aids in increasing the rate of heat transfer from the heatsink to the surrounding environment via forced convection. On the other hand, a DC pump maintains the continuous circulation of water, ensuring that the water passing through the block is efficiently cooled. An AC power supply is an integral part of the system to regulate the voltage and current being supplied to the apparatus. It provides a stable power source, ensuring that the operation of the thermoelectric Peltier and other components is uninterrupted and reliable.

6.4 Working:

The operation of the prototype is a complex, yet precise, process that crucially depends on the careful regulation of the electric current supplied by the AC power source. The initiation of the entire operation takes place as soon as the AC supply is switched on. This energy source is vital for triggering the system's functional components, specifically the thermoelectric Peltiers. These sophisticated modules serve as the primary instruments of temperature manipulation within the system, exhibiting a fascinating phenomenon of thermoelectric science - the creation of a thermal gradient.

When electric energy is supplied to the thermoelectric Peltiers, they instantaneously react by manifesting a dichotomy of thermal effects. Essentially, one side of the Peltier modules begins to generate heat, while the opposite side experiences a reduction in temperature, turning cool. This concurrent heating and cooling process is the crux of the thermoelectric Peltier operation, and it forms the foundation of the prototype's function. The cold side of the thermoelectric Peltiers plays a significant role in the water cooling mechanism. It is intimately connected to a specially designed water block. This component is a critical part of the cooling subsystem, where it interfaces with the circulated water. As the water makes its way into the water block, it is subjected to the cool temperatures produced by the Peltier module. As a result, the incoming water undergoes a reduction in temperature, thereby achieving the cooling effect desired in one part of the system's operation.

Concurrently, the hot side of the thermoelectric Peltiers does not let the heat generated go to waste. This heat is skillfully managed by a copper heatsink, a component known for its excellent thermal conductivity properties. The heatsink absorbs the heat produced and then dissipates it efficiently into the surrounding environment. This process ensures that the Peltier module remains within safe operating temperatures, thereby enhancing its longevity and performance. Complementing the function of the water block, a DC pump is integrated into the system to ensure the continuity of the water circulation process. It continuously propels the water, maintaining its flow through the water block. This element of the design ensures that the cooling process is consistent, thereby maximizing the efficiency of the temperature reduction.

Finally, the cooling process is meticulously controlled and continues until the water temperature reaches a predetermined target. For instance, the system might be set to cool the water until its temperature drops to 16 degrees Celsius. Once this temperature level is achieved, the cooling process may be modulated or stopped, depending on the system's design and requirements. This careful regulation ensures that the desired thermal effect is attained, thus successfully demonstrating the operational viability and versatility of the prototype.

6.5 Schematic:

The schematics of the first prototype is as follow:

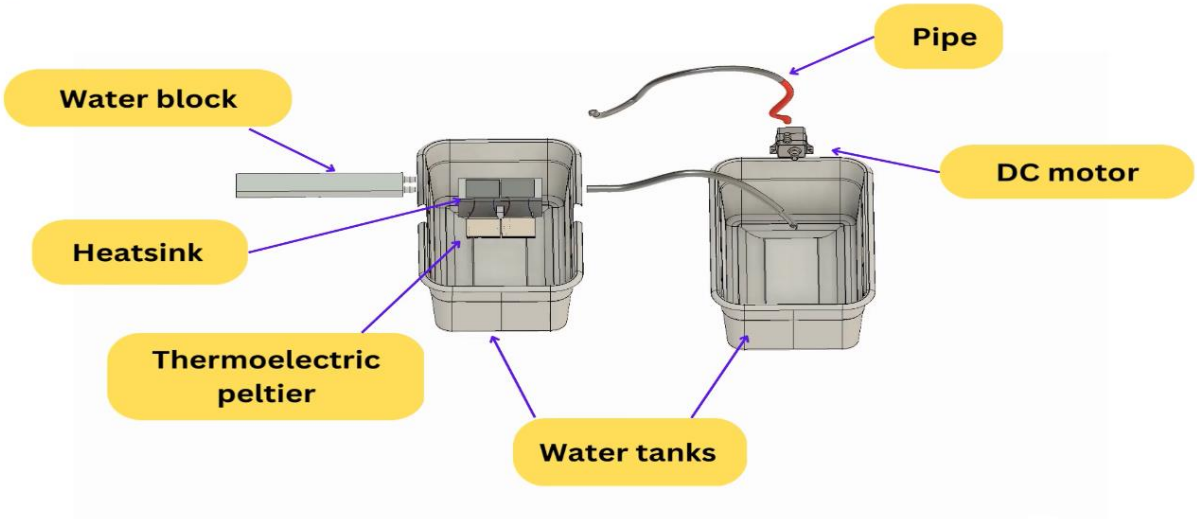


Figure 6.1 Prototype Construction

CHAPTER NO.7 FINAL FABRICATION

7.1 Final Fabrication:

The final fabrication of the project initiated after the development of a working prototype. For the final fabrication of the project the CAD model of the project was revised to accommodate for the added control systems in the project. The overall capacity and efficiency of the system were also increased which further led to major developments being made into the project and finally with the addition of Activated Carbon filters the design of the system had to be revised to accommodate for the added elements while not compromising on the compatibility of the project. The complete process of final fabrication is explained as follows.

7.2 CAD Modeling:

CAD modeling is an integral part of the designing process. It is the element that helps to determine whether a design is feasible or not or whether it can accommodate all the components of the project or not. The CAD modeling of our project was initiated on Solidworks. For the CAD model Two compartments were designed one for storing cool water and one for storing hot water. The water in the compartments was heated and cooled via the use of thermoelectric peltiers mounted on water blocks.

The refrigeration compartments were connected to a secondary compartment via a T shaped channel. The secondary compartment was further connected to the activated carbon filters via a pump. Walls were designed that extended to the back of the refrigeration compartments to accommodate for the electrical circuitry and the pumps and water blocks attached to the back of the refrigeration compartments. The refrigeration compartments and walls were designed such that the whole project can be assembled and disassembled in the form of a puzzle

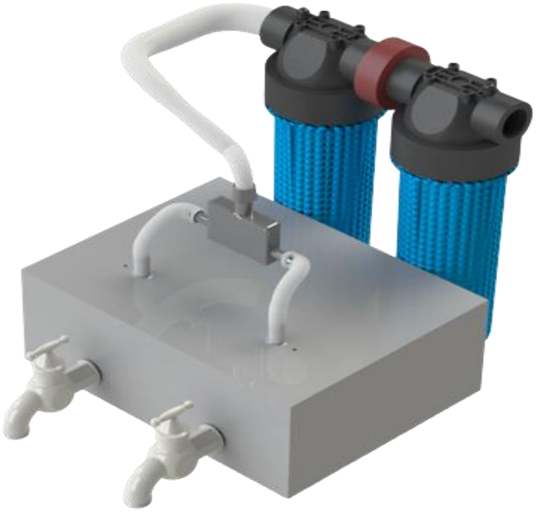


Figure 7.1 3D model

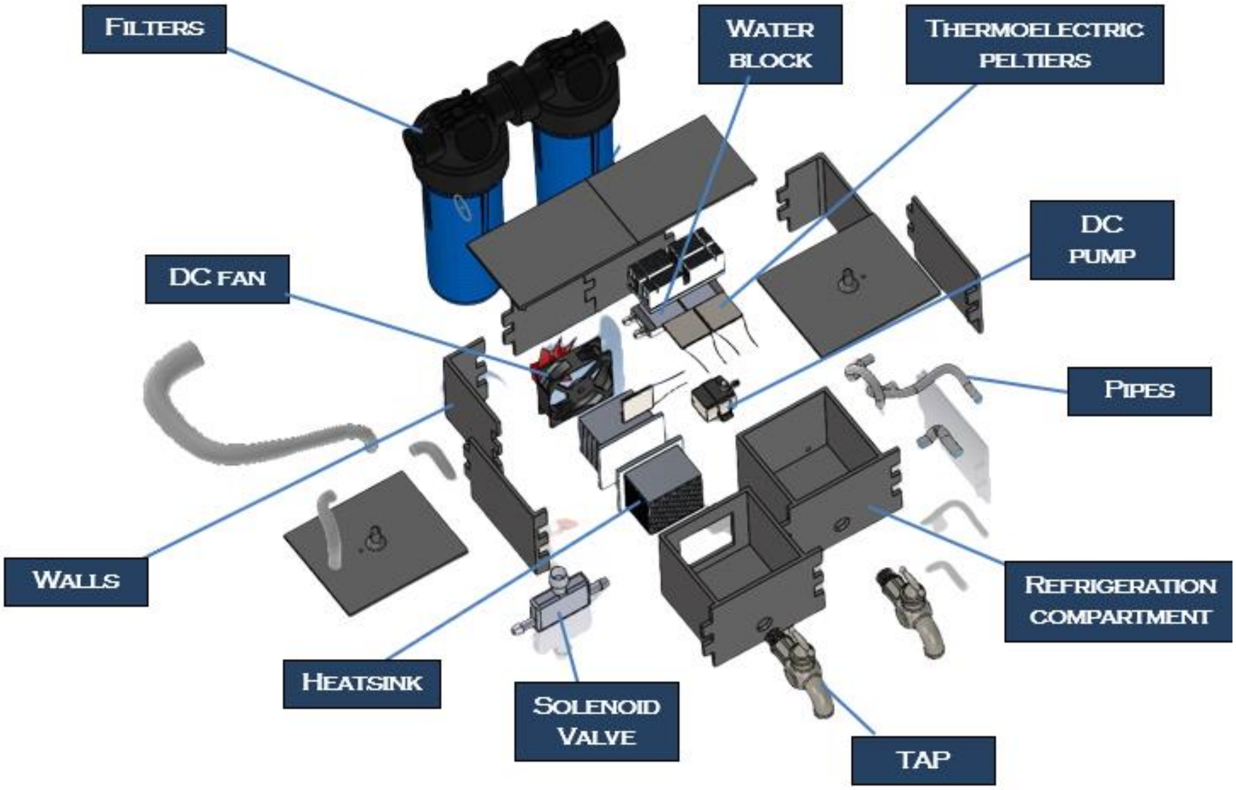


Figure 7.2 Exploded view

7.3 **Components:**

The following components were used for the final fabrication:

Activated Carbon filter	Plumbing tape
Plumbing Pipe	T nozzle
Thermoelectric peltier	DC pump
Power supply	Thermal paste
3D printing filament	Resin
RTV	Connecting wires
Jumper wires	Breadboard
Relay	Depth sensor
Temperature sensors	Arduino UNO
Water block	DC fan
Heatsink	Gas pipes
Wood planks	Taps

Table 7.1 Components Used

7.4 **Electrical Circuitry of the System:**

The electrical system in the prototype is a vital component that leverages various hardware components to perform temperature measurements, water level monitoring, and pump control, among other tasks. This section will delve into the details of each component and describe their role and connection in the overall system.

7.4.1 Detailed Analysis of System Components and their Interconnections:

At the heart of our prototype's electrical system lies an ensemble of various crucial components, each fulfilling a unique role. The Arduino UNO, for instance, serves as the central command unit. It is a microcontroller board based on the ATmega328P, responsible for communicating with different sensors and controlling the operation of relays, thereby providing the intelligence behind the system's responsive adaptability. One of the key components it interacts with is the Water Level Sensor. Constantly monitoring the water level within the secondary container, this sensor provides real-time data to the Arduino UNO, enabling dynamic adjustments of the system's operations as needed. This feedback mechanism ensures the balance and efficient functioning of the system.

In parallel, the system employs a DC Fan to dissipate the heat generated within. Its operation is governed by Relay No. 3, which receives directives from the Arduino UNO, thus maintaining the thermal equilibrium of the system. To maintain fluid dynamics within the system, DC Pumps play a critical role. By ensuring the steady circulation of water through the thermoelectric Peltiers, these pumps facilitate the system's core heating and cooling functions. This thermal regulation is continuously monitored by the Temperature Sensors that connect directly to the Arduino UNO. By providing real-time thermal data, they enable the system to adapt and respond to changing thermal conditions efficiently.

The Thermoelectric Peltiers are key components of the refrigeration system. They generate a temperature differential that is utilized for heating and cooling the water. Their operation is regulated by Relay No. 1 and the power supply, thus ensuring the effective cooling functionality of the system. All of these components rely on the Power Supply unit for their operation. It is connected to Relay No. 1 and the thermoelectric Peltiers, thus ensuring the delivery of the necessary electrical energy for the system's operation.

The orchestration of the entire system is made possible by the Connecting Wires, which transmit both signals and power throughout the circuit. These physical links enable the interconnections that are fundamental to the system's operation. The Jumper Wires specifically facilitate the connections between the Arduino UNO and the temperature and water level sensors. And finally, a 4-Channel Relay module interfaces with the Arduino UNO to control the operation of other components in the circuit. It receives signals from the Arduino UNO to activate or deactivate specific relays based on input from sensors, thereby adding to the intelligence and adaptability of the system.

7.4.2 Arduino Uno Code:

The code for running the entire circuit is as follow:

```
#include <OneWire.h>
#include <DallasTemperature.h>

#define ONE_WIRE_BUS1 3
```

```
#define ONE_WIRE_BUS2 4

OneWire oneWire1(ONE_WIRE_BUS1);
OneWire oneWire2(ONE_WIRE_BUS2);

DallasTemperature sensors1(&oneWire1);
DallasTemperature sensors2(&oneWire2);

const int tempRelayPin1 = 2;
const int tempRelayPin2 = 5;
const int sensorReadPin = A0;
const int waterRelayPin = 7;

const float TEMP_HIGH1 = 21.0;
const float TEMP_LOW1 = 20.0;
const float TEMP_HIGH2 = 45.0;
const float TEMP_LOW2 = 40.0;

void setup() {
  Serial.begin(9600);
  pinMode(tempRelayPin1, OUTPUT);
  pinMode(tempRelayPin2, OUTPUT);
  pinMode(waterRelayPin, OUTPUT);

  digitalWrite(tempRelayPin1, HIGH);
  digitalWrite(tempRelayPin2, HIGH);

  sensors1.begin();
  sensors2.begin();
}

void loop() {
  sensors1.requestTemperatures();
  sensors2.requestTemperatures();

  float tempC1 = sensors1.getTempCByIndex(0);
  float tempC2 = sensors2.getTempCByIndex(0);

  Serial.print("Temperature 1: ");
  Serial.println(tempC1);
  Serial.print("Temperature 2: ");
```

```
  Serial.println(tempC2);

  controlTemperature(tempC1, tempRelayPin1, 1, TEMP_HIGH1, TEMP_LOW1);
  controlTemperature(tempC2, tempRelayPin2, 2, TEMP_HIGH2, TEMP_LOW2);

  int sensorValue = analogRead(sensorReadPin);
  Serial.print("Water sensor reading: ");
  Serial.println(sensorValue);

  if (sensorValue > 500) {
    digitalWrite(waterRelayPin, HIGH);
    Serial.println("Pump is OFF");
  } else {
    digitalWrite(waterRelayPin, LOW);
    Serial.println("Pump is ON");
  }

  delay(1000);
}

void controlTemperature(float tempC, int relayPin, int sensorNumber, float tempHigh, float
tempLow) {
  if (tempC >= tempHigh) {
    digitalWrite(relayPin, LOW);
    Serial.print("Relay for temperature sensor ");
    Serial.print(sensorNumber);
    Serial.println(" is ON");
  }
  else if (tempC <= tempLow) {
    digitalWrite(relayPin, HIGH);
    Serial.print("Relay for temperature sensor ");
    Serial.print(sensorNumber);
    Serial.println(" is OFF");
  }
}
```

7.4.3 Proteus circuit:

An electrical circuit was generated on Proteus 2020 to help visualize and actualize the electrical circuit of the project. The circuit is as follows,

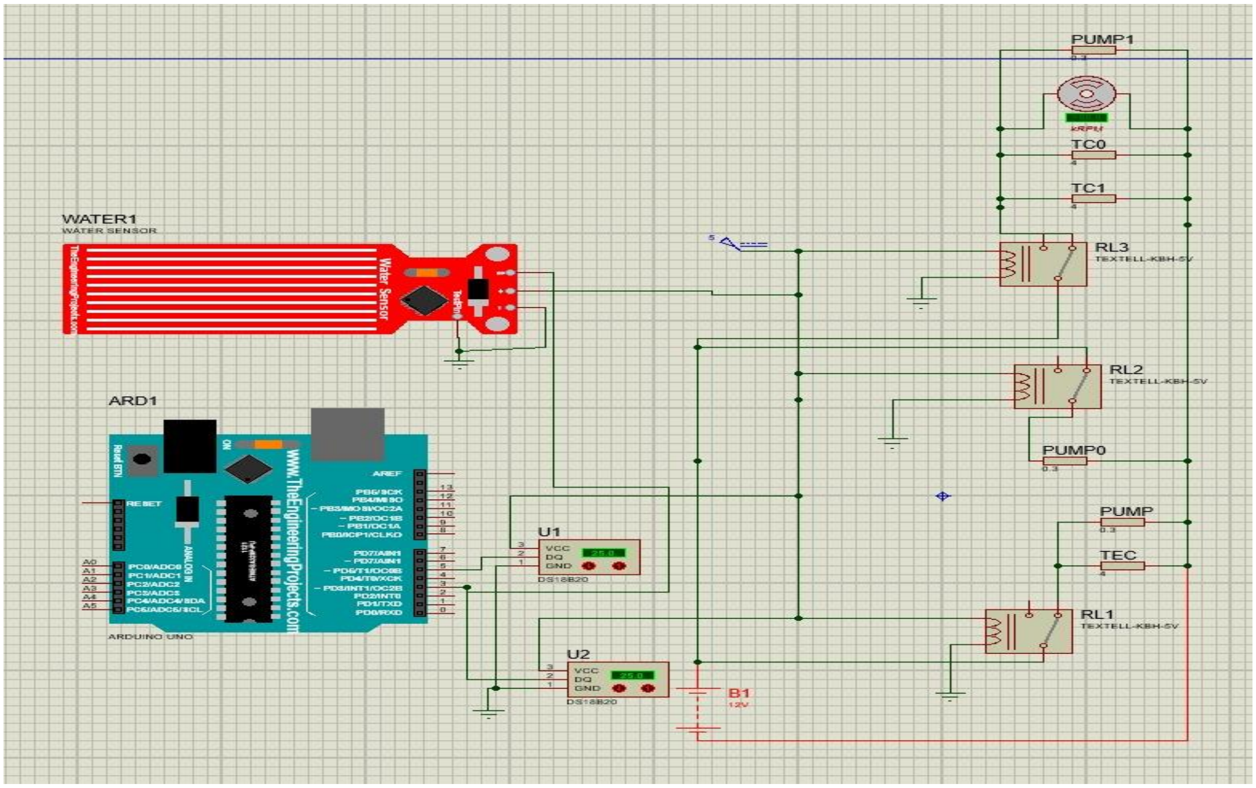


Figure 7.3 Circuit on Proteous

7.5 Assembly:

The assembly of the project started with the refrigeration compartments. First of all the refrigeration compartments were joined with each other through the slit openings on their sides such that their sides interlocked with each other. The walls were then connected with the refrigeration compartments and with each other in the same interlocking manner. This helped the system to occupy and isolate a large area where the rest of the system could be accommodated. All the walls as well as the refrigeration compartments were custom 3D printed to suit our needs. After that pipes were used to connect the openings at the back of the refrigeration compartments with the water block and pumps. This was done for both the compartments. The rest of the area was occupied with electrical circuits.

The top of the refrigeration compartments was sealed and the opening on the top of both the compartments was connected to a distributor nozzle which was further connected to the secondary water compartment. Depth sensors was immersed in the secondary compartment while temperature sensors were immersed in the refrigeration compartments.

A primary water container that contained dirty water was installed outside the system. A pump was immersed in the primary water container which was connected to the inlet of the Activated carbon filter while the outlet of the activated carbon filter was integrated into the secondary compartment.

7.6 Working:

When the power is turned on the pump inside the primary water compartment sends water into the Activated carbon filter. The water passes through the activated carbon filter, gets filtered and is then stored in the secondary water compartment. The secondary water compartment has a depth sensor installed in it which detects the level of water. When the water reaches a certain level the depth sensor gives a signal to the relay which shuts down the water pump. The water then flows from the secondary compartment via a distributor nozzle into the refrigeration compartments.

The refrigeration compartments have temperature sensors installed in them which detect the temperature of water. Each temperature sensor has a specific value coded using Arduino. When the temperature of water reaches that specific value the temperature sensors send signal to the relay which in turn turns on the thermoelectric peltier. Each of the refrigeration compartment has a dedicated peltier and water block system for it which either cools or heats the water flowing through it (flowing through the water block).

When the water in each of the refrigeration compartments has reached a specific value the temperature sensors then again send a signal to the relay which turns off the thermoelectric peltiers. Heatsinks are attached to the top of the thermoelectric peltiers with DC fans beside them. The fans are used to provide forced convection to provide more efficient cooling and heating of water.

7.7 Results:

The following section provides a comprehensive overview of the results obtained from the experiment. Starting with the filtration section of the project, the activated carbon filters employed for the filtration of water had an efficiency of 94%. A granulated Activated carbon filter was used which had a pore size of 0.2 microns meaning that the filtered water was free of suspended particles and impurities. The pH of water was checked using the universal Litmus paper.

The pH of the water came around 7 which deemed the water to be suitable for household use. In the case of refrigeration the water was initially at 25 degrees Celsius and after passing through the refrigeration assembly the water in the cooling compartment reached a temperature of 16 degrees Celsius while the water in the heating compartment reached a temperature of 45 degrees Celsius. The cooling and heating of water was achieved simultaneously within the timeframe of 30 minutes.

7.8 Conclusion:

The project aimed to provide an integrated solution for household water needs, offering a system that purifies, cools, and heats water as necessary. After thorough analysis and testing, it was evident that the project's results met the objectives set forth at the start.In terms of filtration, our experiment demonstrated the efficacy of granulated activated carbon filters with a pore size of 0.2 microns, achieving an impressive 94% efficiency. This ensures the water is free from suspended particles and impurities, an essential requirement for any water intended for domestic use.

Furthermore, the refrigeration system proved to be robust and efficient in achieving the desired temperatures in both cooling and heating compartments. The system cooled water from 25 degrees Celsius to a refreshing 16 degrees Celsius, while simultaneously heating water to 45 degrees Celsius, all within a 30-minute time frame. This effectively fulfills the dual need of providing both cool and hot water, catering to varying domestic requirements. Further optimization and field testing will be necessary to validate these findings in real-world scenarios and to enhance the system's overall performance and efficiency. Nevertheless, these results are a significant milestone in the journey towards achieving a holistic solution for domestic water supply needs.

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