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HOT AND COLD-WATER GENERATION BY REVERSIBLE REFRIGERATION CYCLE

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ABSTRACT
This study investigates the feasibility and effectiveness of utilizing a reversible refrigeration cycle for the simultaneous generation of hot and cold water. Traditional refrigeration systems are designed primarily for either cooling or heating applications, but a reversible refrigeration cycle, also known as a heat pump, has the capability to provide both heating and cooling simultaneously. This paper explores the thermodynamic principles underlying the reversible refrigeration cycle and examines its potential applications in water heating and cooling.
The reversible refrigeration cycle operates by circulating a refrigerant through four main components: compressor, condenser, expansion valve, and evaporator. By controlling the direction of refrigerant flow, heat can be transferred from a low-temperature source (such as ambient air or water) to a high-temperature sink (such as hot water storage or a heating system), simultaneously generating hot water while cooling the low-temperature source.
Key factors influencing the performance of the reversible refrigeration cycle include the selection of appropriate refrigerants, optimization of component design and operation, and consideration of environmental and economic factors. The study evaluates the energy efficiency, environmental impact, and cost-effectiveness of this approach compared to traditional water heating and cooling methods.
Overall, the findings demonstrate the potential of reversible refrigeration cycles as an energy-efficient and versatile solution for hot and cold-water generation in various applications including residential, commercial, and industrial settings. Further research is recommended to optimize system design, improve component efficiency, and explore integration with renewable energy sources to enhance sustainability and affordability.
In the refrigeration industry, we usually get the cold-water devices called water coolers. With an addition of heater, we are getting the hot water too. But these employ heating element, which is causes scaling after some time and further causes contamination. This also needs periodic replacement, increasing the maintenance costs. In case the heating element gets burnt, this may cause any safety incident. There is a need to replace the heating element and simultaneously achieve the heating. If it is achieved in same circuit, it will be quite cost effective. So, this activity undertaken is crucial.

INTRODUCTION
The basic functioning of a water cooler consists of a basic Vapour compression Refrigeration cycle. It is the basic refrigeration cycle which is used for refrigeration function in industries as well as domestic applications. The Cycle generally consists of four major components
1.Compressor
2.Condensor
3.Expansion Device
4.Evaporator

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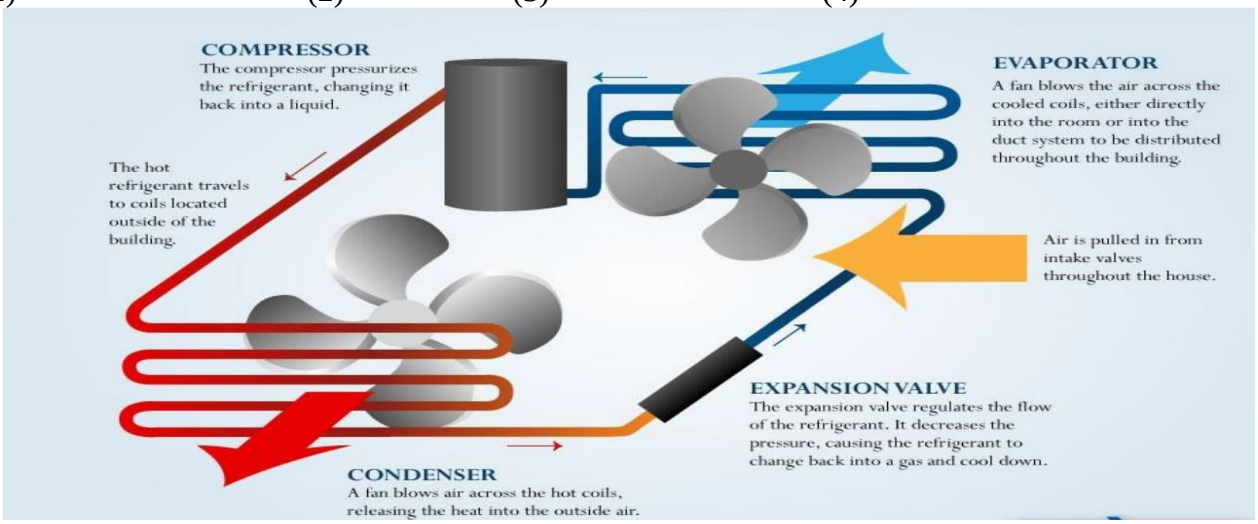

Fig: Basic Vapour Compression Refrigeration Cycle

The Basics

Essentially, a vapor-compression refrigeration system is a system that uses liquid refrigerant in a closed system which circulates the refrigerant through four stages in which it is alternately compressed and expanded, changing it from liquid to vapor. As this change happens, heat is either absorbed or expelled by the system, resulting in a change in temperature of the surrounding air that is passing over the unit's components. Nearly all of the refrigeration systems we use today use this cycle to accomplish cooling.

The Four Components

The VCRS system is made up of four main components: the evaporator, condenser, compressor and expansion valve. The evaporator and condenser are both a series of coils that are designed to create more surface area for the refrigerant to react with. Meanwhile, the compressor and expansion valve are mechanical units that control the amount of pressure and temperature change that occurs between the two stages. The evaporator and condenser are at opposite ends of the system where they manage the exchange of heat into and out of the system.

How Water cooler Works

water cooler or water dispenser is a device that cools and dispenses water. Water coolers come in a variety of form factors, ranging from bottle filler water cooler to storage tank type water coolers. The bottled water coolers require delivery (or self-pick-up) of water in large bottles from vendors, which are generally used at shops, gyms and saloons etc. Bottled water coolers can be top-mounted or bottom-loaded, depending on the design of the model. Bottled water coolers typically use 5 or 10-gallon dispensers commonly found on top of the unit.

On the other hand, in storage type water coolers the water is continuously stored and cooled in a permanent storage tank attached to the water cooler. These types of water coolers are generally used in industrial uses as in automobile industries, textile industries and other manufacturing facilities.

Bottled Water-coolers

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To install the bottle, the bottle is tipped upside down and set onto the dispenser; a probe punctures the cap of the bottle and allows the water to flow into the machine's internal reservoir. These gravity-powered systems have a device to dispense water in a controlled manner. These machines come in different sizes and vary from table units, intended for occasional use to floor-mounted units intended for heavier use. Bottled water normally is delivered to the household or business on a regular basis, where empty bottles are exchanged for full ones. The bottle size varies with the size of the unit, with the larger versions in the US using 5-US-gallon (19 L) bottles. This is also the most common size elsewhere, labelled as 18.9 liters in countries that use the metric system. These units usually do not have a place to dump excess water, only offering a small basin to catch minor spills. On the front, a lever or pushbutton dispenses the water into a cup held beneath the spigot. When the water container is empty, it is lifted off the top of the dispenser, and automatically seals to prevent any excess water still in the bottle from leaking.

Storage Type water cooler

The Storage type water coolers used in most of the industries uses VCRS (Vapour Compression Refrigeration System) for cooling of stored water. Generally, these water coolers do not contain a heating function or uses an electric heating road for supplying hot drinking water. The storage type water cooler generally consists of following main components.

Constructional details- A storage type of water cooler consists of the following parts.

1) Compressor, 2) Condenser, 3) Fan with motor, 4) Water storage tank, 5) Expansion device, 6) Evaporator, 7) Thermostat

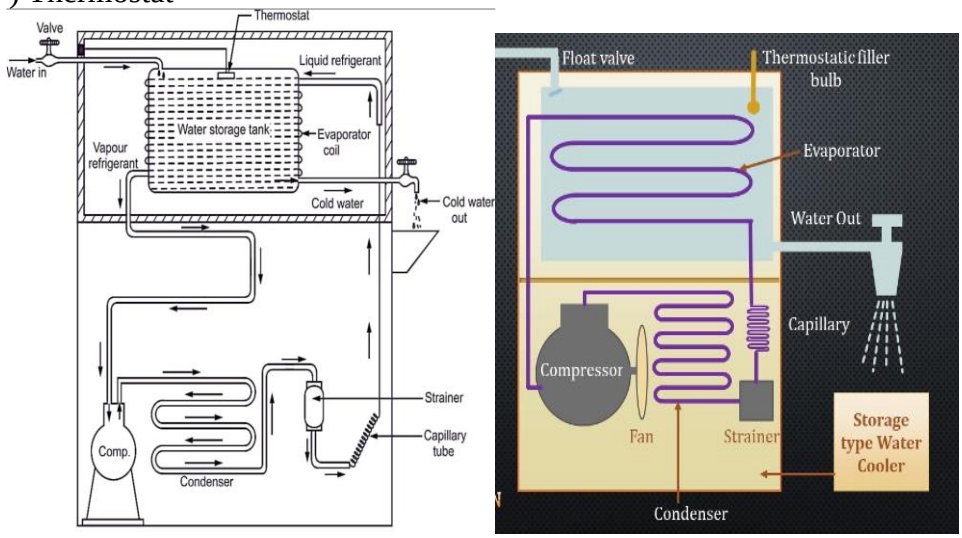

Fig: Basic Structure of a storage type water cooler

a) **Compressor: -** Hermetically sealed motor reciprocating compressor is commonly used for water cooler. They are similar to those used in household refrigerators. The range is between 0.06 kW to 0.56 kW.

b) **Condenser: -** Fan cooled condensers are most commonly used. Natural-convection condensers are used when the capacity of the cooler is less than 19 L/h. On models used in high ambient temperature, water-cooled condensers of tube-on tube construction are used.

c) **Fan with motor:** - The fan used is the fixed pitch blade propeller fan with motor. The fan is used to circulate air over the condenser to condense the refrigerant in the condenser.

d) **Water storage tank:** - The storage tank shall be of corrosion resistant, non-toxic, non-absorbent and durable materials made up of stainless steel or FDA grade material. The tank shall be provided, where necessary, with overflow and make up correction with ball float and drain. This float valve will maintain constant water level in the tank.

e) **Expansion valve or refrigerant flow control:** - Capillary tubes are almost exclusively used in hermetically sealed systems. In some hermetically sealed systems thermostatic, expansion valves are also used.

f) **Evaporators:** - In water cooler the evaporator formed by refrigerant tubing bonded to the outside of a water circuit is used. The water circuit is usually a tank. It is also a coil of large tubing. The material used are usually non-ferrous metal or stainless steel. Sanitary requirements must be kept in mind since the coolers are cooling water for human consumption. A PUF insulation of 35 mm is usually applied over evaporator.

g) **Thermostat:** - The thermostat is usually located where it is most affected by the compartment temperature that is water storage tank. This will control the operation of the compressor depending upon the temperature of water in the tank. This temperature of the water depends upon the usage of the water cooler.

h) **Overload protector: - OLP** protects compressor motor winding from damage from one or combined effect of low voltage, high voltage, high suction and discharge pressure, high load, incorrect charging. Insulation of motor winding burns above 250o C and hence overload protector is selected such that it opens the circuit before the winding temperature can go to a high value. An oversize OLP would not protect motor winding from damage and an under size OLP trips unnecessarily.

The thermal insulation for the cooling unit, connections therefrom to the outlets, and for suction pipe of the condensing unit shall be of vapour proof materials or covered with external vapour-proof barrier. The insulation shall have no interior air gap and shall be of sufficient thickness to prevent condensation on the exterior cold surfaces. The inspection lid for storage type water cooler shall be of rigid construction and hinged. It shall be provided with a gasket to keep the storage tank dustproof. The drain tray shall be made of sufficiently strong corrosion resistant material which shall not warp or get deteriorated in constant use with cooled water under varying weather conditions. This shall be of ample size to prevent any splash outside its periphery.

Working Principle: - As we switch on the water cooler, then:

1) The compressor (1) starts working. The compressor compresses the refrigerant gas and pushes it through the discharge line into the condenser.

2) In the condenser (2) the refrigerant gas is cooled with air circulated by a fan. This process of cooling is known as forced air cooling of the refrigerant gas in the condenser.

3) From the condenser (2), the liquid refrigerant enters the filter strainer (3). This will filter and dehydrate the refrigerant flowing through it.

4) The refrigerant enters the expansion device (4)

5) From the expansion device (capillary tube) the liquid refrigerant at low temperature and pressure enters the evaporator.

6) The evaporator coil is brazed around the water tank. The water tank is made from stainless steel.

7) From the outlet of the evaporator, the refrigerant gas enters the accumulator (not shown in figure). This accumulator is a protective device. It prevents any liquid refrigerant entering the compressor suction during off cycle from evaporator.

8) The overload protector (17) operates when the motor is overloaded. The bimetallic overload gets heated and disconnects the power supply.

9) The water to be cooled is stored in a tank (6). This tank is properly insulated. This insulation will prevent heat penetration from outside. This type of cooler finds a variety of applications such as in colleges, schools, hotels, etc.

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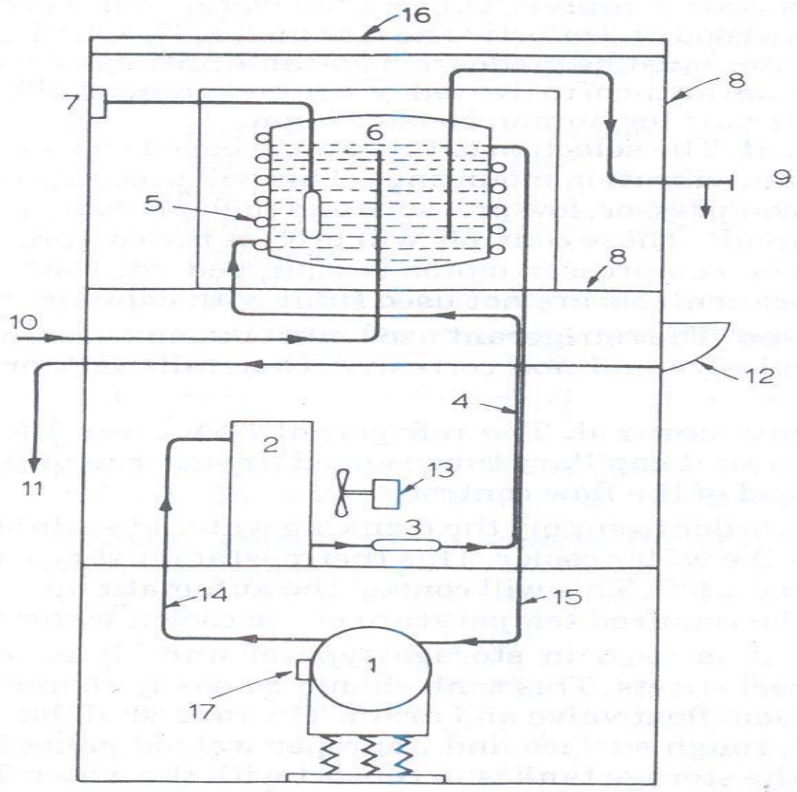

1. Compressor 2. Condenser 3. Strainer
4. Capaillary tube 5. Evaporator 6. Storage Tank
7. Thermostat 8. Insulation 9. Water outlet
10. Water inlet 11. Drain pipe 12. Waste Water drain
13. Fan 14. Discharged line 15. Suction line
16. Inspection lid (Top cover) 17. Overload Protector

Hot Water Generation through water cooler

Traditional Method

The traditional method of generation hot drinking water from a water cooler employs an electric heating road inside the storage tank. This electric heating road is supplied with electrical current then the electricity is converted into heat and subsequently water gets heated in the storage tank.

There are various disadvantages associated with this technique, which are:

1.Scaing of electrical heater.
2.Contamination of drinking water.
3.Smell in drinking water.
4.Safety issues due to electrical component and water in contact.
5.Chances of dry run of heater and heater burnout.
6.Periodic checking and replacement of heaters.
7.High replacement cost of heater.

To outcome these dis-advantages of electrical heater in hot water generation, we are using a heat pump (Reversible solenoid switch) to reverse the VCR cycle to produce hot drinking without the need of an electric heater.

Hot water generation by reversible VCRS

The hot water generation by reversible VCRS employs the use of a reversible solenoid switch between the Compressor and condenser unit of the water cooler. The reversible switch is simply a solenoid

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operated 3-way valve which directs the flow of superheated vapour refrigerant to either condenser of evaporator thus reversing the flow of basic VCRS.

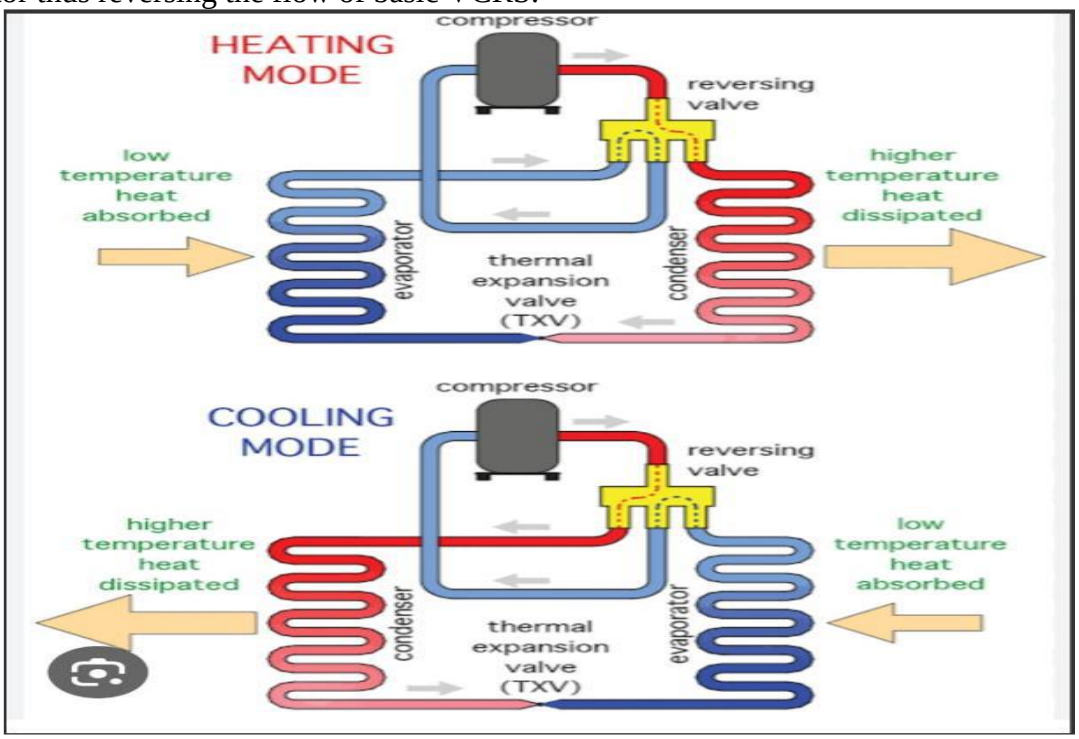
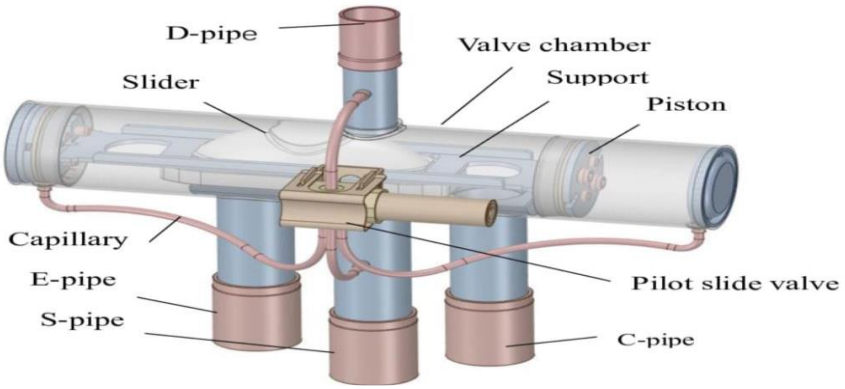


Fig: Cooling and Heating refrigeration Cycles

Reversing Switch of Three-way solenoid valve



4-way reversing valve has four pipe connections. Three of these connections are placed on one side and one on the opposite side. The three copper pipe connections have a larger diameter than the single one on the opposite side. The middle of the three large connections is permanently on the suction side and the single, small connection is always on the pressure side. Since the other two can be either on the suction or on the pressure side - depending on how it is switched - they are designed in the dimension of the permanent suction line connection to take pressure drops into account. A 4-way valve also has a pilot solenoid valve with a coil, which can be used to change the refrigerant flow direction by energizing it

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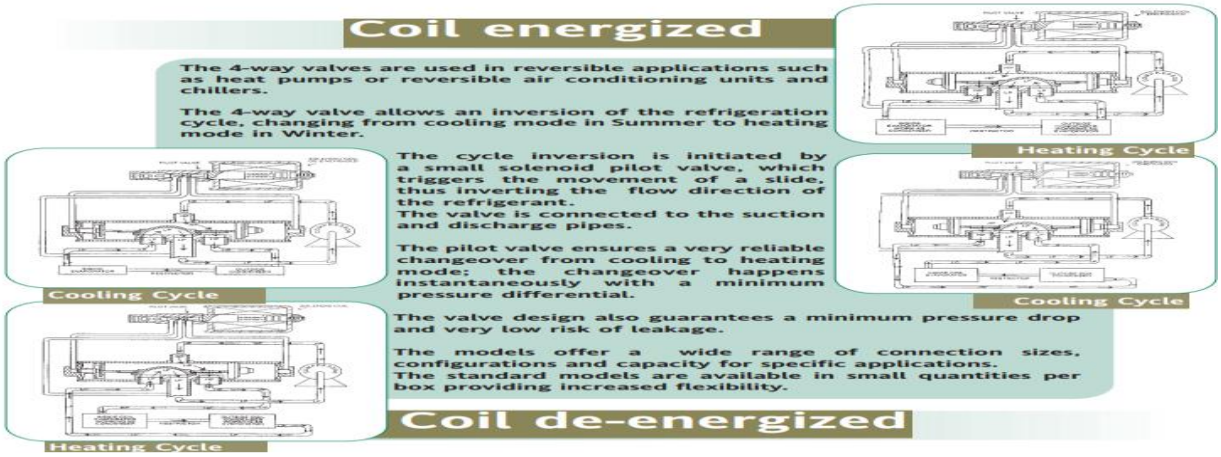

Specifications of water cooler components

Capacity	20L
Compressor	R134a KCE 419 HAG
Condenser	9”X9” (LxH) 2 Rows 3/8” OD Tube 10-12 FPI Air cooled
Condenser Fan Motor	1/83HP, 1350RPM
Condenser Fan	8inch Dia. 4 Blades
Capillary Tube	0.050inch x 10 ft x 1No
Evaporator Size	3/8 Inch OD 30ft length
Storage tank Size	300mmX300mmX300mm

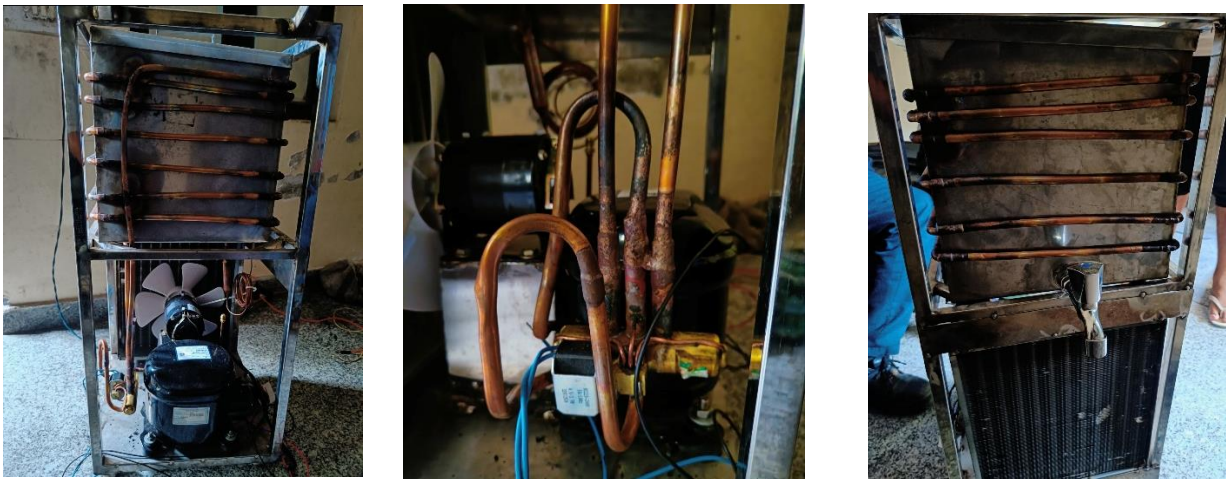

Fig: Working Model of Water cooler working on reversible switch (3-Way valve)

Readings & Observations

Capacity – 20L/Hr
Suction Pressure: 35PSI
Discharge Pressure: 150PSI
Coil Temp: 50^{O} C
Inlet water Temp: 20^{O} C

Outlet water Temp: 30^{O} C
Condenser fan current: 0.2A
Compressor amperes: 2.1A
Compressor rated current : 2A

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