



REPUBLIC OF TURKEY
ALTINBAŞ UNIVERSITY
Institute of Graduate Studies
Mechanical Engineering

**HEAT TRANSFER MODEL IN A HOT/COLD
FOOD CONTAINER USING PELTIER**

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Master's Thesis

Supervisor

Asst. Prof. Dr. Yaser ALAIWI

Istanbul, 2022

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2022

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ABSTRACT

HEAT TRANSFER MODEL IN A HOT / COLD FOOD CONTAINER USING PELTIER

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Date: 12 / 2022

Pages: 77

On a global scale it is considered that, a notable part of the overall electrical energy is consumed in refrigeration and air conditioning sectors. Refrigeration sector is also known as an important and critical industry in the field of food and pharmacy sectors. In general refrigeration and also freezing applications are based on the extracting thermal energy from the freezing or cooling medium to keep the temperature at the specified standard levels suitable for storage foods or medicines. Vapor compression refrigeration systems are mostly employed for cooling, heating and air conditioning purposes, but comparative investigations focused on thermoelectric devices and their efficiency with well-known vapor compression refrigeration systems are less regarded in the literature. In this study, Peltier thermoelectric performance was obtained in two different ways and the results were compared. First, the COP value was obtained when cooling was carried out in an insulated box and then in different mode, the heating of the box was carried out. It was observed a big difference between COP values of heating and cooling modes. According to the achieved experimental results of this study, the COP or coefficient of performance value in the heating mode is approximately 200% greater than that of cooling mode.

Keywords: COP, Energy Efficiency, Two Stage Thermoelectric Refrigerator.

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ABBREVIATIONS

CFM :	Cubic Feet Per Minute
COP :	Coefficient Of Performance
DC :	Direct Current
HVAC :	High Voltage Air Conditioning
IC :	Integrated Circuit
LED :	Light Emitting Diode
N- type :	Type Of Semiconductor With Electrons As A Majority Of Carriers Inside The Material
Nd:YAG :	Neodymium- YAG
P- type :	Type Of Semiconductor With Holes As A Majority Of Carriers
PCM :	Phase Change Material
PHE :	Plate Heat Exchanger
PV :	Photo Voltaic
R&AC :	Refrigeration And Air Conditioning
TE :	Thermoelectric
TEC :	Thermoelectric Cooler
TE-RAC :	Thermoelectric Radiant Air-Conditioning
TER :	Thermoelectric Refrigerator

LIST OF SYMBOLS

Bi_2Te_3 :	Bismuth telluride
T_{max} :	Maximum temperature
T_{min} :	Minimum temperature
ΔT :	Temperature variation rate with time
T_{O} :	Object temperature
T_{HS} :	Heat sink temperature
T_{amb} :	Ambient temperature
ΔT_{HS} :	Variation of heat sink temperature
dT :	Difference between t_o and t_{hs}

1. INTRODUCTION

1.1 INTRODUCTION

With the increase of technology and development, the needs of electrical strength for each day sports increased. Oppositely, the fossil gasoline used for generating power reducing rapidly. Besides, environmental pollutants additionally emerge as worse than before. Therefore, thermoelectric cloth has been studied widely. Thermoelectric involves strength conversion among thermal and electric strength, heating and cooling substances in addition to generates power.

Preserving medicine, sparkling meals and greens in appropriate and easy situations is a severe difficulty for human health. Generally, vapor compression cycles are used for cooling and heating programs in houses and industry. However, thermoelectric gadgets may be additionally hired to offer cooled and heated mediums, that's a critical opportunity for the vapor compression.

There is regularly want of heating and cooling of meals and tender beverages. Normally beverages are stored in a fridge for cooling and microwave warmers, resistance warmers and conventional fuel line burners are used for heating. During tenting or at far off web website online in which electric deliver isn't to be had it's far hard to apply such instruments.

Refrigeration and cooling of meals and liquids has emerged as a important want withinside the international today. Without right temperature control, sparkling meals will cross bad, beverages may be lukewarm, and those may be unhappy. For those reasons, whilst far from the home, coolers are very famous for maintaining meals and liquids cool at the cross. Whether being whilst out tenting, tailgating at a wearing event, or on an avenue experience in a car, humans will make use of coolers to preserve their meals and liquids at the precise favored temperature. This luxurious has emerge as predicted and part of regular life. One issue of those well-known coolers is that during fact they may be truly in reality suitable insulators, they do now not truly provide any cooling. Instead, ice is wanted to be positioned with in the cooler to kick back the food and drinks.

While this is typically on hand and cheap, it might be excellent if there were a way to kick back food and drinks without the need of ice. This is wherein a Thermoelectric Cooler (TEC) is beneficial. A TEC does now not require ice to kick back products but instead it cools the usage

of electric powered power. This application may want to allow for food and drinks to be cooled at any time while not having to rely upon ice. With simplest the requirement of electrical electricity, batteries may be taken for a decided quantity of time and the opportunity of cool meals and liquids is to be had everywhere at any time.

A transportable tool that is battery operated and has a choice to recharge the batteries with as an example sun electricity can be the first-rate solution for this form of situation. The Peltier impact is the presence of heating or cooling at an electrified junction of extraordinary conductors and is called after French physicist Jean Charles Athnase Peltier who found it in 1834. When a contemporary is made to go with the drift thru a junction among conductors, A and B, warmness can be generated or eliminated on the junction.

In thermoelectric materials, electric electricity may be at once transformed into thermal electricity and thermal electricity into electric electricity. Direct conversion among electric and thermal electricity is feasible due to crucial thermoelectric effects: the Seebeck impact and the Peltier impact.

The Seebeck impact refers to the life of an electric powered capability throughout a thermoelectric fabric challenge to a temperature gradient. The Peltier impact refers to the absorption of warmth into one stop of a thermoelectric fabric and the discharge of warmth from the other stop because of a contemporary go with the drift thru the fabric.

Thermoelectric modules use the versions with inside the electricity tiers of electrons to offer warmness switch. The electricity is carried through the contemporary among low electricity degree P-kind semiconductors and excessive energy level N-kind semiconductors from the bloodless floor to warm floor. The Peltier version is fabricated from a serial connection of P-kind and N-kind elements. The Peltier impact is produced while electric powered contemporary flows thru extraordinary forms of semiconductor metals. The contemporary begins off evolved to switch warmness from one facet to other. The bloodless facet of the Peltier module may be used as a cooler whilst the opposite facet will constantly warmness. It is crucial to chill the recent facet to keep away from the hazard of unfavorable itself. Therefore, the Peltier should be mixed with a cooler which includes warmness sink to deplete the warmth of the recent facet. The complete info of Peltier impact might be mentioned with inside the subsequent chapter.

Thermoelectric cooling, normally called cooling generation the use of thermoelectric coolers (TECs), has many blessings which includes:

- a. excessive reliability, no mechanical transferring parts, compact in length and mild in weight and no running fluid,
- b. Reduces using traditional refrigeration system, consequently, impact of pores and skin cancer, ozone depletion capability, and worldwide warming capability reduced.
- c. Thermoelectric cooling is a technique used for cooling reason in numerous applications, which includes:
- d. Cooling of electronic, optoelectronics, telecommunication and scientific equipment.
- e. Thermoelectric refrigeration and air conditioning (R&AC).
- f. Space cooling with use of Phase Change Material (PCM).
- g. Portable energetic sun molecular module.
- h. Industry: in extraordinary fields which includes (Food, Automobile, etc.).

In this work, a temperature-controlled device using Peltier effect is designed and implemented. The variations of temperature during the cooling and heating cycles were studied at different times with and without food. Cooling and heating of food using Peltier effect is experimentally tested using an insulated box.

1.2 BACKGROUND INFORMATION

Current energy conversion methods on Earth adversely affect the environment and lead to global warming. In the United States only, an average of 426 million metric tons of carbon dioxide (CO₂) was emitted per month during the year of 2017. This emission was primarily from nonrenewable energy sources including petroleum, coal, and natural gas, where these sources were 78.8% of the primary energy conversion processes [1]. If this issue is left unresolved, the atmospheric concentration of CO₂ can cause a significant impact on the climate and economy. Therefore, there is an increasing interest in incorporating the use of clean and renewable energy sources in energy conversion processes, such as solar, hydro-electric, biofuels, wind, and geothermal sources of energy. The focus on renewable energy, especially solar energy with particular research on fuel and commodity production, started to increase within the past decade.

In addition to reducing emissions of greenhouse gases, another major pressing need is to meet the expanding global energy demand. This is not only due to an increase in the population size, but is also due to an increase in the energy usage per capita [2]. Although solar energy is very promising to meet considerable amount of this demand, it is very intermittent and diffuse. Approximately 75,000 Terawatts of solar power from the sun reaches the Earth's surface [3]. Therefore, it is essential to develop new technologies to efficiently capture and store intermitted solar energy to achieve self-sustained energy economy. An example of a successful technology to capture solar energy is the implementation of photovoltaic (PV) panels for the direct generation of electricity. However, a large portion of the world's energy demand, especially at the industrial level, requires direct use of thermal energy. This is in addition to the efficiency challenges and high costs that can increase due to relatively long-term storage of electricity. Therefore, alternative uses of solar energy via concentrating solar power (CSP) applications and technologies offer promising pathways for industrial use of solar energy in processes in addition to power generation [4].

1.3 LITERATURE SURVEY

On a worldwide scale a critical a part of the electric power is eaten up in heating, refrigeration and air con sectors e.g., to hold meals and pharmacy in a right temperature. As a result, research on the sphere of heating and refrigeration are be counted with inside the literature wishes to be investigated.

Recently, Peltier impact has discovered many software fields and merchandise as an opportunity supply of power. There is much research targeted on Peltier impact in particular the thermoelectric gadgets and their overall performance to apply with inside the area of heating and refrigeration structures.

The Peltier impact literature survey with inside the following fields may be reviewed:

- a. Refrigeration and Air Conditioning (R&AC).
- b. Heating and Cooling.

Refrigeration and Air Conditioning:

Desai and Prasad defined the contemporary-day strategies of refrigeration and air con strategies which may be used for specific purposes.[3], reviewed specific programs of thermoelectric

power primarily based totally on Peltier impact. [4] wrote an assessment papers on thermoelectric air-conditioner the use of Peltier Module [1] [2].

Authors wrote an assessment approximately the current advances of the thermoelectric substances, modelling approaches, and programs. The improvement of thermoelectric substances has been given and the achievements in beyond decade were summarized. Finally, the thermoelectric cooling programs were reviewed in components of home refrigeration, digital cooling, medical software, and car air con and seat temperature control, with summaries for the commercially to be had thermoelectric modules and thermoelectric refrigerators [5] [6].

In addition, others supplied an experimental and numerical look at of a thermoelectric air-cooling and air-heating device. They have reached a cooling energy of 50W according to module, with a COP among 1. five and 2, through offering an electrical depth of 4A and preserving the five °C temperature distinction among the recent and bloodless sides [7]. In comparison performances of thermoelectric and traditional vapor compression air-conditioners. Results display that the real COPs of vapor compression and thermoelectric air-conditioners are with inside the variety of 2.6-3. zero and zero.38-zero.45, respectively. However, thermoelectric air conditioners have numerous positive capabilities in comparison to their vapour-compression counterparts [8].

In the same context a Numerical look at of Theoretical and experimental research of a thermoelectric cooling and heating device pushed through solar is Conducted. In summer, the thermoelectric tool works as a Peltier cooler whilst electric energy furnished through PV/T modules is implemented on it. The minimal temperature 17 diploma C is achieved, with COP of the thermoelectric tool better than zero.45. Then evaluating simulation end result and experimental data [9]. Further an experimental look at of comparative research of thermoelectric air conditioners as opposed to vapor compression and absorption air conditioners is conducted. Three varieties of home air conditioners are in comparison and compact air conditioner became fabricated [10].

Other authors are investigated a completely unique thermoelectric radiant air-conditioning tool (TE-RAC). The tool employs thermoelectric modules as radiant panels for indoor cooling, similarly to for vicinity heating thru without troubles reversing the input present day. Based on the assessment of a commercial thermoelectric module they have acquired a maximum cooling COP of 1.77 while utilising an electric powered present day of 1.2 A and keeping cold side temperature at 20°C [11]. Another study accomplished an experimental study of the COP with

inside the thermoelectric refrigeration through the optimization of heat dissipation. In thermoelectric refrigeration based totally absolutely on the principle of a thermosyphon with segment extrude is supplied. In the experimental optimization segment, a prototype of thermosyphon with a thermal resistance of 0.110 K/W has been developed, dissipating the warm temperature of a Peltier pellet with the size of 40*40*3.9 cm, experimentally proved that using thermosyphon with segment extrude will growth the coefficient of ordinary overall performance as an awful lot as 32% [12]. Further some researcher accomplished a study on reading thermoelectric refrigerator ordinary overall performance. The refrigeration tool of thermoelectric refrigerator (TER; 25 × 25 × 35 cm³) have become fabricated through using a thermoelectric cooler (TEC; 4 × 4 cm²) and applied electric powered strength of 40 W. The TER have become decreased from 30 °C to 20 °C for 1 hr and slowly reducing temperature for twenty-4 hrs. The maximum COP of TEC and TER were 3.0 and 0.65 [13]. In the same context some studies accomplished a numerical study of thermoelectric System. The thermoelectric systems have attracted renewed interest as problems with the inexperienced use of electricity resources, and the minimization of environmental damage, have end up essential present-day problems. This paper offers of numerical simulation for numerous the thermoelectric substances. Numerical simulation is accomplished with the aid of using the use of a finite detail bundle ANSYS [14] and others carried out an experimental research of thermal consolation have a take a observe of compact thermoelectric air conditioner [15].

In this paper examine the cooling overall performance of compact thermoelectric air-conditioner. TEC1-12708 kind thermoelectric modules used for heating and cooling application. The compact TE air conditioners COP turned into calculated to its best parameters. Then examine the cop with recognize to time and calculated cop at diverse considerations. An experimental carried out have a take a observe of thermoelectric air cooling for cars. They try to conquer those demerits with the aid of using changing the present HVAC device with newly rising thermoelectric couple or cooler which fits on peltier and seebeck impact [16] and other provided an experimental overall performance evaluation of mini channel water cooled-thermoelectric fridge. The cooling device of fridge is consisted of thermoelectric modules incorporated with the mini channel warmness sinks in its warm facet and the warmth dissipaters in its bloodless facet [17].

Their experiments accomplished for one-of-a-kind device voltages and one-of-a-kind float quotes of cooling water with inside the mini channel. They determined the internal temperature of water cooled-thermoelectric fridge is set 2 °C for 0.8 L/min float price whilst it's miles about

-0.1 °C for 1.5 L/min flow rate on the give up of 2-h experiment. They concluded that the overall performance of mini channel warmness sink used is ideal as different liquid water-cooled structures used to soak up warmness from thermoelectric modules warm facet. In addition a new study provided blended experimental and theoretical have a take a observe of thermoelectric substances and application [18].

The gift has a take a observe develops an optimization layout technique for thermoelectric fridge. This tool is fabricated with the aid of using combining the usual n- and p-channel solid-country thermoelectric cooler with a -detail tool inserted into every of the 2 channels to put off the solid-country thermal conductivity. Another experimental is carried out have a take a observe of layout technique of thermoelectric cooler. They are fabricated the thermoelectric cooler and examine diverse considerations. The device simulation suggests that there exists a most inexpensive warmness sink for the layout of a thermoelectric cooler [19]. It is likewise proven that the device simulation coincides with experimental information of a thermoelectric cooler [20] provided an experimental have a take a observe of novel capability inexperienced refrigeration and air-conditioning era. They are analysing the purpose and impact of a current air-situation device.

Thermoelectric cooling affords a promising opportunity R&AC era because of their awesome advantages. The to be had literature suggests that thermoelectric cooling structures are commonly handiest round five–15% as green as compared to 40–60 achieved with the aid of using the traditional compression cooling device. Further a brand-new concept has been used in Peltier module. They are used the Peltier module with water blocks (as proven in Fig. 1.1) in place of the Aluminium warmness sink (fins). They used three layers concept i.e., Iron casing, Thermocol insulation and Aluminum cabin which acts as a cooling chamber. This is to increase the system efficiency [21].

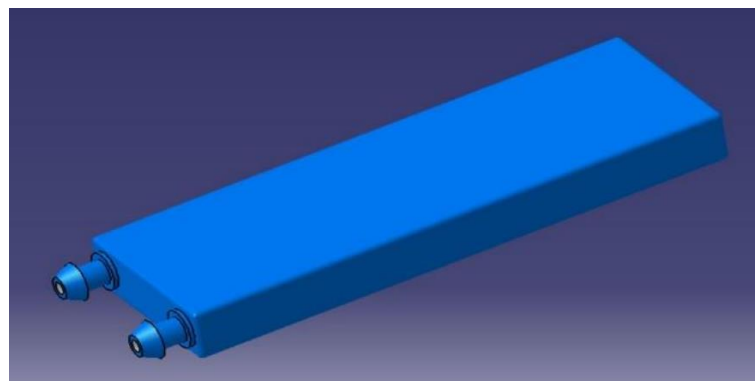


Figure 1.1: Water blocks.

In the same context, a theoretical and experimental have been performed evaluation of a thermoelectric air con gadget. They constructed a prototype thermoelectric air conditioner of 286 W cooling capability with a checking out enclosure crafted from plywood and Styrofoam. They located that thermoelectric air con took four mins to attain its favored temperature of 22°C while the usual air con gadget (Refrigeration Cycle) took 20 mins to chill to a room temperature. Economically it became additionally located that thermoelectric air con gadget is 50% less expensive than the refrigeration cycle air con systems [22]. Some other study designed and built a transportable mini thermoelectric fridge pushed via way of means of a Peltier detail. The Peltier detail mixed with fanatics on each facet is set up onto a fridge box. He finished the optimization for the working situations of the thermoelectric fridge. The working situations of the gadget are the ambient temperature and voltages of the fanatics and Peltier detail. Performance evaluation for the most fulfilling situations received is presented. His proposed thermoelectric fridge can be used to hold drinks, meals or drug treatments sparkling and cool [23]. In addition, authors designed and simulated new answers with thermoelectric fridges in humanitarian and refugees' camps, to provide a good enough fine of lifestyles to human beings dwelling in emergency situations wherein electricity deliver may be very essential to stand with the principal issues regarding meals cooking and meals preservation [24].

Furthermore, thermoelectric fridges may be utilized in any position, do now no longer rely upon a circulating refrigerant fluid, and aren't touchy to mechanical vibrations. These homes are beneficial for brief installations that need to be moved from time to time. They studied the electric traits of a thermoelectric fridge linked to the strength grid in a microgrid-like installation. A brand-new air con ceiling fan module have been proposed which has addition of thermal effects. This invention is thermal enhancement in operating of ceiling fan. The air circumstance ceiling fan include thermoelectric module which paintings on D.C deliver [25].

They were given 6-7 °C inside 15 min much less than traditional ceiling fan. Also, they introduced moisture manage components to obtain higher air [26] carried out a brand-new idea in Automobile industry. It is the concept of Engine Cooling and Pre-Heating of Fuel the use of Peltier Element. This gadget isn't always a present gadget and is absolutely a completely new idea with inside the subject of engine cooling. He extended the cooling performance of an engine. A refrigeration chamber has been designed and fabricated via way of means of the use

of Peltier modules. The evolved module became experimentally examined and simulated with Spice software program [27].

The theoretical and experimental outcomes are compatible. A fridge jacket (the use of Peltier impact) has been designed and fabricated which goes in line with the atmospheric situations. It offers a quantity of heat to the human frame whilst the ecosystem is cooler than the desired circumstance [28]. In the same context a transportable air con gadget has been involved the use of Peltier thermoelectric warmness pump to provide the cool air. They used Peltier and Seebeck Effects. Three volumes had been used with inside the experiments: 1000,4000, and 9000 cm³. Seebeck impact became used to provide a voltage of round 12 V in 30 mins. The heating and cooling temperatures performed with inside the gadget became (16 – 40 °C). [30] designed and carried out a compressor much less Peltier fridge with inner quantity of 3045 m³. One litre of water became cooled to a temperature of (-5) °C [29]. Another thermoelectric cooler has been designed with excessive performance. He utilized in his layout a segment alternate fabric to differentiate it from its opposition and permit for advanced cooling and performance [31].

The layout can even function vacuum-sealed chambers to offer excellent insulation and permit for most reliable cooling for lengthy periods. The cooler on this file became capable of cool up 14 cans of soda from 25 °C to 12 °C in about 86 mins given a regular 12 V strength deliver. Two different methods were used to check Peltier thermoelectric performance. The first is to obtain the COP at cooling cycle. The second cycle is the heating. He found that the COP value in the heating mode is about 200% greater than that at cooling mode.

A thermoelectric cooling (TEC) module is designed and implemented of a thermoelectric cooling (TEC) module using bulk thermoelectric materials. The TEC system has been integrated into a closed-loop water circulation system. A heat removal rate of 160 W was achieved during firefighter cooling and about 250 W during the environmental tests [33].

In the field of air-conditioning, "Many studies investigated the thermoelectric air-cooling module for electronic devices. They examined experimentally the effects of heat load of heater and input current to thermoelectric cooler. Also, they developed a theoretical model of thermal analogy network to predict the thermal performance of the thermoelectric air-cooling module. At a specific heat load, the thermoelectric air-cooling module reaches the best cooling performance at an optimum input current [34]. Author studies tried to increase the performance coefficient of Peltier Module using different techniques. The efficiency of TEC cooperation is low compared to the air-cooled air cooler used today but with advanced production techniques

and forced delivery of cold liquid that increase effective device cooling and humidity control using humidity suction and capillary tube as a heat sink to reduce heat in the hot sink instead of air fin to reduce the surrounding heat radiation they hope to get a better COP [35].

In other hand, the studies in the literature focused on simulation of a thermoelectric refrigerator maintained at 4°C. They simulate the performance of the refrigerator using MATLAB under varying operating conditions. Their results showed that (COP) is a function of the temperature between the source and sink. For maximum efficiency the temperature difference should be kept to the minimum [36].

Some authors gave a brief introduction of thermoelectricity, principal of thermoelectric cooling, thermoelectric materials, and cost- effective of this technology. The research and development work carried out by different researchers on development of novel thermoelectric R&AC system has been thoroughly reviewed. They calculated the COP of their thermoelectric refrigeration cabinet was 0.1 [37]. In the same time another study designed and implemented a thermoelectric refrigerator using “Peltier” modules to produce cooling or heating. Also, they simulated their work. They used two different thermoelectric materials: Bismuth telluride (Bi_2Te_3) and Antimony telluride (Sb_2Te_3). The first is performed better as compared to the second due to its low thermal conductivity [38].

1.3.1 Principle of Heat Transfer

Heat transfer analysis is highly necessary to operate different mechanisms like Convection, Conduction and Radiation. The principals of heat transfer were followed while designing of heat exchangers and energy conversion systems. For our thesis, we have considered the basic principles of heat transfer and some simple applications. Conduction is a type of heat transfer mode in which heat is transferred in the opaque solid medium under a certain temperature gradient, that exists in the particular body. In general, heat is transferred from the high-temperature region to the lower temperature region. The rate at which heat is transferred through conduction is proportional to the temperature gradient times the area through which the heat is transferred.

In general, heat transfer applications are divided into three types namely - dimensional, Two-dimensional, and Three-dimensional, on basis of relative magnitudes of heat transfer in two different directions. In the general case, the temperature distribution along the medium at a certain time and heat transfer rate at a specific location can be termed in three coordinate

systems namely x,y,z in a rectangle. Whereas, in a polar coordinate system the cylindrical coordinates at time and location are specified as r,ψ and z . The rate of heat conduction along with the specific medium in a specific direction is proportional to the temperature difference across the medium and the area perpendicular to the direction of heat transfer, but inversely proportional to the distance in the direction.

1.3.2 Heating and Cooling

At the first, authors studied the cooling and heating the usage of Peltier module. Also, she investigated a passive era primarily based totally on integration of a thermal diode and thermoelectric modules for constructing included warmth pump. The warmth pump uses thermoelectric modules to provide cooling or heating, and the thermal diode to transfer warmth in or out of the constructing and save you opposite warmth go with the drift with inside the occasion of power failure. She investigated the capacity software of segment extrude substances (PCMs) to improve the overall performance of a thermoelectric fridge in addition to the cooling storage capability [39]. Another paper maximized the cooling energy of a TEC and studied its impact with appreciate to versions with inside the TE geometry. She evolved a 1D analytical version the usage of Math CAD and a three-D version of the equal has been numerically simulated the usage of ANSYS software. She observed that cooling energy of the TEC may be dramatically progressed at low leg lengths and with higher warmth sink material [40].

In addition another studies designed and fabricate a modified TEC gadget to settle down the temperature of a Pulsed Mode 1064 nm Diode Pumped Nd:YAG Laser. He discovered that the laser diode can feature longer even as copper warm temperature sink is used in preference to the aluminum one [41].

In the same context some study used techniques to settle down the temperature of the brand-new spots with inside the protected circuit (IC) chip. The first is the silicon micro cooler with a protected SiGe super lattice layer. The 2nd is the mini contact advanced conventional thermoelectric cooler (TEC). Others proposed a thermoelectric cooling based dental pulp finding out device capable of reaching cryogenic temperatures and varying this temperature below 0°C as plenty as -60°C . He explored the software program of the phase extrude cooling method withinside the form of heat pipes and vapor chambers. He significantly applied simulation in COMSOL Multiphysics software program [42]. In addition, some projects

investigated the feasibility and general overall performance of a transverse thermoelectric device constructed from commercial enterprise thermoelectric materials from Marlow, Inc., to be applied in commercial enterprise applications [44]. Further, an experimentally, analytically, and thermally an energetic cooling approach for three-dimensional protected circuits the usage of a multidimensional configured thermoelectric cooler is investigated. This is to overcome the non-uniform warm temperature dissipation of three-D-IC [45].

[46], succeeded for the number one time in adapting the Peltier principle for extra powerful laboratory appliances, and then heating and cooling them with a single gadget with an interior volume of as plenty as 2140 L, which might be cooled and heated with Peltier technology with inside the temperature range amongst 0 and 70 °C.C. [47] designed a self-regulating heating/cooling blanket the usage of Peltier impact wished in hospitals to continuously display hyper/hypothermic sufferers whilst looking to go back a patient's middle frame temperature to secure value. it's far a reasonably priced and smaller opportunity to the huge high-priced applications which might be available.

Other studies, wrote a evaluate paper approximately the latest advances of thermoelectric materials, modelling approaches, and applications. The modelling strategies had been additionally defined for each the thermoelement modelling and thermoelectric cooler (TEC) modelling such as preferred simplified electricity equilibrium model, one-dimensional and 3-dimensional models, and numerical compact model. [49] invented a sporting apparel that's appropriate to chill or heat the human frame in line with its temperature. It is beneficial in unique seasons and places. [50], carried out a picture graph voltaic pushed cooling and heating system. Refrigerator jacket works in line with the atmospheric conditions, Fig. (1.2). If the surroundings is cooler than the desired condition, then it offers the quantity of warmth to the human frame, without inflicting any aspect consequences and vice versa [48].

In the same context some papers, analyzed warmth switch traits with inside the plate warmth exchangers (PHE) experimentally and numerically. Design /methodology /method Computational fluid dynamics evaluation has been used to simulate the trouble with the aid of using the usage of the ANSYS fluent sixteen software program. Also, he investigated the impact of the usage of TiO₂/water Nano fluid as operating fluid. His outcomes confirmed that using TiO₂/water Nano fluid improved the overall heat transfer coefficient averagely as 6%, whereas maximum improvement in overall heat transfer coefficient was 10% [51].

Further, a portable cold and hot tumbler with volume of around 300 cc which depends on Peltier module are designed. The achieved cooling temperature was up to 20 °C for 30 minutes. A temperature of 60 °C is reached to heat a soft drink can of water /tea/coffee. [53] Designed and Manufactured a thermoelectric refrigerator working on Peltier effect. Their objective is to maintain food at 40°C and to reduce the water temperature by 5°C. They noticed that temperature is maintained between 25 to 45 °C.

In addition, a thermoelectric refrigerator by using of thermoelectric modules to lower the temperature of an insulated chamber is fabricated. He found out that in the absence of cold plate (heat sink), the convective heat transfer is very low even when he installs a fan. Only a temperature of 1 °C is obtained at middle portion of chamber and a difference of about 10°C is obtained near the surface of the module, regardless of the time [54].

1.4 AIM OF THE WORK

The major purpose of this studies is to layout and put in force a check heating and cooling insulated container the use of Peltier thermoelectric impact. Then a calculation of variant of heating and cooling parameters must be done.

1.5 THESIS LAYOUT

This thesis is split into 5 chapters:

Chapter One offers the overall advent approximately thermoelectric warmness transfer. Also, it consists of a literature survey approximately Peltier impact applications.

Chapter Two offers the theoretical history of Peltier impact all through cooling and heating cycles.

Chapter Three offers complete research to layout a compact and low fee insulating container with the opposite additives of the Peltier module required with inside the heating and cooling cycles.

Chapter Four offers the consequences received with the dialogue of all the experimental steps: cooling, heating, with and without meals in the insulating container.

Chapter Five offers the principal conclusions drawn from this look at and offers tips for destiny work.

2. THEORETICAL BACKGROUND

2.1 INTRODUCTION

In this bankruptcy the theoretical history of the heating and cooling the use of Peltier impact may be discussed. This will encompass the concept of Peltier module shape and the way the warmth switch inside.

2.2 THERMOELECTRIC (PELTIER) EFFECT

A thermoelectric cooler is a form of insulated cooler that makes use of the electric strength among the junction of substances to reason a temperature drop. These coolers function the use of the Peltier impact. The Peltier impact states that there's a presence of heating or cooling at an electrified junction of exceptional conductors. Jean Charles Athanase Peltier located this impact in 1834 and it's far nonetheless being researched.

As a cutting-edge is flowing via a junction of conductors, warmth may be created or dissipated on the junction. The Peltier impact can display the quantity of warmth created or eliminated in step with unit time. It is beneficial in knowledge how lots of warmth is carried in step with unit charge. The Peltier impact is frequently taken into consideration the back-movement counterpart to the Seebeck impact.

The Seebeck impact is the conversion of warmth at once into power on the junction of conductors. As the Seebeck impact is conversion of warmth at once into power, via the Peltier impact, power can create or do away with warmth. Also called a Peltier cooler, a thermoelectric cooler is a solid-country energetic warmth pump that transfers warmth from one facet of the tool to the opposite whilst ingesting electric energy. TECs are lots much less typically used than conventional vapor-compression refrigeration for cooling. However, TECs do have some blessings over vapor-compression refrigeration such as: they haven't any transferring components or circulating liquid, offer excellent longevity, are invulnerable to leaks, and are small.

The negative aspects of TECs are their excessive fee and terrible strength performance. Figure (2.1) describes an average TEC that it's far an item with aspects which can be each conductor. DC cutting-edge is dispatched via the item, bringing warmth from one facet to the opposite. The hotter facet is attached to a warmth sink inflicting it to live close to ambient temperature. This switch of warmth reasons the cooler facet to drop beneath room temperature and may be

used as a cooler. As proven in Fig. (2.1) the 2 semiconductors, one n-kind and one p-kind as it's far necessary, they have got exceptional electron densities. These semiconductors are located such that they're thermally in parallel and electrically in collection with every other. A voltage is implemented to the open ends of the semiconductors inflicting a glide of DC cutting-edge over the junction of the semiconductors ensuing in a temperature difference.

The cooling plate absorbs warmth and actions it to the opposite facet of the TEC in which the warmth sink is. A not unusual place exercise is to attach TEC facet through facet and placed them among ceramic four plates. Advantages of TECs are that they have got no transferring components and require rare maintenance, they do now no longer use chlorofluorocarbons, they have got very correct temperature control, they may be utilized in environments wherein conventional fridges cannot, and they're controllable through converting the enter voltage or cutting-edge. While those blessings make TEC favorable in lots of situations, the shortcomings concerning heating and cooling overall performance nonetheless makes TECs now no longer the maximum feasible solution. When the use of TECs, there's handiest a restricted quantity of warmth flux that may be dissipated. Also, in assessment to standard cooling systems, vapor-compression, TECs aren't almost as green.

TECs offer a performance of (10-15%) of the appropriate Carnot cycle fridge as compared to the (40-60%) of conventional refrigeration cycles (Rankine cycles the use of compression and expansion). Because of those performance differences, TECs are commonly handiest observed in software in times wherein the character of the cooler (low maintenance, no transferring components, and compact size) is desired over natural performance.

One problem with TECs is that the greater warmth they generated through Joule, the much less green they become. The quantity of warmth that may be absorbed may be decided through:

$$Q = Pit \dots\dots\dots (2.1)$$

Where, P is the Peltier Coefficient, I is the cutting-edge, and t : is the time.

The Peltier Coefficient is decided through the ambient temperature and the substances that the TEC is fabricated from in addition to the warmth switch overall performance, the Peltier module geometry, and Peltier electric parameters. Selection of substances for the perimeters of the TEC are depending on their thermoelectric capabilities. The semiconductors ought to have slim band-gaps due to the fact they function in room temperature conditions. Materials which can be heavy and feature excessive mobility with low thermal conductivity are ideal. The

maximum not unusual place thermoelectric cloth used presently is bismuth telluride with lead telluride and silicon germanium additionally being used.

2.3 ADVANTAGES AND APPLICATIONS OF THERMOELECTRIC EFFECT

Advantages:

Thermoelectric modules have many benefits:

- a) No transferring parts – truly renovation free.
- b) small size – a whole lot smaller than conventional cooling.
- c) Can cool under ambient – higher than conventional warmth sink.
- d) Can warmth and funky with equal module – switching polarity of DC strength enter can extrude among heating and cooling.
- e) Temperature Control – can manage temperature through voltage and modern enter.
- f) Very Reliable – stable kingdom production can result in lifestyles of over 200,000 hours.
- g) Quiet – makes no noise throughout operation.
- h) Orientation independent – may be used even in non-gravity environments.
- i) Environmentally Friendly – does now no longer generate any gases.
- j) Can generate electric strength – going for walks procedure in opposite will generate DC strength.

Disadvantages:

- a) Able to deplete restrained quantity of warmth flux.
- b) Lower coefficient of overall performance than vapor-compression systems.
- c) Suitable to low warmth flux applications.

Applications:

On an business degree, this sort of a setup is used broadly with inside the area of:

- a. Electronic,

- b. Optoelectronic,
- c. Medical,
- d. Aerospace,
- e. Telecommunications,
- f. Food enterprise and
- g. Automobile enterprise.

2.4 PELTIER TYPES AND SPECIFICATIONS

There are exceptional varieties of Peltier modules in keeping with the producer and software. Figure. (2.2) suggests a different form of Peltier Modules for a exceptional producer. In this paintings varieties of Peltier modules are used.

The complete specification of the 2 Peltier modules which might be used (Type-1: TEC1-12704 and Type -2: SP 1848 /27145 SA) on these paintings are referred to in chapter -3.

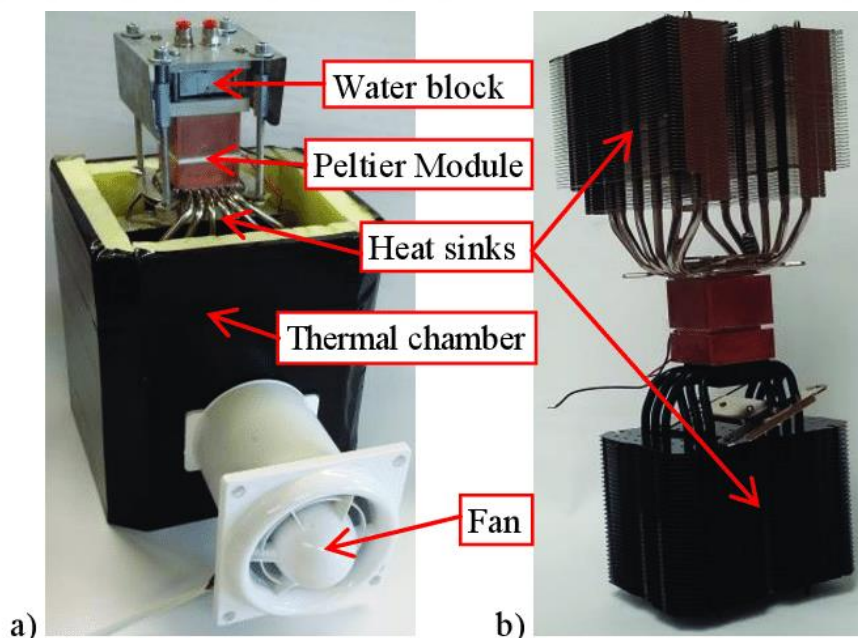


Figure 2.1: (a). Different multimolecular Peltier modules, (b) One of the Peltier modules with warmth sink and fan

2.5 COEFFICIENT OF PERFORMANCE (COP)

The COP of Single level thermoelectric cooler is a non-dimensionless parameter referred to as the Coefficient of Performance is consequently used to degree the overall performance of a cooling machine. The coefficient of overall performance (COP) of a thermoelectric module that's the thermal performance need to be taken into consideration for a TE system. COP is the ratio of the thermal output strength and the electric enter strength of the TEC. COP may be calculated through dividing the quantity of warmth absorbed on the bloodless aspect to the enter strength [60, 61].

$$\text{COP} = \text{QL/Energy furnished(W)}$$

Heat absorption is calculated as under.

$$\text{QL} = - [\text{SITc} - \text{I}^2\text{R} - \text{k} (\text{Th} - \text{Tc})] = 58.21185$$

From the primary regulation of thermodynamics, the Energy furnished is:

$$\text{Energy furnished, W} = \text{QH} - \text{QL}$$

$$= \text{SI} (\text{Th} - \text{Tc}) + \text{I}^2\text{R}$$

$$= 103.13395$$

The Coefficient of Performance (COP) is received through the subsequent empirical equation:

$$\text{COP} = \text{QL/Energy furnished}$$

$$\text{COP} = 0.564432$$

Where:

S: Seebeck co-efficient

T: Temperature

Tc: bloodless aspect temperature

Th: warm aspect temperature

I: modern

R: Electric Resistance

K: Thermal conductivity

QH: warmth rejection

QL: warmth absorption

Here it's far tremendous that the cost of COP remains decrease than the expectation. Although the COP of a TE module is decrease than that of traditional VCR system, efforts were made to expand thermoelectric home coolers to take advantage of the benefits related to this stable-kingdom electricity conversion technology [63].

Further development with inside the COP can be viable using multi-level thermoelectric module, enhancing module touch resistance, thermal interfaces and warmth exchanger. Among those opportunities use of multistage thermoelectric module is the most effective and currently to be had approach. Due to the overall performance limits of thermoelectric materials, a single stage thermoelectric cooler can most effective be operated over a small temperature range. If the temperature ratio among the warmth sink and the cooled area is huge, a single-level thermoelectric cooler will lose its effectiveness. Thus, the software of two or multi-level mixed thermoelectric coolers is an essential approach of enhancing the overall performance of thermoelectric coolers [66].

2.6 HEAT SHIPPING IN THE MODULE

There are numerous strategies which may be hired to facilitate the switch of warmth from the floor of the thermoelectric to the surrounding, Fig. (2.3).

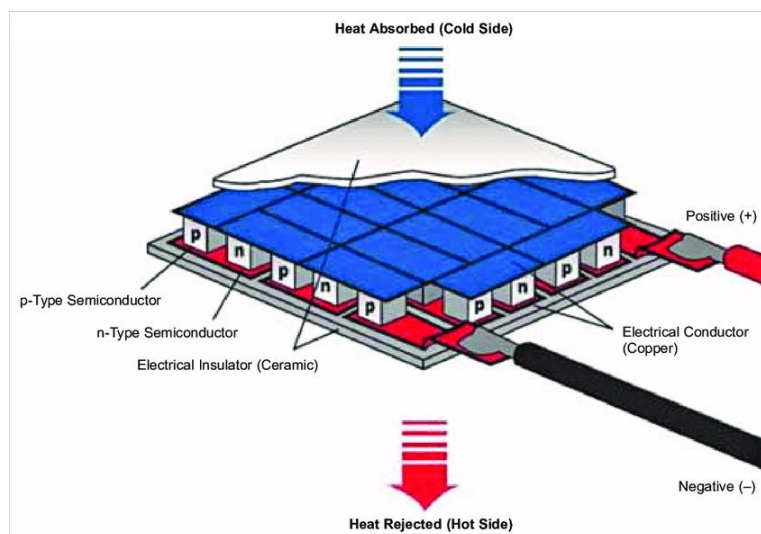


Figure 2.2: Peltier module and the guidelines of the absorbed and rejected warmth from it

i- Electrons can journey freely with inside the copper conductors however now no longer so freely with inside the semiconductor.

ii- As the electrons go away the copper and input the new aspect of the p-kind, they need to fill a "hole" on the way to flow thru the p-kind. When the electrons fill a hole, they drop right all the way down to a decrease electricity degree and launch warmth with inside the procedure [70].

iii- Then, because the electrons flow from the p-kind into the copper conductor at the bloodless aspect, the electrons are bumped again to a better electricity degree and soak up warmth with inside the procedure.

iv- Next, the electrons flow freely thru the copper till they attain the bloodless aspect of the n-kind semiconductor. When the electrons flow into the n-kind, they need to bump up an electricity degree on the way to flow thru the semiconductor. Heat is absorbed whilst this occurs.

Finally, whilst the electrons go away the new-aspect of the n-kind, they could flow freely with inside the copper. They drop right all the way down to a decrease electricity degree and launch warmth with inside the procedure [56, 57].

To boom warmth shipping, numerous p kind or n kind thermoelectric (TE) additives may be installed in parallel as proven earlier than in Fig. (2-1). However, the tool calls for low voltage and consequently, a huge modern that's too incredible to be commercially practical.

3. EXPERIMENTAL SETUP

3.1 INTRODUCTION

In this chapter, the setup of the gadget might be discussed. The designing parameters and the information of the gadget additives with its specs also are explained. three.2. System Setup In these paintings a gadget for cooling and heating the usage of Peltier impact is designed and fabricated. The temperature of the meals with inside the insulating field is measured at distinct instances in the course of the and night time instances. Hot and bloodless meals are used during the experiments. Three Designing Parameters The following steps are taken into consideration whilst designing the gadget: A. Estimation of warmth of the item to be cooled. It needs to be now no longer greater than (70 °C). B. Define temperature running variety of item and warmth sink. C. Choose a Peltier detail that satisfies the necessities from the nearby market. D. Choose a transfer as a easy controller. E. Choose a warmth sink for the Peltier detail and a fan to ventilate the warmth sink. F. Choose the virtual thermometer to examine the meals and inner temperatures. G. Choose a electricity deliver for the gadget in line with the Peltier kind. A battery of 12 V is appropriate for that. Usually, the mission is to chill or to warmth an item to a few given temperatures. If the item to be cooled is in touch with the bloodless floor of the thermoelectric module, the temperature of the item may be taken into consideration to be same the temperature of the bloodless facet of the Peltier detail after a positive time. Two layout parameters are important, whilst outlining a thermoelectric cooling application. • (TO) item temperature (bloodless facet temperature) [°C] • (THS) warmth sink temperature (warm facet temperature) [°C]

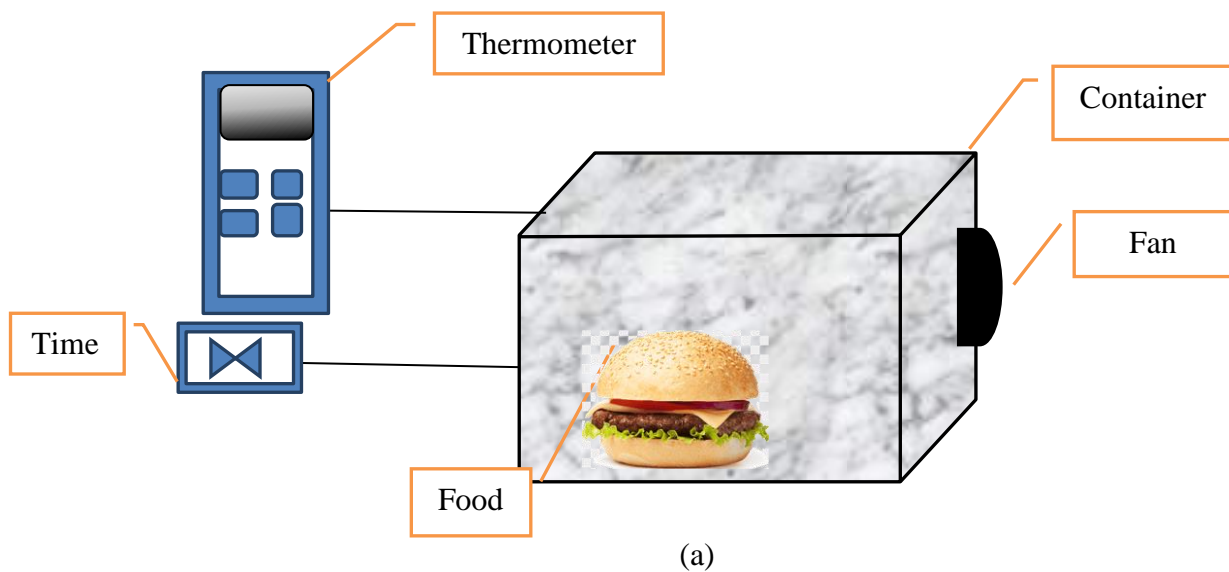
$$THS = T_{amb} + \Delta THS \dots\dots\dots (3.1)$$

The distinction among TO and THS is called dT (ΔT or delta T)

$$dT = THS - TO = T_{amb} + \Delta THS - TO \dots\dots (three.2)$$

Where: (T_{amb}) ambient temperature (°C). System Components The primary additives of the gadget are the following: 1. The insulated box field. 2. Peltier tool for cooling and warmth generation. three. Electrical accessories, like: electricity deliver, warmth sink, cooling fan, electric transfer, connection wires. Table (3-1) suggests the listing of gadget additives with a short description. Table 3-1). List of gadget additives No. Part call Details 1 Insulated Container outdoor dimensions of: Height of twenty-two cm Width of 18 cm Length of 25 cm

Inside dimensions: Height: 19 cm Width: 15 cm Length: 21.5 cm the outdoor jacket is product of plastic, The internal is crafted from parts: the decrease element is of a skinny plate of aluminum (with peak of 12 cm), whilst the top element is from plastic. Isolation sheet: a thermocol sheet is inserted among the internal and outer facets of the box to save you warmth trade among the internal and outer environments. Storing capacity: 6 litres 2 Peltier module Type-1: TEC1 - 12704 Type-2: SP 1848 /27145 SA three Battery 12 V automobile battery four Heat sink Aluminum Table (three-1).continued five Electricals additives Normal electric Switch: to replace the gadget on/off, Controller: to manipulate the modern direction, LED: to suggest the operation of the gadget, Fan: to ventilate the warmth sink and to lessen it temperature, Connection wires among the gadget additives. 6 Measuring devices Heat: is measured through thermometer Time: is measured through a Timer Current and Voltage: is measured through mustimeter 7 Food Type For cooling cycle: coca cola cans For heating cycle: Hamburgers from rapid meals service. The schematic and real shapes of the gadget are proven in Fig. (three-1). The specification of every factor of the gadget is proven below: A). Insulated box field: Its dimensions and cloth kind are proven in Table (3-1) above. Most of researchers take gain of thermocol (Polystyrene Foam) for its financial cost and true insulation assets because it does now no longer permit the internal temperature of cooling medium to head down. Also, with inside the heating cycle, it maintains the indoors temperature strong for a very good duration of time. It is sandwiched among plastic partitions as proven in Fig. (3.2).





(b)



(c)

Figure 3.1: System shape, a). schematic, (b). The experimental system from outside, c). The interior volume of the system

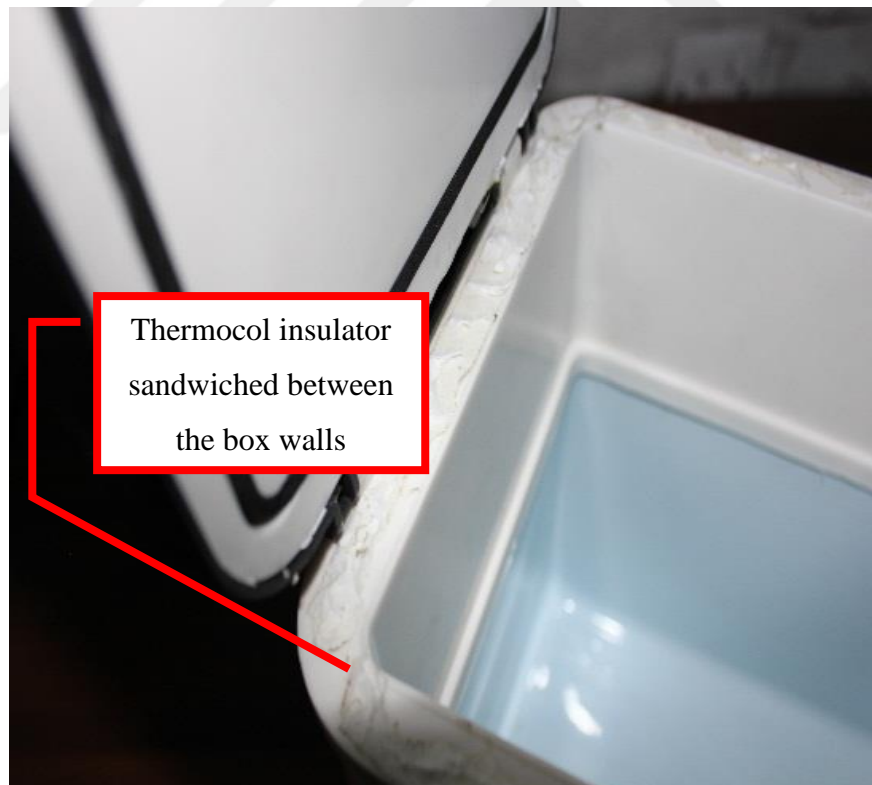


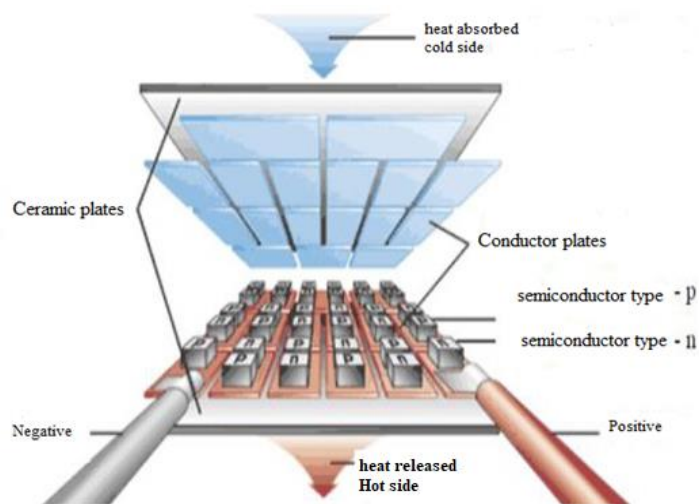
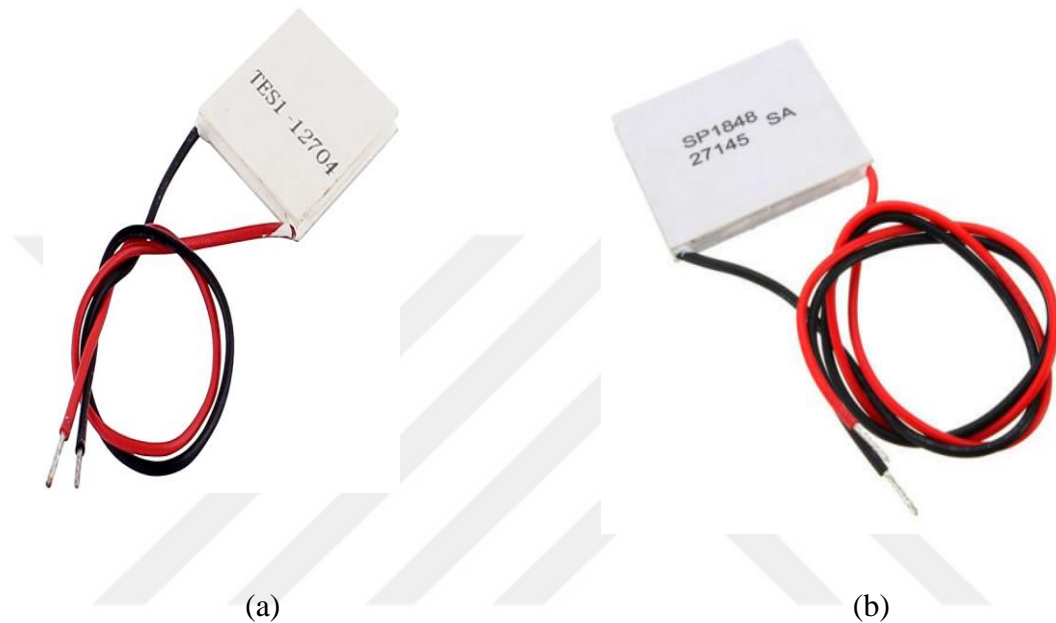
Figure 3.2: Thermocol insulator between outside and inside walls

b. Peltier Device

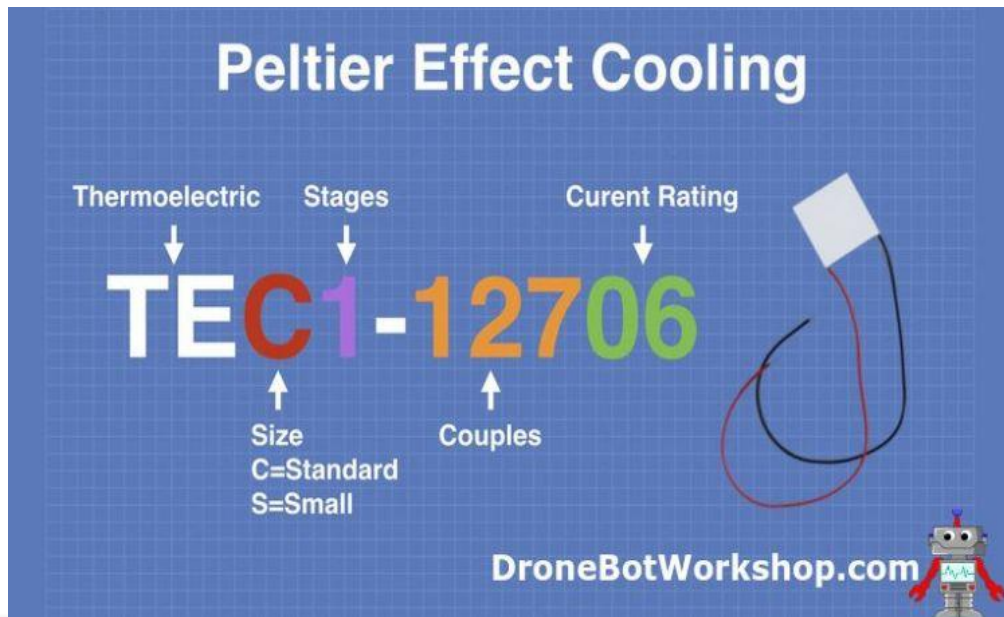
Peltier devices are semiconductor components that use the Peltier effect to transfer heat from one side of a module to another.

Two types of Peltier devices are used in this work as shown in Fig. (3-3):

- i- Type-1: TEC1 - 12704
- ii- Type-2: SP 1848 /27145 SA



(c)



(d)

Figure 3.3: Peltier types used in this work, (a) Type-1: TES1 –12704, (b) Type-2: SP 1848 /27145 SA, (c) Details of Peltier module inside, (d) The meaning of letters and numbers of Peltier module type

Table (3-2) shows the general technical specifications of the two Peltier types (TEC1 – 12704 and SP 1848 /27145 SA) used in this work.

Table 3.1: Specifications of the two Peltier devices used in this work.

Peltier type -1 (TEC1 - 12704)	
Thermoelectric cooling module Technical Specification	
Customer	
Type of the products	TEC1-12704
Dimensions	The following picture
Element logarithm	127
Lead standard	20AWG UL1569 105°C Standard tinning wire, PVC insulation skin, Lead length 350 ± 5 mm, End department bare 7 ± 1 mm, Lead welds in heat surface one end
resistance	$2.95 \sim 3.20 \Omega$ (Environmental temperature $23 \pm 1^\circ\text{C}$, 1kHz Ac)
Biggest difference in temperature $\Delta T_{\text{max}}(Q_c=0)$	$65 \sim 68^\circ\text{C}$
electric current I_{max}	12VDC 3.2A, 15.4VDC 4.1A
Voltage V_{max}	15.4VDC
Refrigeration power Q_{cmax}	36W(15.4VDC)
Assembly to withstand the pressure	$98\text{N}/\text{cm}^2$
Work environment temperature scope	$-55^\circ\text{C} \sim 80^\circ\text{C}$
Sealed	704 silicon rubbers
lettering	Hot surface
Package standard	Foam box, 10 Box / carton, 50 pieces / box
Storage conditions	Environmental temperature $-10^\circ\text{C} \sim 40^\circ\text{C}$, Relative humidity $\leq 80\%$, Ventilate and no corrosivity gas

Table 3.2: Cont.

Peltier type -2 (SP 1848 /27145 SA) Thermoelectric Power Generator	
Open Circuit Voltage (V)	4.8
Operating Temperature (C)	0 to 150
Maximum Temperature(C)	150
Wire Length(mm)	350
Length (mm)	40
Width (mm)	40
Height (mm)	3.6
Weight(gm)	30

c. Battery Type:

The common power source used with Peltier modules is the 12 V medium size battery as shown in Fig. (3.4). In this work a car battery 12 V was used. The car battery was used because of its long period stability during the cooling and heating cycles of the food, stability and the required current for long time.



Figure 3.4: 12 V 7 Ah rechargeable lead acid battery [12]

d. Heat Sink:

A warmness sink is an item that absorbs and dissipates warmness from some other item the use of thermal contact. Heat sinks are utilized in a huge variety of programs anywhere green warmness dissipation is required, primary examples encompass refrigeration, warmness engines and cooling digital devices. Heat sinks characteristic with the aid of using effectively moving thermal strength from an item at a enormously excessive temperature to a 2d item at a decrease temperature with a miles more warmness capacity. This speedy switch of thermal strength quick brings the primary item into thermal equilibrium with the 2d, reducing the temperature of the primary item, pleasurable the warmth sink's position as a cooling tool. Heat sink overall performance is a characteristic of cloth, geometry, and ordinary floor warmness switch coefficient. Generally, pressured convection warmness sink thermal overall performance is progressed with the aid of using growing the thermal conductivity of the warmth sink materials, growing the floor location and with the aid of using growing the general location warmness switch coefficient. A warmness sink is an digital tool that consists of a fan and a Peltier tool to hold the recent element cool. A warmness sink is crafted from an aluminum cloth with a decrease thermal impedance than the digital tool to which it's far connected and plays its cooling characteristic with the aid of using growing the floor location to be had for air convection. Heat Sink prevents a tool from overheating with the aid of using soaking up its warmness and dissipating it into the air. They are silent, passive, cheaper additives that are available in quite a few sizes and styles and are surprisingly reliable. While large warmness sinks offer higher cooling, their elevated quantity may be difficult in a few programs. Alternatively, pairing a smaller warmness sink with a cooling fan may be similarly or extra powerful than a large, passive warmness sink. Figure (3-5) indicates the form of the warmth sink used on these paintings inserted among the Peltier module and a fan using Araldite epoxy adhesive. This epoxy Stabilizing and mounting of the DC fan and Peltier at the Heat sink. Its traits are (Fig.3.6): • Stress Proof • Heat proof • Waterproof • Non-corrosive • Non-Toxic • Resistant to maximum chemicals.



(a)



(b)

Figure 3.5: (a). The shape of the heat sink, fan and module, (b). The heat sink attached to the outside container wall

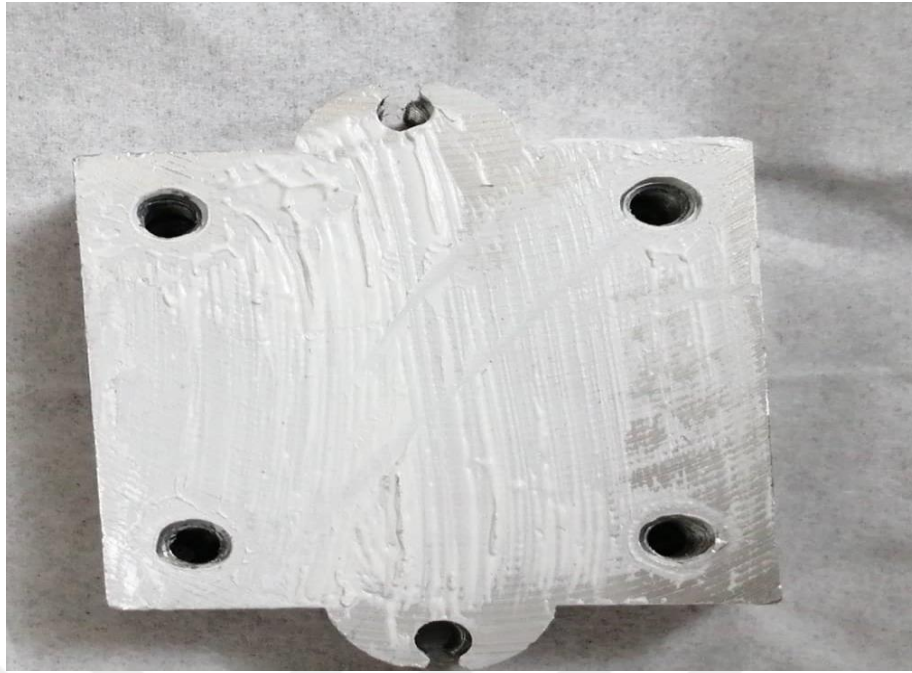


Figure 3.6: Araldite is used as a Standard Epoxy Adhesive

e. Fan

Fan (or blower) work by moving warm air away from the surface of a heat sink or device and quickly replacing it with fresh, cooler air in a continuous process that is more efficient than normal convection. Fans are available in a variety of form factors and operating voltages. The airflow produced is typically measured in cubic feet per minute (CFM) and is determined by the shape and size of the fan. Some fans provide variable speed control that can be used in feedback systems to actively adjust the CFM. While they have the advantage of reducing the size of the heat sink required and are relatively inexpensive, fans have the disadvantage of being active devices that require power. Also, the fact that they use moving parts makes them noisy and subject to mechanical failure. Figure (3-5) shows the fan at the top of the Peltier system used in this work, while in Fig. (3.7) it is separated. Figure (3-7) The fan to move the air from the heat sink. F). Electrical Components: Other electrical components are used in this system such as: • Electrical switches:(Fig.3.8), the slide switch is to change the direction of the current. In the first position the current applied to the Peltier module from the positive terminal. This is the cooling cycle. When the switch changed its position, the current direction is reversed, and the Peltier module is in the heating cycle. The toggle switch is for on/off the system. • LED lights to indicate the working condition of the system as shown in Fig. (3.8). Fig. (3-8) Two switches are used. The left toggle switch is for on/off the system, the

other slide switch for changing the current polarity. Two LEDs indicated the cooling (green) and heating (red) cycles of the system. • Connecting wires: to connect between the different system components. G). Clips and Fasteners: It is important that heat sink always remain securely attached to the component they are being used to cool. In the event of a heat sink becoming loose and detached, a component can quickly overheat, causing damage to or destroying equipment. To prevent this from happening, it is important to use a fastener or clip that matches the form factor of the selected heat sink. H). Measuring Instruments: The following measuring instruments are used in this work experiments during the cooling and heating cycles. • Temperature: Different temperature measurements are needed such as: the temperature of the internal volume of the insulating box, food temperature at the beginning and at the end of each experiment and the ambient temperature. A digital thermometer with probe was used for these measurements as shown in Fig. (3.9).



Figure 3.7: Digital Thermometer for temperature measurements.

Time: the time intervals and the beginning of experiment till the end are measured with a Timer as shown in Fig. (3.10).



Figure 3.8: Digital Timer for the time measurements.

Voltage and Current: The current passing to the Peltier device and the power supply (Battery) voltage is measured by a standard Maplin -M6000 digital multi meter as shown in Fig. (3.11).



Figure 3.9: Maplin Digital multimeter for voltage and current measurements

i. Food Types

Cold drink: Two Coca Cola cans are used during the cooling cycle.

Hot Food: Hamburger or Fried chicken from Fast food service are used.

3.2 FIXING METHOD OF PELTIER DEVICE ON THE INSULATING BOX

It is necessary to fix the Peltier module on the side wall of the insulating box. It takes the following four steps.

Step 1: Cutting an area equal to that of Peltier module from the insulating box wall, Fig. (3.12).



Figure 3.10: Cutting a space for Peltier module in the thermocol wall of the box

Step 2: Insertion of the thermocol box between the two plastic sides of the insulating box as shown in Fig. (3.13). All the empty spaces and voids are managed to prevent or reduce the heat transfer between the internal and outer sides of the box.

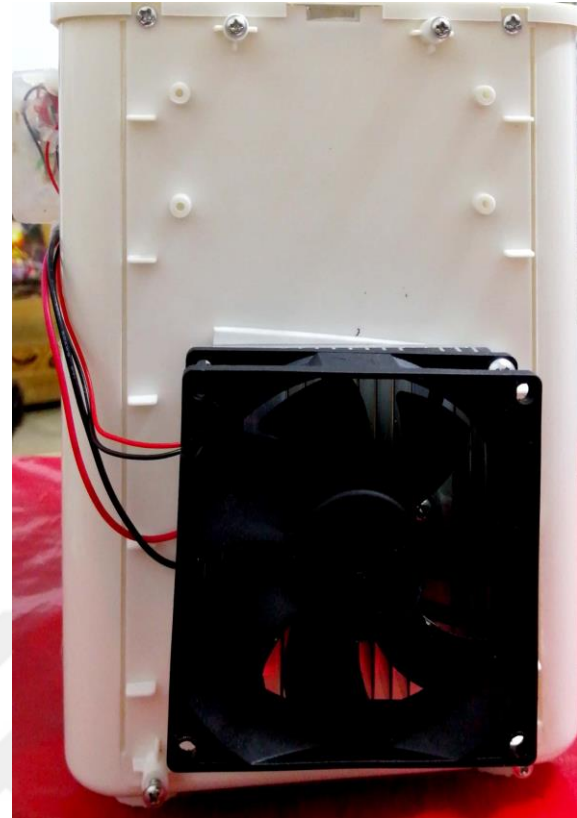


Figure 3.11: Insertion of the thermocol box between the inner and outer plastic walls of the box.

Step 3: Fixing the attachment of Peltier module with the heat sink and fan on the side wall of the box securely as shown in Fig. (3.14).



(a)



(b)

Figure 3.12: Fixing the Peltier module (a) with its fan and heat sink (b) on the outer side of the box.

Step 4: Fixing the control box on the side wall of the box as shown in Fig. (3.15).



Figure 3.13: Fixing the control box on the insulating box.

The basic 2D heat transfer model is based on the Dynamic Wall model. The dynamic wall model can explain how the internal temperature is affected as the external temperature changes for a wall with thermal mass. Only one node is considered. The area of an actual object, the distance between nodes, etc. are not expressed geometrically, but are added as an element added to the matrix when setting the matrix differential equation. Based on this, it is assumed that 3D heat transfer can be achieved with a network of several 2D dynamic wall models to simulate the thermal behavior of a 3D space. A visual description of how to replace 3D heat exchange with a network of 2D heat exchange models is given below. Therefore, the basic 2D heat transfer model starts by assigning a node to every component involved in heat transfer and establishing what kind of heat exchange occurs between the nodes. In this project, coding started from an Excel file containing all information about heat exchange between different nodes, so the most basic algorithm required to complete the coding from the Excel file is presented first, and then the response including Warmup. Let's move on to the used version of the code. Figure 1 shows the basic algorithm flow chart. Import the Excel file (File 1) that contains information on the heat exchange and ventilation and solar radiation between nodes mentioned above, and the Excel file (File 2) that stores the temperature and SHGC for one year and information. After saving as a variable, the M and S matrices are set using file 1, and the f matrix is set using the specified initial temperature value and file 2. By solving the differential equation using the M, S, and f matrices set in this way and ODE23t of MATLAB, continuous temperature changes of all nodes can be simulated.

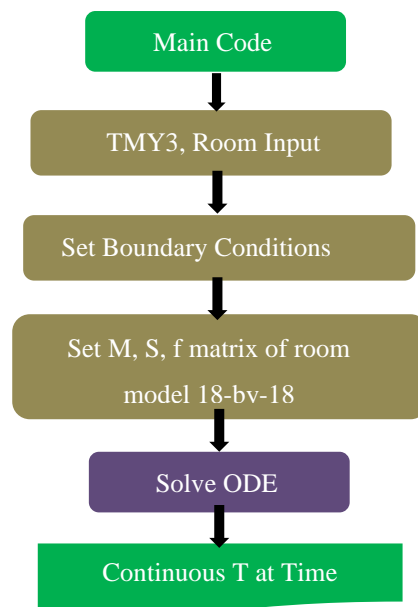


Figure 3.14: Algorithm Flowchart of Basic Model

As can be seen from the flowchart, the differential equation using the three matrices M , S , and f is solved and the temperature of all nodes over time is output as a result. In order to understand the meaning of differential equations made of matrices, we need to explain the steady-state model first, so we will briefly explain only the meaning of the M , S , and f matrices. M matrix is a matrix related to the thermal mass of an object. When each node receives thermal energy over time, its own temperature rises. The higher the thermal mass, the slower the temperature rises. change the heat received by a node is sometimes proportional to the temperature difference between the two nodes exchanging heat, and sometimes not. Heat exchange proportional to the temperature difference between the two nodes is added as an element to the S matrix. The temperature of the node corresponding to the boundary condition is added as an element to the f matrix.

Differential equations made of M , S , f matrices update and update the input temperature information by outputting the temperature change for each node according to unit time when the initial temperature of each node for a specific time is input as an input value. The calculated temperature information is input again as the initial temperature condition and the calculation is repeated. As a result, a temperature value that changes with time is output. Naturally and importantly, in order to see the result, the initial temperature of each node must first be set as an input value. Since we do not know the temperature of each node, we are trying to find the expected value by running the simulation, so the initial temperature of each node is the actual expected value of the node. There is no choice but to set the value apart from the temperature. If the initial temperature is set in this way, the temperature is maintained within the normal temperature range of each node while the computer repeats the calculation. Have no choice but to. If the time to reach the normal temperature range is long and the period for which you want to check the simulation result is short, the simulation result becomes more meaningless. To avoid this problem, the warmup period should be considered so that the temperature for each node reaches within the normal temperature range. In the default heat exchange model, if there is a specific period in which you want to see simulation results, we will design to enter the period initially. There are two methods to output only the results of the period in the simulation with the period set. One is to finish the simulation for the entire period and select and output only the results for the period, and the other is to output only the results for the period set from the beginning. How to do a simulation. The latter method is much more efficient to use when the amount of data to be dealt with becomes large or the heat exchange model is complicated and the calculation time is long compared to the period to be analyzed. method is no problem.

However, in the latter method (the method expected to be more efficient) among the former method and the latter method, the simulation starts from the start period to check the result, so it is necessary to have a warmup period in advance. There are various ways to warmup, and I will focus on the method that was conceived and used in this code.

3.3 WARMUP MODEL

In order to create a warmup model, it is necessary to consider how to deal with a situation in which there is no data on the warmup period although there is a warmup period before the simulation period.

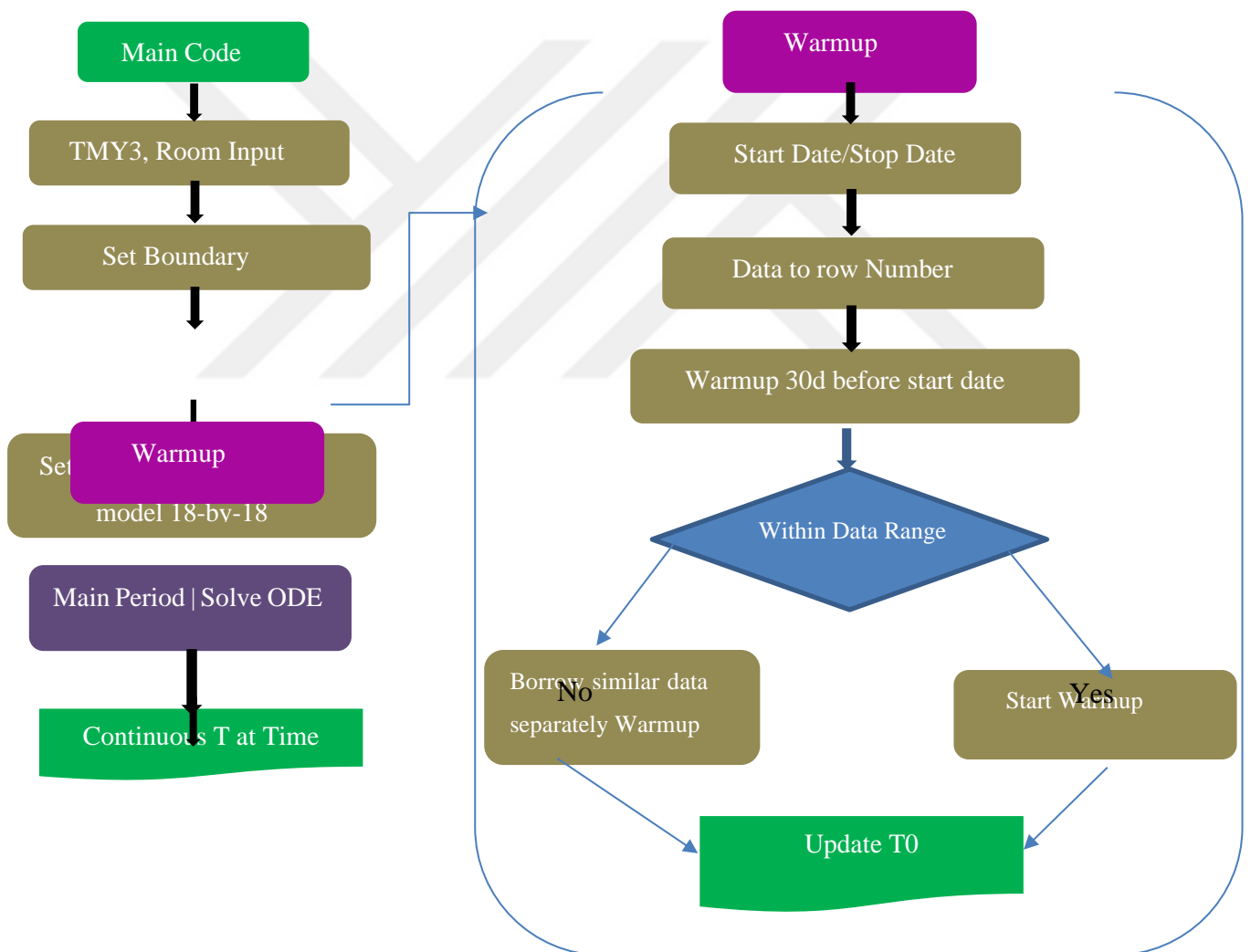


Figure 3.15: Algorithm flow chart of warmup model using if statement

For example, in a simulation that takes at least one month for the warmup period, when the given temperature data is for one year from January 1 to December 31, 2021, the simulation results from January 15 To report, the warmup from December 15, 2021 to December 31, 2021, which is a month before January 15, cannot be performed in a normal way. In this case, it is necessary to use the borrowing method from which information is expected to be similar among the given data. You can borrow the materials from and proceed with the warmup, and then proceed with the warmup from January 1, 2021 to January 15, 2021. This method should include an if statement, and the detailed algorithm flow chart is shown in Figure 2.

Before proceeding with the warmup, you must first set the period for the warmup. The required warmup period should be set in consideration of the largest value among the thermal masses of the nodes exchanging heat. Since the basic model is simple and the simulation time is not long, rather than determining the warmup period by predicting it, it is simply a simulation without warmup. It is preferable to look back and determine the warmup period as a result.

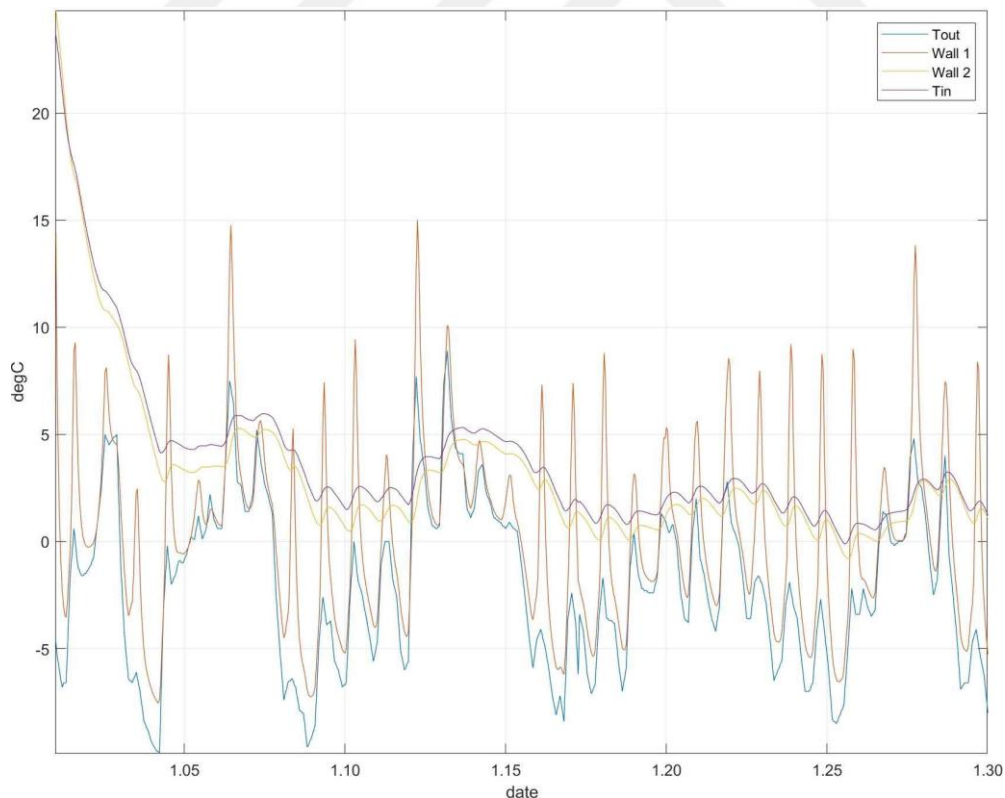


Figure 3.16: General heat exchange model without warmup period

The above plot result is a general heat exchange model without warmup, and all nodes start with an initial temperature of 25°C. The simulation was conducted from January 1 to January

30, and since the given weather data starts from January 1, there is no data before January 1. Therefore, if the warmup period is set to 1 month, the data from December 1 to December 31 of the given data is borrowed and warmup is performed for 1 month. The simulation will run until the 30th of each month. The simulation results including warmup in this way are as follows.

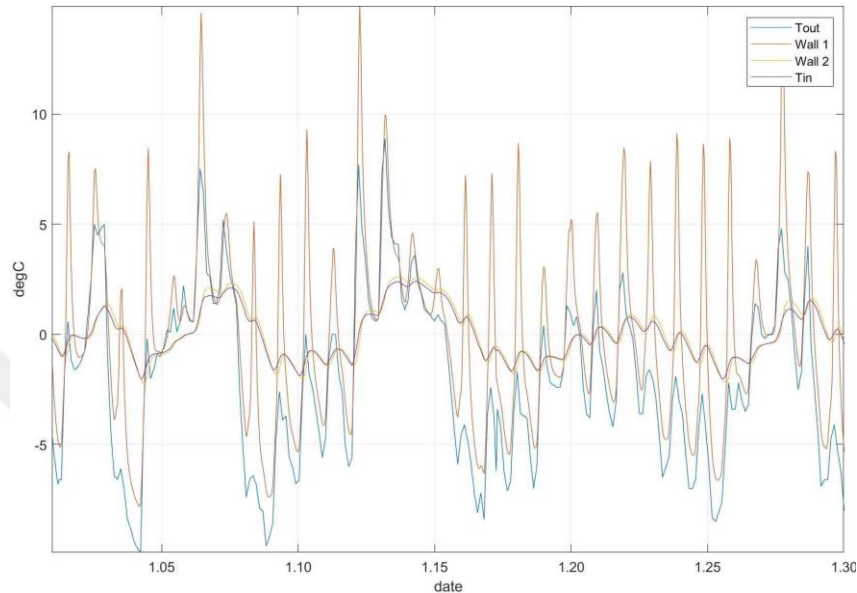


Figure 3.17 : Heat exchange model with warmup period

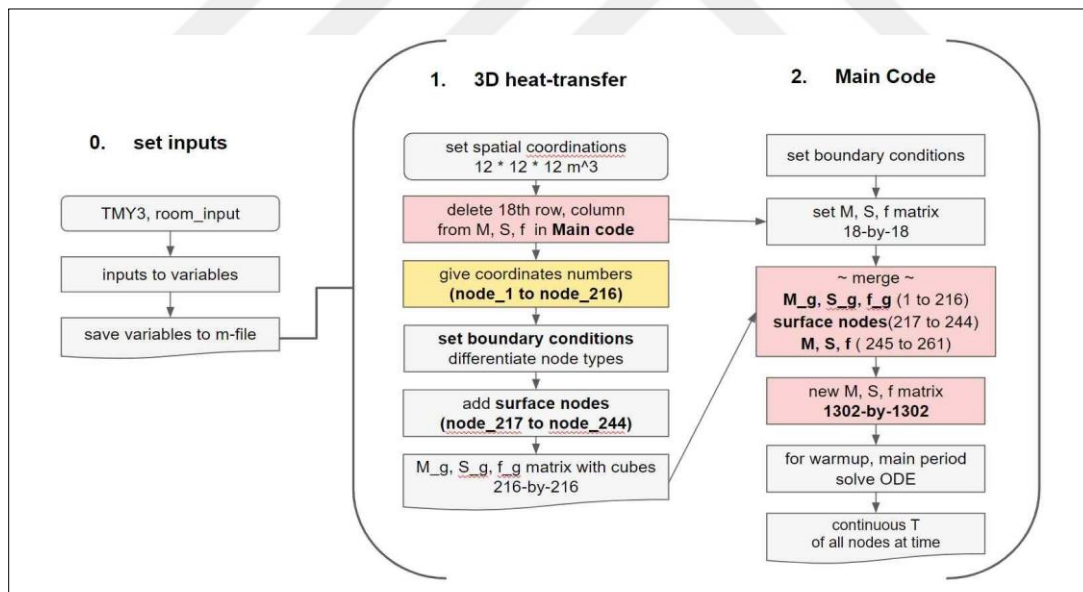
3.4 3D HEAT TRANSFER MODEL FOR GROUND NODES

The 3D heat exchange model was a network format of the 2D heat exchange model. It is different from the previous model. The main difference is that one node no longer represents one object. One object has the number of nodes proportional to its volume, and several nodes constituting one object have the same material properties and the same type of heat transfer if the object is homogeneous. According to this change, one object is represented by several nodes, and heat transfer within the object is expressed, so even one object may have a different temperature distribution according to various points in the object. The condition that could not be expressed in the 2D heat exchange model and was necessary for the ground to be perceived as a single object is the condition of ‘dividing one object into multiple nodes. The method of dividing one object into several nodes was conceived by dividing the 3D object by a certain interval in the assumed direction, and dividing it into cubes with constant horizontal and vertical heights. However, considering the actual land, the density will vary depending on the depth and location, and since it is not composed of a single material, the physical properties will also vary depending on the distribution of water and the distribution of stones. In other

words, the earth is not a homogeneous object. However, it is assumed that the soil in the ground is always homogeneous, because the assumption of soil properties according to depth is not in line with the purpose of this report, which is to shape the model in a simple way. The basic assumptions required for the 3D model are as follows.

3.4.1 Algorithm for 3D Heat Transfer Model

One of the problems of the basic 2D model lies in the ground node (hereinafter the soil node), which the basic model does not explain effectively while assuming the 3D heat exchange model as an aggregate of the 2D heat exchange model. The floor of a building (assuming it is attached to the ground) exchanges heat with the ground (soil) through conduction, and the soil node that exchanges heat is not actually a boundary condition unlike the setting in the basic model, and it is not a boundary condition. It must be a node whose temperature changes continuously. Therefore, in order to solve the differential equation, the soil node must be connected to a node of a certain boundary condition, and the boundary condition connected here can be reached through countless paths, not through one path. These various heat exchange paths have limitations in simply expressing them in 2D, so it is much more reasonable to express them in



3D.

Figure 3.18: Algorithm Flowchart of 3D Heat Exchange Model

According to the limitations of the 2D heat exchange model, a 3D heat exchange model was designed by limiting it to the ground in order to explain the heat exchange transferred in the ground on a more reasonable basis. Figure 5 shows the basic concept and process. The basic concept was to determine the space to be analyzed, divide the space into cubes with the same

horizontal and vertical heights, and designate one node to each cube. It is similar to the mesh method used in CFD, which is a fluid mechanics program. In the 3D simulation program, the section where the properties do not change well in the space to be analyzed is divided into large pieces, and the section where the properties change well is divided into small pieces. It was also confirmed that various types of mesh methods such as triangles and hexagons were used instead of the cube-shaped mesh used in this project.

First, the range of the space to be analyzed must be determined. The depth of the space is set to about 40, the maximum depth at which the temperature starts to remain constant depending on the depth in the ground, and the width and length are also the same value as the depth was used as That is, the space to be analyzed is a space of the size of $4 \times 4 \times 4$, and the length, width, length, and height of the cube, which is the unit that divides this space after several trials and errors . This length was determined by the time spent in the simulation, and the total

$4 \times 4 \times 4$ nodes are added to the ground, which will be described later, but the number of nodes is not sufficient for accurate analysis. These problems will be described later along with boundary conditions in 3) Issues of 3D Heat Transfer Model. A visual explanation of the above is shown in Figure 6.

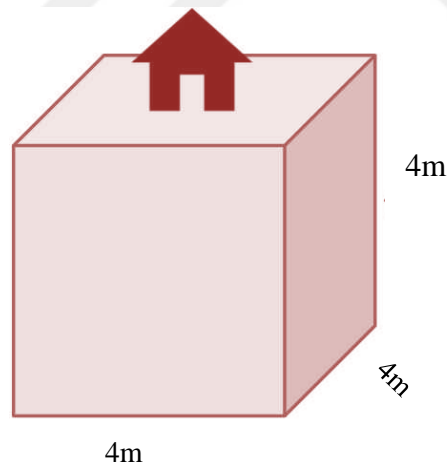


Figure 3.19: Determining the size of the space to be analyzed

To set the M, S, f matrix, 216 nodes expressed in spatial coordinates must be numbered from 1 to 216. The node numbering method must be set so that there is no difficulty in determining adjacent nodes for each node or finding nodes in boundary conditions.

After that, adjacent nodes are set for each node, and the node number of the boundary condition, the node number located on the surface, the node number located under the building, etc. are

checked in advance and stored as information. Based on that information, the 216-by-216 size M_g , S_g , f_g matrix of This 3D model is a model that enters like a module instead of the ground node of the 2D model in order to explain the 2D model more rationally, so 18 nodes set in the 2D model are valid. By doing so, the existing M , S , and f matrices become 17-by-17 matrices. In addition, 28 nodes are additionally set to add convection with the atmosphere at the earth's surface, radiant energy from the celestial sphere, and solar radiant energy from the sun. As a result, the total number of nodes is It should be of size 261-by-261 (261-by-1 for f matrix) by adding the heat exchange for the detailed method of creating the M , S , f matrix will be described later in 2-4) M , S , f matrix.

A detailed description of this will be described later in 2-2) M , S , and f matrix, and only the description of which node is set as the boundary condition among the 216 nodes created through the mesh will be described below.

1) In the basic model described in 2D Heat Transfer Model with Warmup, three boundary conditions were set as the sky node, the external atmospheric node, and the ground node, which correspond to the celestial sphere. Among them, the ground node is replaced with a 3D heat exchange model, so the boundary conditions are two nodes: a Sky node and an external atmospheric node. Some of the 216 new soil nodes need to be set as boundary conditions, and the nodes set as boundary conditions are 'nodes that are not adjacent to 6 cubes in the plane direction except for nodes located on the surface'.

Looking at Figure 7, there are five faces located at the outermost part of the six faces of the regular hexagonal space except for the ground surface, and all the nodes located on these faces correspond to boundary conditions.

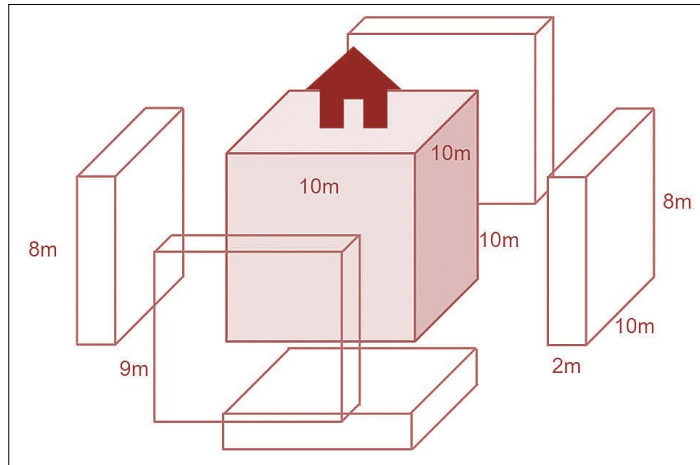


Figure 3.20: Boundary Conditions

The nodes in the boundary condition make an S matrix and then, when the number of the node is n, all row components are changed to 0, and then one component at the position is made 1. After that, if a fixed (or time-updated) temperature value of the corresponding node is put in the position of the f matrix, the temperature of the node corresponding to the boundary condition when solving the matrix is written in the f matrix. It can be made to always have the same value as the temperature value.

As mentioned above, what kind of problems the boundary conditions bring in simulations meshed on a small scale like the code used in this report will be described later in 3) Issues of 3D Heat Transfer Model.

final M, S matrix (261 - by - 261)

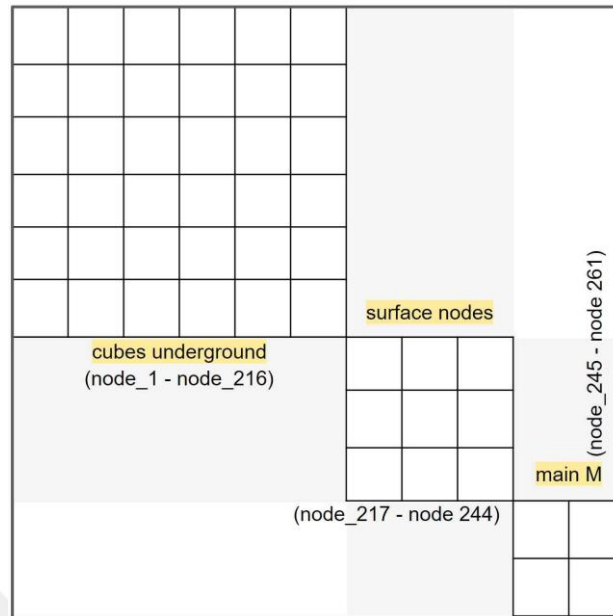


Figure 3.21: Create M, S, f matrices of scale 261-by-261

M, S, and matrices are all combined in the same way, and the f matrix simply adds a row after it. In the case of the M matrix, no components are added to the gray space of <Figure 2-4>. After creating a matrix in this way, 1) solve the differential equation in the same way as the basic model used in 2D Heat Transfer Model with Warmup.

When creating the S matrix, the 17-by-17 M, S, f matrix of the basic model can be used as it is, and the M, S, f matrix for the 216-by-216-scale soil node can be obtained by using a for-loop. You only need to add heat mass to the M matrix and only heat conduction to the S matrix. However, the M, S matrix should be created with care for No. 13 (node under the building) of the existing model, which corresponds to the junction between the surface node, the soil node, and the basic room model. First, in making the M matrix, the ground surface node is set on the surface and has half the heat mass, and the node under the building needs to add half the heat mass of the soil to the node as well. To make the S matrix, the heat exchange shown in the figure below must be added.

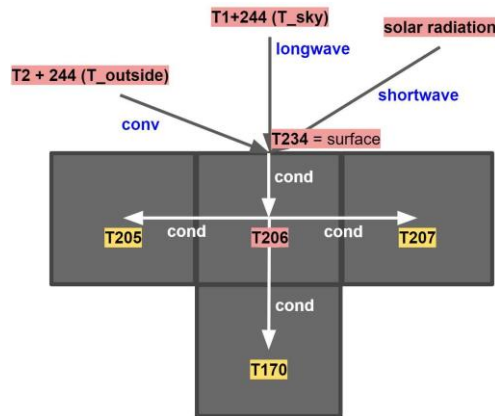


Figure 3.22: Heat exchange at the surface

First, there are four types of heat exchange at the surface. The above figure brings the nodes 206 and 234 used in actual coding as examples. Node 206 is located on the upper surface of the mesh space among the soil nodes and is adjacent to the surface node No. 234 above the head. The surface node conducts convective heat exchange with the atmospheric node (No. 246) and radiative heat exchange with the celestial node (No. 245). Under the feet, heat exchange with node 206 through conduction. Since these three types of heat exchange are heat exchange methods according to the difference in temperature, they must be added to the S matrix. It also receives solar radiation energy regardless of the temperature difference, which must be added to the f matrix.

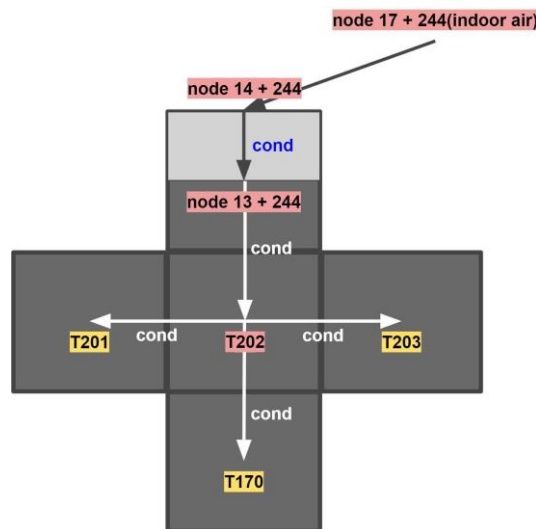


Figure 3.23 : Heat exchange at the surface

The heat exchange model at the surface also brought the node number used in the actual code as it is. Node 202 exchanges heat through conduction with the node (No. 257) under the building directly above it. Since heat conduction is heat exchange made by the difference in temperature, it must be added to the S matrix.

4. RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the heating and cooling results with food and without will be discussed. The experiments are implemented in two different times: daytime and night time.

In this work, two types of Peltier modules are used. This is to see the effect of Peltier type on the results. Two cases of box inside were taken (with and without food) at different times (Day time and Nighttime).

The result is output as color expression on the specified surface using the images command, and the rough result is as above. The resulting values for nodes are output by cutting the 4×4×4 space on the plane of 4, the surface nodes above it, and the node under the building (node 13 of the basic model).

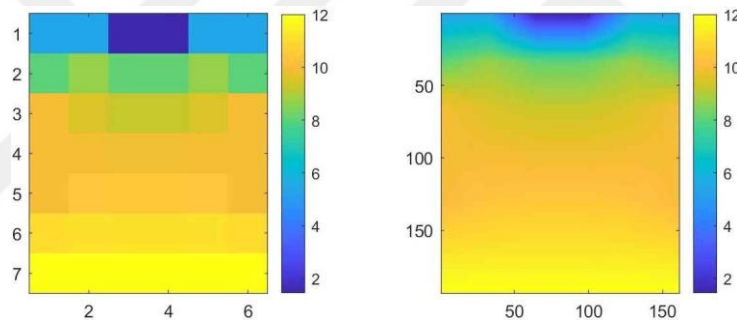
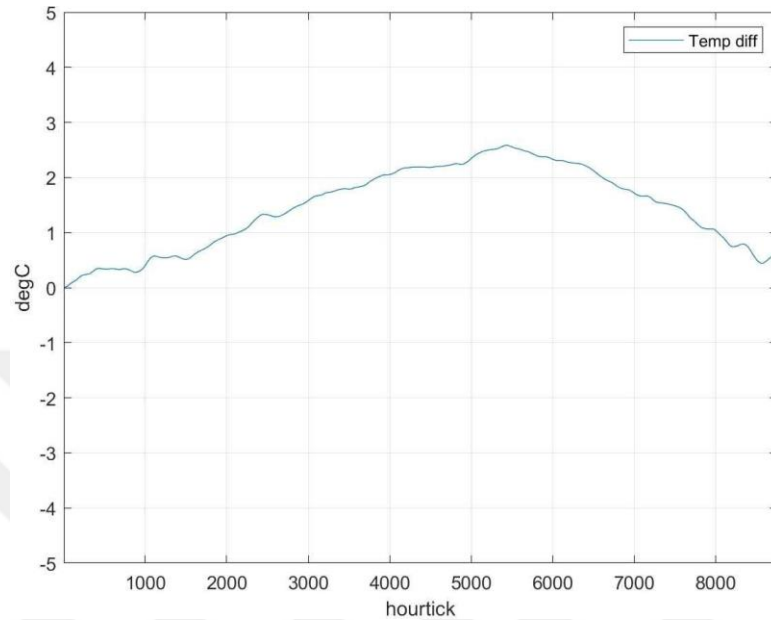


Figure 4.1: Temperature distribution for 5 o'clock on January 10th' interpolated and interpolated plots

The most important question is, what effect does the temperature of the room have when adding a 3D model? Before confirming the simulation results of the 3D model, there is a point to point out. In the case of the 3D model, the warmup was only partially performed. In the process of merging the basic 2D model and the 3D model, the 2D model uses the warmup period as it is, and nodes 1 to 17 in the 2D model have the initial temperature at which the warmup was performed. On the other hand, the added 244 nodes used the initial temperature condition estimated to be affected by the depth without a warmup period. By considering Figure 12, at the moment the simulation starts, the temperature of the indoor node included in the existing model is the same as the initial temperature after 2D warmup, so there is no temperature difference and it appears as 0 degrees. As time goes by, heat exchange occurs between soil nodes gradually, and especially in summer, the soil temperature is indirectly influenced (heat exchange) by the surface node that exchanges heat with the outside, and the existing 2D model

was fixed at 12 degrees. It rises about 2.5 degrees higher than the This difference decreases again around winter when the ground cools down, and on December 31st, the two heat exchange models show a difference of about 0.5 degrees.

Figure 4.2: Difference in room temperature for one year in basic heat exchange model and 3D heat



exchange model (3D heat exchange model - basic 2D model)

Assuming that the data follow a typical one-year temperature distribution, the room temperature difference between the two heat exchange models, which appeared at 0 degrees on January 1, is also expected to be about 0.5 degrees, which is similar to the information on December 31 of the data. For more accurate confirmation, the soil node of the 3D heat exchange model should also be warmed up to correct the initial temperature.

Next, the land for 2 months from noon (12 o'clock) on February 1, noon on April 1, noon on June 1, noon on August 1, noon on October 1, and noon on December 1 I will present the temperature distribution results in a pair of non-interpolated plots and interpolated plots.

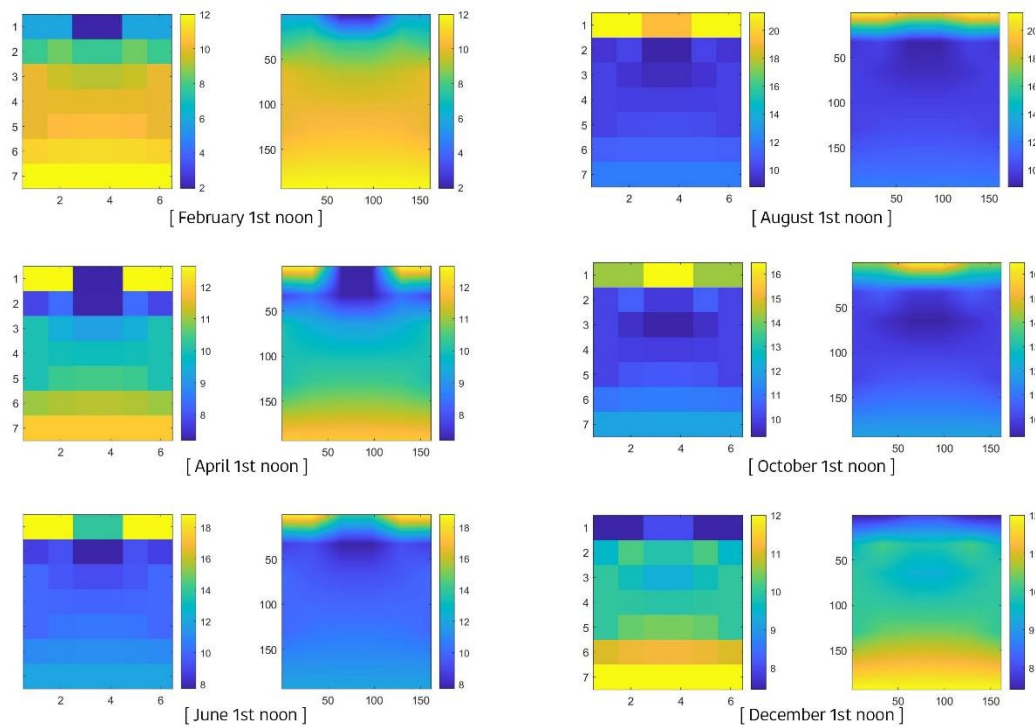


Figure 4.3: The result of temperature of the nodes on the $x=3$ plane (when we define one vertex at the bottom of the 6-6-6 space as origin).

The main purpose of heat transfer model is to predict indoor air temp under changing outdoor air temp. ODE starts to calculate from one boundary condition node to another, and the nodes that are at the path of the ODE will get the temperature difference through time as a result. So, the result of simulation unconditionally depends on the temp of boundary conditions. In 216 nodes additionally added, 116 nodes are boundary conditions, so the ratio of boundary condition nodes in all nodes is approximately near half. As the number of boundary condition nodes is quite large, and those 116 boundary condition nodes' temperatures are fixed, result of the simulation should be sadly inaccurate. As it is hard to expect that there will be the data of cubes (newly defined by me), we have to simulate the boundary conditions' thermal behavior. What I suggest is to delete building part in the 3D heat transfer model and simulate with only soil and surface nodes. With this simulation and fixed boundary condition temperature, we can get the temp difference through time and depth of the vertical nodes at the center of $4m * 4m * 4m$ space (in this case, $(3, 3, z)$ nodes) as a result. Then re-input the temp data to the boundary condition nodes, depending on depth and updating through time intervals and re-simulate. The result of the vertical nodes at the cent, will converge to certain data. This data can be the temperature data of boundary condition nodes. This 'updating simulated temp data to boundary condition nodes' can be one solution.

For nodes with large thermal mass, in order to effectively warmup, it is possible to set a small thermal mass by limiting the warmup period. When the thermal mass is set to be small, the temperature fluctuation range is large and the temperature changes rapidly. Compared to the case of large thermal mass, the change pattern of temperature may be completely different, but it can be expected that the average value of the temperature will come out almost the same over the previous period. Therefore, it is possible to set the initial temperature condition by averaging the temperature values according to each time obtained by performing the warmup with a small thermal mass for the longest period of time. In this case, the advantage is that the expected temperature of the node with high thermal mass can be easily obtained. This is because nodes with high thermal mass have small fluctuations in temperature even through summer or winter, so the change from the average temperature will not be large. In addition, it has the advantage of knowing the general temperature distribution of several nodes as a result of the warmup. However, the biggest disadvantage is that since the average temperature is used, the initial temperature must be used, which is not related to the duration of the simulation. Warmup is meaningful in that it finds the initial temperature at a more reasonable value, so it is not a process that requires a lot of accuracy. However, for nodes with high thermal mass, the accuracy of the simulation varies greatly depending on how wrong the initial temperature is.

4.2 COOLING AND HEATING RESULTS WITHOUT FOOD IN BOX

The first part of experiments used type-1 Peltier module (TEC1 - 12704). To compare the system performance, two cases were taken. The first is the cooling system without any food inside the box. This will help in system calibration. The second case, some food was placed inside the box.

4.2.1 Cooling Results Without Food In Box

Cooling experiments without food in the insulated box are performed at two different times under the conditions shown in Table (4.1).

Table 4.1: Initial conditions of the experiment without food and Peltier type-1(TEC1 - 12704)

Parameters	Day Time	Night time
Ambient temperature (°C)	34	29
Experiment Duration (minutes)	35	35

The results are depicted in Fig. (4.1) for the day time.

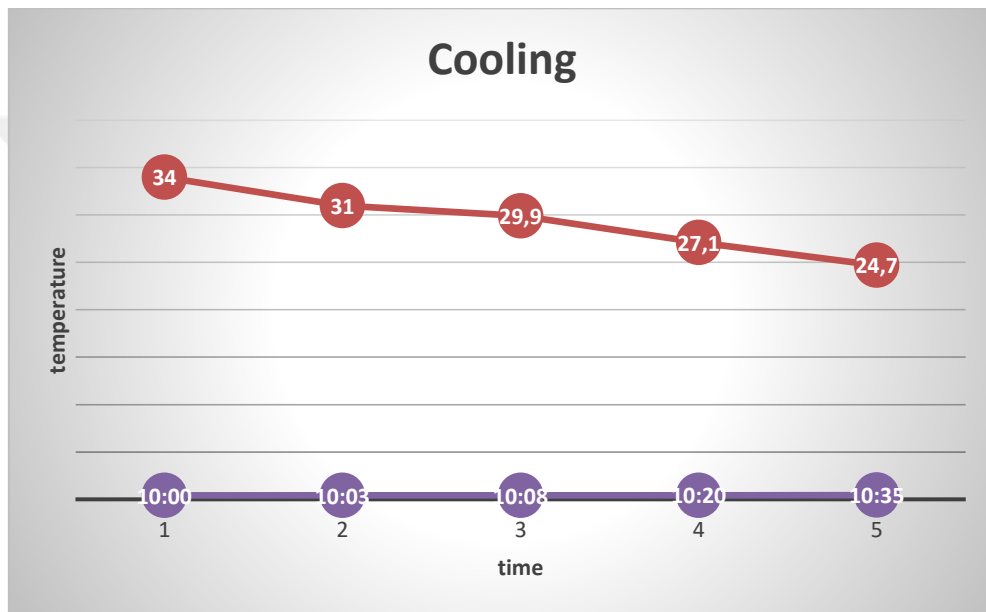


Figure 4.4: Cooling results with no food in the box in the day time.

The temperature is decreased from 34 °C to 24.7 °C for 35 minutes almost in a linear situation.

This means that the decrement rate is:

$$\Delta T = (34 - 24.7) / 35 = 0.27 \text{ } ^\circ\text{C}/\text{min} \quad (4.1)$$

While in the night time, the results are shown in Figure (4.2).

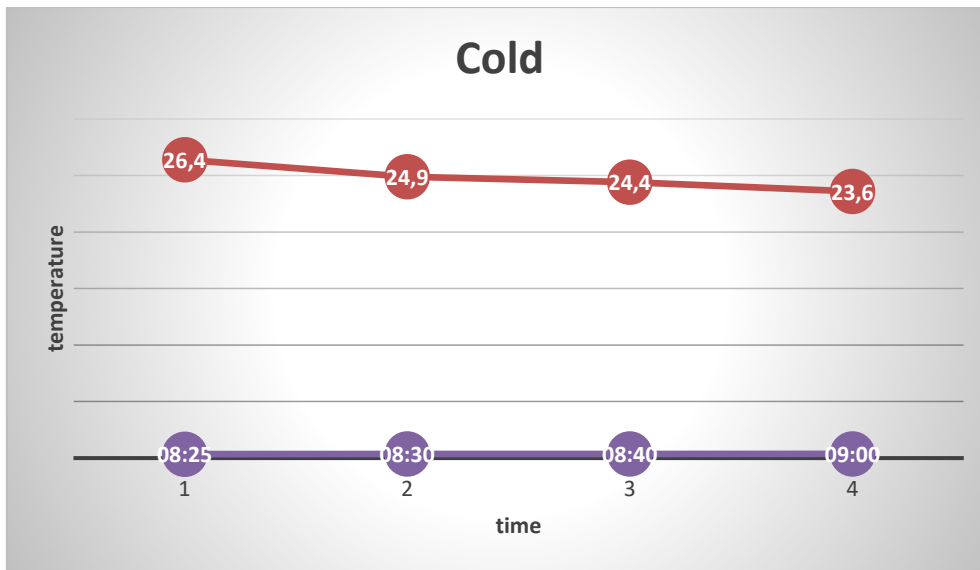


Figure 4.5: Cooling results with no food in the box in the nighttime.

The temperature is decreased from 26.4 °C to 23.6 °C for 35 minutes. this means that the decrement rate is:

$$\Delta T = (26.4 - 23.6) / 35 = 0.08 \text{ } ^\circ\text{C}/\text{min} \quad (4.2)$$

4.2.2 Heating Results Without Food In Box

Heating experiments without food in the insulated box are performed at two different times under the conditions shown in Table (4.6) above. The results are depicted in Fig. (4.3) for the day time.

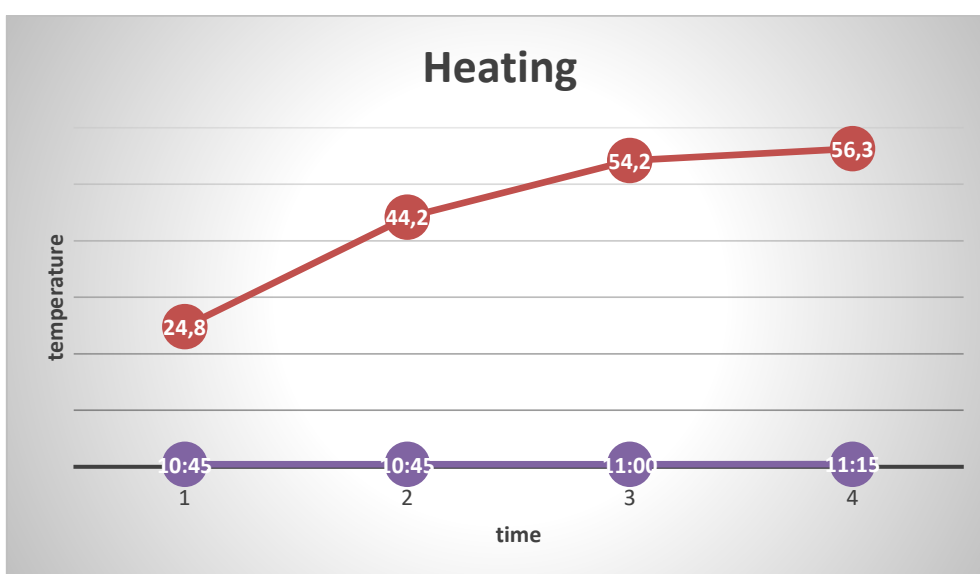


Figure 4.6: Heating results when there is no food in the box in the daytime.

The temperature is increased from 24.8 °C to 56.3 °C during 30 minutes in a non-linear situation. This means that the increment rate is:

$$\Delta T = (56.3 - 24.8) / 30 = 1.05 \text{ } ^\circ\text{C}/\text{min} \quad (4.3)$$

While in the night time, the results are shown in Fig. (4.7).

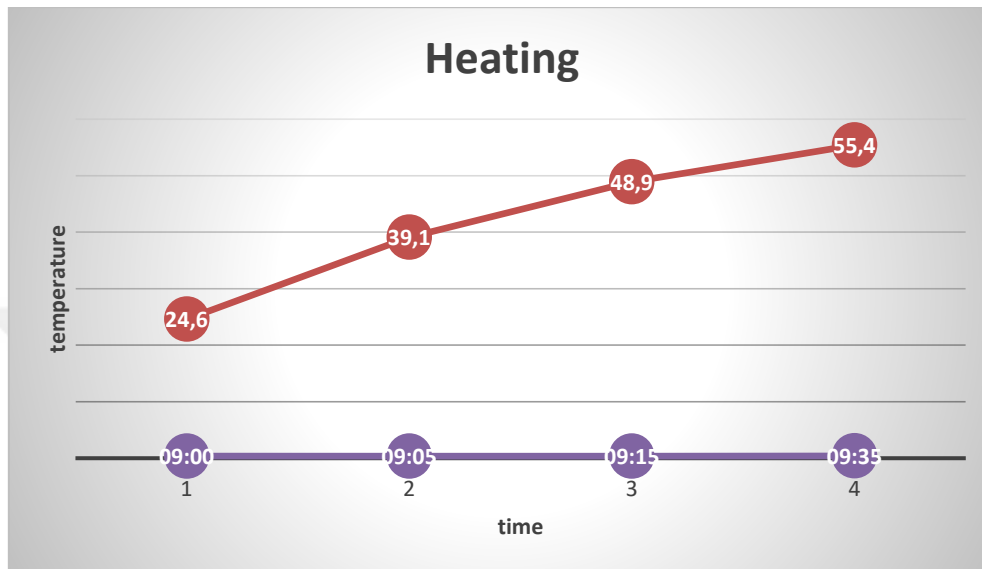


Figure 4.7: Heating results with no food in the box in the nighttime.

The temperature is increased from 24.8 °C to 56.3 °C during 30 minutes in almost linear situation. This means that the increment rate is:

$$\Delta T = (55.4 - 23.6) / 35 = 0.91 \text{ } ^\circ\text{C}/\text{min} \quad (4.4)$$

The following points can be concluded from the above results:

- i. The heat rising was faster than the cold dropping.
- ii. There is a difference in the readings of the day time and night time
- iii. The heat was constant on a specific degree (56.3)c after a period of time
- iv. The cold was constant on a specific degree (24.7)c after a period of time

4.3 COOLING AND HEATING RESULTS WITH SOME FOOD IN BOX

Some food was placed inside the box to see the variation of temperature during the cooling (some drinks Coca Cola cans) and heating (warm fast food) cycles.

4.3.1 Cooling Results With Food In Box

Two (Coca Cola) drinking cans are placed inside the box at initial temperature of 36 °C in the day time. The variation of temperature during 30 minutes from the beginning of system operation is shown in Fig. (4-8).

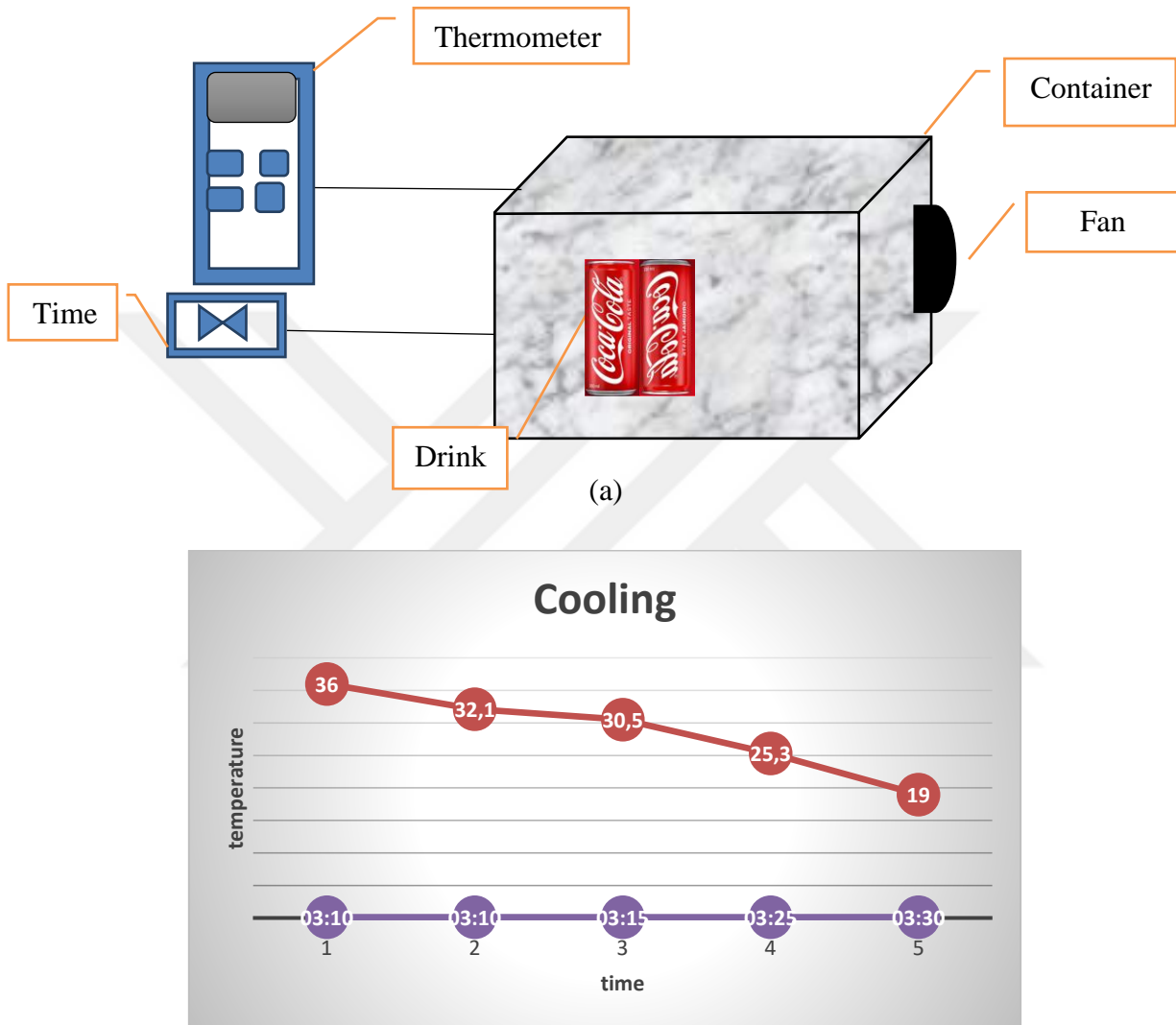


Figure 4.8: Cooling results when there is food in the box in the day time, (a). experiment setup, (b). cooling results

The temperature is decreased from 36 °C to 19 °C during 30 minutes almost in a linear situation. This means that the decrement rate is:

$$\Delta T = (36 - 19) / 30 = 0.57 \text{ } ^\circ\text{C}/\text{min} \quad (4.5)$$

While in the night time, the results are shown in Fig. (4.9).

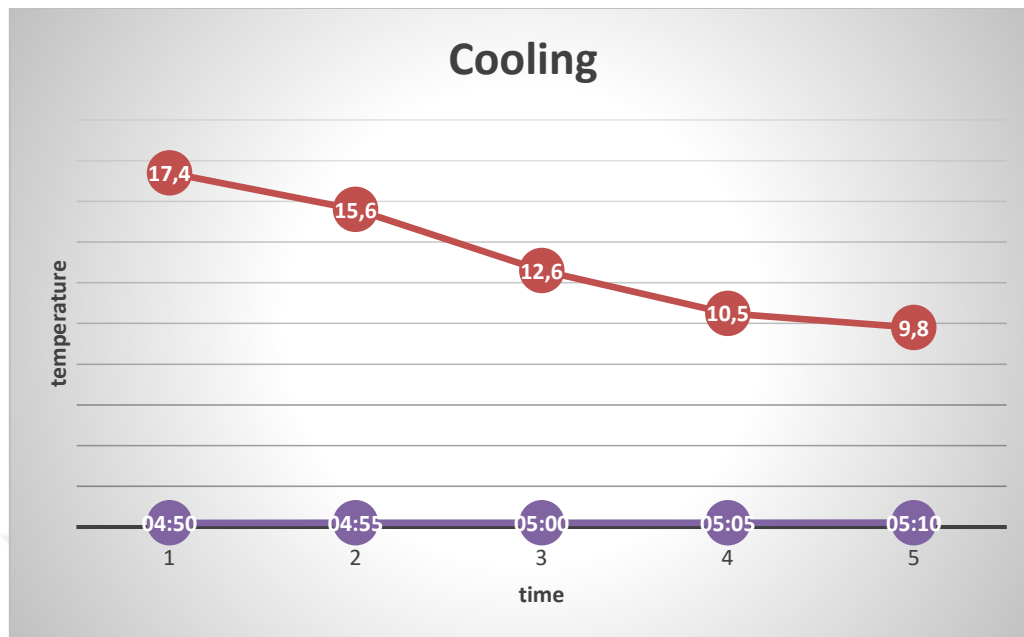


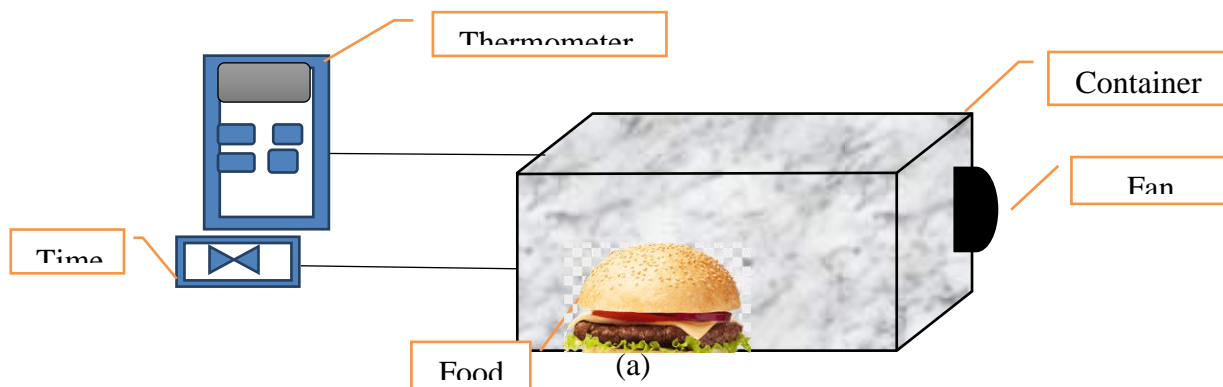
Figure 4.9: Cooling results with some food in the box in the nighttime.

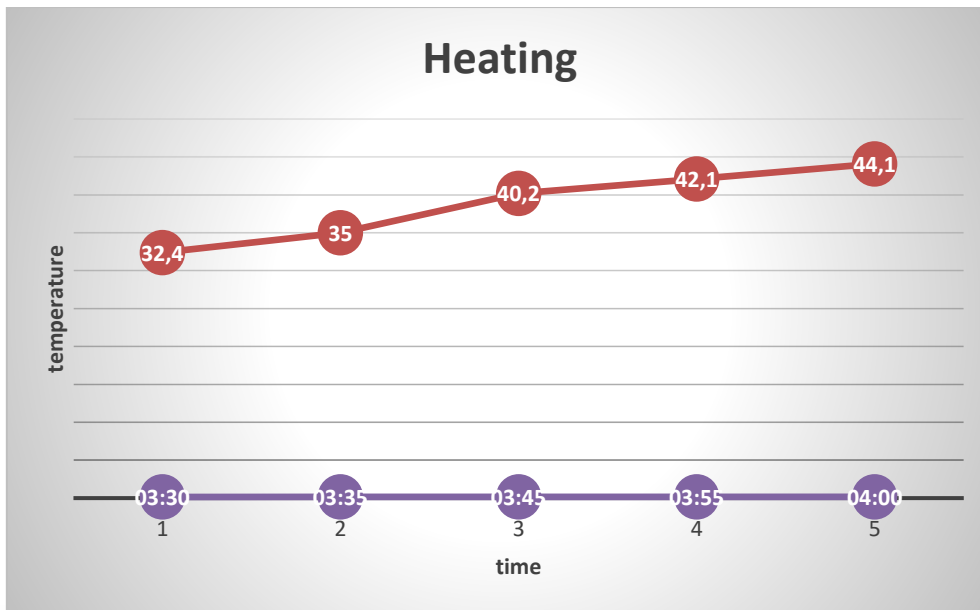
The temperature is decreased from 17.4 °C to 9.8 °C during 25 minutes in a nonlinear situation. This means that the decrement rate is:

$$\Delta T = (17.4 - 9.8) / 25 = 0.30 \text{ } ^\circ\text{C}/\text{min} \quad (4.6)$$

4.3.2 Heating Results with food in box

Some fast food is placed inside the box at initial temperature of 32.4 °C in the daytime. The variation of temperature during 30 minutes from the beginning of system operation is shown in Fig. (4-10).





(b)

Figure 4.10: Heating results with some food in the box in the daytime, (a). The experiment setup, (b).

Heating results

The temperature is increased from 32.4 °C to 44.5 °C during 30 minutes in almost linear situation. This means that the increment rate is:

$$\Delta T = (44.5 - 32.4) / 30 = 0.40 \text{ } ^\circ\text{C}/\text{min}$$

While in the night time, the results are shown in Fig. (4.11).

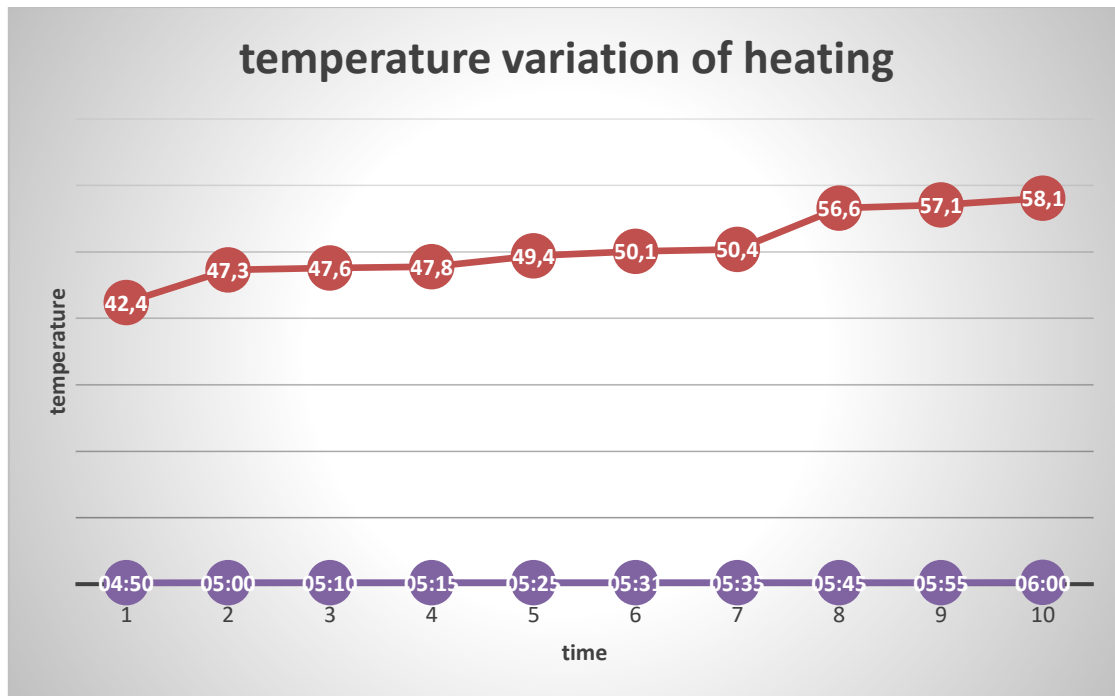


Figure 4.11: Heating results with some food in the box in the nighttime.

The temperature is increased from 42.4 °C to 58.1 °C during 70 minutes in almost linear situation. This means that the increment rate is:

$$\Delta T = (58.1 - 42.4) / 70 = 0.22 \text{ } ^\circ\text{C}/\text{min} \quad (4.7)$$

4.4 PELTIER TYPE -2 (SP 1848 /27145 SA) RESULTS

To see the effect of changing Peltier Module, another type of Peltier Module was used. The second type is:(SP1848/27145 SA). The results of cooling and heating with some food inside the box will be discussed in the following sections.

4.4.1 Cooling Results With Food In Box

Two (Coca Cola) drinking cans are placed inside the box at initial temperature of 17.4 °C in the daytime. The variation of temperature during 25 minutes from the beginning of system operation is shown in Fig. (4-12).

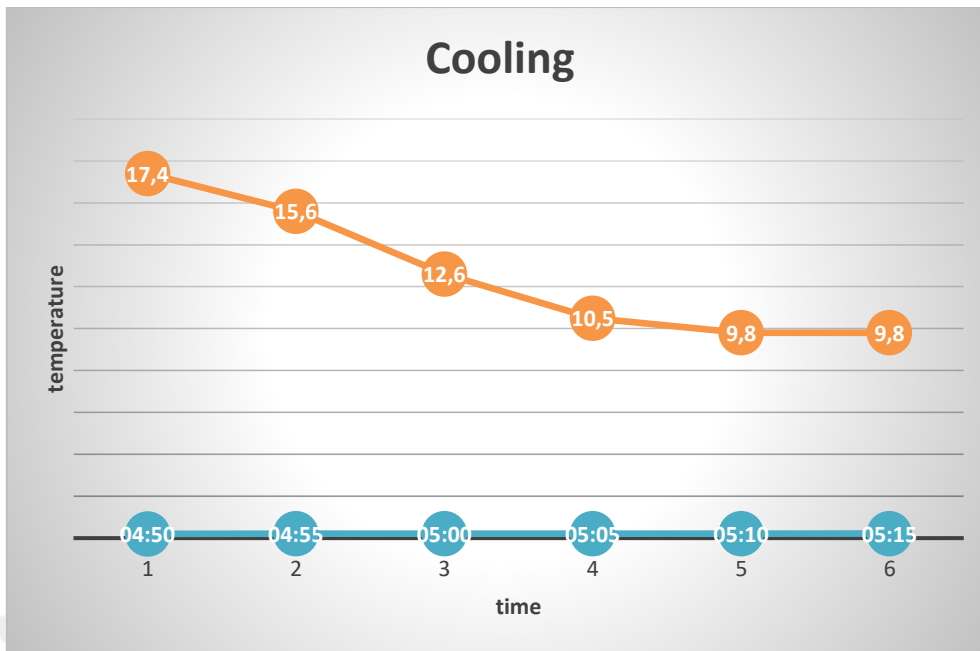


Figure 4.12: Cooling results when there is some food in the box in the daytime using Peltier type-2.

The temperature is decreased from 17.4 °C to 9.8 °C during 25 minutes in a nonlinear situation.

This means that the decrement rate is:

$$\Delta T = (17.4 - 9.8) / 25 = 0.30 \text{ } ^\circ\text{C}/\text{min} \quad (4.8)$$

4.4.2 Heating Results With Food In Box

Some food was placed inside the box in the daytime. The variation of temperature is shown in Fig. (4-13).

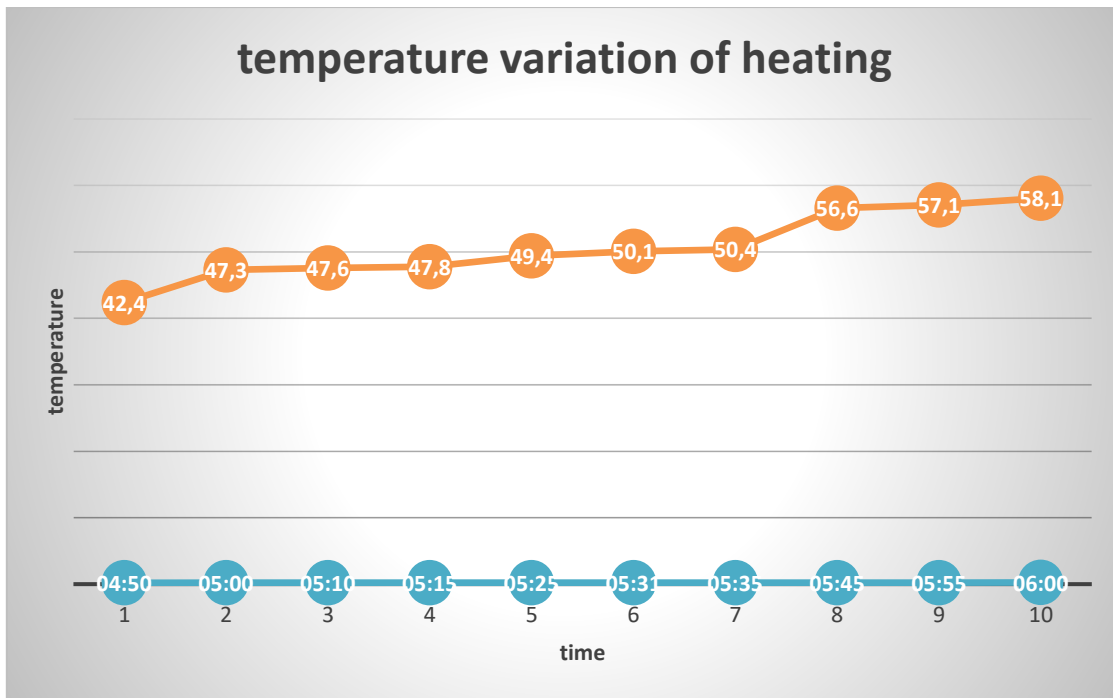


Figure 4.13: Heating results when there is some food in the box in the day time using Peltier type-2.

4.5 DISCUSSION OF RESULTS

Table (4-2) shows the summary of the different experimental results of cooling and heating cycles with and without food. These results are for Peltier type no. 1.

Table 4.2: Summary of Results

Time	Box inside	Parameters	Peltier Type- 1 (TEC1 - 12704)	
			Cooling	Heating
Day Time	Without Food	$T_{max}^{\circ C}$	34	56.3
		$T_{min}^{\circ C}$	24.7	24.8
		$\Delta T \text{ }^{\circ C}/\text{min}$	0.27	1.05
	With Food	$T_{max}^{\circ C}$	36	44.5
		$T_{min}^{\circ C}$	19	32.4
		$\Delta T \text{ }^{\circ C}/\text{min}$	0.57	0.40
Nighttime	Without Food	$T_{max}^{\circ C}$	26.4	55.4
		$T_{min}^{\circ C}$	23.6	23.6
		$\Delta T \text{ }^{\circ C}/\text{min}$	0.08	0.91
	With Food	$T_{max}^{\circ C}$	17.4	58.1
		$T_{min}^{\circ C}$	9.8	42.4
		$\Delta T \text{ }^{\circ C}/\text{min}$	0.30	0.22

From the results of cooling cycle without food (Fig. 4.1-4.2), the temperature is decreased for the first 10 minutes about 3°C during the daytime, while it decreased about 2 °C in the nighttime. These are relatively small numbers. This is because no food inside the insulating box to heat transfer. In the heating cycle without food (Fig.4.3-4.4), the temperature is increased by 19.4 °C during the first 15 minutes in the day time, while in the night time it is increased by 25.3 °C in the first 15 minutes. This may be due to two reasons. The first is that the insulating box is empty from food i.e., no heat transfer. The second reason is due to the decrease in the ambient temperature during the nighttime.

The second case in which we put some food inside the box (two Coca Cola cans for cooling or Kentucky chicken fast food for heating). In the cooling cycle, the temperature decreased by 5.5 °C for the first 15 minutes (Fig.4.5) during the daytime. In the nighttime, it is decreased by

6.9°C during the first 15 minutes (Fig. 4.6). It seems that the night ambient temperature increases the temperature drop.

In the heating cycle, the increment in the temperature during the first 15 minutes daytime was 7.8 °C(Fig.4.7). In nighttime, the increment was 5 °C for the first 15 minutes (Fig.4.8).

Changing the Peltier Type Result:

A few results were taken after changing the Peltier type from type -1 to type -2. Table (4.3) shows these results.

Table 4.3: Results with two different Peltiers

Time	cycle	Peltier type 1	Peltier type 2
		TEC1-12704	SP 1848/27145 SA
Day time with food	COOLING	5.5°C/15 minute	4.8 °C / 15 minute
	HEATING	7.8°C/15 minute	5.2 °C/15 minute

From Table 4.2, it seems that there is no big change during the cooling cycle. The big change (2.6 °C) appears at the heating cycle when Peltier Type -2 is used. Comparing the specifications of the two Peltiers shows that the specifications of the first Peltier is better than that of the second.

Generally, the results obtained shows that the system can achieve about 10°C for cold system and about 58 °C for hot system which enables it for operating in both conditions. From the result, it shows that the Peltier devices itself is dominant to hot temperature, apart from this to spreading the hot temperature within the container is faster compared to cold temperature.

The experiments carried out on the system show that it can work the way it was designed for, i.e., for heating and cooling of the food and liquids.

5. CONCLUSIONS AND FUTURE WORKS

5.1 CONCLUSIONS

In this work the details of the design and performance investigation for cooling and heating (using Peltier module) temperatures at different time conditions with and without food inside the container box have been introduced. The following points are concluded from this work:

- i. The insulator type (Thermocol) is suitable for this purpose. It is low cost and good insulator.
- ii. Peltier type -1 gave a sufficient heat to the food during the experiment time. Also, it works properly during the cooling cycle.
- iii. The power supply of the system is a car battery; it is stable during the long period of experiments.
- iv. The temperature of the food is acceptable when it reaches the end user after a time of around one hour.
- v. The rate of temperature increase or decrease is between (0.1 – 1.05 C/ minute)

5.2 FUTURE WORKS

This work can be extended in future to cover the following issues:

- i. Larger insulating box and different shapes to take more amount of food and drinks.
- ii. Different bigger and more efficient Peltier module with the help of special software.
- iii. Adding solar cell module to charge the battery during the daytime to decrease the cost.
- iv. Using a small battery instead of the car battery to drive the Peltier module. This is suitable for small volumes like electronic devices and medicine.
- v. To keep the temperature constant for long period, an automatic control system may be used. This will add more complexity and cost.
- vi. Use another Peltier module attached to the insulating box to convert the heat liberated into electrical energy using Seebeck Effect.

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