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EFFECT OF SINGLE EXPANSION VALVE COMPARING WITH MULTIPLE EXPANSION VALVES ON THE PERFORMANCE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

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Abstract

Now-a-days majority of the refrigerators works on the vapour compression refrigeration system. Vapour compression machine is a refrigerator in which the heat removed from the cold by evaporation of the refrigerant is given a thermal potential so that it can gravitate to a natural sink by compressing the vapour produced. The system mainly consists of components like compressor, condenser, expansion valve, capillary-tube and evaporator. The pressure gauges and temperature indicate joints are integrated with the system at appropriate positions. The performance of the system depends on all the components of the system.

The design of expansion valve plays a very important role in the performance of a vapour compression refrigeration system. Effective new design is possible through theoretical calculations, however may fail due to the reason that the uncertainties in the formulation of pressure difference from the refrigerant inside the expansion valves. Hence experimental investigations are the best in terms of optimization for certain design parameters.

This project deals with the effect of single expansion valve comparing with multiple expansion valves on the performance of a vapour compression refrigeration system.

The refrigerant used in the vapour compression refrigeration system is R-134a and experimentally investigated. The main objective of the present work for verifying the effect of single expansion valve comparing with multiple expansion valves on the performance of a domestic refrigerator.

Finally an attempt is made to verify the performance of the system, it is observed that operating with single expansion valve gave a better COP comparing with multiple expansion valve on the performance of vapour compression refrigeration system.

I. INTRODUCTION

The term *'refrigeration'* may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below temperature of its surroundings. In a refrigerator, heat is virtually pumped from a lower temperatureto a higher temperature. According to second law of thermodynamics, this process can only be performed with the aid of some external work. It is thus obvious that supply of power is regularly required to drive a refrigerator. Theoretically, a refrigerator is a reversed heat engine or heat pump which pumps heat from a cold body and delivers it to a hot body. The substance which works in a pump to extract heat from a cold body and to deliver it to a hot body is known as refrigerant.

'Refrigeration cycle' is a thermodynamics cycles that explains the processes required for the production of refrigeration. There are various refrigeration cycles.

- Air refrigeration cycle
  - Reversed Carnot cycle (most efficient cycle)
  - Bell –Coleman cycle (modified Carnot cycle for practical)
- Vapour refrigeration cycle
- Steam-jet refrigeration cycle

To provide the refrigeration there are various refrigeration systems are improved working with above refrigeration cycles. In different types of the refrigeration systems, some physical property of matter is used for producing cold.

In vapour refrigeration systems instead of air, vapour like ammonia, carbon dioxide, and sulphur-dioxide is used as working fluids. The pump in the steam power plant is replaced by throttle valve, boiler is replaced by refrigerator and the turbine is replaced by a compressor.

The heat carried away by the air from the refrigeration in the air refrigeration systems is in the form of sensible heat as there is no change of phase so that the effectiveness of the air refrigeration system is less. In vapour refrigeration system heat carried away by the vapour in the refrigerator is in the form latent heat of refrigerant so that the capacity of refrigerant of vapour refrigeration system per kg of refrigerant is far superior to the air refrigeration system.

The most common types of refrigeration systems use the reverse-Rankine vapour compression refrigeration cycle, although absorption heat pumps are used in a minority of applications.

Cyclic refrigeration can be classified as:

- vapour cycle, and
- gas cycle

A) vapour cycle refrigeration can further be classified as:

- vapour-compression refrigeration
- vapour-absorption refrigeration

1.1 Vapour Compression Refrigeration cycle:

Vapour-compression refrigeration Isone of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled and frozen storage of foods and meats, refrigerated trucks and railroad car, and a host of other commercial and industrial services. Oil refineries, petrochemical and chemical processing plant, and natural gas processing plants are among the many types of industrial plants that often utilize large vapour-compressing refrigeration systems.

1.2 Vapour absorption refrigeration cycle:

The absorption cycle is similar to compression cycle for the method of raising the pressure of the refrigerant vapour. In the absorption system, the compressor is replaced by an absorber which

dissolves the refrigerant in a suitable liquid, a liquid pump which raises the pressure and a generator which, on a heat addition, drives off the refrigerant vapour from the high pressure liquid. Some work is needed by the liquid pump but, for a given quantity of refrigerant, it is much smaller than needed by the compressor in the vapour compression cycle.
In an absorption refrigerator, a suitable combination of refrigerant and absorbent is used. The most common combinations are ammonia (refrigerant) with water (absorbent), and water (refrigerant) with lithium bromide (absorbent).

II. LITERATURE REVIEW

The basis of modern refrigeration is the ability of liquids to absorb enormous quantities of heat as they boil and evaporate. Professor **William Cullen** of the University of Edinburgh demonstrated this in 1755 by placing some water in thermal contact with either under a receiver of a vacuum pump. The evaporation rate of ether increased due to the vacuum pump and water could be frozen. This process involved to thermodynamic concepts, the vapour pressure and the latent heat. A liquid is in thermal equilibrium with its own vapour at a pressure is called the saturation pressure, which depends on the temperature alone. If the pressure is increased for example in a pressure cooker, the water boils at high temperature. The second concept is that the evaporation of the liquid requires latent heat during evaporation. If latent heat is extracted from the liquid, the liquid gets cooled. The temperature of ether will remain constant as long as the vacuum pump maintains a pressure equal to saturation pressure at the desired temperature. This requires the removal of all the vapour formed due to vaporization. If a lower temperature is desired, then a lower saturation pressure will have to be maintained by the vacuum pump. The component of the modern day refrigeration system where cooling is produced by this method is called evaporator.
If this process of cooling is to be made continuous vapours have to be recycled by condensation to the liquid state. The condensation process requires heat rejection to the surroundings. It can be condensed at atmospheric temperature by increasing its pressure. The process of condensation was learned in the second half of eighteen century. **U.F.CLOUET** and **G. MONGE** liquefied SO_2 In 1780 while van **Marum** and **Van Troostwijk** liquefied NH_3 in 1787.

John Hague made Perkin's design into working model with some modifications. The earliest vapour compression system used either sulphuric (ethyl) or methyl ether. The American engineer **Alexander Twining** (1801 – 1884) received a British patent in 1850 for a vapour compression system by use of ether, NH_3 and CO_2..

2.1 DOMESTIC REFRIGERATION:

The domestic refrigerator using natural ice was invented in 1803 and was used for almost 150 years without much alteration. The domestic ice box is used to be made of wood with suitable insulation. Ice used to be kept at the top of box, and low temperatures are produced in the box due to heat transfer by natural convection. A drip pan is used to collect the water formed due to the melting of ice. The box has to be replenished with fresh ice once all the ice melts. Through the concept is quite simple the domestic ice box suffered from several disadvantages. The user has to replenish the ice as soon as it is consumed, and the lowest temperatures that could be produced inside the compartment are limited.

In addition, it appears that warm winter caused several shortage of natural ice in USA. Hence, efforts starting from 1887 have been made to develop domestic refrigerators using mechanical systems.

The initial domestic refrigerators were costly, not completely automatic and were not reliable. However, the development of mechanical household refrigerators on a large scale was made possible by the development of small compressors, automatic refrigerant controls, better shaft seals, developments in electrical power systems and induction motors. General electric company introduced the first domestic refrigerator in 1911, followed by Frigidaire in 1915. Kelvinator launched the domestic mechanical refrigerator in U.S.A.

In 1925, U.S.A had about 25 million domestic refrigerators of which only 75000 were mechanical, however the manufacture of domestic refrigerators grew very rapidly, and by 1949 about 7 million domestic refrigerators were produced annually. With the production volume increasing the price fell sharply the initial domestic refrigerators used mainly sulphur dioxide as refrigerants were replaced by Freon-12 in 1930s. in the beginning these refrigerators were equipped with open type compressors driven by belt drive. General electric company introduced the first refrigerator with a hermetic compressor in 1926. Soon the open type compressors were completely replaced by the hermetic compressors. First refrigerators used water cooled condensers, which were soon replaced by air cooled condensers. Through the development of mechanical domestic refrigerators was very rapid in USA. It was still rarely used in other countries in 1930. Only rich families used domestic refrigerators in Europe. The domestic refrigerators based on absorption principle as proposed by **Platen** and **Munters**, was first made by Electrolux company in 1931 in Sweden. In Japan the first mechanical domestic refrigerator was made in 1924. The first dual temperature (freezer-refrigerator) domestic refrigerator was introduced in 1939.

The use of domestic refrigerators grew rapidly all over the world after the Second World War. Today, a mechanical domestic refrigerator has become an essential kitchen appliance not only in highly developed countries but also in countries such as India. Except a very few almost all the present day domestic refrigerators are mechanical refrigerators that use as a hermetic compressor and an air cooled condenser. The modern refrigerators used either HFC – 134a (hydro-fluoro-carbon) or iso-butane as refrigerant.

III. VAPOUR COMPRESSION REFRIGERATION SYSTEM WITH SINGLE EXPANSION VALVES:

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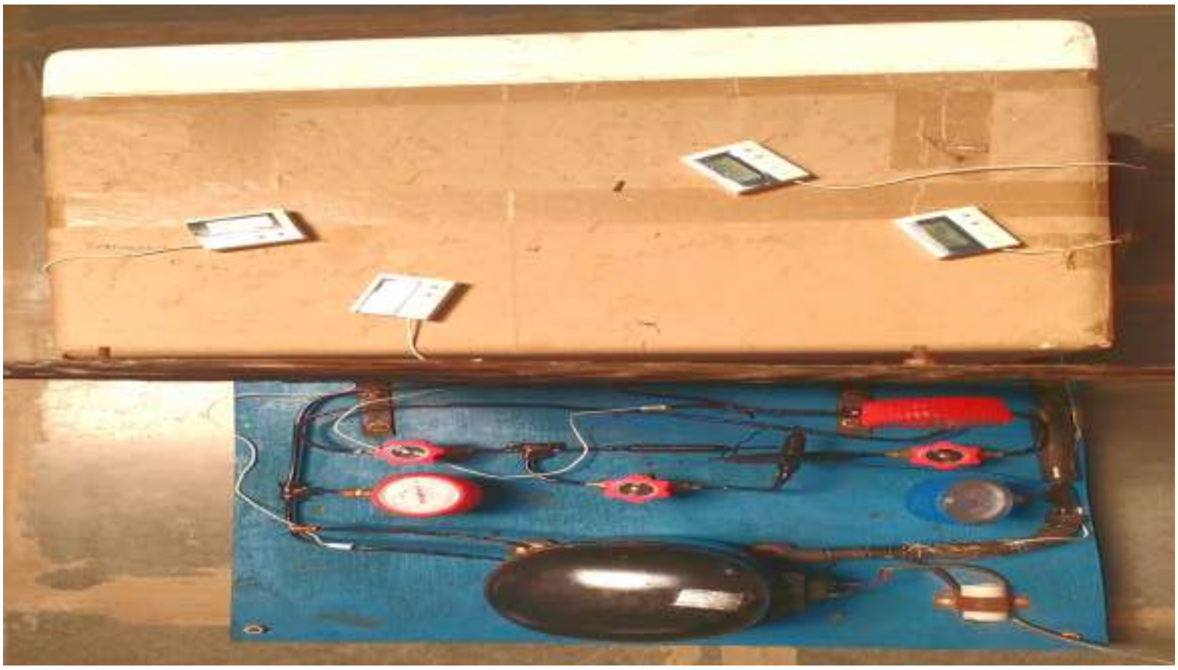

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IV. EXPERIMENTAL READINGS AND CACULATIONS

4.1 Operating with one expansion valve with 1 kg load

Suction temperature T1	3.9°C
Discharge temperature T2	53.5 °C
Condenser coil out temperature T3	46.3 °C
Evaporator coil temperature T4	-14.2 °C

From the PH-chart (R-134a)

h1 =393 KJ/Kg

h2 =417.8 KJ/Kg

h3 =260.6 KJ/Kg

h4 =260.6 KJ/Kg

1. Coefficient of performance = Refrigerant effect/work done

Refrigerant effect (R.E) = h1-hf3 (or) h1-h4

= 393-260.6=132.4KJ/Kg

Work done (w) = h2-h1

=417.8-393 =24.8 KJ/Kg

Coefficient of performance = (h1-hf3) / (h2-h1)

= 132.4/24.8

C.O.P = 5.51

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4.2 Operating with 3 expansion valve with 1 kg load:

Suction temperature T1	20°C
Discharge temperature T2	50 °C
Condenser coil out temperature T3	35 °C
Evaporator coil temperature T4	-8.3 °C

From the PH-chart (R-134a)

h1 =394 KJ/Kg

h2 =426 KJ/Kg

h3 =270 KJ/Kg

h4 =270 KJ/Kg

1. Coefficient of performance = Refrigerant effect/work done

Refrigerant effect (R.E) = h1-hf3 (or) h1-h4

= 394-270

= 124 KJ/Kg

Work done (w) = h2-h1

=426-394

=32 KJ/Kg

Coefficient of performance = (h1-hf3) /(h2-h1) =124/32=3.8

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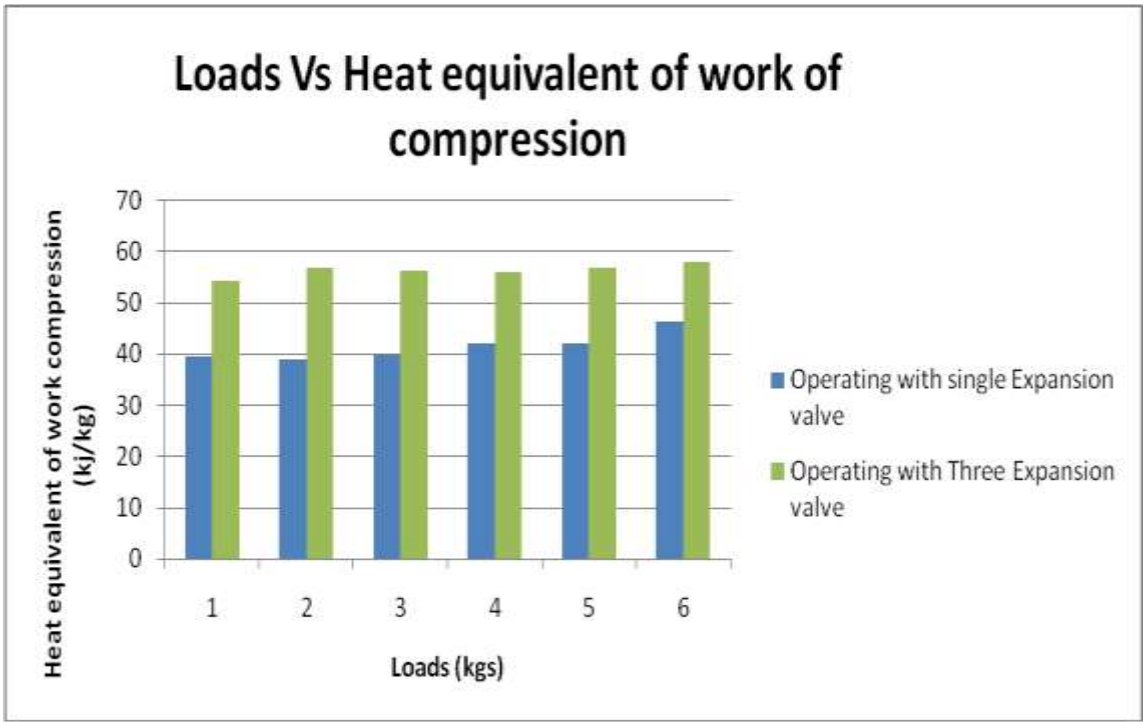
V. RESULTS AND DISCUSSIONS

Tabular column 5.1 : Comparing the loads Vs Heat equivalent of work of compression with Multiple Expansion valves on VCR System

Load's in (kg's)	Heat equivalent of work of compression with single Expansion valve….KJ/Kg	Heat equivalent of work of compression with Three Expansion valve….KJ/Kg
1	39.33	54.19
2	38.83	56.74
3	39.61	56.23
4	42	55.88
5	41.83	56.80
6	46.06	57.75

Graph 5.1: For Comparing the loads Vs Heat equivalent of work of compression with Multiple Expansion valves on VCR system.



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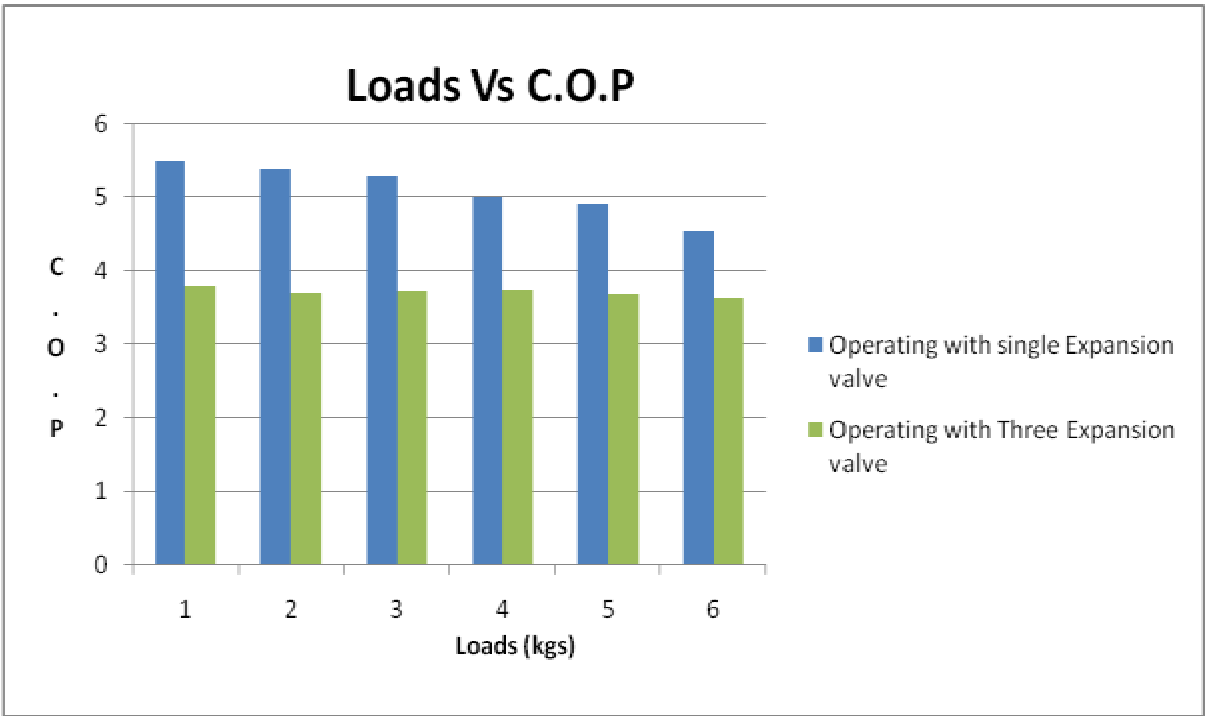
Tabular column 5.2 : Comparing the loads Vs C.O.P with Multiple Expansion valves on VCR System

Load's in (kg's)	C.O.P with single Expansion valve	C.O.P with Three Expansion valve
1	5.51	3.80
2	5.40	3.70
3	5.30	3.73
4	5.01	3.75
5	4.92	3.69
6	4.55	3.63

Graph 5.2 : For Comparing the loads Vs C.O.P with Multiple Expansion valves on VCR system



VI. CONCLUSIONS

Experimental studies have been carried out to evaluate the Refrigeration system performance under various operating conditions. A separate experimental set up has been used for determining the pressure, temperature and coefficient of performance with multiple expansion valves. From the investigations, the following conclusions are drawn:

- In the present work the performance of refrigeration system with R-134a refrigerant is optimized through experimental investigation using multiple expansion valves.
- Test results shows that the compressor work increases as the number of expansion valves increases.
- It is seen that mass flow rate of refrigeration system increases as number of expansion valves increases.
- The compressor pressure decreases as the number of expansion valves increases. It is seen that compressor power decreases as the number of expansion valves increases.
- Test results shows that the net refrigerating effect decreases as the number of expansion valves increases.
- Test results shows that the C.O.P decreases as the number of expansion valves increases.
- It is seen that heat equivalent of work of compressor increases as the number of expansion valves increases.
- From the above experimental analysis of vapour compression refrigeration system with multiple expansion valves, we concluded that the net refrigerating effect, Coefficient of performance, Mass flow rate of refrigerant, Heat equivalent work of compression, Heat rejected in the condenser is considered as optimum for the single expansion valve in the vapour compression refrigeration system.

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