Evaluating Geometric Parameters of Ejector Expansion Refrigeration Cycle using R-1270 as Refrigerant

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Abstract— According to Internal Energy Agency (2012), the world energy demand will increase by 35 percent from 2010 to 2035, by taking care of three E'S (EARTH, ENVOIRNMENT and ECO FRIENDLY). This increase is associated with world population and pollution, economic and global growth especially in developing countries. The consumption of HVAC amounting up to 40% of the total electricity consumption. That is why it is very important to develop highly efficient HVAC products. Combination of Energy, Efficient and Eco Friendly HVAC product is key focus for HVAC industry, many highly energy efficient as well as ecofriendly products are developed, and still huge advancement are required. There are several ways to improve the performance of HVAC products either household or industrial, sometimes advancements and improvements requires high capital cost in order to maintain sustainability. One of the finest, simple and economic way to maintain all these aspects is the use of Ejector as an expansion device by replacing expansion or throttling valves. Complete cycle named as EJECTOR EXPANSION REFRIGERATION SYSTEM WITH LIQUID VAPOUR HEAT EXCHANGER inside the mixing chamber of Ejector (EERS), by using one Eco Friendly refrigerant Propylene (R1270). This paper provides the description of the geometric parameters of ejector cycle using R-1270 as a refrigerant.

Key words: Coefficient of Performance, R-1270, Vapor Compression Cycle, Ejector Expansion Refrigeration, Mixing Chamber

I. INTRODUCTION

Now a day's world suffers from electricity crisis. The demand for electricity in world has been growing at an average rate around 6% annually over the last years, since the early 2000s [1]. The electricity consumption in the field of refrigeration and air conditioning systems is about 23% of the total electricity consumption. In order to reduce this demand a high energy efficiency systems should be adopted. The most commonly used system in refrigeration and air conditioning industry is a vapor compression refrigeration system [4]. Ejector has been widely used in different cycles for refrigeration purposes, such as recovery of expansion work, utilization of low-grade energy (solar energy, geothermal energy and waste heat). Ejector expansion device is attractive and has great market potential, because it is simple to construct and provide robust operation without moving parts while still yielding significant performance improvements. Ejector expansion device has long service life and low maintenance cost.

II. SYSTEM DESCRIPTION AND ANALYSIS:

A. *Modified Ejector Expansion Refrigeration:*

The primary flow from the condenser passed through primary nozzle where it expands form P3-P4 and entrains the refrigerant vapor from the evaporator with a pressure drop from P8-P9. Mixing of both the phases of refrigerant takes place in a constant mixing chamber at constant pressure point 10. Cold mixed refrigerant at point 10 exchanges heat with the liquid coming out from the separator point 6, so that sub cooling takes place from 6-6' with temperature of 30C.

High pressure motive stream expands in the motive nozzle and entrains the low pressure super-heated suction stream in to the mixing section, then the two streams are mixed in the mixing section , and the mixed section flows through the diffuser and increasing its pressure along the way as shown in Fig 1 and 2 these pressurized mixed streams passed through a separator where vapor and liquid refrigerants are separated, the vapor refrigerant moves into compressor and liquid refrigerants moves into evaporator just like in simple VCR cycle [5].

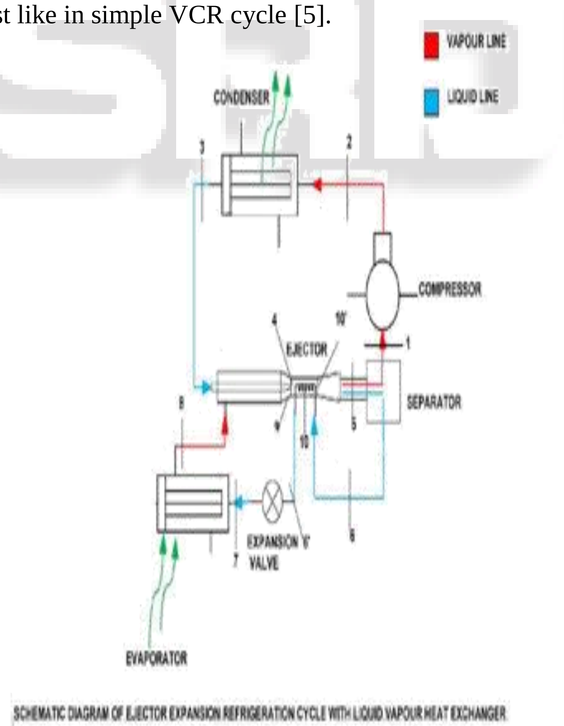

Fig. 1: Schematic Diagram of Ejector Expansion Cycle with Liquid Vapor Heat Exchanger

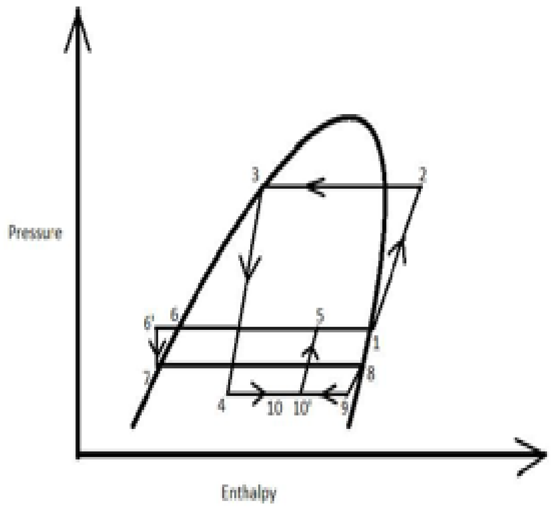

Fig. 2: P-h Curve of EERS with Heat Exchanger

III. Methodology to Calculate the Geometric Dimensions of Ejector

The details calculations of the ejector are detailed below. There are ten physical dimensions which are needed to be calculated. Before calculating it is very important to the basic geometry of ejector. Figure 3 represents the basic geometry of ejector.

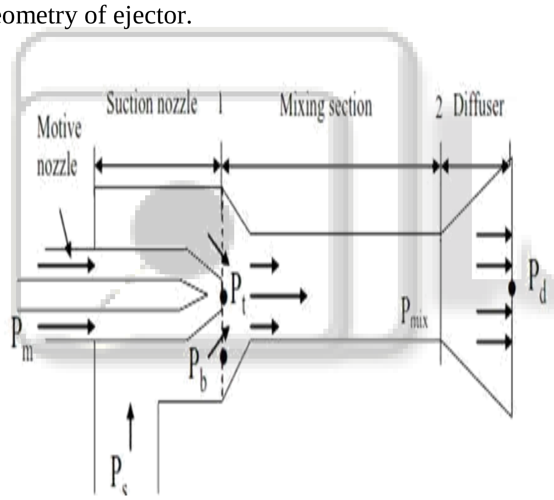

Fig. 3: Ejector

A. Following Are The Dimensions That Need To Be Calculated:

d3 Primary nozzle inlet diameter d4 Primary nozzle exit diameter
l' Convergent length of primary nozzle d9 Secondary nozzle exit diameter
d10 Mixing chamber diameter L Length of mixing chamber
dd Diffuser outlet Diameter l'' Length of Diffuser
θn Convergent Nozzle angle
ω Diffuser Divergent angle.

1) D3 Primary Nozzle Inlet Diameter:

System complete the cycle with the help of connecting pipes which joins the systems and subsystems. Tube diameter which join all the systems and subsystems which is of 6mm

2) D4 Primary Nozzle Exit Diameter:

$$\dot{m} = \rho A V$$

3) Convergent Length Of Primary Nozzle:

In practice, it is found convenient to express the pressure loss for all types of fully developed internal flows.

$$\Delta P_L = f \frac{l'}{d_{mean}} \frac{\rho V_{AVG}^2}{2}$$

4) d9 Secondary nozzle exit diameter:

$$\dot{m}_9 = \rho_9 a_9 V_9$$

5) D10 Mixing Chamber Diameter:

Although the values of cross sectional area of nozzle exits and mixing section depends on ejector design, for simplicity, one can take a10=a4+a9

6) Dd Diffuser Outlet Diameter:

The pressure recovery coefficient is used to determine the diffuser outlet diameter[2].

$$C_t = \frac{P_d - P_{mix}}{\frac{1}{2}\rho_{mix} V_{mix}^2}$$

Pd=Diffuser Pressure
Pmix=Mixing Pressure
ρmix= Mixing density
Vmix=Mixing Velocity

7) L Length Of Mixing Chamber:

The length of constant mixing chamber is 5-7 times of mixing chamber diameter and mix streams are always subsonic.

L is 10-20 times of d10, this principle is applicable when we designing any convergent divergent geometry like in case of venturimeter we also follow the same procedure.

8) L'' Length Of Diffuser:

$$\Delta P_L = f \frac{l'}{d_{mean}} \frac{\rho V_{10}^2}{2}$$

9) Θn Convergent Nozzle Angle:

By joining all the lengths diameters we easily come to know the convergent angle ,with the help of geometry as shown in Annexure 3;figure 3

θ_N comes out to $=10.2^0$

10) Ω Diffuser Divergent Angle:

Similarly we get ω by joining diameters and lengths.

ω comes out to $=6^0$

IV. Results

All the geometric parameters has been calculated by applying above numerical analogy, however concepts of fluids mechanics, nozzle and diffuser flow mechanism is also applied to solve the above equations. Followings are the results mentioned in table 1.

Primary nozzle inlet diameter	6 mm
Primary nozzle exit diameter	3.198 mm
Convergent length of primary nozzle	14.06 mm
Secondary nozzle exit diameter	19.79 mm
Mixing chamber diameter	20.05 mm
Diffuser outlet Diameter	34.13 mm
Length of Mixing Chamber	100.25 mm
Length of Diffuser	108.28 mm
Convergent Nozzle angle	10.2^0
Diffuser Divergent angle	6^0

Table .1

Based on the above dimensions the ejector obtains the geometry as shown in figure 4.

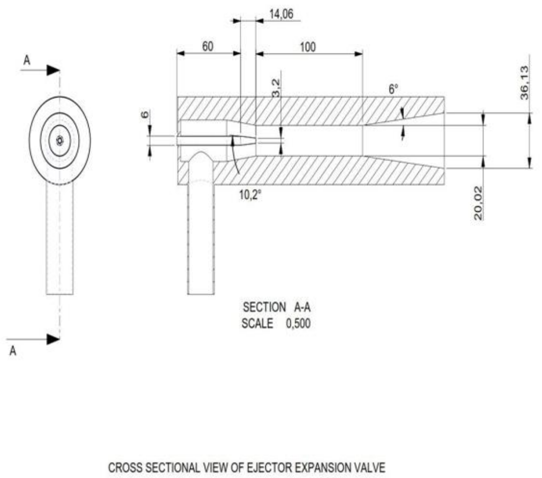

Fig. 4: cross sectional view of ejector expansion cycle

V. Conclusion

This paper provides you the complete geometry of Ejector cycle by applying the principle of conservation of mass and momentum equation. This paper is the continuation of the previous paper which explains the efficiency as comparison with conventional VCR cycle Proposed EERS is better than the conventional systems as it increases the refrigeration effect and reduces the compressor work at the same time.

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