Experimental Investigation of vapour compression refrigeration system with an Ejector And Secondary Evaporator using R-134 as a refrigerant

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Abstract **The purpose of the present study to utilise ejector and the low grade energy absorbe from secondary evaporator to flow the refrigerant in liquid phase left after primary evaporator through secondary evaporator and produce an refrigeration effect in the secondary evaporator without external work and study COP of the new refrigeration system over a range of evaporating temperature of Primary evaporator from 20^{0}C to -26^{0}C,secondary evaporator temperatures from 70^{0}c to 35^0 C**

Keywords —— **COP, Ejector , Energy Saving, R-134a Refrigerant, VCR System , Accumulator**

I. Introduction

Refrigeration is the process of cooling of a system below the temperature of the surrounding , which is obtain by various cyclic and non-cyclic process. Vapour compression refrigeration system is a cyclic refrigeration process proposed by Oliver Evans an American inventer in 1805. First working Vapour compression refrigeration system was buit in 1834 by another American scientist name Jacob Jenkim. After which it gain large popularity in the field of refrigeration and become an interesting field of investigation for the researchers. Vapour compression refrigeration system is generally used for refrigeration purpose due to its small size and high COP. There are various factor which effect the coefficient of performance of Vapour compression refrigeration system [1] . Improvement in the performance of Vapour compression refrigeration system COP will result in energy saving of the system. The investigation of a new cycle for Vapour compression refrigeration system with an ejector as an expansion device and secondary evaporator was carried out within this project Vapour compression refrigeration system consist of mainly four component compressor , condenser , expansion device and evaporator . The compressor remove the refrigerant from the evaporator rising its pressure and temperature to such a point such that it can condensate in the condenser. The refrigerant than pass through the condenser which provide heat transfer surface through which heat is passed from the hot refrigerant vapour. Then the refrigerant is expaned by an expansion valve which meter the proper amount of refrigerant to the evaporator reducing the pressure of the refrigerant entering the evaporator. The evaporator evaporate the refrigerant by absorbing heat from the surrounding or the substance to be refrigerated. VCRS use capillary tube ,thermostatic expansion valve and other throttling device to reduce the pressure of the refrigerant from the condenser to the evaporator .Theoretically this pressure drop is an isenthalpic process causing a loss of energy during throttling process. An ejector can be use for achieving isentropic condition during throttling process in which no loss of energy can take place. After expansion the refrigerant pass through the evaporator and enter the compressor . Sometime ,the liquid refrigerant passing through the evaporator is not completely evaporate , if the liquid refrigerant passed through the evaporator without completely evaporated to gaseous phase, than an extra work has to be done by the compressor to evaporate and rise the temperature of the liquid refrigerant. If the amount of refrigerant inliqud phase entering the compressor is large it may not only effect the lubricating system of the compressor but also chocked the refrigerating cycle. Hence to protect the liquid refrigerant from entering the compressor an ACCCUMULATOR is used with an secondary evaporator through which liquid refrigerant left after the primary evaporator circulated again and again with the help of an ejector which not only increase the refrigeration effect by secondary evaporator but also decrease the compressor work by increasing the pressure of the refrigerant and allowing only gaseous phase to enter the compressor

The purpose of present study is to investigate a new cycle for Vapour compression refrigeration system with an ejector as an expansion device and secondary evaporator and is based on ejector refrigeration system.

An ejector may be used as a fluid -driven compressor in a refrigeration cycle.

The ejector refrigeration system was first developed by Macurice Leblance in 1910 [2] by using mainly heat energy

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instead of electrical energy to drive the cycle. Since it has no movable part ,it has low wear and highly durable. However it is not used for refrigeration purpose due to its low COP.

Ejector refrigeration is a low grade energy driven technology . But have a much lower COP than vapour compression systems but offer advantages of simplicity and no moving parts. Their greatest advantage is their capability to produce refrigeration using low grade energy or unused heat which is rejected to the surrounding.

A typical ejector refrigeration cycle is shown in Fig. 1

Ejector refrigeration system consist of vapour generator

- Ejector
- Condenser
- Expansion valve
- evaporator
- liquid pump

In ejector refrigeration system as shown in Fig.1

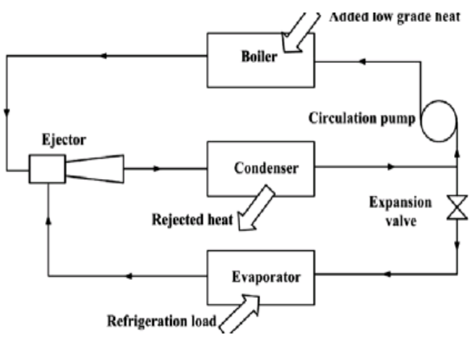

FIG.1.Ejector refrigeration system

The ejector, the boiler (or steam generator) and the **circulating pump** are used to replace the compressor of the refrigeration cycle or vapor compression cycle. The high pressure refrigerant produce in the boiler , is the primary fluid feeding to the primary nozzle. It is then expands through the nozzle throat at supersonic speed and causes a low pressure area which is connected to the evaporator decreasing its pressure causing the refrigerant to evaporate by absorbing lattent heat from the system or space to be refrigerated Thus, a cooling effect is produced. Since the fluid always flow from higher pressure to lower pressur ,the refrigerant after goes to the mixing chamber. These refrigerant is the secondary fluid which after mixing with primary fluid pass through the diffuser rising its pressure to condenser pressure. After rejecting heat in the condenser some refrigerant goes to the evaporator and rest goes to the boiler or generator by pump to vapourised again . Thus, a cooling effect is produced.

The performance of such a system depend on the performance of the ejector which flow the refrigerant through the evaporator by producing a pressure difference between the inlet and outlet of the evaporator.

The performance of the ejector mainly depend on two parameters

1 Entrainment ratio (Em)

$$\text{Entrainment ratio Em} = \frac{\text{mass flow rate of secondary flow}}{\text{mass flow rate of primary flow}}$$

2 critical back pressure (CBP)

CBP is the final pressure (condensing pressure) with the ejector working at its maximum capability.

Based on the mixing concept at the primary nozzle exit ejectors are of two type.

1. The constant mixing area (CMA) ejector: In the constant mixing area (CMA) ejector the exit of the primary nozzle is placed at the constant area throat.
2. The constant pressure mixing (CPM)ejector: In the constant pressure mixing (CPM)ejector the exit of the primary nozzle is placed at the converging area throat.

The setup of both the CMA and CPM ejector are shown in Fig. 2.

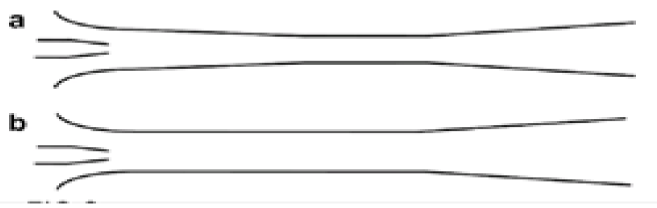

FIG.2 Two typical ejector types: (a) constant pressure mixing ejector and (b) constant mixing area ejector

These two ejectors are suitable to use in different situations. The CMA is capable of drawing more mass flow rate than the CPM, but the CPM is more flexible or suitable to operate in wider condensing pressure ranges. Ejector as an expander in vapour compression refrigeration cycle have been an attractive research subject for a lot of researcher due to being low grade heat driven system and having immovable parts. But the two main drawback of these system are the low COP of the refrigeration system and use of high grade energy that is electrical energy for driving pump.If these disadvantages could be eliminated ,the system could find a wide area of application in air-conditioning and refrigeration industries. If an ejector refrigeration system without the pump could be developed, then the systems will be independent of electrical energy. Various researches on the ejector refrigeration system have done on improving the performance of the system. Studies carried out to increase their efficiencies are generally on a better design of ejector, the selection of a proper refrigerant, the optimization of operating conditions and the addition of various (secondary) devices such as a pre-cooler and regenerator to the refrigeration cycle. Scientists have densely studied on these research subjects for several decades and have achieved a significant improvement in the coefficient of performance of the systems using one or more methods,

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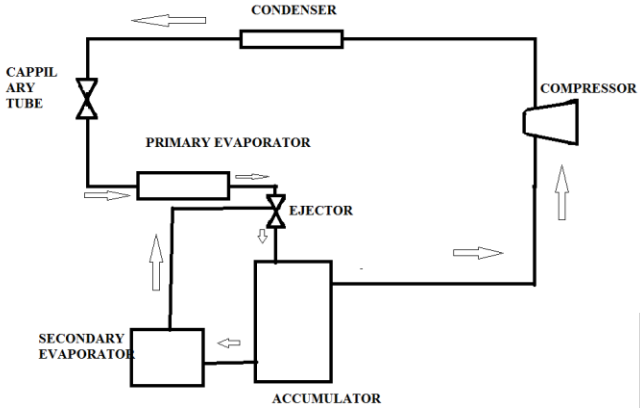
II. Working Principle Of Vapour Compression Refrigeration System With An Ejector As An Expansion Device And Secondary Evaporator

In the vapour compression refrigeration system with an ejector and secondary evaporator, the ejector and secondary evaporator is connected between primary evaporator and compressor as shown in Fig. 3



(a)Schematic diagram of the vapour compression refrigeration system with an ejector and secondary evaporator

(b) Actual Setup of the vapour compression refrigeration system with an ejector and secondary evaporator

Fig. 3: (a)Schematic diagram of the vapour compression refrigeration system with an ejector and secondary evaporator (b) Actual Setup of the vapour compression refrigeration system with an ejector and secondary evaporator

The ejector considered in the present experimental setup consist of a primary nozzle, a secondary nozzle , a convergent mixing section followed by a constant area section and a diffuser section .In ejector ,the primary fluid (motive fluid) from primary evaporator is expands through the nozzle throat at causes a low pressure area which is connected to the secondary evaporator causing the refrigerant in secondary evaporator that is Secondary fluid to flow into the mixing chamber These secondary fluid which after mixing with primary fluid pass through the diffuser rising its pressure .After diffuser it enter the accumulator which separate the liquid refrigerant from its gaseous phase . Due to difference in density the refrigerant in liquid phase accumulated at the bottom of the accumulator and enter the secondary evaporator connected to the bottom of accumulator while the low density refrigerant at the upper portion of the accumulator is taken by the compressor and compressed to condenser pressure. The refrigerant after evaporating in the secondary evaporator goes up and enter the ejector where it mixed with the primary fluid. In the present study a converging-diverging (CD) nozzle is used as the primary nozzle, in which the primary fluid or motive fluid expands from sub-critical primary evaporator pressure to a sub-critical pressure, that is less than or equal to the secondary evaporator pressure .The ejector is modelled using the following assumptions:-

- The flow inside the motive nozzle is steady and one dimensional
- The nozzle is a converging nozzle and its throat is at its exit.
- At the nozzle throat, the flow reaches the critical flow condition
- The inlet flow velocity is neglected.
- The heat transfer between the fluid and the nozzle & ejector wall is neglected.
- The gravitational force effect on the flow is neglected.
- The mixed stream at the outlet of the mixing section is in homogeneous equilibrium.
- The divergent section is designed as to prevent the flow separation effect.
- The length of divergent section limited as to avoid back flow occurs at exit.

II. Experimental Procedure

This setup has been fabricated in the Heat-Engine laboratory at BIT, SINDRI

All component of new VCRS are connected as shown in fig .3.

In this experiment tested individualy tradition VCRS and new VCRS with ejector and secondary evaporator with R-134a as an refrigerant .

The procedure are as follows:

- First 0.5 ml of ethanol is putted in the evaporator of tradition VCRS.then change in temperature of ethanol for 360 joule power consumption of compressure is measured.
- Same experiment is carried with 0.5 ml of ethanol and 0 .5 ml of water is putted in primary and secondary evaporator in new VCRS with an ejector as an expansion device respectively for .

III. OBSERVATION

After measuring change in temperature of the liquid (i.e. 0.5ethanol & 0.5 water) various refrigeration parameters like

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refrigeration effect ,compressor work, and COP is calculated as shown in table no.1

Refrigeration effect= Heat absorb by refrigerant in evaporator
=mass of liquid in evaporator *specifice Heat*change in temperature

Compression work=Power consumption of compressor

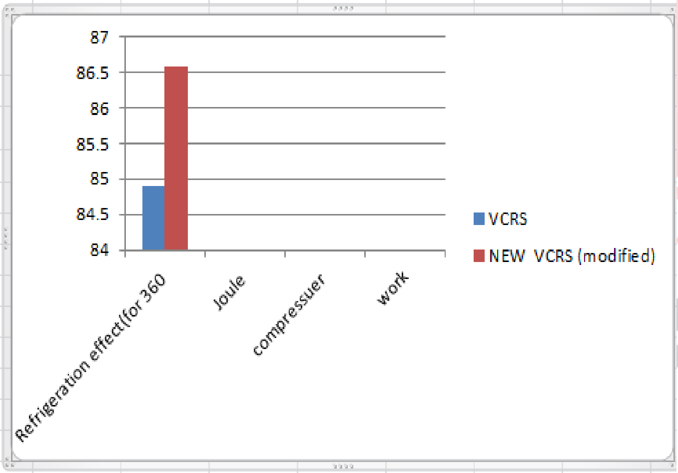
$$COP = \frac{\text{REFEGERATION EFFECTS}}{\text{COMPRESSION WORKS}}$$

Table Number :01

Parameter	VCRS(JOUL	NEW VCRS ,modified(JOUL	Percentage improve%
Refrigeration effect(for 360 Joule compressuer work	**84.9**	**86.57**	**1.9**
COP	**.2358**	**.2402**	**1.86**

IV. RESULT AND DISCUSSION

The aim of the project is to improve the COP of the VCRS through inducting some modification. The graph 01 show the refrigeration effect in traditional VCRS and modified VCRS for 360 joule power consumption of compressor.



Graph.01.REFRIGERATION EFFECT OF VCRS and modified VCRS

VI. FUTURE SCOPE

The performance of the ejector is influenced by evaporation and condensation temperatures; therefore, future research challenge is on how to design an ejector that can be regulated by the dimensions of the nozzle section and the suction chamber in accordance with the required conditions. This is due to these parts that are relatively critical in determining the efficiency of ejectors. The use of variable two-phase ejector will accelerate the implementation of this device to replace a conventional expansion device. However, to accomplish this, more intensive study on the characteristics of two-phase ejector as an expansion device is still required

V. CONCLUSION

I have compared the performance of traditional VCRS with modified VCRS .After completing the experiment .I have found that Percentage increment of COP of new VCRS cycle with respect to tradition VCRS cycle is about 1.9%.

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