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# A Review on use of Ejector as expansion device in Vapour Compression Refrigeration Systems

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**Abstract - Ejectors have been used to improve the efficiency and the capacity of vapour compression cycles in the past decade by means of expansion work recovery. The design, performance and the effect of ejector on the cycle has been the prime focus of the researchers but lately, it was found that architecture of cycle, cycle control and improvement in evaporator performance play a crucial role in the cycle performance.**

**In this paper three ejector cycles have been discussed theoretically and their advantages and disadvantages are mentioned. These cycles are standard ejector cycle, liquid recirculation cycle and condenser outlet split ejector cycle. The standard ejector cycle uses the pressure rise in ejector to increase the suction pressure and reduces the power of compressor. The liquid recirculation cycle recirculates the excess liquid through the evaporator with the help of ejector to improve the evaporator performance. The condenser outlet split cycle uses ejector to provide cooling effect at two different temperatures.**

***Keywords —COP, Ejector, Evaporator, Isenthalpic, Isentropic, Refrigerant***

## I. INTRODUCTION

Vapour compression cycle (VCR) is widely used in air conditioning and refrigeration systems, but it does have few disadvantages. Firstly, the expansion process in the VCR cycle is isenthalpic process which leads to throttling losses and secondly, the workload on the compressor is high. To overcome these disadvantages a device called ejector is used in the VCR cycle. Ejector is a device in which the expansion process is isentropic unlike the isenthalpic process in traditional VCR cycle resulting in higher cooling effect and also increase in suction pressure of the compressor i.e increase in the COP of the system. This paper presents a review on different refrigeration cycles in which ejector can be used as an expansion device.

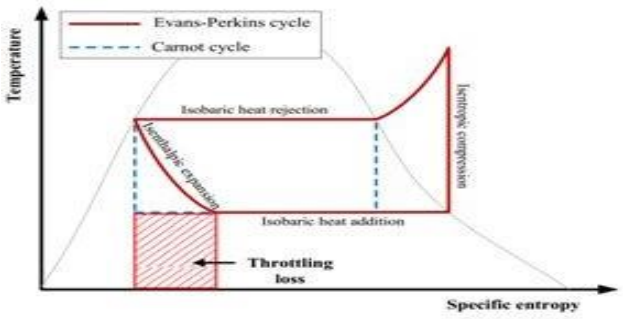


Fig 1: Conventional VCR cycle

## II. LITERATURE REVIEW

The need for refrigerators and air-conditioners is rising day by day due to rising temperatures. But the cost of refrigerators and air-conditioners has not decreased proportionately. The high cost of these equipments may be attributed to many factors such as capacity of the compressor, capacity of the system, mass of refrigerant used etc. Thus use of ejectors in refrigeration and air-conditioning applications can substantially reduce their costs as well as increase their performance. Ejectors were first known to be used in refrigeration applications, back in 1910. Steam Ejectors were used in refrigeration till 1930,but vapour compression refrigeration replaced ejector refrigeration system due to its simplicity in operation. But the high cost and adverse environmental effects of VCR systems encouraged researchers for further study into the use of ejectors in refrigeration systems. Recently in the early 2000's experimental investigations were done on the transcritical cycle using ejector as expansion device using CO2 as refrigerant and the results were encouraging, showing 15-30% improvement in the COP.

## III. BASIC OVERVIEW OF EJECTOR

An ejector consists of primary nozzle, mixing chamber and diffuser. The high pressure fluid from condenser is expanded is entropically in the primary nozzle. Thus the enthalpy drop due to isentropic expansion is converted into kinetic energy and the refrigerant coming out of the nozzle is of low pressure and high velocity. At the same time low pressure vapour coming from the evaporator enters the ejector and is mixed with the primary refrigerant from the nozzle in the mixing chamber. The velocity of the mixed flow is then reduced in the diffuser and there is a rise in the pressure. Thus the mixed flow coming out of the ejector is a two phased flow at an

intermediate pressure between evaporator and condenser pressures. Thus the diffusing section in the ejector partially compresses the low pressure vapour and helps in increasing the suction pressure of the compressor.[7]

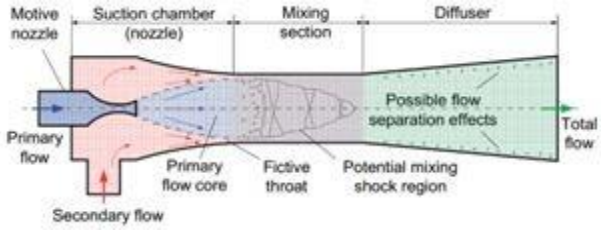


Fig 2: Ejector

## IV. EJECTOR EXPANSION REFRIGERATION CYCLES

*Standard ejector refrigeration cycle:*

In the standard ejector refrigeration cycle, the ejector is connected after the condenser in the liquid line. After the ejector there is a vapor liquid separator which separates the vapor and the liquid. The separator is connected to the compressor and the evaporator. The vapor after compression flows into the condenser and the condensed high pressure liquid, flows into the ejector for expansion. After expanding isentropically in the primary nozzle, the low pressure high velocity liquid coming out of the nozzle, mixes with the low pressure vapor coming into the ejector from the evaporator. The pressure of the mixed flow then increases in the diffuser and the two phase flow coming out of the ejector flows into the vapor liquid separator where the liquid and vapor phases are separated. The vapor then flows back to the compressor for compression and the liquid flows into the evaporator to give the required cooling effect. Thus the cycle is repeated.[1]

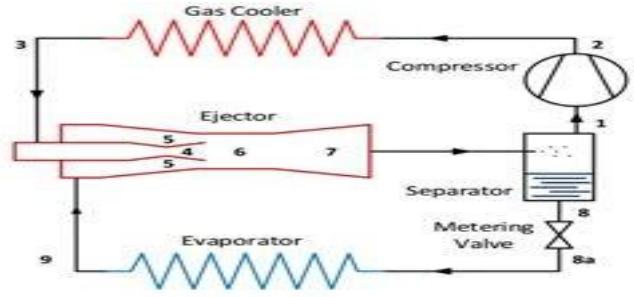


Fig 3: Standard ejector refrigeration cycle schematic

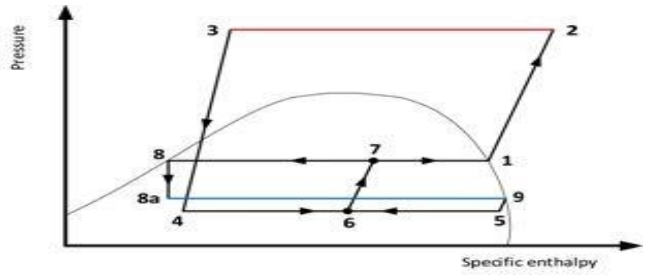


Fig 4: P-H Diagram

Advantages of standard ejector refrigeration cycle:

1) The expansion work recovered in the ejector is used to increase the suction pressure of the compressor thus reducing the work of the compressor.
2) Also the refrigerating effect obtained in ejector expansion refrigeration cycle is more as compared to the traditional VCR cycle.
3) Hence there is an overall increase in the COP of the system due to enhanced refrigerating effect and reduced compressor capacity.

Disadvantages of Standard ejector refrigeration cycle:

1) There is no means of recirculating excess liquid in the evaporator. Hence in case of high loads, the evaporator may dry out and the system may be inefficient.

*Liquid Recirculation cycle:*

In the standard ejector expansion refrigeration cycle, the ejector is used to increase the compressor suction pressure. However this is not the only way in which the work recovered by the ejector can be used in improving the cycle performance. In liquid recirculation cycle, the work recovered by the ejector is used to make excess liquid flow through the evaporator, resulting in overfeeding of the evaporator with the refrigerant. This refrigerant overfeed or liquid recirculation effect results in increased mass flux through the evaporator and avoids drying out of the evaporator in case of high loads, thus improving the evaporator performance. Hence the work recovered in the ejector can be used to improve the performance of the evaporator which indirectly reduces the load on the compressor. The improvement in the COP of the system depends on the amount of liquid refrigerant being recirculated. The amount of liquid refrigerant recirculated is can be determined by a term called circulation number. The circulation number is defined as the ratio of total mass flow rate of refrigerant in the evaporator to the mass of refrigerant vaporized.[1]

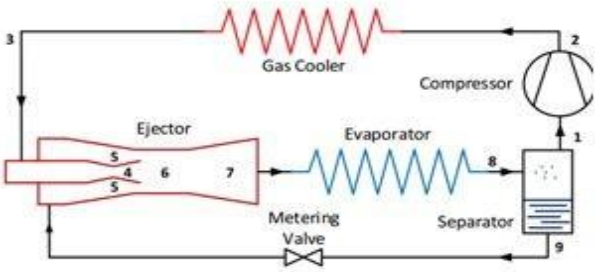


Fig 5: Liquid recirculation cycle schematic

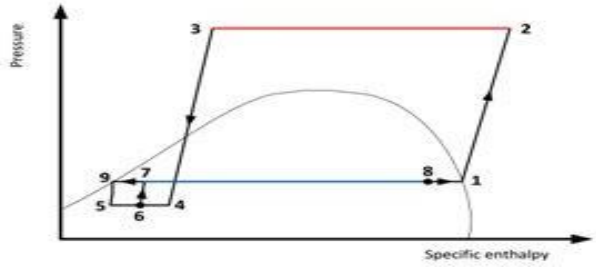


Fig 6: P-H Diagram

Advantages of Liquid Recirculation Cycle:

1) Drying out of Evaporator is avoided by continuous recirculation of liquid through the evaporator.
2) Compressor power required is less as mass flow rate of refrigerant flowing through the compressor is reduced.
3) Overall COP of system increases.

Disadvantages of Liquid Recirculation Cycle:

1) There is no rise in the suction pressure of the compressor despite the use of ejector. Hence compressor work is not reduced in this cycle.

*Condenser Outlet Split (COS) Ejector cycle:*

In the COS Ejector cycle, the high pressure liquid coming from the condenser is split into 2 streams. One stream of liquid flows into the primary nozzle of ejector as motive fluid. The second stream expands is enthalpically through an expansion device and passes through a low pressure evaporator to give the desired cooling effect. The low pressure vapour coming out of the low pressure evaporator acts as the secondary fluid of the ejector and mixes with the primary liquid in the mixing chamber. The mixed flow coming out of the ejector passes through a high pressure evaporator to give further cooling effect. The vapour coming out of the high pressure evaporator is then sent to the compressor and the cycle is repeated. Thus COS Ejector cycle can be used in refrigeration applications requiring cooling at two different temperatures. However the difference between the temperatures of two evaporators and the ratio of their capacities depends on pressure lift in the ejector and the entrainment ratio of the ejector respectively. Hence poor design of ejector may lead to very low difference between the temperatures of the two evaporators which may not be suitable for the application.[1]

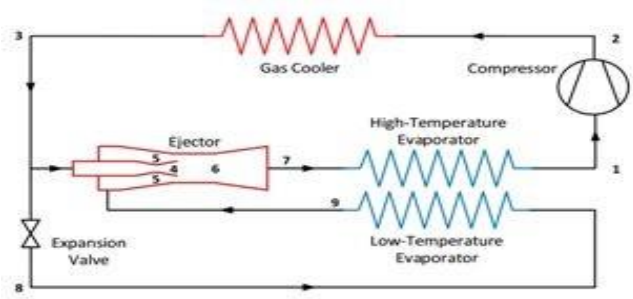


Fig 7: COS ejector cycle schematic

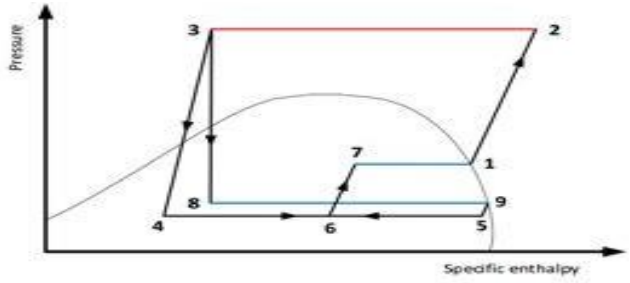


Fig 8: P-H Diagram

Advantages of COS cycle:

1) The COS cycle does not use a vapor liquid separator. This is an advantage as the large size and inefficient working of the separator may not be suitable for certain applications.
2) In a standard EER cycle if sufficient mass flow rate is not entrained due to poor design of ejector or low recovery of work, the system will be inefficient. However in a COS Ejector system, in case of low entrainment of mass flow by the ejector, the cycle will not lose capacity in both evaporators because all the mass flow (refrigerant) passes through the compressor.

Disadvantages of COS cycle:

1) Due to poor design of ejector the cycle may not be suitable for applications requiring two different evaporation temperatures, which is the main purpose of the cycle

## V. Conclusion

From the above discussion on various ejector expansion refrigeration cycles, it can be concluded that there is significant scope for the use of ejectors in refrigeration systems, replacing the traditional capillary or expansion device due to the above discussed advantages of the use of ejectors. Ejector refrigeration: A comprehensive review

## Acknowledgment

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