Thermal Analysis of dual effect Vapour compression refrigeration system with cooling and heating of water

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ABSTRACT

As the vapour compression refrigeration system has being utilized worldwide in domestic as well as industrial purpose. Waste of energy in terms of heat through condenser is exposed directly into the environment which has been the major issue in global warming of earth. So for reducing the waste of energy into the environment the existing model associated with maximum utilization of waste heat via installation of water chamber in between compressor and condenser. The recovered hot water could be put to use for home purpose like heating water, bathing, washing in addition to large scale industrial purpose like fabricating, processing, diluting, incorporating water into product.

In a vapour compression water cooling system, a box has situated after compressor as water where heat of hot vapours from compressor was utilized to heat the water and then after it supplied to air cooled condenser which exposed to the environment. Experiments were conducted for cases of free and forced convection of water in heat pump and parameters as temperature of water in water cooler, heat pump, condenser temperature and COP of refrigerator and heat pump were recognized and compared. After conducting the experiment, conclusions were drawn that the minimum evaporator temperature was found 3°C in free convection and 2°C in forced convection at 02:15.p.m. The maximum temperature of heat pump was found 62°C in free convection. The temperature heat pump was found 63°C at 02:15.p.m. in forced convection at 02:15.p.m. The COP of refrigerator during forced convection was received 1.2 times more than that of during free convection and in case of heat pump during forced convection it was received 1.1 times more than that of free convection.

Key Words- VCRS, Waste heat, heat pump, water cooler, evaporator and condenser temperature and COP

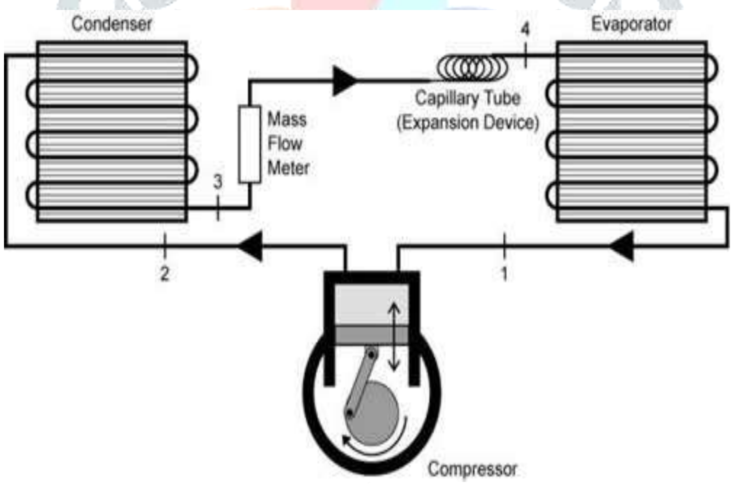
1. Introduction

In today’s generation, refrigeration industry is passing through evolutionary changes. Prominence is given to save energy and to protect the environment. Refrigeration technology is expected to develop technologies which are cheap and using refrigerant other than CFC. Many food industries, textiles industries, hotels, hostels, trains require both refrigeration and water heating. In case of textile mill, it requires central air conditioning plant which requires chilled water and hot water for steam generation and heating purpose, while in food industries refrigeration is required for product preservation and hot water required for cleaning, sterilization or process heating, whereas in hotels, hostels, trains refrigeration is required for air conditioning and hot water is required for cooking. It is common for the refrigeration and water heating systems to be separate and unconnected, and both consuming purchased energy. This approach wastes considerable energy, contributing to the depletion of fossil fuel reserves and the release of greenhouse gases.

The first objective of the VCR system is to produce cooling effect, with the simultaneous mode heating and cooling energies can produce using the same electric energy input at the compressor. In this paper, attention has been focused on studying, from an experimental point of view; utilize the waste heat from the condenser by simultaneous mode and how operating variables affect the performance of a Refrigeration plant when using R134a as working fluids.

1.1 Refrigeration System

Refrigeration is a technology which absorbs heat at low temperature and provides temperature below the surrounding by rejecting heat to the surrounding at higher temperature. Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to air conditioning units [1, 2].



Schematic diagram of V.C.R.S. [1]

Types of Refrigeration System [3].

1. Air refrigeration	4. Vapor Absorption refrigeration
2. Laser cooling/Refrigeration.	5. Vapor Compression refrigeration
3. Solar refrigeration.	6. Magnetic Refrigeration.

1.2 Heat Pump

Heat naturally flows from hot side to cold side, like everybody knows. Heat pump is doing this against the natural flow. A heat pump is a device that transfers heat energy from a source of heat to a destination called a "heat sink". Heat pumps are designed to move thermal energy in the opposite direction of spontaneous heat transfer by absorbing heat from a cold space and releasing it to a warmer one. A heat pump uses a small amount of external power to accomplish the work of transferring energy from the heat source to the heat sink [3].

1.3 Waste Heat Recovery in VCR system

Waste heat is heat, which is generated in a process by way of fuel combustion, electricity used or chemical reaction, and then “dumped” into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its “value”. The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved. The waste heat generated can be used for heating water which has number of applications in industries as well in domestic purposes. For utilizing the waste heat generated by the condenser coils are submerged in the water which results in heating it [4].

2.0 Literature Review

Elumalai et al. [4] have studied about heat retrieval from the condenser in the Vapour Compression Refrigeration system by using oven and heating unit that could be installed between compressor and condenser parts. The existence of oven enables us to retrieve the superheat from the discharge vapour and put it to use for raising the temperature of the space inside hot oven and raise the temperature of the fluids in the heater**.** Prati Kumbhar et.al [5] have done an experimental study on waste heat recovery from domestic refrigerator .In this paper they placed water cooled heat exchanger instead of condenser exposed to open atmosphere in vapour refrigeration system. After experiment they found that the System Performance Improved and Hot water Output. Sreejith K et al.. Vedil et al. [6] have analyzed hypothetical method to retrieve the waste heat liberated out of vapour compression cycle that is used to operate vapour absorption cycle. The required heat has been provided by solar powered energy. The work examined the effectiveness of combined cooling cycle. Sreejith K et al. [7] presented their experiment in which designed, fabricated and experimentally analyzed a waste heat recovery system for domestic refrigerator. They analyzed the system in three conditions without load, 40W load and 100W load, and also carried out the techno-economic analysis by simply comparing the waste heat recovery system with conventional geger. From experimental result data they found that the waste heat recovery system performs well along with the household refrigerator. Kaushik et al. [8] have dealt with the waste heat retrieval from the commercial refrigeration by featuring Canopus heat exchanger. There is a significant amount of low-grade heat obtainable in large-capacity systems. To recuperate this sub-standard heat, a Canopus heat exchanger is presented in between compressor and condenser elements. The device feasibility is normally studied with various working ranges and the influence on heat recovery aspects and general COP of the machine

Ch Mary et.al. [9] has analyzed the different process of the system and founds that convection coefficient increased due higher fan speed, heat convey in the evaporator and condenser with the surroundings increases, thus reduce the work done by the compressor on the refrigerant. Vapor compression cycle was more efficient with fans. Chethan et.al. [10] analyzed the VCR system with ammonia refrigerant and results were recorded. The suction & delivery pressure of compressor, temperature of evaporator and condenser are recorded and coefficient of performance is calculated. The results achieved will be validated through CFD simulation. Further between compressor and condenser diffuser has been installed, so that power input to the compressor has been deducted there by enhancing the COP. The enhancement will be made through CFD simulation. G.Maruthi et al. [11] performed the experiment to investigate the performance of vapour compression refrigeration of a domestic refrigerator of capacity160 liters by using R-134a and R-404a as working fluid refrigerant. Momin et al. [12] have retrieved waste heat coming from condenser unit of the home refrigerator to enhance the overall performance of the system. Retrieval of heat is from the home refrigerator is by thermos siphon. From the experimentation, it had been noted that after heat retrieving process from the condenser of the home refrigerator its overall COP got raised when compared to conventional refrigerator.

3.0 Experimental Setup

Different components used are: Compressor, Evaporator, Condenser, Capillary Tube and Expansion Valve. After collecting all the components they are assembled for the construction of a mini refrigerator. The major difference made was putting the condenser coil in external water storage; so as to use the heat dissipated from the condenser. A submersible pump motor is used for water circulation inside the condenser to make it forced convection.

Experimental V.C.R.S setup [8]

4.0 List of components used in the experiment:

S.N.	Component
1	Condenser
2	Compressor
3	Evaporator
4	Expansion valve
5	Thermometer
6	Capillary tube
7	Pressure gauge
8	Submersible motor

5.0 Specification of VCR System in the experiment setup:

For conducting the experiment on VCR system a condenser, evaporator, expansion valve and compressor with following specifications was employed:

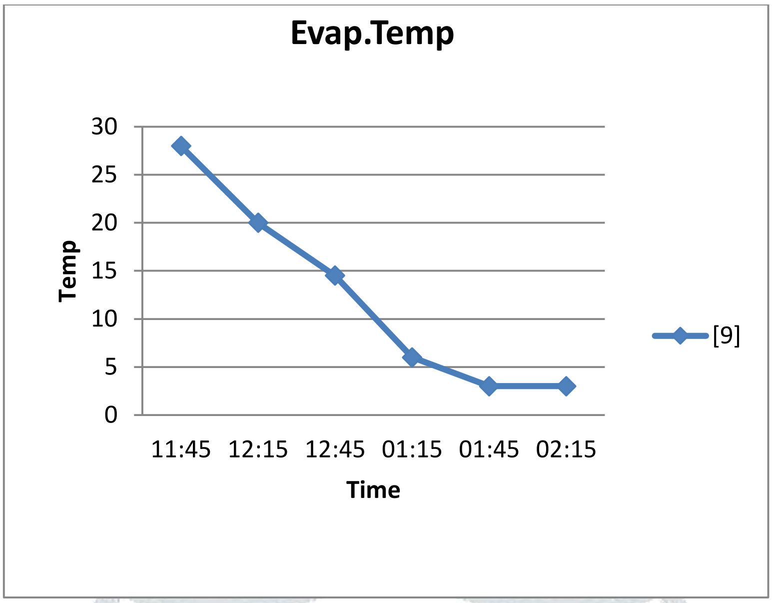
- LG. Compressor (Displacement 4.2cc/rev)
- Refrigerant R134a LBP.
- RSIR (Resistance Start Inductance Run) motor.
- PTC (Positive Temperature Coefficient).
- Condenser coil is made of copper whose diameter is 5.2mm, motor used is of 13W.

6.0 Observations:

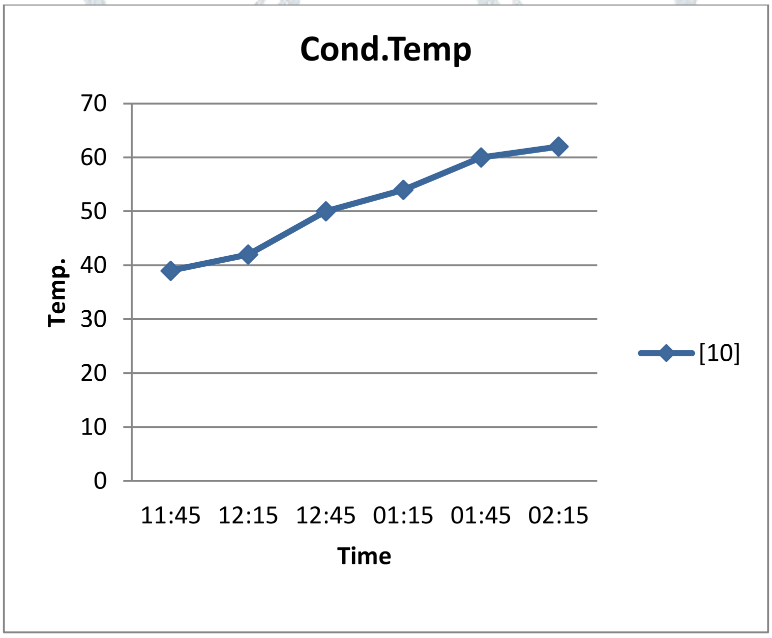
All observations have taken during the experiment at ITM university Gwalior RAC lab. Experiments are done basically to determine the COP of heat pump and refrigerator as well as the heat is being extracted from the condenser. There is no any additional input required for heating the water. Observations are given in the table no 1 and 2.\

7.0 Results and Discussion:

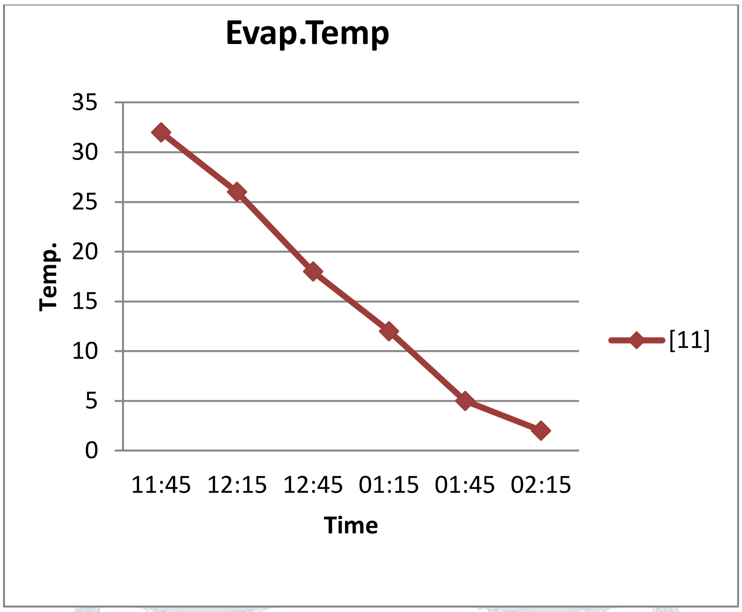
(a) Variation in temperature of condenser during free convection is as follows:



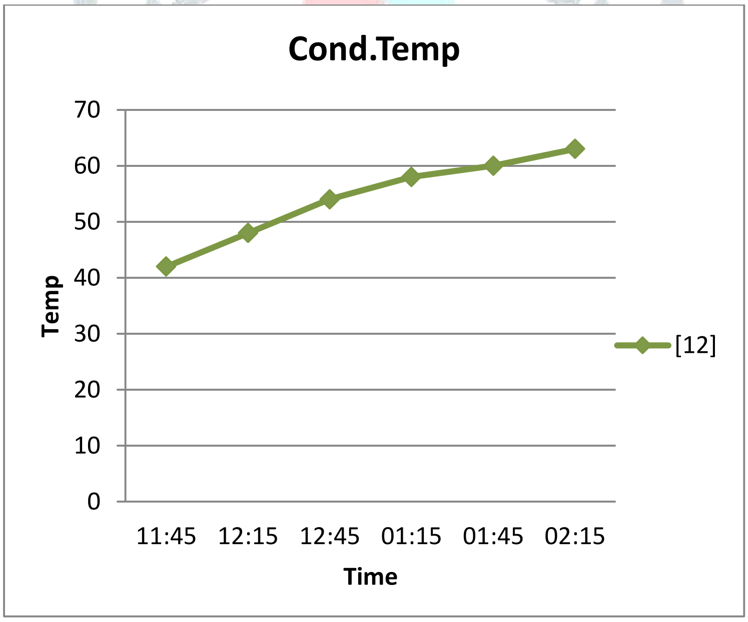
(b) Variation in temperature of condenser during free convection is as follows:



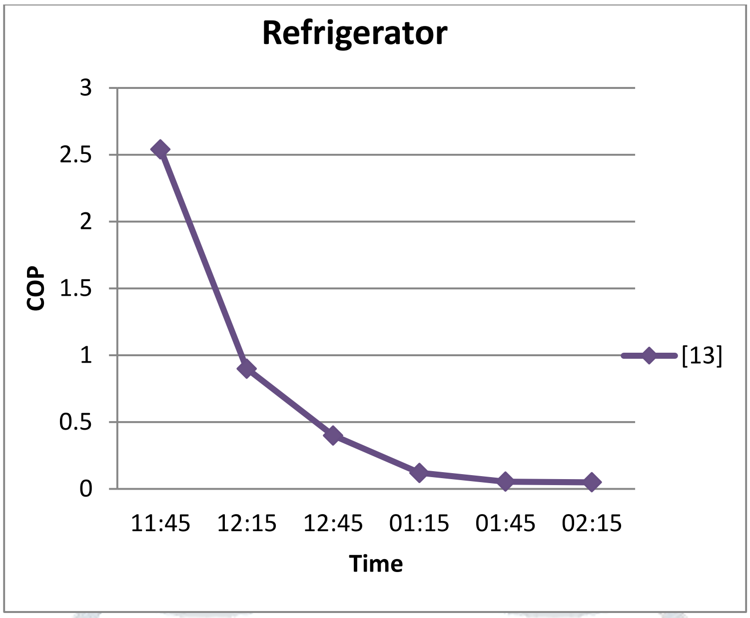
(c) Variation in Temperature of evaporator during forced convection is as follows:



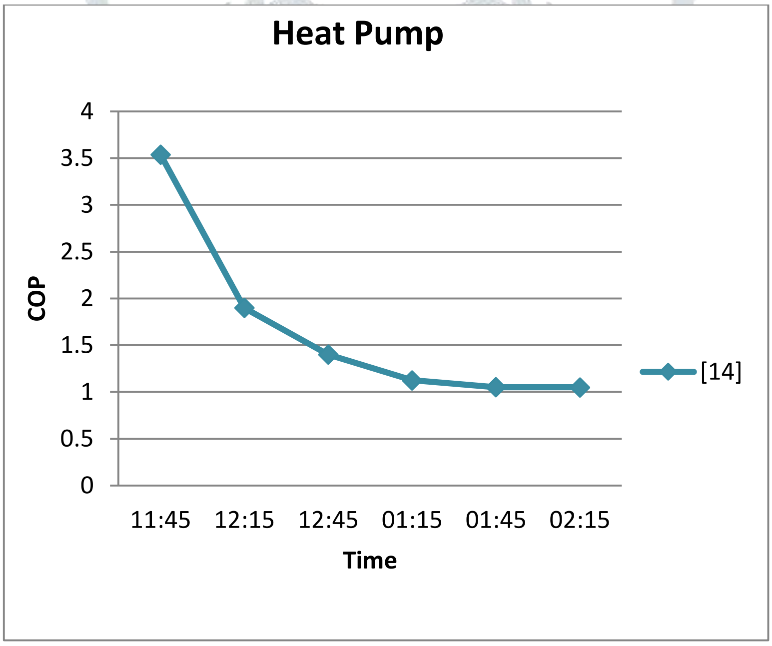
(d) Variation in temperature of condenser during Forced convection:



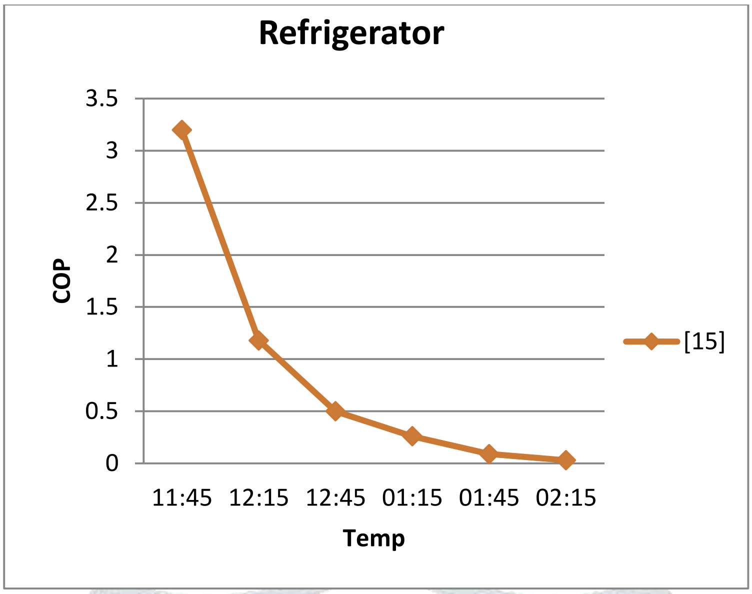
(e) COP of refrigerator during free convection:



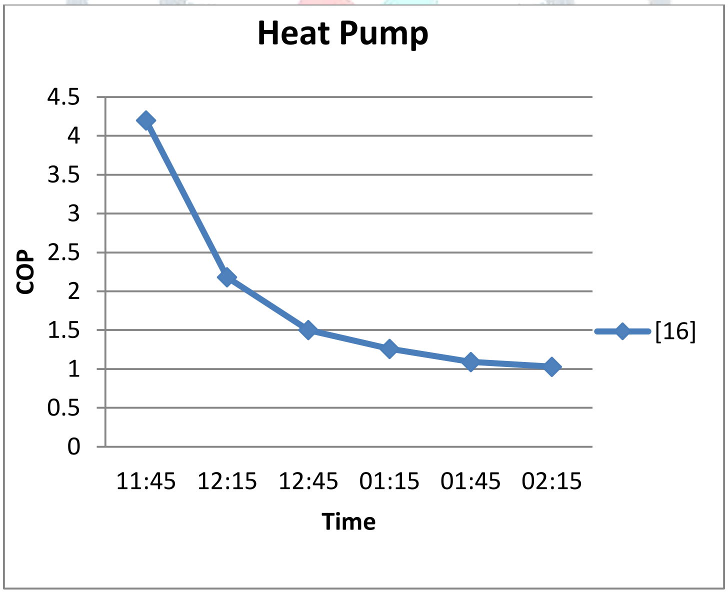
(f) COP of heat pump during free convection:



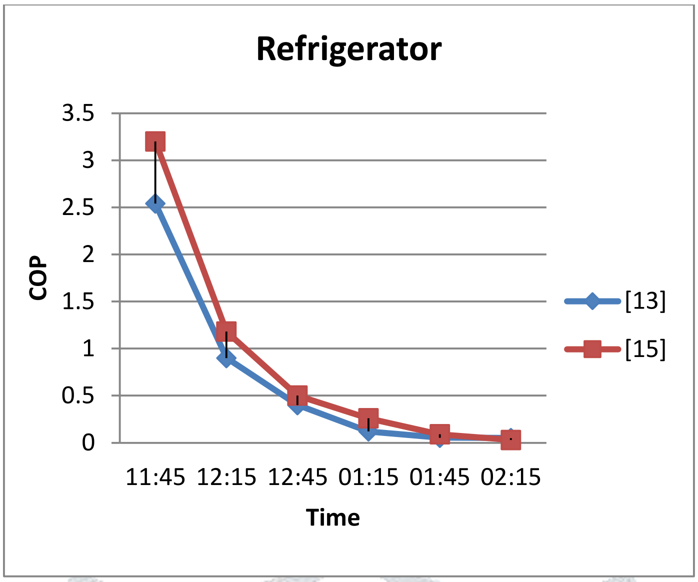
(g) cop of refrigerator during forced convection:



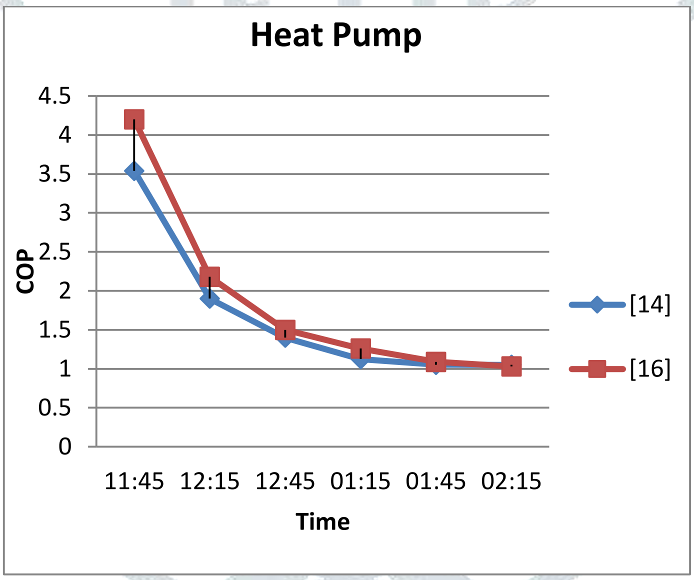
(h) cop of heat pump during forced convection:



(i) Comparison of COP of refrigerator during free and forced convection:



(j) Comparison of COP of heat pump in free and forced convection:



8. Conclusions:

After conducting the experimental analysis on the particular experimental setup following conclusion has been made.

The temperature of evaporator was found minimum 3°C at time 02:15.p.m in free convection and 2°C at time 02:15.p.m. in forced convection.

The temperature of condenser was found maximum 62°C at time 02:15.p.m. in free convection and 63°C at 02:15.p.m. in forced convection. The COP of refrigerator during forced convection was received 1.2 times more than that of during free convection and the COP of heat pump during forced convection was received 1.1 times more than that of during free convection.

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ANNEXURE 1

Table-1 Experiment no. 1: The variation of evaporator temperature and condenser temperature with respect the mbient temperature during the free convection.

S.N	Time	Evaporater temp (°c)	Condenser Temp(°c)	Ambient Temp(°c)
1	11:45	28	39	39
2	12:00	24	40	39
3	12:15	20	42	38
4	12:30	18	46	39
5	12:45	14.5	50	38.5
6	01:00	11	52	39
7	01:15	06	54	39
8	01:30	04	58	38
9	01:45	03	60	38.5
10	02:00	03	60	38
11	02:15	03	62	38

Table-2

Experiment no. 2: The variation of evaporator temperature and condenser temperature with respect to the ambient temperature during the forced convection.

S.N	TIME	EVAPORATOR TEMP (℃)	CONDENSER TEMP(℃)	AMBIENT TEMP(℃)
1.	11:45	32	42	39.5
2.	12:00	26.5	42.5	39
3.	12:15	26	48	39.5
4.	12:30	24	52	39.5
5.	12:45	18	54	39.5

6.	01:00	14	58	40
7.	01:15	12	58	40
8.	01:30	7	59	39.5
9.	01:45	5	60	39
10.	02:00	3	62	39
11.	02:15	2	63	39