AN EXPERIMENTAL INVESTIGATION ON AIR CONDITIONING UNIT BY USING HELICAL COIL WATER COOLED CONDENSER WITH ALTERNATIVE REFRIGERANT

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Abstract: In the present energy crisis situation, maximization utilization of energy use is vital matter, especially an air conditioning unit which is one of the largest energy used in our daily life. Air conditioning units are designed to remove heat from interior spaces and rejected it to the ambient air. Waste heat rejected from the air conditioning units, which is a large quantity, can be recovered and applied for use in another system such as a water heating system. From an energy conversion standpoint, it would be desirable to reclaim this waste heat in a usable form. In the present work a heat exchanger is used, working as water cooled condenser, consists of a shell and helically coiled tube unit which is fabricated by bending a straight copper tube into a helical coil tube which is mounted inside of the shell. The refrigerant flow inside of the copper tubes is cooled by the water which is surrounded by copper coils in shell. The rejected heat at the condenser is used to heat the water, the heated water is collected at the water outlet and it is used for other purposes. All the above stated conditions are obtained by using a one horse power of the compressor that means it is able to produce cooling and heating effects. Due to the ecological problems like ozone depletion and global warming certain refrigerants like R-22 have to be replaced. HCFC's (Hydro Chloro Fluoro Carbon) have been identified as prime foremost cause of ozone depletion. HFC's (Hydro Fluoro Carbon) are substantially less damaging to the ozone layer than HCFC's. Several HCFC have emerged as substitute to replace R-22. The most widely used fluoro carbon refrigerants such as R-134A, R-407C, R- 410A, R- 407A and R-417A. In the present work R-417A is used as alternative for R-22.The main objective of the work is performance evolution of the Air conditioning unit by varying water flow rates using the refrigerants R-22 and R-417A and calculates the performance parameters like Net Refrigerating Effect, Mass flow rate, Compressor power, Heat rejection ratio, and C.O.P of the unit. The calculated results are compared for both refrigerants R-22 and R-417A.

Key Words: Refrigerants, Air conditioning Unit, Condenser, Water cooler.

1. INTRODUCTION:

This section briefly describes the main features of the refrigeration and Air conditioning.

1.1 AIR – CONDITIONING

Control of temperature, humidity, purity, and motion of air in an enclosed space, independent of outside conditions is called air-conditioning. Refrigeration air conditioning equipment usually reduces the humidity of the air processed by the system. The relatively cold (below the dew point) evaporator coil condenses water vapour from the processed air, (much like an ice-cold drink will condense water on the outside of a glass), sending the water to a drain and removing water vapour from the cooled space and lowering the relative humidity. Since humans perspire to provide natural cooling by the evaporation of perspiration from the skin, drier air (up to a point) improves the comfort provided. The comfort air conditioner is designed to create a 40% to 60% relative humidity effective air dehumidifying units.

1.2 REFRIGERATION:

Refrigeration is the process of removing heat from an enclosed space, or from a substance, and moving it to a place where it is unobjectable. Remove a bucket of water from a tank, the surrounding water rushes in to fill the cavity. Similarly heat rushes in to replace the heat when the heat is removed from refrigerated space. Whatever heat enters through insulation into the refrigerated space has to be removed with the help of refrigerating machine. Refrigeration is used to cool products. The Refrigeration system (R) transfers heat from a cooler low-energy reservoir to a warmer high-energy reservoir as shown in figure

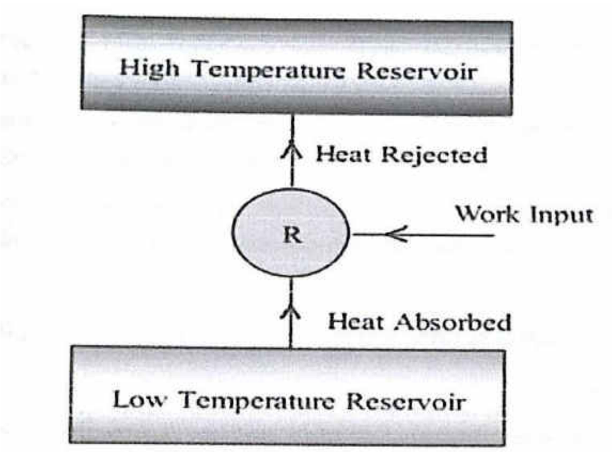

Fig. 1.1 Schematic representation of refrigeration system

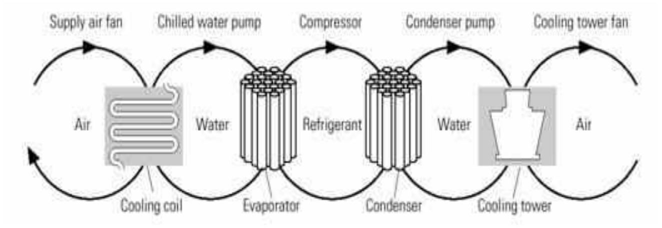

Fig. 1.2 A typical heat transfer loop in refrigeration system

There are several heat transfer loops in a refrigeration system as shown in Figure 1.2. Thermal energy moves from left to right as it extracted from the space and expelled into the outdoors through five loops of heat transfer.

- **Indoor air loop:** In the left loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.
- **Chilled water loop:** Driven by the chilled water pump, water returns from the cooling coil to the evaporator to be re-cooled.
- **Refrigerant loop:** Using a phase-change refrigerant, the compressor pumps heat from the chilled water to the condenser water.
- **Condenser water loop:** Water absorb heat from the condenser, and the condenser water pumps sends it to the cooling tower.
- **Cooling water loop:** The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.

1.2 REFRIGERATION SYSTEM BY PROCESS:

The following refrigeration systems exist for industrial process (e.g. chilling plants) and domestic purposes (modular units, i.e. refrigerators):

- Small capacity modular units of the direct expansions type similar to domestic refrigerators.
- Centralized chilled water plants with chilled water as a secondary coolant for a temperature range over typically 5°C. They can also be used for ice bank formation.
- Brine plants, which use brines as a lower temperature, secondary coolant for typically sub-zero temperature applications, which come as modular unit capacities as well as large centralized plant capacities.
- The plant capacities up to 50TR (tons of refrigeration) are usually considered as small capacity, 50 – 250 TR as large capacity units.

A large company may have a bank of units, often with common chilled water pumps, condenser water pumps, cooling towers, as an offsite utility. The same company may also have two or three levels of refrigeration and air conditioning such as a combination of:

- Comfort air conditioning (20 - 25°C)
- Chilled water system (80 - 100°C)
- Brine system (sub-zero applications)

1.4 PRINCIPLE TYPES OF REFRIGERATION SYSTEMS:

This section describes the two principle types of refrigeration systems found in industry

Vapour Compression Refrigeration (VCR) and Vapour Absorption Refrigeration (VAR), (VCR) uses mechanical energy as the driving force for refrigeration, while VAR uses thermal energy as the driving force for refrigeration.

1.4.1 Vapour Compression Refrigeration System:

Compression refrigeration cycles take advantage of the fact that highly compressed fluids at a certain temperature tend to get colder when they are allowed to expand. If the pressure change is high enough, then the compressed gas will be hotter than our source of cooling (outside air, for instance) and the expanded gas will be cooler than our desired cold temperature. In this case, fluid is used to cool a low temperature environment and reject the heat to a high temperature environment.

Vapour compression refrigeration cycles have two advantages. First, a large amount of thermal energy is required to change a liquid to a vapour, and therefore a lot of heat can be removed from the air-conditioned space. Second, the isothermal nature of the vaporization allows extraction of heat without raising the temperature of the working fluid to the temperature of whatever is being cooled. This means that the heat transfer rate remains high, because the closer the working fluid temperature approaches that of the surroundings, the lower the rate of heat transfer.

The refrigeration cycle is shown in fig can be broken down into the following stages.

- **Compression process (1-2).** The superheated vapour enters the compressor from the evaporator where its pressure is raised. The temperature will also increase, because a proportion of the energy put into the compression process is transferred to the refrigerant.

- **Condensing Process (2-3).** The high pressure superheated gas passes from the compressor into the condenser. Here the refrigerant looses the heat to the surroundings without changing the pressure.

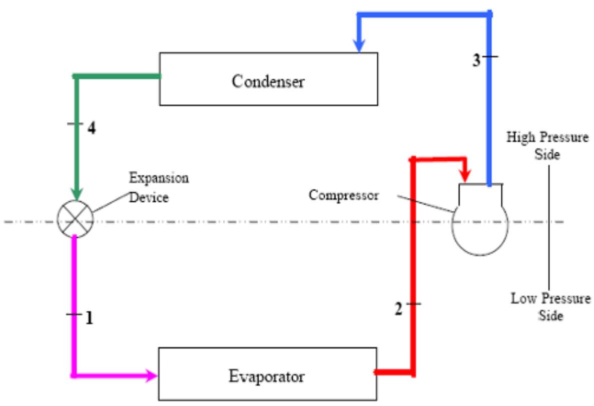

Fig. 1.3 Schematic representation of Vapour compression refrigeration cycle

- **Expansion Process (2-3).** The high-pressure sub-cooled passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.

- **Vapour Process (4-1).** Low-pressure liquid refrigerants in the evaporator absorb heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

1.5 BASIC CONCEPTS OF AIR CONDITIONING

Dry Air

The mixture of nitrogen and oxygen neglecting the water vapour and other gases are known as dry air.

Moist Air

It is the mixture of dry and water vapour.

Moisture

The quantity of water vapour present in air is known as moisture.

Dry Bulb Temperature

The temperature of air measure by ordinary thermometer is known as dry bulb temperature

Wet Bulb Temperature

The temperature of air measured by a thermometer when its bulb is covered with wet cloth and is exposed to a current of air is known as wet bulb temperature.

Dew Point Temperature

It is defined as the temperature at which the moisture present in the air begins to condense when air is cooled.

Humidity

It is the mixture of moist air and dry air. It signifies the amount of moisture in dry air.

Specific Humidity

It is the mass of water vapour present with 1 kg of dry air. It is generally given in grams per kg of dry air.

Relative Humidity

It is approximately equal to the ratio of mass of water vapour in a given volume, to the mass of water vapour in the same volume of air is saturated at the same temperature.

Effective Temperature

Comfortable air cooling calls for the careful consideration of controls of the following factors.

- Temperature
- Air movement
- Quantity of air
- Noise

In addition to the foregoing factors, when there are many other factors such as

- Clothing
- Economical states of person
- Climate to which person is accustomed

Unfortunately, it is not practically feasible to study the combined effects of all the factors on human comfort, therefore it is usual practice to consider for a foresaid four factors for most applications which are included in a term called the effective temperature.

Air Conditioning

Air conditioning means conditioning of air for maintaining specific conditions of temperature, relative humidity and low dust levels inside an enclosed space.

Generally air-conditioning is subdivided into industrial air-conditioning and comfort air-conditioning. The controlled atmosphere which gives maximum comfort to the human being is known as comfort air-conditioning. The controlled atmosphere which is required for the manufacturing process for engineering goods is known as industrial air-conditioning.

The comfort air-conditioning is further subdivided into summer air-conditioning and winter air-conditioning. The air cooling and dehumidification used in summer is known as summer air-conditioning and the heating and humidifying used in winter is known as winter air-conditioning.

1.6 NEED FOR AIR-CONDITIONING

Human beings give off heat around an average of 100 kcal per hour per person, due to what is known as 'metabolism'. The temperature of around 56.9°c (98.4°F). But the skin temperature varies according to the surroundings temperature and relative humidity. To dissipate the heat generated by metabolism in order to maintain the body temperature at the normal level, there must be a flow of heat from the skin to the surroundings temperature is very low, as on a cold winter day the rate of heat flow from the body, and do there cannot be floe of heat from the skin to the surroundings, thus the person feels hot. In such a situation water from the body temperature. But if the surrounding air is not only hot but highly humid as well, very little evaporation of water can take place from the skin surface and so the person feels hot and uncomfortable

1.7 REVIEW OF LITERATURE

In the olden days around 2500 years B.C. Indians, Egyptians, etc., were producing ice by keeping water in the porous pots open to cold atmosphere during the night period. The evaporation of water in almost cool dry air accompanied with recitative heat transfer in the clear night caused the formation of ice even when the ambient temperature was above the freezing temperature. Further references are available which support the use of ice in China 1000 years BC. Nero, the emperor, was using ice for cooling beverages. Further, the East Indians were able to produce refrigeration by dissolving salt in water as early as 4th century A.D., of course, on very small scale. The use of evaporative cooling is another application of refrigeration used olden days. The cooling of water in earthen pots for drinking purpose; is the most common example where the evaporation for water through the pores of earthen pot is accompanied with cooling of water.

The fore said methods of the production of cooling were not feasible for the commercial use due to very small amount of ice production. Availability of natural ice in limited regions and unavailability of good quality insulation confined the application of ice to those localities only. These all led to the development of artificial refrigeration side, a few would be presented here. Thomas Harris and John Long got the earliest British parent in 1790. Later on in 1834 Jacob Perkins developed hand operated refrigeration system using ether (volatile) as the working fluid. Ether vapor is sucked by the hand-operated compressor and then high temperature and pressure either vapour is condensed in the water cooled chamber (condenser). Liquid ether is finally throttled to the lower pressure, and thus evaporation of this liquid in chamber A lowers the temperature of water surrounding the vessel. Finally ice is formed. In this system, ether is used again and again in the cyclic process with negligible wastage.

In 1851, Dr. John Garrie of Florida, a physician obtained the first American patent of a cold air machine to produce ice in order to cure people suffering from the high fever. Instead of air or ether, sulphuric ether was used by Dr. James Harrison of Australia in 1860, the world's first installation of refrigeration machine for brewery. The steam engine works as a power source which drives the compressor for the pressurization of sulphuric ether vapour, which is, in turn, condensed and is allowed to expand and evaporate in order to produce refrigeration. Dr. Alexander Kirk of England constructed a cold air machine is 1861 similar to that of Dr. Gorrie. The air was compressed by a reciprocating compressor driven by a steam engine running on coal. His actual machine consumed about 1 kg of coal to produce 4 kg of ice (approximately).

In the 19th century, there was tremendous development of refrigeration systems to replace natural ice by artificial ice producing machines. Unfortunately steam engine, a very low speed power developing source, was used to drive the compressor, rendering very poor performance of the refrigeration system.

Some Recent Advancements of in Refrigeration

In the beginning of 20th century, large sized refrigeration machines were under progress. By 1904 about 450 ton cooling system for air conditioning the New York Stock Exchange was installed. In Germany people used air conditioning in theatre for comfort purposes. In around 1911 the compressor speed was raised between 100 to 300 rpm. The first two-stage modem compressor was brought under use in 1915.

During the civil war there was an acute shortage of the supply of natural ice from the north. Hence, Ferdinand Care of the USA developed vapour-absorption refrigeration system ammonia as a refrigerant and water as an absorbent. The system consists of an evaporator, an absorber, a pump, a generator, a condenser and an expansion device. The evaporated vapour is absorbed by the weak ammonia-water mixture in the absorber yielding strong aqua ammonia. The pump delivers this strong solution into the generator where heat transfer from a burner separates ammonia vapor and the weak ammonia water returns to the absorber. On the other hand the ammonia vapour condenses in the condenser before being throttled. The throttled ammonia liquid enters the evaporator resulting in completion of the cyclic process.

In the beginning of two decades of the twentieth century, the development in refrigeration system was confined to refinement in cold air machines and vapor compression thermoelectric, pulse tube refrigeration systems, etc. The developments are vortex tube, steam-jet refrigeration system, availability of materials of specific properties for thermoelectric materials. The possible use of waste heat or solar energy in case of vapor-absorption and thermoelectric systems has led to development of several commercial units these days especially due to the like hood of future energy crisis, the world is going to face.

2. EXPERIMENTAL SETUP AND CHARGING:

After assembled all the components the unit is allowed to carry out the experiments with R-22 and R417A, because of using the water cooled condenser sufficient water is available to run the unit and continuous water flow is required. In the present work to obtained continuous water flow, the heat exchanger water inlet is connected to the water tap as shown in the fig. The line diagram of the setup with water connection is shown in the fig.6.1. In the fig. The yellow pipe connected to the water inlet tap and black pipe is connected to the water outlet where the hot water from the condenser is collected and used for other purposes.

Fig. 2.1 Experimental Setup with Water Connection

2.2 CHARGING OF THE REFRIGERANT

The following procedure is adopted for charging the refrigerant in the vapour compression system

Charging:

Even though there are various methods of charging of refrigerant in the system the charging through suction valve gauge port is applied.

Charging Through the Suction Valve

A small installation, which needs a few kilograms of refrigerant, is usually charged through suction service valve gauge port. The system is fully evacuated and charged as follows:

- The suction valve B is back – seated and valve A is discharged. Charging line is connected to the suction valve gauge port. Attach a gauge to the discharge valve and open half turn
- The other end of the charging line is connected to a refrigerant cylinder, which should be standing upright.
- The cylinder valve is opened slightly and the flare out is loosened at the compressor end. This operation removes air from the line. When the sound of escaping gas is heard, the nut is tightened.
- Suction valve is turned into close the suction line, thus drawing the gas directly from the cylinder by the compressor.
- Compressor is started drawing the requisite quantity of refrigerant, the suction pressure should not be allowed to exceed 2 bar gauge pressure.
- The cylinder valve is closed and the compressor is allowed to run sufficient time in the charging line to 0 bar gauge.
- Compressor is stopped and the suction valve is back –seated. The charging line is detached and compound gauge is attached. The valve is turned in one half turn. The system is ready for testing and normal operation

2.3 EXPERIMENTAL PROCEDURE:

Apparatus:

Digital temperature indicator

Measuring jar

Stop watch

Procedure

1. Check whether the condenser or heat exchanger container is filled with water or not.
2. Check whether temperature readings (Digital thermometers) are placed in the required positions on the unit and also the discharge and suction pressure gauges at the respective places
3. Now the condenser water inlet is connected to the water tap and allows the continuous circulation of water by rotating the valve in open position.
4. After that measure the required water flow rate (i.e., 0.5 to 2.0 l/min) in the measuring jar at the condenser outlet by adjusting the water flow controller by using the stop watch
5. Now start the unit by switch ON it respective switch
6. After that switch ON the compressor
7. Then after every 5 minutes take the readings of temperatures and pressures
8. Run the unit for a certain period of time up to the steady state will be obtained
9. Then switch OFF the compressor first and then switch OFF the unit.
10. The same experiment is repeated for remaining water flow rates and calculates the C.O.P and other performance parameters in each case.
11. The same procedure is repeated for the both refrigerants R-22 and R-417A.

FORMULAE FOR COOLING CAPACITY

1. Net Refrigerating Effect (NRE) = h_1-h_4 kJ/kg
2. Mass flow rate to obtain one TR , (m) = $\frac{210}{NRE}$ kg/min
3. Work of Compression = h_2-h_1kJ/kg
4. Heat Equivalent of work of compression per TR = m x (h_2-h_1) kJ/min
5. Theoretical power of compressor = $\frac{\text{m x (h2−h1)}}{60}$ KW
6. Coefficient Of Performance = $\frac{\text{h1−h4}}{\text{h2−h1}}$
7. Heat to be rejected in condenser = h_2-h_3 kJ/kg
8. Heat rejection per TR = m x (h_2-h_3) kJ/min
9. Heat rejection ratio = $\frac{\text{m x (h2−h3)}}{\text{m x (h1−h4)}}$
10. Maximum temperature of hot water at water outlet = °C

3. RESULTS AND DISCUSSION

From the calculations we can observe that the performance of Air conditioning – Heat Pump system has been evaluated experimentally with R – 22 and R – 417A.

REFRIGERANT MASS FLOW RATE Vs WATER FLOW RATES

The figure below is the plot of Mass flow rate with respect to Water flow rates for refrigerants R – 22 and R – 417A. The figure indicates that the refrigerant mass flow rate required per ton of refrigeration is maximum for R – 417A and minimum for R – 22. It can also be observed that the mass flow rate of R – 417A with 2.0 l/min water flow rate is the least value obtained.

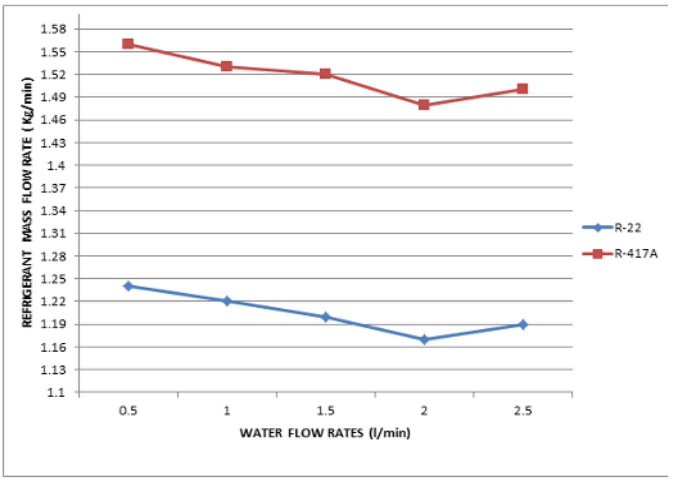

Fig. 3.1 Refrigerant Mass Flow Rate Vs Water Flow Rates

COMPRESSOR POWER Vs WATER FLOW RATES

The figure below is the plot of Mass flow rate with respect to the refrigerants R – 22 and R – 417A at various water flow rates. The figure indicates that the compressor power needed to run the unit is maximum for R – 22 and minimum for R – 417A. It can also be observed that the compressor power for R – 417A with 2.0 l/min water flow rate is the least value obtained.

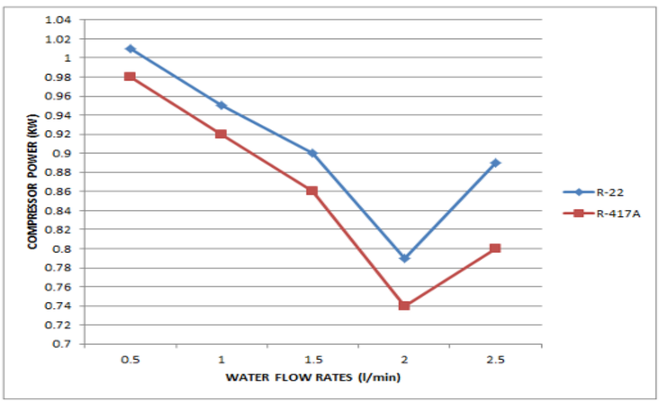

Fig. 3.2 Compressor Power Vs Water Flow Rates

HEAT REJECTION RATIO Vs WATER FLOW RATES

The figure below is the plot of Heat rejection ratio with respect to water flow rates for the refrigerants R – 22 and R – 417A. The figure indicates that the heat rejection ratio of the system is maximum for R – 22 and minimum for R – 417A. But the experimental work is concerned with retrofitting for R – 22. So it can be inferred that the best retrofitting conditions for R – 22 is R – 417A.

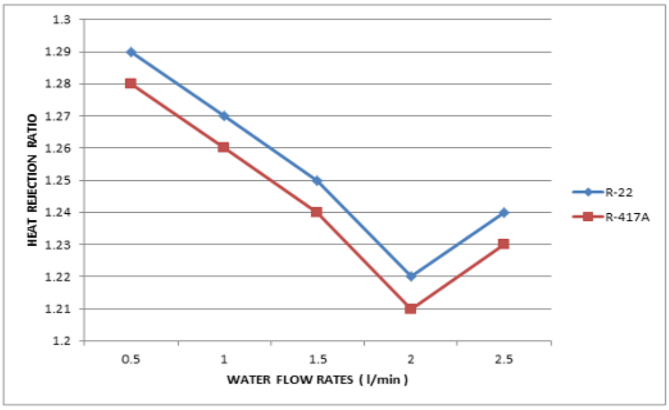

Fig. 3.3 Heat Rejection Ratio Vs Water Flow Rates

COEFFICIENT OF PERFORMANCE Vs WATER FLOW RATES

The figure below is the plot of C.O.P of the system with respect to water flow rates for R – 22 and R – 417A. The figure indicates that the C.O.P. values of refrigerants increases up to 2.0 l/min and then decrease after that decreases. It can be observed from the fig, the C.O.P for each refrigerant is maximum at a water flow rate of 2.0 l/min. The maximum value of C.O.P of the system for R – 417A is 4.7 and for R – 22 is 4.39. So it can be inferred that the best retrofitting conditions for R – 22 is R – 417A at 2.0 l/min of water flow rate.

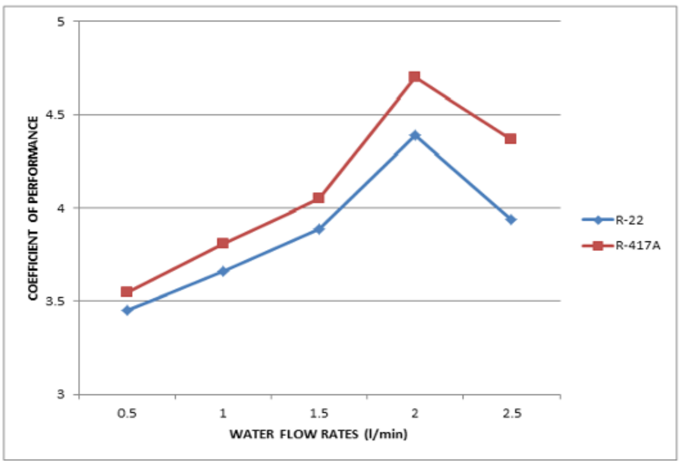

Fig. 3.4 Coefficient of Performance Vs Water Flow Rates

TEMPERATURE OF HOT WATER Vs WATER FLOW RATES

The figure below is the plot of Temperature of the hot water collected at the water outlet of the system with respect to water flow rates for R – 22 and R – 417A. The temperature of the water is countinuosly decreases when the water flow rates are increase from 0.5 to 2.5 l/min. R – 22 gives the high temperature of the hot water for all water flow rates than R – 417A but the difference the temperature between these two are small. The experimental work is concerned with retrofitting for R – 22 so it can be inferred that the retrofitting conditions for R – 22 is R – 417A.

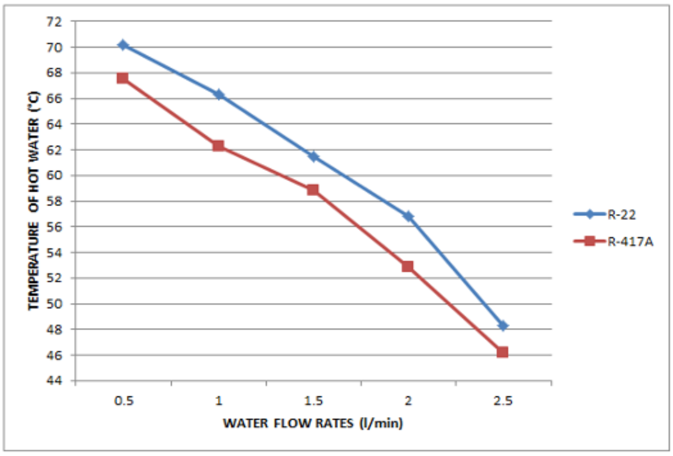

Fig 3.5 Temperature of Hot Water Vs Water Flow Rates

4. CONCLUSION:

In the present work the experiments are carried on the Air Conditioning unit using the two refrigerants R-22 and R-417A.The following conclusions are drawn.

- Because of using water cooled condenser the C.O.P of the Air Conditioning unit more than the .O.P of the conventional Air Conditioning unit. The maximum values of C.O.P. for this unit for R-22 and R-417A are 4.39 and 4.70 respectively at the water flow rate of 2.0 l/min.
- The Air Conditioning unit gives the best results at the water flow rate of 2.0 l/min for the both refrigerants R-22 and R-417A. Out of these refrigerants R-417A gives the better values than R-22, so it can be inferred that the retrofitting conditions for R – 22 is R – 417A.
- The Air Conditioning unit increases the temperature of the water in the condenser by 15-40°C using the rejected heat in the condenser, so using the unit the same amount of the energy required to heat the water is saved.
- By using this unit with the same compressor power, both cooling and heating effects are obtained simultaneously, due to the advantage of the unit it is useful in the commercial buildings where Air conditioning and Warm water at the same time or use as pre-heater for water.

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