A PROJECT REPORT

ON

"DUAL USE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM (VCRS)"

Submitted to

UNIVERSITY OF MUMBAI

In Partial Fulfilment of the Requirement for the Award of

BACHELOR'S DEGREE IN MECHANICAL ENGINEERING

BY

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UNDER THE GUIDANCE OF
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Khandagaon, New Panvel - 410206

2018-2019

AFFILIATED TO

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CERTIFICATE

This is certify that the project entitled

"DUAL USE OF VCRS"

submitted by

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is a record of bonafide work carried out by them, in the partial fulfilment of the requirement for the award of Degree of Bachelor of Engineering (Mechanical Engineering) at ***Anjuman-I-Islam's Kalsekar Technical Campus, Navi Mumbai*** under the University of MUMBAI. This work is done during year 2018-2019, under our guidance.

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KHAN REHMAN FEROZ
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Project I Approval for Bachelor of Engineering

This project entitled ¨*Dual Use Of Vcrs*¨ by ***Khan Rehman Feroz, Lore Ubed Basheer, Mogal Usama Zafar, Momin Mohammad Imtiaz*** is approved for the degree of ***Bachelor of Engineering in Department of Mechanical Engineering.***

Examiners

1. ....
2. ....

Supervisors

1. ....
2. ....

Chairman

....

Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

STUDENT NAME :
ROLL NUMBER :

ABSTRACT

As we all know heat is one of the different forms of energy and to alleviate the problem of protection of global environment saving of energy is very important. Whenever the heat is evolved from any system to the environment, the surrounding temperature increases which nothing but leads to global warming. So in any field the conservation of energy should be done up to the best. So considering the above points we took one of the most usable appliances i.e. water cooler or domestic refrigerator. Of course, condenser is the part which evolves the heat to surrounding atmosphere. So we attempted to recover or utilize the heat which is been wasted from the condenser to surrounding.

Normally water cooler or refrigerator is having air-cooled condenser which we have replaced with water-cooled condenser. We are working on water cooler, so we have arranged two insulated tanks, one for cold water which is usually present in the water cooler and other for hot water which is additional tank we modified. We have dipped condenser tube in additional tank filled with water. Now because of this the heat from condenser which is been getting evolved, rising the temperature of water in the tank which is additionally placed. So this hot water can be used for household purpose replacing geyser. As power consumption of this heat recovery system is very much lesser than geyser although its heating capacity somewhat falls below the capacity of geyser we can substitute the geyser with above system as heating required for household purpose is fulfilled by our system. Here the heating of water will be carried out with the same input power given to cool the water. Hence, energy is been saved up to better extent which leads to the increment of COP (Co-efficient Of Performance) along with provision of hot water besides cold water. After all this system rejects negligible amount of heat in the surrounding, so it will affect global environment near to nothing.

Keywords: Alleviate , Global Environment, Water-Cooled Condenser, Water Cooler, Insulated Tanks, COP

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Chapter 1

Introduction

A household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. Heat rejection may occur directly to the air in the case of a conventional household refrigerator having air-cooled condenser or to water in the case of a water-cooled condenser.

Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators and automobile air- conditioners and are using POE oil as the conventional lubricant Heat can be recovered by using the water-cooled condenser and the system can work as a waste heat recovery unit. The recovered heat from the condenser can be used for bathing, cleaning, laundry, dish washing etc. The modified system can be used both as a refrigerator and also as a water heater. Therefore by retrofitting a water-cooled condenser it produce hot water and even reduce the utility bill of a small family. This design consists of an inlet for the cooling water and an exit for collecting the hot water. The hot water can be used instantly or it can be stored in a thermal storage tank for later use. The survey of the literature regarding the waste heat recovery and using of various compressor oils in the household refrigerator and air-conditioners are we conducted an experimental investigation on a split air conditioner having water cooled condenser we developed a simple water - cooled condenser utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operation. The experimental investigation verified that the water- cooled condenser and cooling tower results in decreasing the power consumption of the compressor. therefore we designed and developed a thermosyphon heat recovery system which can recover heat from a domestic refrigerator. we analyzed the performance of the system with heat exchangers. The circulation of water through the heat exchanger is done with the themosyphon effect which completely eliminates the need of a pump. For having that, the heat exchangers are connected to a water storage tank and when the water in the heat exchanger get heated up by the super-heated refrigerant of the storage tank and at the same time the cold water from the cold tank will chilled into the heat exchanger. The test results show that the concentric heat exchanger produce hot water.

1.1 Purpose

Waste heat is the energy associated with the air and liquid that leaves the boundary of the system and enters into the environment. So some part of energy is lost due to which some part of electricity consumed is wasted. So we have to utilize this energy for some useful purpose. If this waste heat is utilized then in leads to decrease in power consumption and it also makes the surrounding comfortable as the heat is not rejected to atmosphere.all food manufacturing businesses that use refrigeration and hot water.if the decision is based purely on cash, for anyone using oil, LPG or electricity to heat water then this system should be modified.

- Heat removed from the controlled space and heat added in the compressor during compression is rejected in the condenser to the ambient which should be utilized by any means.
- It is the challenge to create cooling capacity using the lowest possible amount of energy.
- Also COP increases by involvement of another condenser or heat exchanger for sub cooling process (before throttling).
- Recovery of this waste heat and to increase COP, an experimental setup is developed by fitting water cooled heat exchange to an existing refrigeration application.
- Waste heat recovered will be used for water heating, which will be stored in an insulated tank, and can be used for various applications here.

1.2 Project Scope

We have designed this system for domestic purpose that is to be used in water coolers and refrigerators. But this system can also be incorporated in industries such as chiller plants, ice plants where larger refrigeration systems are used for cooling purpose. It can also be incorporated in corporate offices and hotels where water coolers cum heaters are used. As the system used in experiment is small capacity, it can be replace by system of higher capacity which can extract large amount of heat with good design can improve rate of heat transfer. In future we can add solenoid – float system arrangement for the removing of the heated water. Also when we remove heat from condenser by forced convection instead of natural convection, we will get warm air which can be used to warm the foodstuffs in food warmer.

1.3 Project Goals and Objectives

1.3.1 Goals

- To improve the COP of system by modifying it to water cooled condenser from air cooled condenser.
- Apart from cold water as in normal water cooler ther is an arrangement of hot water is also done to get hot water in separate tank.

1.3.2 Objectives

The objective of this project is to utilize an alternative eco-friendly refrigerant for producing a temperature usually encountered in a conventional refrigerator. By manufacturing such type of dual refrigerator adds new dimension to the world of refrigeration and oven. This dual refrigerator waste heat recovery system gives some amount of relief to the electricity consumption by making it independent on same electric power supply to the compressor and utilize that power to get in cooling as well as heating or keep the food or water warm. The main objectives of this project are as follows:

- To evaluate the performance of refrigeration system when combined with condensing heat recovery system.
- To save energy of heating water using heat recovery unit.
- Improve overall system efficiency by using water cooled condenser.
- To reduce the power consumption.
- To make system economical.

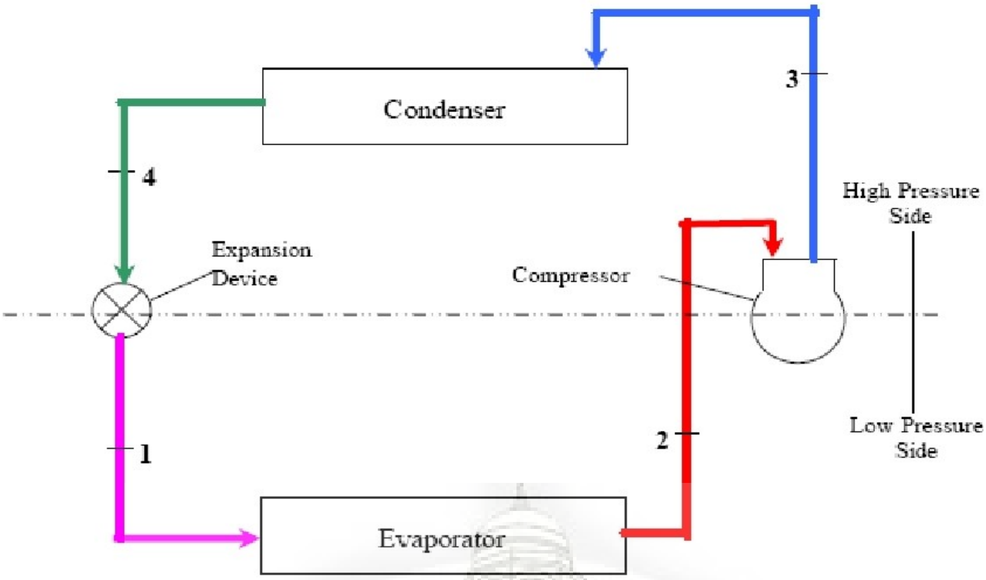


Figure 1.1: Vapour Compression Refrigeration System

1.4 Organization of Report

The rest of this dissertation is organized as follows. In the next chapter we review some of previous works done by the scholars on different heat recovery systems and we will get an idea about the types of refrigeration system and other components to be used for our model. Chapter three includes the basic principle of vapour compression refrigeration cycle in chapter four all the idea had been explored, chapter four indicates all the necessary components required for the construction of a Dual purpose refrigeration system in details and in chapter four we show the construction and assembly of the model. Chapter four concludes the working of the Dual purpose of vapour compression Refrigeration system. Design calculations, Design diagrams and material consideration are included in chapter five, whereas, the result of the designed and fabricated dual purpose refrigerator is shown in chapter six. In chapter six, the advantages, disadvantages and applications are described. Conclusion and future scope of the designed model are concluded in chapter eight. The remaining of the dissertation are the references and appendixes of the research of heat Recovery system.

Chapter 2

Literature Survey

2.1 Refrigerator coupling to the water heater

Various Authors came forward and discussed about the design, development, analysis and fabrication of dual purpose refrigerator with good key words using various methodology. Some of them were as follows:

Romdhane, et, al., (2012) have studied the refrigerator coupling to a water-heater and heating floor to save energy and to reduce carbon emissions. Energy consumption in the world is significant and in continuous growth. It is fundamentally linked to the life level. It promotes the thermal comfort of the citizen, through the heating and cooling systems (air- conditioners, water-heaters, Refrigerator). With the aim of saving energy and to reduce carbon emission, it is necessary to find some innovating solutions in this field and to create megawatts the heat recovery system does not have any modification on the basic refrigeration cycle. To obtain cold inside the refrigerator, heat is extracted with the air and food and then is rejected by the condenser in the kitchen by this project, they tried to widen the use of a refrigerating system for the water heating, spaces or buildings, and this by the exploitation of the energy previously rejected by the condenser. With this manner the refrigerator can contribute to heat water and/or floor-heating; while keeping its principal function to cool Finally, the results obtained as well theoretically as in experiments show clearly that the heat withdraws coming from the condenser immersed in water or sand, is a reliable source of heat, being able to be useful at least for pre-heating of water or room. The recovered heat enters in the megawatts production concept.

2.1.1 Advantages of Paper

a. Energy saving

b. Reduce carbon emission

c. Thermal comfort for people

2.1.2 Disadvantages of Paper

a. Continuous heating is not achieved

b. As compared to adding additional heating device, getting the same amount of heat is little difficult

2.1.3 How to overcome the problems mentioned in Paper

a. For getting continuous heating an arrangement of storing the energy should done

b. Proper insulation should be done

2.2 Domestic refrigerator with water cooled condensor and various compressor oils

Sreejith., (2013) has studied the domestic refrigerator having water-cooled condenser using various compressor oils. in a household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. Heat rejection may occur directly to the air in the case of a conventional household refrigerator having air-cooled condenser or to water in the case of a water-cooled condenser. designed two types of heat exchangers, concentric type heat exchanger and coiled heat exchanger and then it is retrofitted in to the air conditioning system. he analyzed the performance of the system with these two types of heat exchangers. The circulation of water through heat exchanger is done with the themosyphon effect which completely eliminates the need of a pump. For having that, the heat exchangers are connected to a water storage tank and when the water in the heat exchanger get heated up by the superheated refrigerant the hot water flow upward through the connecting pipe into the top of the storage tank and at the same time the cold water from the bottom of the tank will flow into the heat exchanger. The energy consumption of the HFC134a refrigerator using SUNISO 3GS mineral oil as the lubricant reduced the energy consumption of the household refrigerator between 8 percent and 11 percent for different loads.

2.2.1 Advantages of Paper

a. Water cooled condensor is more efficient

b. COP obtained is more in water cooled condensor compared to air cooled condensor

2.2.2 Disadvantages of Paper

a. As water was still in water cooled condensor arrangement heat started flowing reverse after some time

2.2.3 How to overcome the problems mentioned in Paper

a. to overcome reverse flowing of heat condensor coil should be cooled in such a manner that water must be flowing continuously and must not be remain still

2.3 Recovering heat from domestic refrigerator to enhance COP

Momin, et. al., (2014) have studied the COP enhancement of domestic refrigerator by recovering heat from the condenser. Waste heat which is rejected from a process at a temperature enough high above the ambient temperature permits the recovery of energy for some useful purpose in an economic manner. The strategy of how to recover this heat depend not only on the temperature of the waste heat sources but also on the economics involves behind the technology incorporated. Using water cooled condenser instead of air cooled condenser we can utilize the heat of hot water in condenser for other purposes namely, water bath (Gyser), for heating of cool air in other system, drying of clothes. So by this we can enhance the performance of the domestic refrigerator. About 200 litres of hot water at a temperature of about 58^{o}C over a day from the outlet of water cooled condenser and this modification made the household refrigerator to be work as both refrigerator and water heater. The hot water which was obtained from the water-cooled condenser can be utilized for household applications like cleaning, dish washing, laundry, bathing etc.

2.3.1 Advantages of Paper

a. COP Increases

b. Hot water can be used as water bath,drying of clothes,etc

c. As system is water cooled more chilled water is obtained as compared to air cooled condensor

2.3.2 Disadvantages of Paper

a. After running the system for sometime the cycle is to be made OFF to avoid reverse heat flow which will damage the system

2.3.3 How to overcome the problems mentioned in Paper

a. Use the thermostat and set the required temperature to cut off the line so as to prevent the reverse flow of heat

2.4 Investigation of waste heat recovery system for household refrigerator

Sreejith, et. al., (2016) have studied the experimental investigation of waste heat recovery system for the household refrigerator. In this Generally, heat from the condenser side is dissipated to room air. If this heat is not utilized, it simply becomes waste heat. By retrofitting a waste heat recovery system this waste heat can be recovered and can be utilized for water heating purpose. The hot water thereby produced can be used for several residential and commercial usages. The hot water can also be stored in a tank for later use. The modified system results in energy saving due to non-usage of electricity for heating the water and cost saving by combining both utilities (refrigeration and heating) in one system. The hot water which was obtained from the water-cooled condenser can be utilized for household applications Techno economic analysis was done by comparing the WHRS with the conventional geyser and it was found that the installation cost and running cost of the waste heat recovery system in 24 hours of operation is much lower than the geyser.However the water collected in one day is less compared to a geyser but this amount is enough for the hot water requirement of a small family.

2.4.1 Advantages of Paper

a. Without additional power input water can be heated

b. Hot water can be used for several residential and commercial usage

c. Installation and running cost of the waste heat recovery system in 24 hours of operation is much lower than the geyser

2.4.2 Disadvantages of Paper

a. As compared to geyser, water collected with waste heat recovery system is less

2.4.3 How to overcome the problems mentioned in Paper

a. The above disadvantage is not applicable much for household purpose but for large scale this can be disadvantage and to overcome this evaporator tank can be made bigger to get higher temperature in condensor tank

2.5 Waste heat recovery through refrigeration system

Pathak, et. al., (2017) have studied the Waste Heat Recovery through Refrigeration system. The aim of this study is to design, construct and evaluate dual refrigeration system by manufacturing an experimental apparatus of heat recovery system from the condenser. Although studies have been done before on dual refrigeration systems, more research could be done to further enhance the results obtained by experimenting using different sets of working pair's material and testing them in different conditions and shape and sizes. Refrigerator has become an essential commodity rather than need. Very few of us are aware about the fact that lot of heat is wasted to ambient by the condenser of refrigerator. If this energy can be utilized effectively then it will be an added advantage of commodity our project aims towards the same goal. With an increase in the time interval the water and food temperature can be increased in Condenser and can be decrease in Evaporator considerably as per the requirement of the user. If this system made full insulated then we can get better result then the above result.

2.5.1 Advantages of Paper

a. Heating the food or water in condensor tank

b. Better utilization of waste

c. With increase in the time interval the water and food temperature can be increased in condensor

2.5.2 Disadvantages of Paper

a. Shape and size of the tank matters the result

b. Average result was obtained

2.5.3 How to overcome the problems mentioned in Paper

a. Proper shape and size of the tank must be designed to get maximum COP

b. Proper insulation was not done by them with conducting the test, So with proper insulation better result can be obtained

2.6 Technical Review

From all the above described consequences we came to conclude that the required design of dual use of vapour compression refrigeration system (waste heat recovery unit) the possible amount of rejected heat should be utilized in a meaningful purpose to save energy. So we developed the dual purpose refrigerator which can give us cooling as well as heating effect in same applied energy in useful manner.

- The water cooled condenser Coil should be arranged such that the the maximum waste heat should be utilized.
- A 240 Volt, 50 Hz, Single phase Energy Meter (Impulsing Meter) will be better for Calculation of Energy supply to the compressor to find out the work done of the compressor.
- To maximize the efficiency of the VCRS system the mechanical efficiency of the compressor should considered and the fan should be provided over air cooled condenser to increase the efficiency of the system. We can also use the waste heat of the condenser for air heating purpose in winter season with some modifications.

2.6.1 Advantages of Technology

a. Waste heat is utilised in a efficient and very effective manner

b. As compared to air cooled condensor an arrangement with water cooled condensor gives more cooling effect

c. No additional energy or power is required to heat the water or food in the condensor tank

2.6.2 Reasons to use this Technology

a. To save the energy which is here nothing but electricity as it is non renewable source of energy and there is scarsity of eletricity also

b. With some modifications we can also use the waste heat of condensor for air heating purpose in winter

c. This system can replace the geyser for household purpose which will save the installation as well as running cost

Chapter 3

Project Planning

3.1 Members and Capabilities

Table 3.1: Table of Capabilities

SR. No	Name of Member	Capabilities
1	Khan Rehman Feroz	Fabrication and Aesthetics
2	Lore Ubed Basheer	Modeling and Design
3	Mogal Usama Zafar	Design and Calculation
4	Momin Mohammad Imtiaz	Fabrication and Aesthetics

3.2 Roles and Responsibilities

Table 3.2: Table of Responsibilities

SR. No	Name of Member	Role	Responsibilities
1	Lore Ubed Basheer	Team Leader	Parts Purchasing Modelling and Designing
2	Khan Rehman Feroz	Co-Leader	Fabrication, Aesthetics
3	Mogal Usama Zafar	Co-Leader and Treasurer	Designing and Calculation
4	Momin Mohammad Imtiaz	Co-Leader	Fabrication, Observation of Test and Aesthetic Works

3.3 Work Breakdown Structure

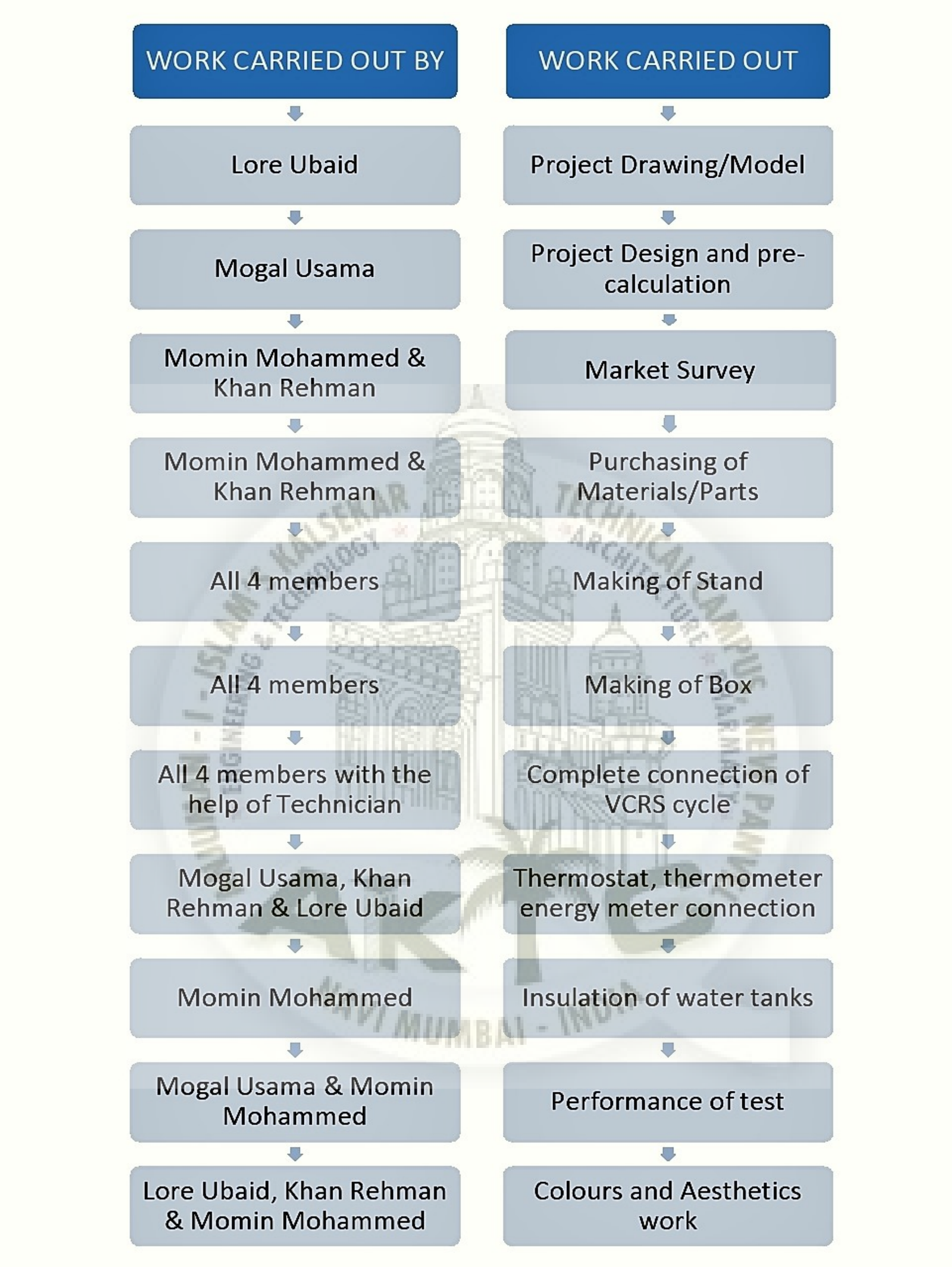


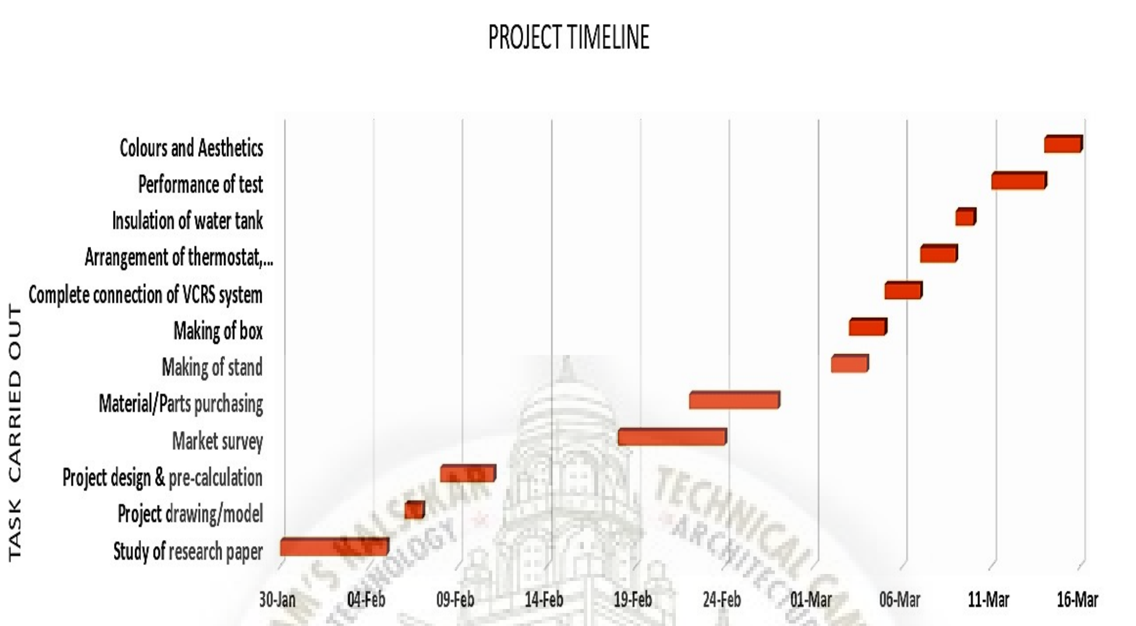
Figure 3.1: Work Breakdown Structure

3.4 Project Budget

Sr.No.	Name of Parts	Quantity	Cost
1	Wooden Tank	1	1070
2	Containers	2	780
3	0.36 Capillary Set	1	96
4	Copper Tube $_{1/4\ inch}$	7 m	462
5	Copper Tube $_{5/16\ inch}$	7 m	698
6	Compressor	1	2450
7	Digital Thermometer	6	1233
8	Stand	1	820
9	Glass wool and Thermocole	-	180
10	Thermostat	1	120
11	Energy Meter	1	300
12	R134a Refrigerant	150 gms	450
13	Screw	-	73
14	Paint and Accessories	-	260
15	Adhesive Material	-	105
16	Three Core Wire	2 m	85
17	Tap	2	156
18	Welding Rod	5	25
19	Socket and Wire	-	110
20	Technician Charges	-	200
21	Miscellaneous	-	200
		Total	**9873/-**

Figure 3.2: Table of Cost

3.5 Project Time Line



	Study of research paper	Project drawing/model	Project design & pre-calculation	Market survey	Material/Parts purchasing	Making of stand	Making of box	Complete connection of VCRS system	Arrangement of thermostat, thermometer & energy meter	Insulation of water tank	Performance of test	Colours and Aesthetics
Start Date	30-Jan	06-Feb	08-Feb	18-Feb	22-Feb	02-Mar	03-Mar	05-Mar	07-Mar	09-Mar	11-Mar	14-Mar
Days to Complete	6	1	3	6	5	2	2	2	2	1	3	2

Figure 3.3: Project Time Line

Chapter 4

Component Requirements Specification

4.1 Compressor

A compressor is a mechanical device that increases the pressure and temperature of the gas by reducing its volume. In water cooler or refrigerating system the compressor continuously circulates the refrigerant through the system. The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve, where it get compressed into high temperature and pressure. This high temperature and pressure gas refrigerant is discharge into the condenser through the delivery or discharge valve Since the compression of refrigerant requires some work to be done on it, therefore, a compressor must be driven by some prime mover.

Specications of Compressor which is used in system:

- Company - LG
- Model - MA42LPJG
- Input Wattage - 96 Watt
- Voltage - 220 V
- Frequency - 50 Hz

Figure 4.1: Compressor

4.2 Condenser and Evaporator Tube

4.2.1 Condenser Tube

Condenser is a device used in high pressure side of system. The vapour refrigerant with high pressure and temperature from the compressor is given to the condenser. Condenser gives its heat to the atmosphere as the refrigerant in the condenser is having higher temperature than the atmosphere. As the heat of the refrigerant is removed, its temperature drops to condensation temperature and it changes its state from vapour to liquid.

Dimensions of condenser tube used:

- Diameter of tube = 1/4 inch
- Length of tube = 7 meter

4.2.2 Evaporator Tube

Evaporator is the part that actually cools the stuff kept in the evaporator tank or container. The refrigerant in the evaporator tube is in liquid state and having low temperature than the space to be cooled.

Dimensions of evaporator tube used:

- Diameter of tube = 5/16 inch
- Length of tube = 7 meter

4.3 Expansion Device

Expansion device is connected after condensor tube. The high pressure liquid refrigerant from the condensor is converted into low pressure liquid refrigerant. It controls the flow of refrigerant according to load on evaporator. Generally 0.5mm to 2.5mm inside diameter and length varies from 0.5m to 5m.

Dimensions of expansion tube used:

- Diameter of tube = 2 mm
- Length of tube = 2 meter

Evaporator and Expansion Tube Arrangement.jpg

Figure 4.2: Condenser, Evaporator and Expansion Tube Arrangement

4.4 Refrigerant

Refrigerant plays vital role in the entire refrigeration system. There are different types of refrigerant available in the market but we have used R134a as it is more efficient and less harmful for ozone depletion as compared to other refrigerants. Its chemical name is tetrafluoroethane.

Description of R134a:

- Chemical Formula : CH_2FCF_3
- Density : 0.00425 gm/cm^3
- Freezing Point : -103.3^{o}C
- Boiling Point : -26.3^{o}C

4.5 Energy Meter

Energy Meter or Watt-Hour Meter is an electrical instrument that measures the amount of electrical energy used by the consumer. Energy Meter is used to calculate the energy consumed by the compressor. With the help of pulse count on the energy meter the energy consumption is calculated.

meter.jpg 

Figure 4.3: Energy Meter

4.6 Thermostat

Thermostat works on the principle of thermal expansion. This principle governs the switching OFF or ON of the electric circuit. The most common types of mechanical thermostats typically use either bimetallic strips or bellows filled with gas.

while digital thermostats use the same principle, but everything is controlled by a chip and built-in minicomputer.

Figure 4.4: Thermostat

4.7 Water Tank

Stainless Steel tanks are used for both hot and cold water in our project. Taps are fitted on each tank to get the water.

- Quantity : 2 units
- Capacity : 10 liters (Each Tank)
- Dimensions :
  1. Diameter : 27cm
  2. Length : 28.5cm

Figure 4.5: Stainless Steel Tanks

4.8 Metal Stand and Wooden Box

4.8.1 Metal stand

Metal stand is made up of Mild Steel. The one inch L-section of M.S. strip is used for making entire stand except the supportive bar at bottom which is made up of square cross section aluminium bar.

- Length : 92cm (2 pieces)
- Height : 83cm (4 pieces)
- Width : 54cm (4 pieces)
- Length of aluminium bar : 92cm (1 piece)

4.8.2 Wooden Box

Wooden box is made up of wooden ply. The box is having the double door adjustment on the top. All the parts of VCR system except compressor are en-housed in the wooden tank which make the aesthetic looks better and on the other hand some insulation is also provided by wooden box. Here the wooden ply is preferred over metal box by keeping in mind the point of cost as metal is costlier than wooden ply.

- The wooden ply of (8*4) ft was purchased and box was made

- Thickness of Ply : 1.2cm
- Length : 91cm
- Height : 45cm
- Width : 53cm

4.9 Insulation

Insulation is the most important aspect in any therma related project as it involves the concept of heat. Here also in our project which is based on VCR system insulation factor is taken into consideration. We have used two types of insulator :

- Glass Wool

  Glass Wool is having very good insulation property. We have surrounded both the tanks i.e. hot and cold water tanks with the glass wool.

- Thermocole

  Thermocole is used in inside area of wooden tank which also provides insulation to some level.

Chapter 5

Calculation of Dual Purpose VCR System

5.1 Basic Calculations

(1) We know That:

- Density of water = 1000kg/m^3
- Specific heat of water = 4.187 kj/kg ^{o}C

(2) Mass Calculation:

- M_{w_c} = Mass of Cold water
- M_{w_h} = Mass of Hot Water
- V_{w_c} = Volume of Cold Water Tank
- V_{w_h} = Volume of Hot Water Tank

5.1.1 Volume of Water in Cold Water Tank

- Cold Water = V_{w_c} = 10 liter
- 1 liter = 10^{-3} m^3
- 10 liter = 10*10^{-3} m^3
- M_{w_c} = 10*10^{-3}*10^3 kg
- M_{w_c} = 10 kg

5.1.2 Volume of Water in Hot Water Tank

- Hot Water = V_{w_h} = 10 liter
- 1 litter = 10^{-3} m^3
- 10 litter = 10*10^{-3} m^3

- $M_{w_h} = 10*10^{-3}*10^3$ kg
- $M_{w_h} = 10$ kg

5.2 Energy Consumption Calculation:

- (EMC) = Energy Meter Constant = 3200 imp/Kw.hr

5.2.1 Energy Consumption By the Compressor OR Work Done

$$E_s = \frac{No.of Imp*3600}{Time for Imp*EMC}$$

$$E_s = \frac{10*3600}{97*3200}$$

$$E_s = 0.1159 \text{ KW}$$

5.3 COP Calculation of System with Air Cooled Condenser

5.3.1 Observation Table:

Time	Condenser Inlet Temp. (°C)	Condenser Outlet Temp. (°C)	Evaporator Inlet Temp. (°C)	Evaporator Outlet Temp. (°C)	Cold Water Temp. (°C)
10:15	29.9	29.8	29.7	30.4	29.8
10:20	44.2	42.5	14.2	29.6	29.8
10:25	50.6	47.6	16.6	29.1	29.2
10:30	55.7	51.8	18.6	28.1	28.2
10:35	60.1	54.6	20.0	27.3	27.3
10:40	63.8	51.6	17.3	26.6	26.4
10:45	67.3	52.5	17.5	25.7	25.6
10:50	70.2	53.9	17.9	24.9	24.7
10:55	72.3	55.0	18.1	24.2	23.9
11:00	74.0	54.6	18.3	23.6	23.1
11:05	75.9	56.1	18.5	23.0	22.5
11:10	77.5	57.0	18.6	22.4	21.9
11:15	79	57.6	18.6	21.8	21.2

Figure 5.1: Readings for 60 min With Air Cooled Condenser

5.3.2 Graph

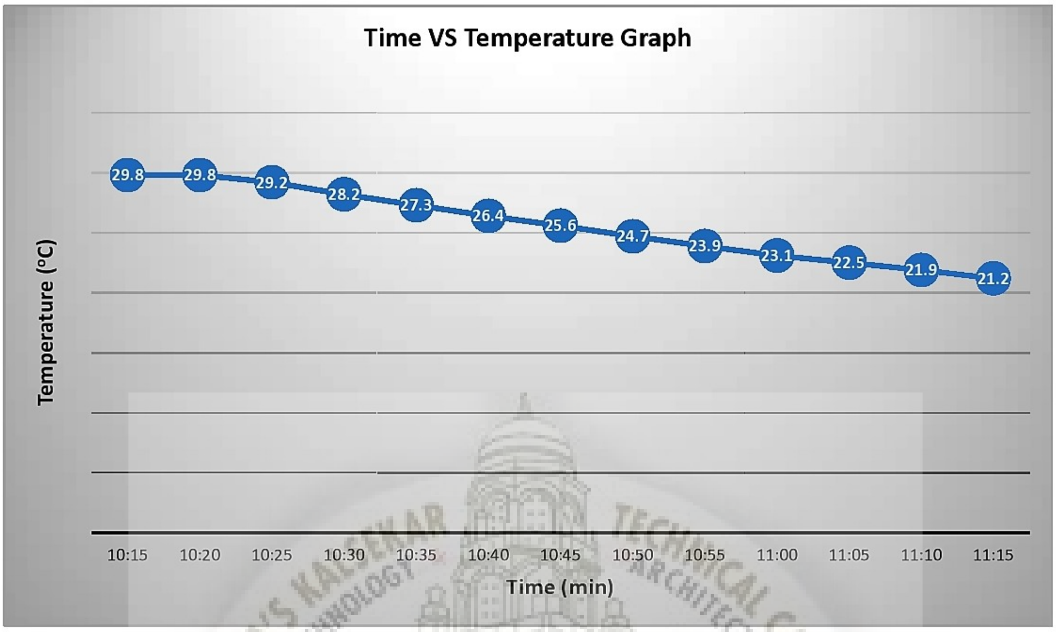


Figure 5.2: Temperature Drop For Air cooled Condenser

5.3.3 Time For Performance Of Test

Time taken for test = 60 min

= 60 * 60 (sec)

= 3600 sec

5.3.4 Refrigeration Effect

C_{p_w} = Specific Heat of Water in KJ/KgK

T_i = Initial Temperature

T_f = Final Temperature

$$RE = \frac{M_{cp} * C_{p_w} * (T_i - T_f)}{Time}$$

$$= \frac{10 * 4.187 * (29.8 - 21.2)}{3600}$$

= 0.1 KW

5.3.5 COP Calculation

COP = $\frac{RE}{W}$

$= \frac{0.1}{0.1159}$

= 0.8628

5.4 COP Calculation of System with Modification i.e. Water Cooled Condenser

5.4.1 Observation Table:

Time	Condenser Inlet Temp (°C)	Condenser Outlet Temp (°C)	Evaporator Inlet Temp (°C)	Evaporator Outlet Temp (°C)	Hot Water Temp (°C)	Cold Water Temp (°C)
12:35	29.6	30.2	30.0	30.6	29.9	29.9
12:40	45.3	31.6	14.3	29.0	30.8	29.6
12:45	51.5	33.5	14.7	27.5	32.7	29.3
12:50	55.3	35.3	15.4	26.1	34.3	28.3
12:55	58.4	37.1	15.9	24.8	36.2	27.1
01:00	60.0	38.9	16.2	23.3	38.0	25.6
01:05	62.9	40.7	16.6	22.1	39.7	23.8
01:10	64.5	42.2	16.6	20.7	41.6	21.2
01:15	66.1	43.9	16.9	19.5	43.9	19.6
01:20	67.2	45.5	17.2	18.3	45.1	17.5
01:25	68.4	47.1	17.2	17.1	47.8	15.8
01:30	69.5	48.6	17.4	15.9	49.6	14.7
01:35	70.1	49.6	17.7	15.2	51.2	13.2

Figure 5.3: Readings for 60 min with Water Cooled Condenser

5.4.2 Graph

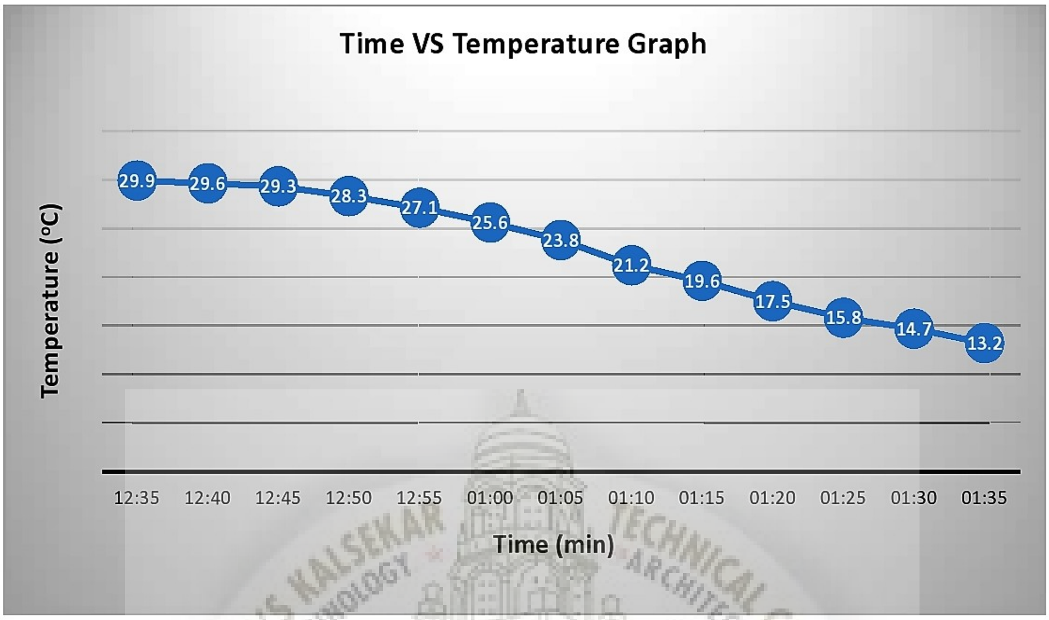


Figure 5.4: Temperature Drop In Cold Water Tank

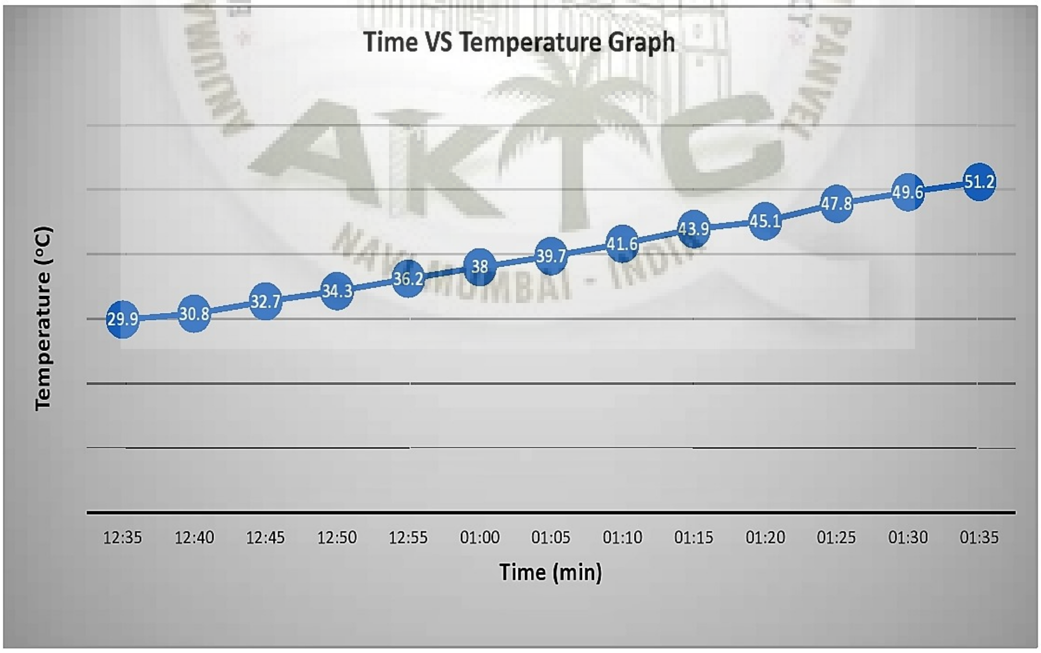


Figure 5.5: Temperature Rise In Hot Water Tank

5.4.3 Refrigeration Effect

C_{p_w} = Specific Heat of Water in KJ/KgK

T_i = Initial Temperature

T_f = Final Temperature

RE = $\frac{M_{cp} * C_{pw} * (T_i - T_f)}{Time}$

= $\frac{10*4.187*(29.9-13.2)}{3600}$

= 0.1942 KW

5.4.4 COP Calculation

COP = $\frac{RE}{W}$

= $\frac{0.1942}{0.1159}$

= 1.6755

5.5 Efficiency Improved

Improvement in COP = $\frac{(COP of Aircooled condenser) - (COP of Watercooled condenser)}{(COP of Aircooled condenser)} * 100$

= $\frac{(1.6755-0.8628)}{0.8628} * 100$

= 94.19 %

5.6 Readings taken after running the system for 60 min and switching off the system

5.6.1 Observation Table:

Time	Condenser Inlet Temp. (°C)	Condenser Outlet Temp. (°C)	Evaporator Inlet Temp. (°C)	Evaporator Outlet Temp. (°C)	Hot Water Temp. (°C)	Cold Water Temp. (°C)
01:35	73.8	40.9	12.9	17.1	51.2	13.2
01:40	51.4	38.2	24.3	21.4	51.1	15.8
01:45	41.6	37.1	24.1	23	51	16.1
01:50	39.6	40	24.2	23.6	50.9	16.4
01:55	38.9	41.3	24.4	24.2	50.8	16.8
02:00	38.4	41.6	24.6	24.7	50.7	17.1
02:05	38.2	41.6	24.6	25.1	50.6	17.3
02:10	38.1	41.5	24.7	25.3	50.5	17.6
02:15	38.1	41.3	24.8	25.6	50.4	17.9
02:20	38	41.3	24.9	25.7	50.2	18.2
02:25	37.9	41.1	24.8	25.9	50	18.5
02:30	37.8	41.3	24.9	25.9	49.8	18.7
02:35	37.8	41.3	25.1	26.1	49.6	18.9

Figure 5.6: Readings taken after switching off the system

5.6.2 Graphs

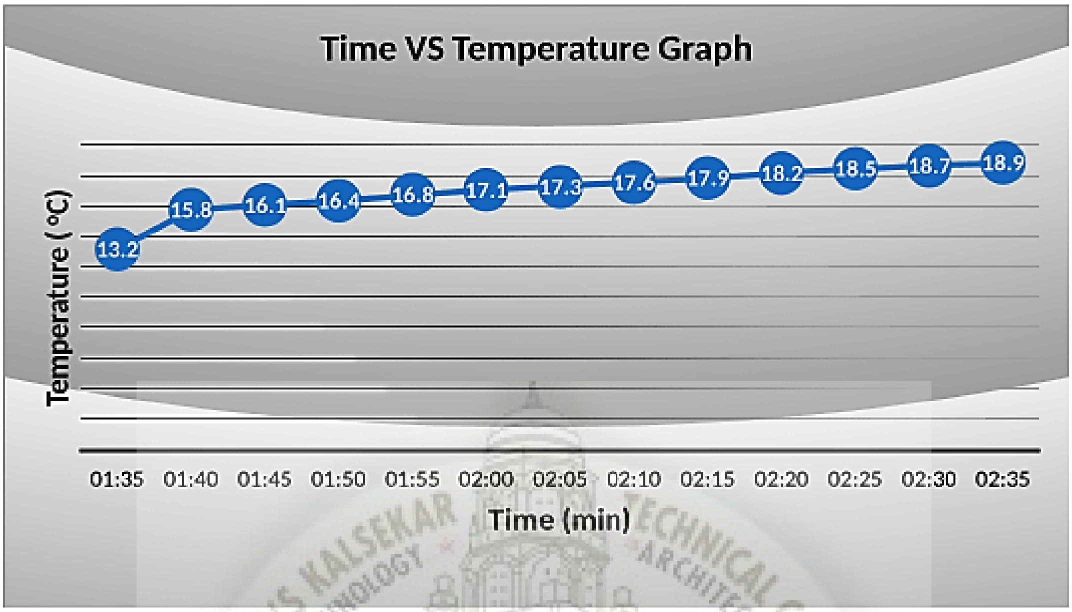


Figure 5.7: Graph for Cold Water

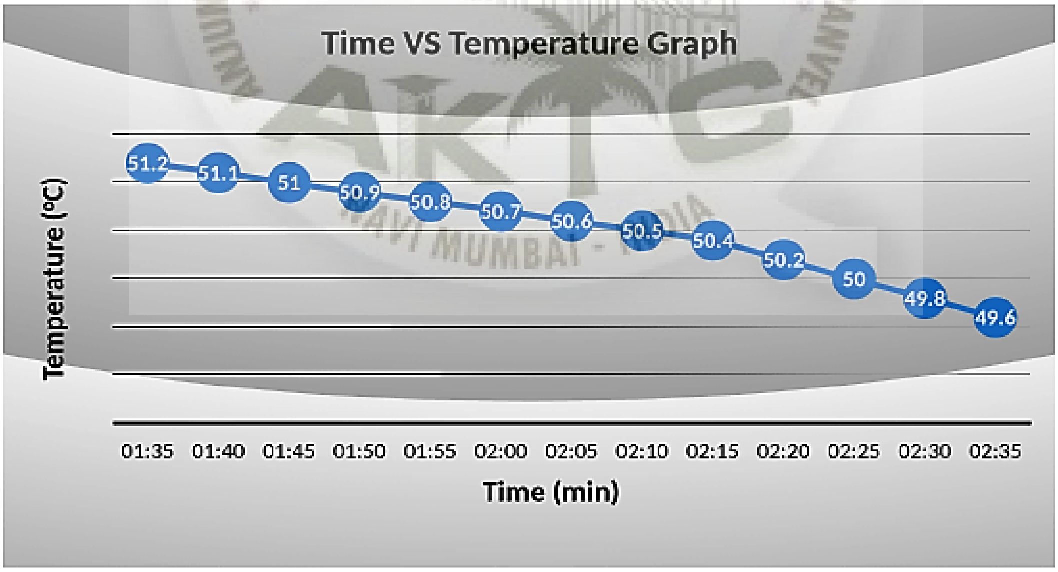


Figure 5.8: Graph for Hot Water

Chapter 6

Conclusion

After studying various research papers and collecting data on domestic refrigerator and water cooler, we designed and developed water cooler in which the heat is been utilized which use to wasted by giving in atmosphere in normal water cooler available in market. From experimental work carried out by us, we are achieving hot water in the additional tank in which condenser tubes are dipped. So the hot water can be utilize whenever required. For example: Bathing, Cooking, Washing utensils, etc. Hence, energy is saved and COP of the system is improved. Also the heat load in kitchen due to direct heat rejection in kitchen atmosphere is reduced as heat is given to water tank for heating the water. Thus the negligible amount of heat is hardly rejected to surrounding which can be eliminated while calculating heat load. Hence, the energy required to cool the kitchen is also reduced. Following are the main conclusion:

- Suitable heat recovery system can be designed and installed in home, office, schools, colleges, etc.
- Technical analysis has shown that it is economical.
- If this can be started from individual level then it can sum up and enormous effect can be obtained. Thus with small addition in cost if we recover and reuse the waste heat, then definitely we can progress towards energy conservation and simultaneously achieve our day today function.

Chapter 7

Future Scope

Using water cooled condenser instead of air cooled condenser we can utilize the heat of hot water in condenser for other purposes namely, water bath(geyser), for heating of cold air in other system, drying of clothes. Some of the important scope in future are as follows:

- The condenser tank can be kept larger than the evaporator tank to get more hot water besides more chilled water in evaporator tank as heating the water will take more time than the time taken with same capacity tanks.
- Using the best insulation material in a sufficient quantity to maintain the temperature for longer period of time.
- In future we can add solenoid float system arrangement for removing of the heated water.
- We can use the compressor with automatic speed changing arrangement according to the load condition.
- Also foodstuff can be kept warmer by making the box arrangement in place of hot water tank. Here instead of water the air inside the box containing condenser tube will become hot and keep the foodstuffs warm for a longer period of time.

References

[1] *Refrigerator Coupling to a Water-Heater and Heating Floor to Save Energy and to Reduce Carbon Emission*,http://www.scirp.org/journal/cweee ROMDHANE BEN SLAMA,January 2013