DESIGN AND FABRICATION OF EJECTOR REFRIGERATION SYSTEM

Vivek Sharma, Munish Kumar, Shazli Al Haque

Chandigarh University,

Abstract

From a long, it has been seen that refrigerators are the machines working right around the year continuously; thus goal of vitality productivity change pulls in much. There are a few different methods of enhancing the execution of a VCR cycle. Using ejector as extension equipment is one of the elective method. This new approach of 'Ejector' into refrigeration framework opened the new scope of reasearch. The fundamental segment, which chooses the compelling activity of the ejector expansion refrigeration framework, is the ejector. Because of the association of no mechanical part in ejector makes it critical segment in change of COP and option for other throttling gadgets. The idea of ejector based refrigeration framework isn't new. There are numerous prior looked into done on this. The outline of ejector is done based on mass protection, force preservation and vitality preservation. Here the ejector is utilized is as a expansion gadget. Albeit narrow tube is likewise being utilized. In ejector two eliminate refrigerant happening to thought process spout and evaporator is blended in blending chamber and after that out of diffuser. We have utilized R-22. The measurement of ejector is appeared in result and discourse part. The blower is of 1.5 ton (15000 Btu) of Kirloskar demonstrate CR 22MK6 PFI. The evaporator and condenser is both air cooled type which is utilized here. Separator is utilized according to our necessity. Result demonstrates the COP of standard and ejector based refrigeration framework.

Keywords: *Refrigeration, throttling, Ejector*

Introduction

This venture depends on the change of traditional VCRS by making an use of EJECTOR as an extension equipment. The real preferred standpoint of utilizing an EJECTOR with a refrigeration framework is that it diminishes the outstanding burden of the blower by giving a high scope of weight to the refrigerant which diminishes the measure of mechanical vitality required by blower for packing the refrigerant and henceforth expands its effectiveness and in this manner enhances its coefficient of execution, i.e., COP. Likewise because of having no mechanical moving part in ejector, basic structure and low support prerequisite makes it all the more encouraging cycle change.

Hypothetically, the drop in pressure is considered as an isenthalpic procedure (i.e enthalpy remain constant). Be that as it may, isenthalpic process is the reason for decline in the limit of evaporator cooling because of vitality misfortune in the throttling procedure. To recoup this vitality misfortune, an ejector can be utilized to create isentropic condition in the throttling procedure and this cycle is known as ejector expansion refrigeration cycle (EERC). The refrigerant is at first compacted in a blower which expands its weight and thus temperature. This high pressurized refrigerant is then consolidated to free its vitality as warmth in a condenser. Here the EJECTOR becomes possibly the most important factor. An ejector is a two stage stream framework which is utilized for the blending of sub-cooled homogeneous fluid originating from the condenser with its vapor stage originating from the evaporator and the blending happens in a throat compose structure called blending chamber. As the speed of the refrigerant at the tip of the spout is at extraordinary which makes the weight zero, so it sucks the vapors from the evaporator chamber itself because of the impact of vacuum expansion. The vapors shaped in the evaporator area get dense in a small amount of ridiculously in contact with the sub-cooled fluid which results in the transformation of two stage stream into the single stage stream. As the temperature and the relative speed of the sub-cooled fluid and the vapor stream varies by a huge sum, it in this manner helps in the substantial measure of warmth exchange between them amid blending. The stream delivered by the blending of sub-cooled homogeneous fluid and the vapors with high temperature and speed is having the weight that is higher than the weight of both the gulf streams. This high weight of the stream created is accomplished toward the finish of the diffuser where the zone of the unique segment is most extreme. This high pressurized stream is then permitted to grow in an extension gadget which therefore diminishes its weight and temperature. A separator is additionally used to isolate the vaporous frame from the fluid and exchange the gas to the blower for preparing and the fluid stage to the evaporator which can vapourize it before it gets blended with the sub-cooled fluid originating from the condenser and the entire cycle proceeds over and over.

Saban Ünal and Tuncay Yilmaz [2] talked about the Air-molding blowers of the transports are typically worked with the power taken from the motor of the transports. Hence, a change noticeable all around molding framework will lessen the fuel utilization of the transports. The change in the coefficient of execution (COP) of the cooling framework can be given by utilizing the two-stage ejector as a expansion valve noticeable all around molding framework. In this investigation, the thermodynamic examination of transport cooling framework upgraded with a two-stage ejector and two evaporators is performed. Thermodynamic investigation is made accepting that the blending procedure in ejector happens at consistent cross-sectional zone and steady weight. The expansion rate in the COP as for ordinary framework is broke down as far as the sub cooling, condenser and evaporator temperatures. The investigation demonstrates that COP change of the framework by utilizing the two stage ejector as a expansion gadget is 15% relying upon outline parameters of the current transport cooling framework.

Kamil Smierciew, Dariusz Butrymowicz [4] examined the paper manages hypothetical and test examinations of the productivity improvement because of inward warmth move in discharge refrigeration framework. The consequences of hypothetical examination of the coefficient of execution (COP) change were introduced. Isobutane was utilized as a working liquid. The testing stand and the exploratory consequences of the examination of isobutane launch framework were available. COP of the discharge framework working with and without inner warmth exchanger for different levels of the thought process vapor superheating were looked at. The effectiveness of the tried inner warmth exchanger was fluctuated between 80% up to 100%. The outcomes demonstrated that the utilization of the inner warmth exchanger prompts the change of COP up to 20%.

The refrigerant is first compacted in a blower which builds its weight and temperature. This high pressurized refrigerant is then consolidated to free its vitality as warmth in a condenser where its weight stays same significance refrigerant is dense isothermally inside condenser. Presently the EJECTOR becomes possibly the most important factor. An ejector is a two stage fly framework as examined in before part of this paper which is utilized for the blending of sub-cooled homogeneous fluid originating from the condenser with its vapor stage originating from the evaporator and the blending happens in a throat compose structure called blending chamber. As the speed of the refrigerant at the tip of the spout is at extraordinary which makes the weight zero, so it sucks the vapors from the evaporator chamber itself because of the impact of vacuum arrangement. As the temperature and the relative speed of the sub-cooled fluid and the vapor stream varies by a substantial sum, it in this manner helps in the expansive measure of warmth exchange between them amid blending. The stream delivered by the blending of sub-cooled homogeneous fluid and the vapors with high temperature and speed is having the weight that is higher than the weight of both the delta streams. This high weight of the stream delivered is accomplished toward the finish of the diffuser where the territory of the different area is greatest. This high pressurized stream is then permitted to grow in an extension gadget which accordingly lessens its weight and temperature. A separator is additionally used to isolate the vaporous shape from the fluid and exchange the gas to the blower for preparing and the fluid stage to the evaporator which can vapourize it before it gets blended with the sub-cooled fluid originating from the condenser and the entire cycle proceeds into two section.

Figure 4.2 below shows the refrigerant stream, weight and speed profile inside the ejector. Figure 4.3 demonstrates a Ph outline The throttling happens from direct number 3 toward 11, while the isentropic throttling happens from guide 3 toward 4. There are two streams in the EERC: essential stream and auxiliary stream. The essential stream is circled by a blower through the condenser, ejector and separator i.e. point 1, 2, 3, 4, 10, 5 and 1, while the auxiliary stream courses in the extension valve, evaporator, ejector and separator i.e. point 6, 7, 8, 9, 10, 5 and 6. The essential and auxiliary streams blend at the consistent region and diffuser i.e. point 10 and 5. The sudden change in weight and speed of the refrigerant from direct 9 toward 10 is ascribed to ordinary stun, incited downstream of the consistent region blending area. This stun causes a pressure impact and in this manner causes a sudden drop in the refrigerant stream velocity. As appeared in Figure 4.3, the pressure at initial point is higher than drop in pressure in the standard cycle shown by number 8 in diagram. This implies blower work of the the standard cycle is more than that of ejector extension cycle.

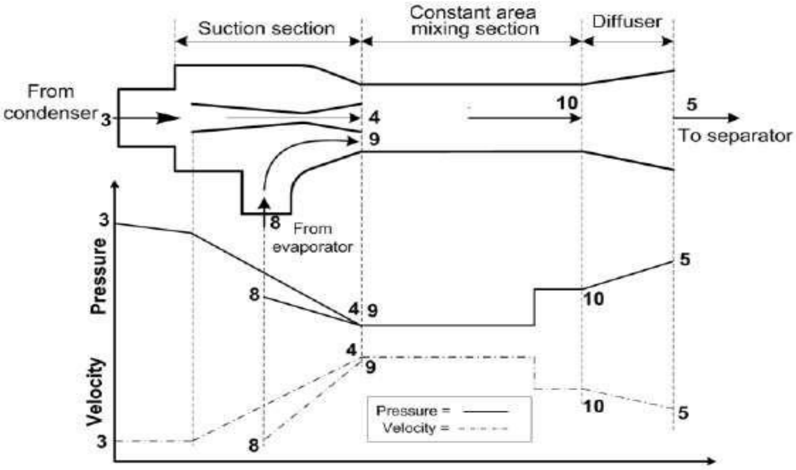

Fig 4. 2: Velocity and pressure profiles for an ejector

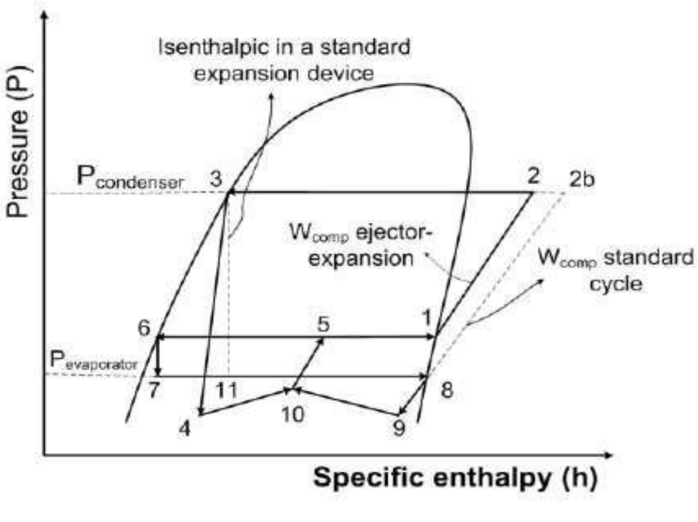

Fig 4. 3: Pressure -Enthalpy diagram of Standard cycle and EERS

Convergent- Divergent Section

* We realize that in merged segment stream is quickened and decelerated in dissimilar area (in subsonic stream) from well known Bernoulli condition (for incompressible, inviscid stream) –

* So in merged segment liquid speed is increments and static weight (p) diminishes and inverse occurs in dissimilar area i.e. static weight (p) increments. The convergent section has negative pressure gradient and divergent section has positive pressure gradient.

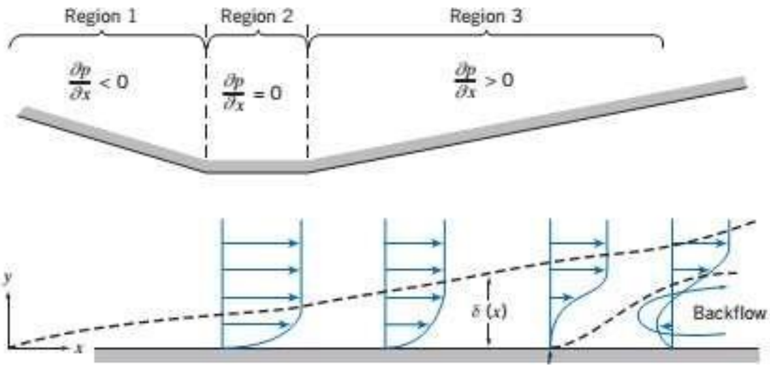

Fig 4. 4: Change in Pressure with respect to angle.

We can see in figure that if pressure gradient (dP/dx) is high, we will see that fluid particles will start to separate from the solid walls and flow in reverse direction.

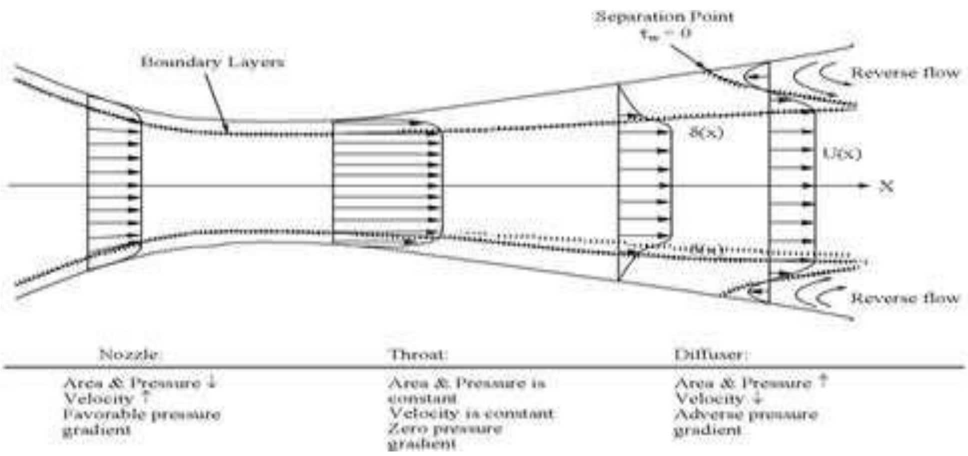

Fig 4. 5: Velocity Profile

This turn around stream prompts make precarious stream and devours vitality. So to lessen invert stream, weight inclination is kept little by altering different point. For expansive different edge, both weight inclination and detachment would be vast.

So it for the most part lies between 5 to 7 deg.

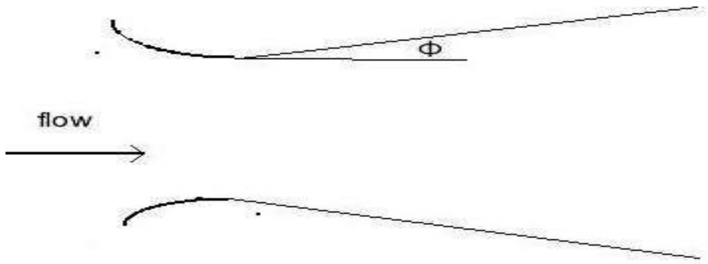

Fig 4. 6: angle of venture.

In the event that the edge is more prominent than that, the weight increments too rapidly and the unfriendly weight angle will cause stream division along the dividers. By keeping the point little, the stream stays connected and carries on pleasantly.

4.2 System Description and Analysis

The ejector expansion vapor pressure refrigeration cycle has been demonstrated dependent on the mass, force, and vitality preservations. To streamline the hypothetical model and set up the conditions per unit mass stream rate at the ejector leave, the accompanying suspicions have been made.

- Ignore the weight drop in the condenser, evaporator, separator, and the association tubes.
- No warm exchanges with nature for the framework aside from in the condenser.
- Both the thought process stream and the suction stream achieve a similar weight at the bay of the consistent weight blending segment of the ejector.
- Kinetic energies of the refrigerant at the ejector gulf i.e. spout bays and outlet i.e. diffuser outlet are irrelevant.

A. Motive Nozzle

Fig. 4.4 shows a schematic diagram of a constant area ejector. By using the definition of motive nozzle's isentropic efficiency the specific enthalpy of the primary fluid at the nozzle exit is given by the following expression:

$$h_4 = h_3(1-\eta_n) + \eta_n . h_{4,} \quad (1)$$

where, h_4, is the corresponding enthalpy at the end of the isentropic expansion process of the motive stream and η_n is the isentropic efficiency of the motive nozzle. Using the energy equation for motive nozzle, the speed at the nozzle exit can be found as:

$$u_4 = [2(h_3 - h_4)]^{0.5} \quad (2)$$

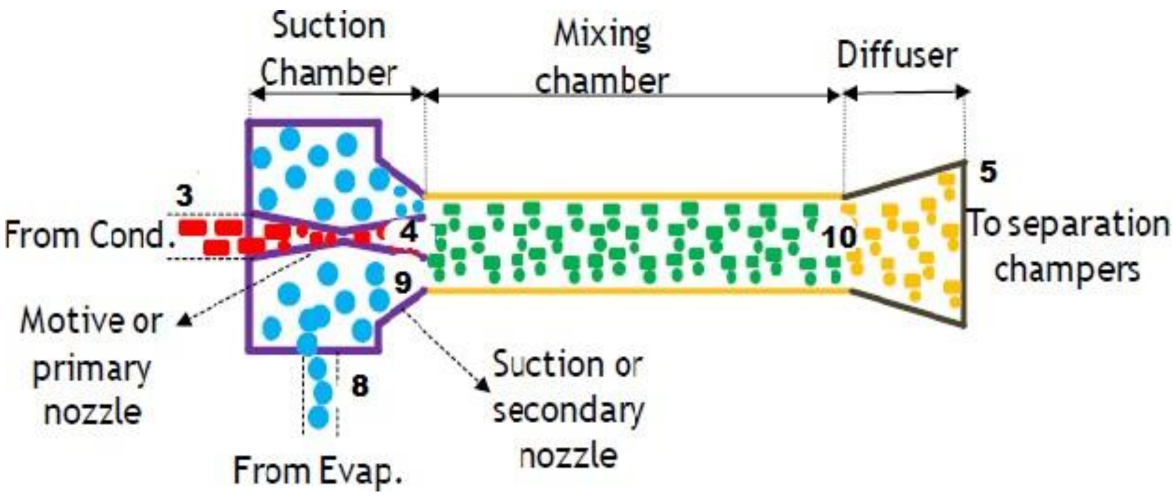

Fig 4. 7: Schematic diagram of flow inside ejector.

B. Suction Nozzle

Similar to the motive nozzle analysis made above, the following equations can be derived;

$$h_9 = h_8(1 - \eta_s) + \eta_s h_{9,is} \quad (3)$$

$$u_9 = [2(h_8 - h_4)]^{0.5} \quad (4)$$

where h_9 is the corresponding enthalpy at the end of the isentropic expansion process of the suction stream and η_n is the isentropic efficiency of the suction nozzle.

C. Constant Area Mixing Chamber

In a constant mixing chamber according to conservation of momentum, the mixed stream speed at the exit of mixing chamber is calculated from the relation given below:

$$u_{10} = (a_4 \quad + a_9) + \frac{1}{1+\omega} u_4 + \frac{\omega}{1+\omega} u_9 - p_{10} a_{10} \quad (5)$$

Using conservation of energy, the enthalpy of the mixed stream at the exit of mixing chamber can be found from:

$$h_{10} = \frac{1}{1+\omega}(h_3 + \omega h_8) - \frac{{u_{10}}^2}{2} \quad (6)$$

For unit flow rate of ejector at the exit of a constant area mixing chamber,

$$\frac{a_{10}u_{10}}{v_{10}} \quad (7)$$

D. Diffuser

The enthalpy of the stream at the diffuser exit

$$h_5 = \frac{h_3+\omega h_8}{1+\omega} \quad (8)$$

The isentropic enthalpy from the diffuser at the exit is given as:

$$hde = (h5 - h10) + h10 \quad (9)$$

where η_d is the isentropic efficiency of the diffuser.

4.3 Performance of Ejector Refrigeration System

COP of the standard refrigeration cycle is calculated as,

$$COP_{std} = \frac{(h_8 - h_{11})}{(h_{2b} - h_8)} \cdot \eta_{comp} \quad (12)$$

Since $\dot{m}_{comp} = \dot{m}_e$

where η_{comp} is the isentropic efficiency of the compressor, which is calculated by an empirical relation in Brunin, *et al[23]*.

$$= 0.874 - 0.01345\frac{P_{disc}}{P_{suct}} \quad (13)$$

COP of ERS cycle is calculated as,

$$COP_{ej} = \frac{Q_e}{W_{comp}} \cdot \eta_{comp} = \frac{\dot{m}_{comp}}{\dot{m}_e} \cdot \frac{(h_8 - h_7)}{(h_2 - h_1)} \cdot \eta_{comp}$$

$$or$$

$$= \frac{Q_{absorb}}{Q_{absorb} - Q_{rejected}} \quad (14)$$

The EERC is characterized using two parameters, the entrainment ratio (ω) and pressure lifting ratio (*Plift*). The definitions of the two parameters are:

$$\omega = \frac{\dot{m}_{comp}}{\dot{m}_e} \quad (15)$$

Both quantities should be as high as possible to obtain optimum COP. A high ejector pressure lifting ratio decreases the compression ratio of the compressor. Increasing the mass entrainment ratio will reduce the compressor mass flow rate for a given cooling capacity.

RESULT AND DISCUSSION

Vapor pressure refrigeration framework yield coefficient of execution 1.534. For the given evaporator channel and outlet temperatures are 1.1 K and 26 K and for the condenser the delta and outlet temperatures are 50 K and 39 K.

Utilizing ejector as a expansion gadget in ejector based refrigeration framework yield coefficient of execution 2.231. For the given evaporator delta and outlet temperatures are 1.1 K and 26 K and for the condenser the bay and outlet temperatures are 52 K and 39 K. Stimulation proportion assumes critical job in COP of ejector refrigeration framework. The ejector involves two sections a rationale or essential spout and optional spout/suction spout. The distance across of intention spout is 3mm. The blending chamber is of distance across 9mm which is same as auxiliary spout throat breadth. The joining and wandering edge is 45 degrees and 10 degrees individually. With increment in blending temperature, diversion proportion increments and COP increments however after a specific ideal temperature the it begins to diminish as stimulation proportion diminishes.

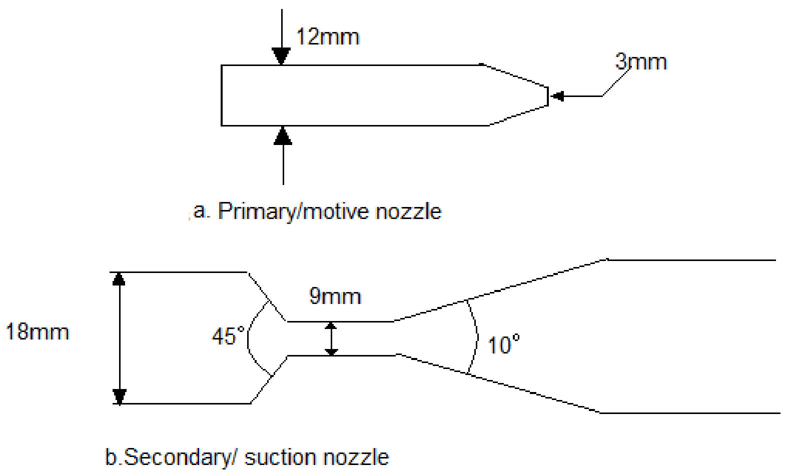

Fig 5: 1 dimension of ejector

REFERENCE

[1] Analysis of application of two-phase injector in ejector refrigeration systems for isobutene by *Kamil _Smierciew , Dariusz Butrymowicz , Roman Kwidzi_nski , Tomasz Przybyli_nski, 2014.*

[2] Thermodynamic analysis of the two-phase ejector air-conditioning system for buses, S¸ aban Ünal , Tuncay Yilmaz, *79 (2015) 108-116.*

[3] Thermodynamic design and simulation of a CO2 based transcritical vapour compression refrigeration system with an ejector, *Md. Ezaz Ahammed, Souvik Bhattacharyya**, *M. Ramgopal, 4 5 (2 0 1 4) 1 7 7-1 8 8.*

[4] Investigation of internal heat transfer in ejection refrigeration systems, *Dariusz Butrymowicz**, *Kamil _Smierciew, Jarosław Karwacki, 40(2014)131-139.*

[5] Performance estimation of ejector cycles using heavier hydrocarbon refrigerants, *Jacek Kasperski**, *Bartosz Gil,*

71(2014) 197-203.

[6] Experimental results with a variable geometry ejector using R600a as working fluid, *Paulo R. Pereira, Szabolcs Varga*, Jo~ao Soares, Armando C. Oliveira, Ant_onio M. Lopes, Fernando G. de Almeida, Jo~ao F. Carneiro, 46(2014)77-85.*

[7] Thermodynamic analysis of an ejector-flash tank-absorption cooling System, *Ranj Sirwan a,**, M.A. Alghoul b,*, K. Sopian b, Yusoff Ali, 58(2013)85-97.*

[8] Elbel, S. & Hrnjak, P., *Experimental Validation of A Prototype Ejector Designed to Reduce Throttling Losses Encountered in Transcritical R744 System Operation*, International Journal of Refrigeration, **31**(3), pp. 411-422, 2008.

[9] Kemper, G.A., Harper, G.F. & Brown, G.A., *Multiple Phase Ejector Refrigeration System*, US Patent Patent No.3, 277, 660, 1966.

[10] Kornhauser, A.A., *The Use of An Ejector As A Refrigerant Expander*, In: Proceeding of the USN/IIR-Purdue Refrigeration Conference, West Lafayette, IN, USA, pp. 10-19, 1990.

[11] Bilir, N. & Ersoy, H.K., *Performance Improvement of The Vapour Compression Refrigeration Cycle by A Two-Phase Constant-Area Ejector*, International Journal of Energy Research, **33**(5), pp. 469-480,2009.

[12] Sarkar, J., *Geometric Parameter Optimization of Ejector-Expansion Refrigeration Cycle with Natural Refrigerants*, International Journal of Energy Research, **34**(1), pp. 84- 94, 2010.

[13] Nehdi, E., Kairouani, L. & Bouzaina, M, *Performance Analysis of The Vapour Compression Cycle Using Ejector as An Expander*, International Journal of Energy Research, **31**(4), pp. 364-375, 2007.

[14] Gourav Patel*, Dr. Sharad Chaudhary, Performance comparison ejector expansion refrigeration cycle using R-170, 2250-3153, 2014.

*[15] Sumeru, K., Ani, F.N. & Nasution, H., A Review on Two-Phase Ejector as An Expansion Device in Vapor Compression Refrigeration Cycle, Renewable and Sustanaible Energy Reviews, **16**(7), pp. 4927-4937, 2012.*

[16] Ananthanarayanan, P.N., *Basic Refrigeration and Air Conditioning*, Third edition, McGraw-Hill Publishing Company Limited.

[17] A text book of Fluid Mechanics and hydraulic Machines by Dr. RK Bansal, Laxmi publication Pvt. Ltd.

[18] A text book of Refrigeration and Air conditioning , Er. RK Rajput ,SK Khataria & sons publication.