INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

COEFFICIENT OF PERFORMANCE OF TWO PHASE CONDENSING EJECTOR REFRIGERATION SYSTEM WITH R-22

Kuldip Kumar[1], Anjani Kumar[2] and Ujjwal Kumar Nayak[3]

[123]***Department of mechanical engineering, B.I.T.Sindri, Dhanbad-828123, Jharkhand, India***
[1]*kuldipkumarrvs@gmail.com*, [2]*anjanik63@gmail.com*, [3]*ujjwalnayak77@gmail.com*

ABSTRACT: - The process of expansion of paper is to minimize losses and improve the basic refrigeration cycle COP with ejector and continue on a description of the development of important refrigeration system with R-22 refrigerant. A refrigerant R-22 is used as the working fluid. In conventional systems some work of compressor is lost for the compression of uncondensed fluid passes through the condenser which is undesirable for performance of refrigeration. Through this experiment the undesirable work of compressor is removed by use very simple separator like device. The two phase flow through the ejector rebirth of pressure that also save the compressor work for novel vapor compression cycle for refrigeration. The new cycle with an ejector device which combines compression, with compression includes a second step. Approximately 4/5 of the final compressor compresses the vapor pressure and addition compression, in an ejector provided, thus the amount of mechanical energy required by the compressor is reduced and efficiency increased. The thermodynamic model was developed for R22 refrigerant, showing a possible efficiency improvement as compared to the traditional vapor compression cycle. The theoretical work followed by prototype and practical demonstration of 20% energy savings in the first attempt.

Keywords: Ejector, Compressor, Evaporator, Refrigerant etc.

---

1 INTRODUCTION

In refrigeration and cooling applications heat is absorbed from a space by the refrigerant during an evaporation portion of the cycle where the refrigerant changes into a vapor phase. The absorption of heat provides useful cooling of the space. The vapor is subsequently compressed in a compressor. Energy is consumed by the compressor during the compression of the vapor. Compression of the vapor facilitates condensation of the vapor into a liquid. Condensation of the vapor is caused by flowing the compressed vapor through a condenser where heat is released into a heat sink thereby condensing the refrigerant into a liquid. The liquid is circulated through the closed loop to a decompression device, typically an expansion valve, where the pressure of the refrigerant is decreased. Typically, the refrigerant pressure is reduced by a factor of five or more. The decompressed refrigerant is returned to the evaporator resuming the cycle.

To improve the efficiency of the cycle which can be used to supplement and reduce the power required by the compressor. The use of a two-phase ejector for improving the efficiency of vapor-compression refrigeration cycles is a new idea, as there have been numerous numerical and experimental studies on two-phase ejector cycles that have been previously published in the open literature. There are additional two-phase ejector cycle possibilities, but very little research has been published on these cycles. However, less attention has been given to lower-pressure refrigerants, such as R22. Despite their lower improvement potential, it is still worth investigating these low-pressure refrigerants with a two-phase ejector cycle to see if they do actually offer some noticeable improvements.

The limited number of two-phase ejector studies using low-pressure refrigerants, there is opportunity to experimentally investigate the performance of these refrigerants on two-phase ejector cycles.

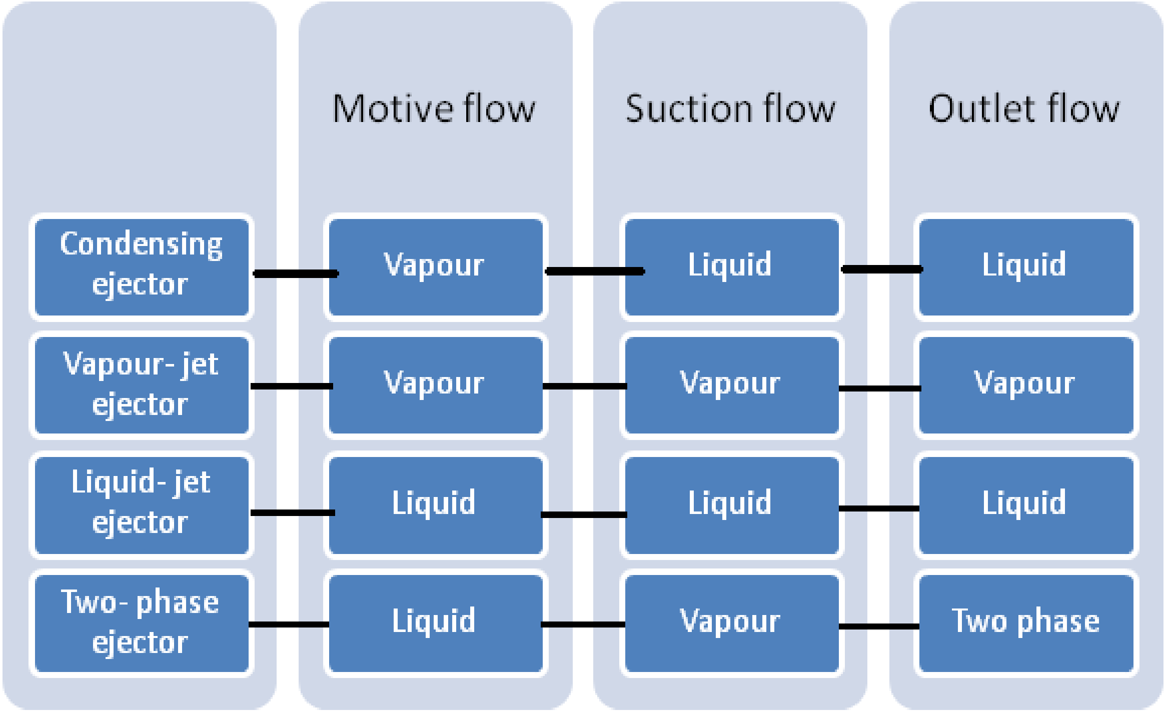
- Experimentally evaluate two-phase ejector performance and the improvement potential of a two-phase ejector cycle with low-pressure refrigerants R22.
- Demonstrate the effect that system components and operating conditions can have on the improvement potential of two-phase ejector cycles.

1.1 Ejector Fundamentals

An ejector is a device that uses the expansion of a high-pressure fluid to entrain and provide compression power to a fluid at a lower pressure. The motive fluid enters the converging nozzle, inside the **injector**, with certain energy. In the converging nozzle, the pressure energy of the motive flow is converted to kinetic energy, and the motive fluid exits the nozzle with high velocity and low pressure. The **mixture zone** is where the vacuum is produced and where the two fluids join and mix. When the motive flow is a vapor, affecting a liquid or multiphase fluid, the mixture zone is a converging nozzle, and the suction pressure takes place at the throat, as it was the case of the original steam jet ejectors. In the particular case being studied here, the motive fluid is a liquid, denser than the vapor it affects, and the liquid phase will take the form of droplets, after passing through the mixture zone, the mixed fluid expands in the **diffuser**, reducing its velocity which results in re-compressing the mixed fluids by converting kinetic energy back into pressure energy.

Chunnanond and Aphornratana (2004) pointed out that the mixing process can be designed to occur with either a cylindrical mixing section, resulting in a constant cross-sectional area, or with a conically-shaped, converging mixing section, resulting in a mixing process that occurs at constant pressure, though it has been observed that constant pressure mixing produces higher ejector performance.

Table 1.1: Classification of different types of ejectors



	Motive flow	Suction flow	Outlet flow
Condensing ejector	Vapour	Liquid	Liquid
Vapour- jet ejector	Vapour	Vapour	Vapour
Liquid- jet ejector	Liquid	Liquid	Liquid
Two- phase ejector	Liquid	Vapour	Two phase

1.2 Ejector Design

The ejector was based on a modular design such that the motive nozzle, mixing section, and diffuser could be changed without having to construct an entirely new ejector. An illustrated section view of the three ejector components assembled together can be seen in Figure 1.2.1 and pressure variation shown in Figure 1.2.2. The ejector motive nozzle throat diameter was designed using an empirical flow correlation determined by **Henry and Fauske (1971).** Additional ejector dimensions were designed using the model of **Kornhauser (1990).** This model required the assumption of efficiencies of the ejector components and an assumed mixing section pressure; reasonable estimates based on earlier ejector work were provided for these parameters. The motive nozzle throat diameter can affect the motive flow rate and can actually limit the motive flow rate if the throat is too small. The length of the nozzle's diverging section determines the amount of time the motive flow has to expand before entering the mixing section. The mixing section diameter affects the mixing process between the motive and suction streams, and the mixing section ratio affects the amount of time available for mixing of the two streams.

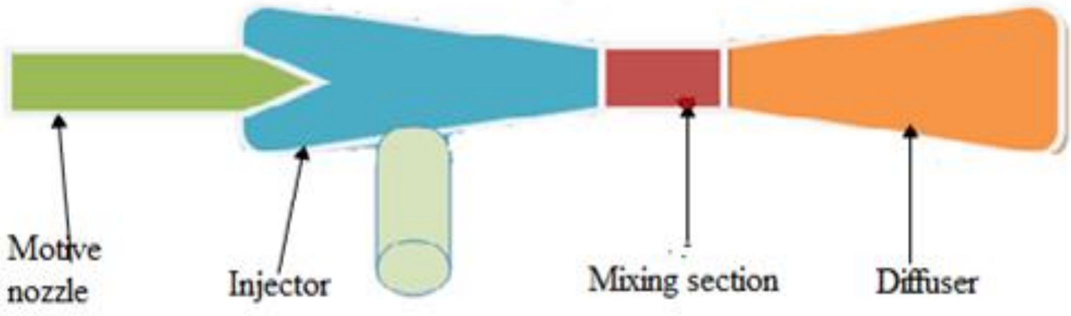


Figure 1.2.1: Section view of modular two-phase ejector assembly

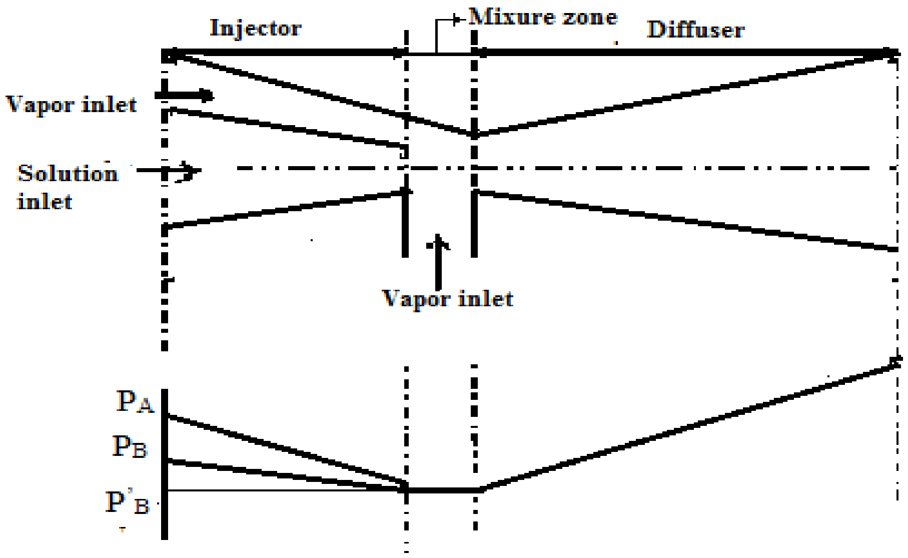


Figure 1.2.2: Ejector's pressure variation indication

2 Experimental Set Up of Two phase condensing ejector Vapor Compresson System

The principle of the condensing ejector, presented above was utilized to construct the refrigeration system shown in Figure 2.1 and Figure 2.2. In this new system, the mechanical compressor compresses the vapor to approximately 4/5 of the final pressure. Additional compression is provided by the ejector device; therefore the amount of mechanical energy required by a compressor is significantly reduced

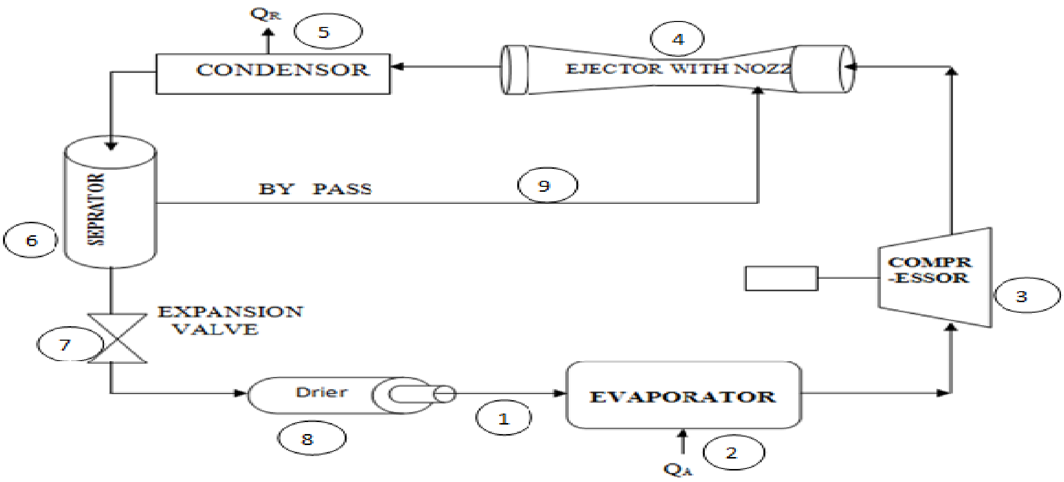


Figure 2.1: Schemetc diagram of experimental setup

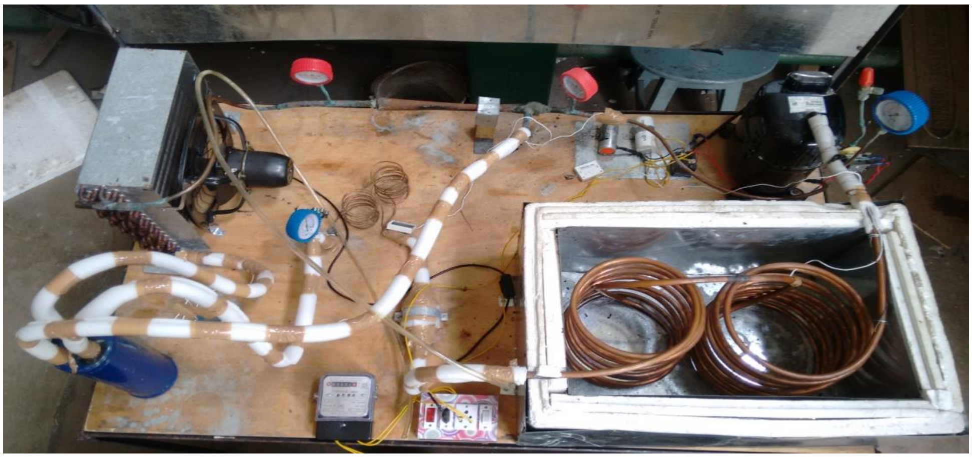


Figure 2.2: Actual Diagram of Experimental Setup

The working medium is compressed in the compressor and is sent to the ejector where it mixes with the liquid flow coming from the separator. The flow of working medium is then directed to the condenser where it is cooled by transferring the heat to the high-temperature receiver. The ejector improves the efficiency of the cycle by decreasing the need for energy to run the compressor. The theoretical energy savings for the new system can be established by analyzing the thermodynamic cycles for the new system vs. traditional single stage compression cycle. Both cycles are presented in Figure 2.3.

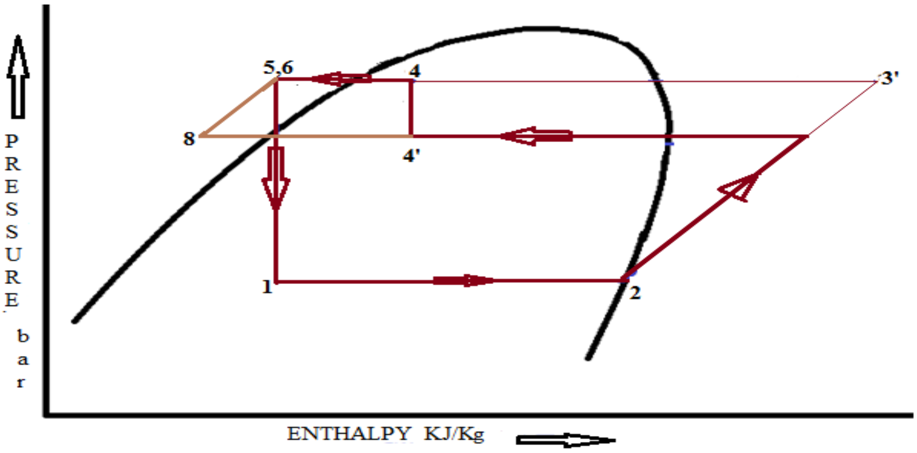


Figure 2.3: Comparison of p-h diagrams of the new refrigeration cycle with a two-phase ejector, Cycle 1 (point 1-2-3-4’-4-5-1) and the traditional cycle 2 (the point 1-2-3’-5-1). 1-2: evaporation of a part of the working fluid; 2-3: compression of vapor in the compressor (the first step); 4-5: isobaric cooling of the liquid working medium; 6-1: throttling of the evaporating part of the working fluid.

3. Performance of system with refrigerant R-22 as working fluid:

For the calculation of performance of this refrigeration system, we have noted all required data with the help of measuring instrument which has been installed in system shown in figure 2.2. With the observed data we calculate system efficiency by some basic formulae and use of refrigerant properties charts.

Table 3.1: Variable parameters of the refrigeration system for R-22 and T_{atm}= 29°C

P_2 (bar)	P_3 (bar)	P_4 (bar)	P_6 (bar)	T_2 (°C)	T_3 (°C)	T_6 (°C)
2	11	12.6	12.2	-8	32	38
2.31	12.03	13.4	13.13	-9.3	40.3	39
2.38	13.07	13.55	13.40	-13.1	47	39.6
2.45	13.14	14.50	13.80	-12.9	49.3	40.8
2.50	13.2	14.5	14	-15.1	50	41.1

Table 3.2: Calculated COP for different temperature of evaporator with the ejector

h_2 (kJ/kg)	h_3 (kJ/kg)	$h_6 = h_1$ (kJ/kg)	$h_2 - h_1$ (kJ/kg)	$h_3 – h_2$ (kJ/kg)	COP_1
402	420	248	154	18	8.5
403	427	243	160	24	6.7
402	430	245	157	28	5.6
400	432	248	152	32	4.7
398	433	250	148	35	4.2
Average COP of the system					**5.9**

Table 3.3: Calculated COP for different temperature of evaporator without the ejector

h_2 (kJ/kg)	$h_{3''}$ (kJ/kg)	$h_6 = h_1$ (kJ/kg)	$h_2 - h_1$ (kJ/kg)	$h_{3''} – h_2$ (kJ/kg)	COP_2
410	426	260	150	16	9.4
400	427	263	137	27	5
398	429	264	134	31	4.3
395	434	266	129	39	3.3
392	437	270	122	45	2.7
Average COP_2 of the system					**4.9**

It has to found that average COP_1 with two phase ejector is 5.9 and average COP_2 without two phase ejector is 4.1. So percentage increments in COP be

$$\textbf{\% increment in COP} = \frac{(COP_1 - COP_2)}{(COP_2)} \times 100$$

$$= \frac{(5.9 - 4.9)}{(4.9)} \times 100$$

$$= 20.40\%$$

Table 3.4: Variation of COP with mean condenser temperature for R-22 and T_{atm}= 29°C

Mean $T_{Cond.}$	33.5	34.0	34.3	34.9	35.05
COP_1	8.5	6.7	5.6	4.7	4.2
COP_2	9.4	5.1	4.3	3.3	2.7

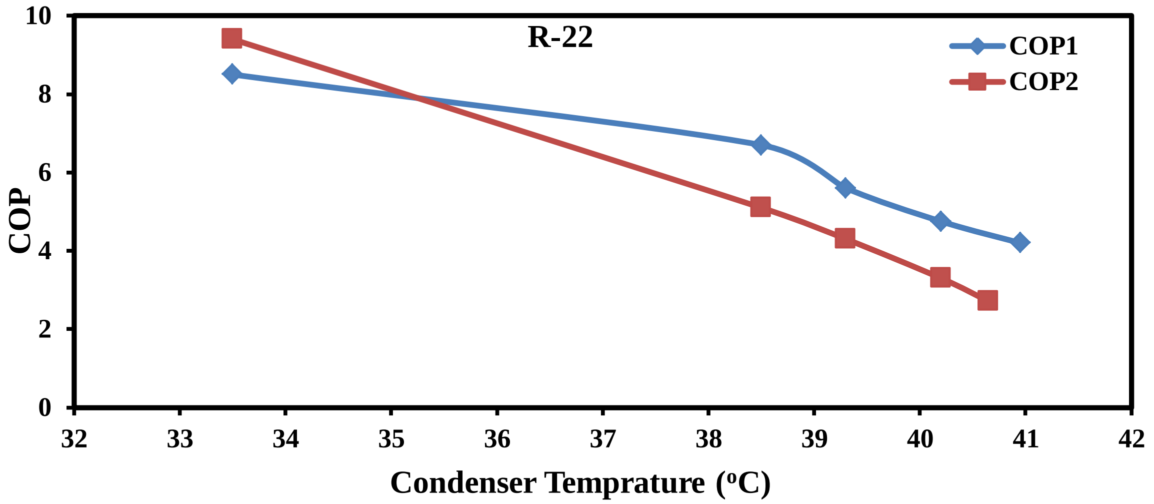


Figure 3.1: Graphical representation of COP_1 and COP_2 vs. condenser temperature

From the above graph it has been shown that as mean condenser temperature increases COP of the system decreases from 8.5 to 4.2. It happens due to a) more compressor work required at elevated temperature and b) not released sufficient amount of heat by condenser. Hence this variation also justified the Carnot principle which was stated that as the higher temperature between condenser and evaporator lower the COP of system.

4. Conclusions

In this paper an experimental analysis has performed with two phase ejector refrigeration system and this novel cycle is compared with traditional refrigeration cycle.

The objectives of the first phase of this project were met by:

- Conducting a state-of-an-art study, which confirmed that this project might represent the first attempt to practically use two-phase flow phenomena with refrigerant as a working medium?
- Developing the theoretical model that showed possible efficiency improvement of 20.40% as compared to the traditional vapour compression cycle.
- The key scientific objective is to obtain the pressure rise with non mechanical by the ejector due to this compressor work reduced.

5. REFERENCES

[1] Kumar A., Kumar K. and Kumar U.K. "Experimental Investigation To Develop The Refrigeration System With Two Phases Condensing Ejector Along With Energy Saving". International Journal of Engineering research & Science, Volume – 1, issue -3, PP – 26 – 30, June, 2015.

[2] Aphornratana S. and Eames I.W., 1997. A small capacity steam-ejector refrigerator: experimental investigation of a system using ejector with movable primary nozzle. Int. J. Refrig.,Vol 20(5), pp. 352-358

[3] Kornhauser, A.A, 1990 .The use of an ejector as a refrigerant expander. Proceedings of USNC/IIR-Purdue refrigeration conference, USA (1990).

[4] Chunnanond K, Aphornratana S. Ejectors: applications in refrigeration tech- nology. Renewable Sustainable Energy Reviews 2004;8:129–55

[5] Arora, C.P, 2004, Refrigeration and Air Conditioning, Tata McGraw-Hill, New Delhi, pp. 466.