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RESEARCH ARTICLE

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# PERFORMANCE EVALUATION AND COST EFFECTIVE MULTIFUNCTIONAL VAPOUR COMPRESSION REFRIGERATION SYSTEM USING REFRIGERANT R134a

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**ABSTRACT**

The invention of refrigerator and air conditioning has changed the lifestyle of people. In present work a refrigerator and air conditioning system is modified to serve the purposes as refrigerator, air conditioning, air cooler and water cooler suitable design and operation conditions were modified with a view to save space, initial cost and maintenance cost. The aim of this paper is to comparatively analyze of air cooler by using a refrigerant (R134a) over an Indian traditional cooler and Air Conditioners. In 21st century the world facing problem of electricity and water to overcome this problem worldwide many researches going on. Further cooler uses water so as cooling air, for this application much more quantity of water has been used every year. Also to make these efficient woods product known as wood wool have been used which became a major reason of deforestation. The refrigerant R134a absorbs the heat from air and makes the cool air by getting vaporized in evaporator and then the cooled air is sent outward from the opening in the research model with help of fan running on motor and gives the cooling effect. This use of VCRS system with eco - friendly refrigerant reduces the consumption of the water, electricity consumption and tree which is used for making wood wool in conventional cooler. This ultimately reduces the global warming

Keywords: Refrigeration, Air conditioning.



## 1. INTRODUCTION

Cooling systems like air conditioning, Refrigerator, Air Coolers, Water Cooler systems are high electric power consumption's; these systems also have huge impacts on the ecosystem. However it has become the prime necessity in 21st century. In over span of three decades, there is continuously increase in energy demand due to everlasting population increases in India. By this product a normal person could have a sound sleep so that his productivity for the next day increases. In India, during summer season the temperature increases up to about range of 45°c to 50°c. During this season there is increase in demand of cooling equipment's such as air coolers, air conditioner etc. If we talk about traditional air coolers, these coolers have very high demand in India because they are cheap and affordable in every aspect and most of the Indian population is belongs to the middle class and thus they can afford these traditional coolers. But these coolers too have disadvantages such as they consumes large amount of water i.e. about 45 to 50 litres of water every day. And also we know that middle class population of India is about 267 million. Although if we consider 250 million of population uses about 50 litres of water every day in their cooler, they consume 12500 million litres of water only in summer season which is very high amount. Also these coolers consumes large amount of wood wool, which is obtained by cutting large amount of trees and trees are the essential parameter which is used for reducing global warming. Now if we come on Air conditioner, the cost this equipment is very high it is about 20000Rs to 25000 Rs. if we go for good AC in India. Also the electricity consumption of this air conditioning equipment is also very high. And this equipment produces adverse effect on the environment which ultimately leads to the global warming. The concept of this project explores the possibility of combining four units So for reducing such huge consumption of water, trees, electricity, which ultimately leads to wealth consumption, this research project includes to provide the cooling effect of air as such like the air conditioners without using water, wood wool and by consumption of low amount electricity. This ultimately leads to reducing the monthly tariff and also having very less effect to the environment.

**2.COMPONENTS**

**I. CONDENSER:**

**Fig.2.1. Condenser**

We used air cooled condenser in which the removal of heat is done by air. The size of tube usually ranges from 6mm to 18mm outside diameter, depending upon the size of condenser. The condensers with steel tubes are used in ammonia refrigerating systems. The tubes are usually provided with plate type fins to increase the surface area of heat transfer.

**II. COMPRESSOR**

**Fig.2.2 Compressor**

We used Hermetic Sealed Compressors because these types of compressor eliminate the use of crankshaft seal which is necessary in ordinary compressors in order to prevent leakage of refrigerant. The hermetic sealed compressor is widely used for small capacity refrigerating systems such as in domestic refrigerators, home freezers and window air conditioners.

**III. EVAPORATOR:**

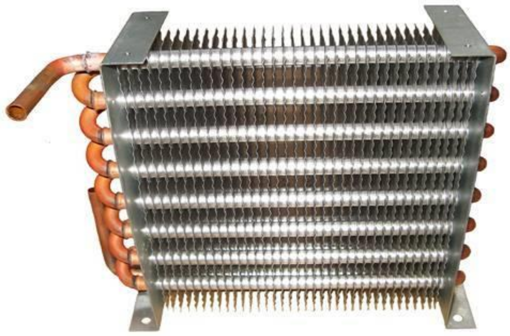

**Fig.2.3 Evaporator**

An evaporator is a device used to turn the liquid form of a chemical into its gaseous form. Liquid refrigerant at a low temperature passes into evaporator where it extracts heat from the product to be cooled. Due to absorption of extract heat liquid refrigerant turns into vapour, and enters in to the compressor. Evaporator is an important component together with other major components in a refrigeration system such as compressor, condenser and expansion device.

**IV. EXPANSION VALVE**

**Fig.2.4 Capillary Tube**

It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporizing the evaporator at the low pressure and temperature. A thermal expansion valve (often abbreviated as TEV, TXV, or TX valve) is a component in refrigeration and air conditioning systems that control the amount of refrigerant flow into the condenser thereby controlling the superheating at the outlet of the evaporator.

**V. FAN**

The fan shall be well balanced. The blade and blade carriers shall be securely fixed so that they do not get loose in operation. The metallic parts shall be powder coated or suitably protected against corrosion.

**VI. REFRIGERANT (134-a)**

A refrigerant is a fluid in a refrigerating system that by its evaporating takes the heat of the cooling coils and gives up heat by condensing the condenser. In CFCs and HCFCs present the chlorine content which contribute to the depletion of ozone layer. But the alternative refrigerant of CFCs and HCFCs is Hydro fluorocarbon HFCs (R134a, R152a, and R32) as there is no Content of chlorine.

| Refrigerant | Molecular wt. | Boiling pt. | Chemical Formula | ODP |
|---|---|---|---|---|
| R134a | 102 | -26.1$^0$C | $C_2H_2F_4$ | 0 |

**3.WORKING**

The vapour-compression refrigeration cycle has four components: evaporator, compressor, condenser, and expansion (or throttle) valve. The most widely used refrigeration cycle is the vapour-compression refrigeration cycle. In an ideal vapour compression refrigeration cycle, the refrigerant enters the compressor as a saturated vapour and is cooled to the saturated liquid state in the condenser. It is then throttled to the evaporator pressure and vaporizes as it absorbs heat from the refrigerated space.

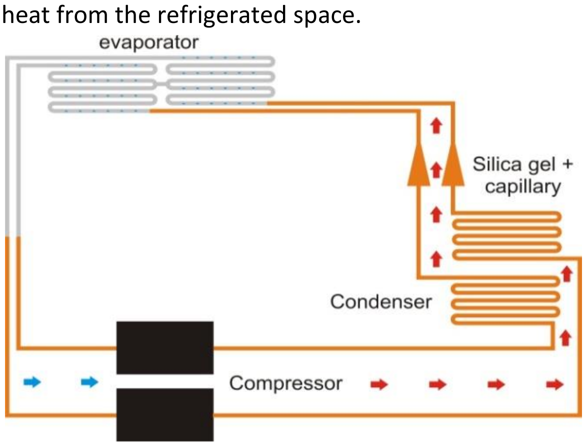


**Fig.3.1 VCRS Cycle**

The ideal vapour-compression cycle consists of four processes. Ideal Vapour-Compression Refrigeration Cycle Process.

1-2 Constant pressure heat addition in the evaporator.

2-3Isentropiccompression

3-4 Constant pressure heat rejection in the condenser

4-1 Throttling in an expansion valve.

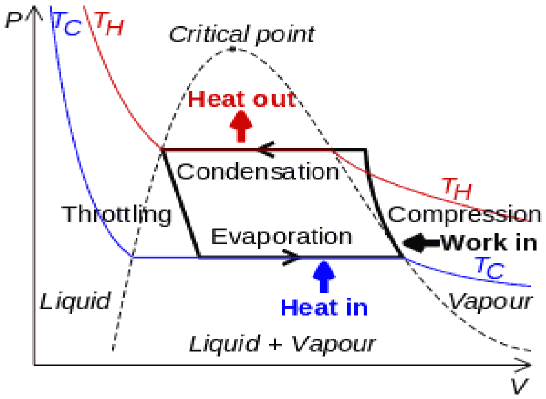


**Fig.3.2. Pressure vs Volume**

**4. Project Model tested Output for VCRS Cycle**

**Table 4.1 : For Data Collection**

| FOR VCRS CYCLE 1 | | | | | | |
|---|---|---|---|---|---|---|
| **Time (Sec)** | **Pe (bar)** | **Pc (bar)** | **T1 (°C)** | **T2 (°C)** | **T3 (°C)** | **T4 (°C)** |
| 300 | 0.5 | 5 | 31 | 36 | 29 | 23 |
| 600 | 1 | 8.6 | 30 | 37 | 31 | 19 |
| 900 | 1 | 9.6 | 28 | 38 | 31 | 18 |
| 1200 | 1 | 10 | 26 | 40 | 32 | 18 |
| 1500 | 1 | 10 | 25 | 40 | 34 | 17 |
| 1800 | 1 | 10 | 23 | 41 | 34 | 17 |

| **Time (Sec)** | **R.E (KJ/Kg)** | **Compressor Work (KJ/Kg)** | **Qc (KJ/Kg)** | **COP** |
|---|---|---|---|---|
| 300 | 152.35 | 38.34 | 190.7 | 3.97 |
| 600 | 135.43 | 41.46 | 176.89 | 3.25 |
| 900 | 129.53 | 46.83 | 176.38 | 2.76 |
| 1200 | 126.9 | 51.78 | 178.68 | 2.45 |
| 1500 | 126.9 | 52.9 | 179.8 | 2.39 |
| 1800 | 126.9 | 56.26 | 183.16 | 2.25 |

**Table 4.2: For Data Collection**

| FOR VCRS CYCLE 2 | | | | | | |
|---|---|---|---|---|---|---|
| Time (Sec) | Pe (bar) | Pc (bar) | T5 (°C) | T6 (°C) | T7 (°C) | T8 (°C) |
| 300 | 0.51 | 5.3 | 28 | 33 | 29 | 21 |
| 600 | 0.9 | 9 | 26 | 35 | 29 | 18 |
| 900 | 0.9 | 9 | 25 | 36 | 29 | 16 |
| 1200 | 1 | 9.5 | 23 | 39 | 30 | 16 |
| 1500 | 1 | 10 | 20 | 41 | 32 | 15 |
| 1800 | 1 | 10 | 20 | 41 | 32 | 15 |

| **Time (Sec)** | **R.E (KJ/Kg)** | **Compressor Work (KJ/Kg)** | **Qc (KJ/Kg)** | **COP** |
|---|---|---|---|---|
| 300 | 149.57 | 39.47 | 189.04 | 3.78 |
| 600 | 131.29 | 45.87 | 177.16 | 2.86 |
| 900 | 131.29 | 48.04 | 179.33 | 2.73 |
| 1200 | 129.53 | 52.76 | 182.33 | 2.46 |
| 1500 | 126.55 | 59.62 | 186.17 | 2.12 |
| 1800 | 126.55 | 59.62 | 186.17 | 2.12 |

**Table 4.3: For Data Collection**

| **Time (Sec)** | **Tw (°C)** | **Tr (°C)** | **Ta (°C)** |
|---|---|---|---|
| 300 | 28 | 20 | 22 |
| 600 | 22 | 18 | 21 |
| 900 | 13 | 15 | 19 |
| 1200 | 10 | 14 | 18 |
| 1500 | 9 | 12 | 16 |
| 180 | 8 | 11 | 15 |

**Table 4.4 : For Combine Cycle I and Cycle II**

| **Time (Sec)** | **R.E (KJ/Kg)** | **Compressor Work (KJ/Kg)** | **Qc (KJ/Kg)** | **COP** |
|---|---|---|---|---|
| 300 | 301.92 | 77.81 | 379.74 | 7.75 |
| 600 | 266.72 | 87.33 | 354.05 | 6.11 |
| 900 | 260.82 | 94.87 | 355.71 | 5.49 |
| 1200 | 256.43 | 104.54 | 364.85 | 4.91 |
| 1500 | 253.45 | 112.52 | 365.97 | 4.51 |
| 1800 | 253.45 | 115.88 | 369.33 | 4.37 |

**Sample Calculation:**

**For observation Table I**

(For 300 Sec time)

At no load Condition

**Temperature**

Ambient Temperature T0 =35 °C

Compressor suction temperature T 1= 31 °C

Compressor Discharge Temperature T2 = 36 °C

Condensing Temperature T3 =29 °C

Evaporator Temperature T4 = 23 °C

**Pressure**

Compressor Discharge Pressure (Pc) = 5 bar

Evaporator pressure (Pe) = 0.5 bar

From pressure enthalpy Chart for r 134a, Enthalpy values at state points 1, 2, 3, 4. The state points are fixed using pressure and temperature and each point.

h1 =374.16 KJ/Kg

h2 =412.5 KJ/Kg

h3 =221.80 KJ/Kg

h4 =221.80 KJ/Kg

**Calculations Performance Parameters**

1. Net Refrigerating Effect (NRE)

= (h1 – h4)

= 374.16 – 221.80

= 152.36 KJ/Kg

2. Heat of compression

= (h2 – h1 )

= 412.5 – 374.16

= 38.34 KJ/Kg

3. Coefficient of performance (COP)

$$= \frac{\text{Net refrigerating Effect}}{\text{Heat of Compression}}$$

= 152.36/38.34

= 3.97

4. Heat rejected in condenser

= (h2 –h3)

= 412.5 – 221.8

=190.7 KJ/Kg

5. **Comparison of project output by graph**

**For Observation Table I and II :**

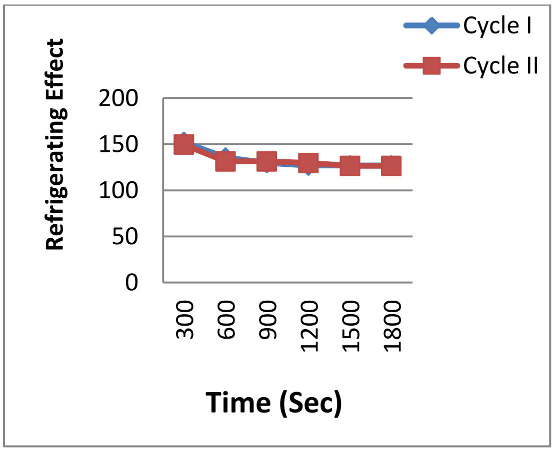


**Fig.5.1. Time Vs Refrigerating effect**

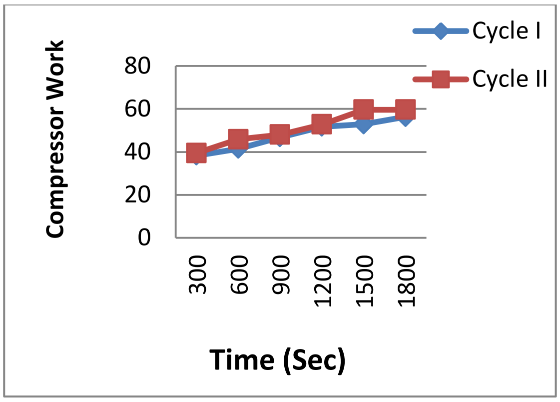


**Fig.5.2. Time Vs Compressor Work**

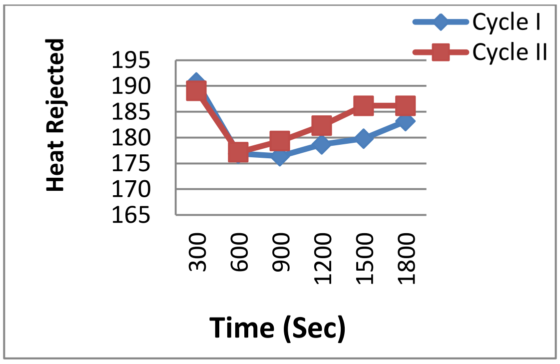


**Fig.5.3. Time Vs Heat Rejected**

**For Observation Table I :**

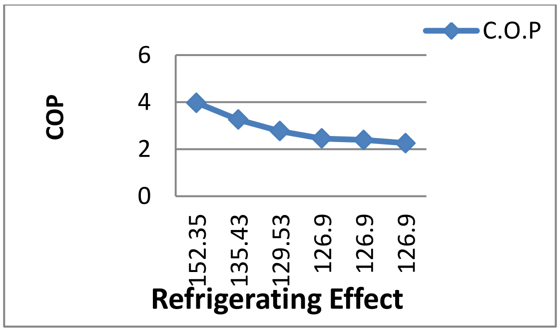


**Fig.5.4 Cop Vs Refrigerating Effect**

**For Observation Table II:**

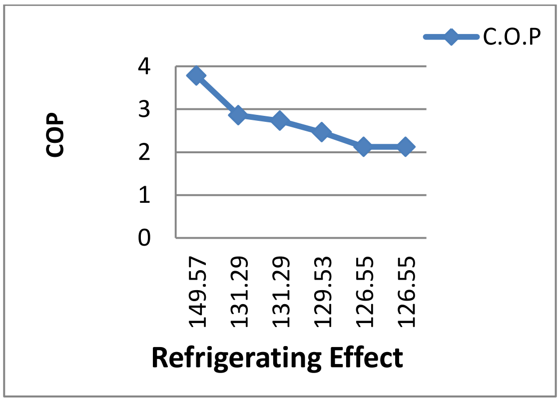


**Fig.5.5 Cop Vs Refrigerating Effect**

**For Observation Table I and II:**

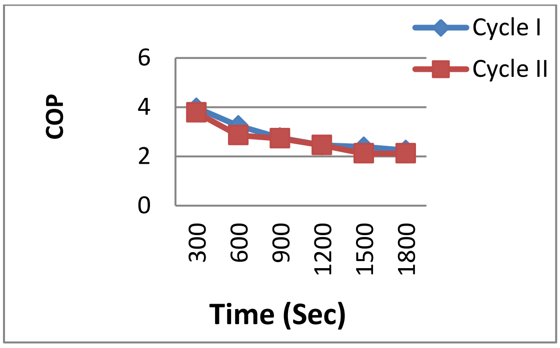


**Fig.5.6 Time Vs COP**

**For Combine Cycle I and Cycle II**

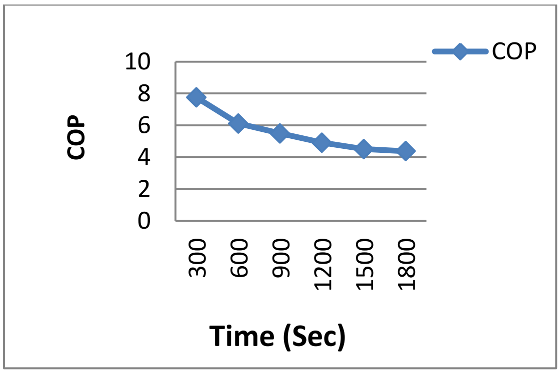


**Fig.5.7 Time Vs COP**

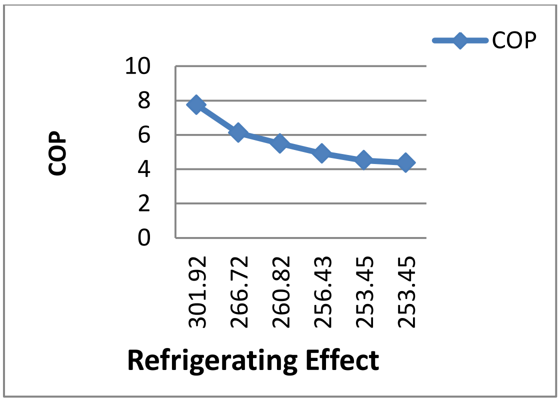


**Fig.5.8. Refrigerating Effect Vs COP**

**For Observation Table III:**

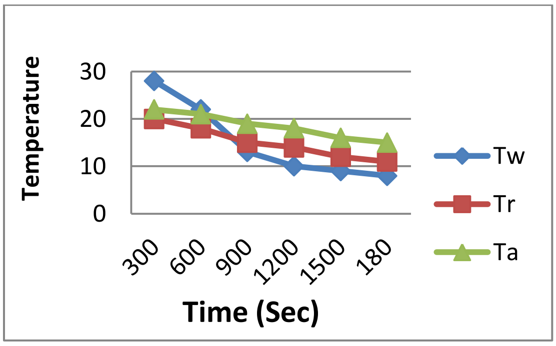


**Fig.5.9 Time Vs Temperature**

## 6. Conclusion

Development of composite Refrigeration cum Air Conditioning, Water Cooling System enhances technological aspects in various fields of engineering applications. In this experimentation a complete Refrigeration process was developed for domestic and medicinal purpose for remote areas with these objectives whose main feature is to made compact, enabling to development of refrigeration system which reduces the occupied floor area as compared to traditional system.

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