Experimental Investigation To Develop The Refrigeration System With Two Phases Condensing Ejector Along With Energy Saving

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Abstract— *This experimental model presents a method of reduce energy consumption and enhance the refrigerating effect. With the help of two phases condensing ejector it is found that ejector work as sub compressor in refrigeration flow cycle. That helps to reduce compressor load effectively and hence improve refrigerating effect. The new cycle includes a second step compression by an ejector device, the compressor compresses the vapour to approximately 4/5 of the final pressure and additional compression (i.e. 1/5 of final pressure) is provided in an ejector, the thermodynamic model has developed for R134 and R22 refrigerant showing a possible efficiency improvement as compared to the traditional vapour compression cycle. The investigation of a new cycle for vapour compression refrigeration with using a novel device for non-mechanical compression of refrigerants is called a condensing ejector has carried out within this project. This novel device is a hybrid of simple vapour compression refrigeration system [SVCRS] and ejector refrigeration system [ERS] is more attractive than traditional refrigeration system because of higher coefficient of performance [COP].That leads the energy saving for same amount of cooling.*

Keywords— Reciprocating Compressor, Two Phase Ejector, Condenser, Refrigerant Separator, Capillary, Drier, Evaporator, Pressure Gauge, Thermostat, Thermocouple and Refrigerant.

I. INTRODUCTION

Vapour compression cycles are used in refrigeration, space cooling and space heating applications. Typical vapour compression cycles involve compressing and decompressing a refrigerant in a closed loop system and circulating the refrigerant through an evaporator and a condenser. The refrigerant serves to absorb thermal energy in the form of heat from the evaporator and transport the thermal energy to the condenser where it can be released. 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 vapour phase. The absorption of heat provides useful cooling of the space. The vapour is subsequently compressed in a compressor. Energy is consumed by the compressor during the compression of the vapour. Compression of the vapour facilitates condensation of the vapour into a liquid. Condensation of the vapour is caused by flowing the compressed vapour 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 and capillary tube 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. The investigation of a new cycle for vapor compression refrigeration with using a novel device for non - mechanical compression of refrigerants, called a “condensing ejector” was carried out within this project. The condensing ejector is a two-phase jet device in which a sub-cooled homogeneous working medium in a liquid state is mixed with its vapor phase, producing a liquid stream with a pressure that is higher than the pressure of either of the two inlet streams. The mixing takes place first in a convergent section and then in a constant area section of the ejector device. There is a large temperature difference and a high relative velocity between both streams, which results in a high rate of a heat and momentum transfer. The vapor phase is quickly condensed onto the liquid stream, producing rapid transformation from two-phase into single-phase flow with a resulting rise in pressure, called “a condensation shock.” While a theoretical basis for the condensing ejector principle has been reasonably established in the past, only two practical applications have been reported—for underwater propulsion and liquid metal MHD power generation (Miguel et al., 1964) .The first theoretical principles of the ejector as reported by Bohdal et al. (2003) in his state-of-the art presentation were elaborated by Parsons (1911) while the first prototype was built by Leblanc (1910) . Further improvements were introduced by Gay (1931). Ejectors were first applied for refrigeration cycles by Heller (1955) for absorption systems and by Badylkes (1958) for vapor compression systems. In the USA, the first application was reported by Kemper (1966), but only the patent is in existence while no experimental or theoretical background has been published. Following up on this early work, a theoretical analysis was conducted, showing the potential efficiency improvement of 21% when compared with a standard vapor compression cycle (Kornhauser, 1990). The prototype unit was built, however its performance was much less than ideal and reached a maximum of only 5% improvement using working fluids CFCs/

HCFCs/ HFCs. In all applications listed above, the ejector is designed as a classic Venturi nozzle, which means that the outlet cross-section of a motive nozzle must be smaller than the cross section of the mixing chamber. The outlet pressure in Venturi nozzles is the intermediate between pressures of the working and transporting medias. The advantage of using the ejector is to raise the pressure of delivered compressed vapor by the primary compressor resulting in reduced compressor work , and increased cycle efficiency. In general, only a few instances of practical use of the ejectors in refrigeration cycles were found. So it is required to develop a simple, lighter, and economical two phase ejector refrigeration system so that is it could be used in regular practice and ultimately save the energy for the same amount of cooling because high efficient performance of the system.

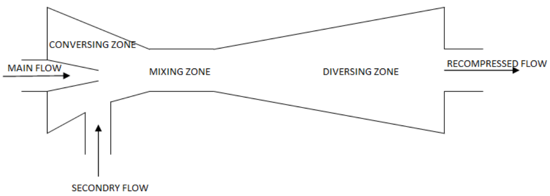
TWO PHASE CONDENSING EJECTOR

The condensing ejector is a two-phase jet device in which a sub-cooled homogeneous working medium in a liquid state is mixed with its vapor phase, producing a liquid stream with a pressure that is higher than the pressure of either of the two inlet streams. A two-phase flow ejector consists of four sub-models: motive nozzle flow, suction nozzle flow, mixing section flow and diffuser flow models. The mixing takes place first in a convergent section and then in a constant area section of the ejector device. There is a large temperature difference and a high relative velocity between both streams, which results in a high rate of a heat and momentum transfer. The vapor phase is quickly condensed into the liquid stream, producing rapid transformation from two phases into single phase flow with a resulting rise in pressure, called “a condensation shock”. While the mixed stream flows through the diffuser, the static pressure of the flow rises as the kinetic energy is converted to static pressure. The advantage of using the ejector is to raise the pressure of delivered compressed vapor by the primary compressor resulting in reduced compressor work.

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.

Fig.1 Illustrates the pressure variation along the ejector.



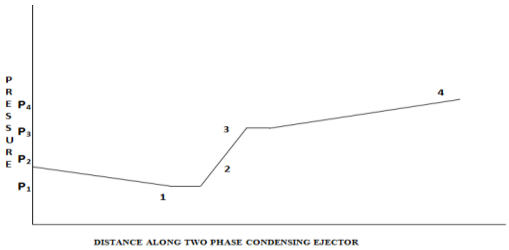


Fig 2,3: pressure variation along the condensing ejector

II. REFRIGRATION CYCLE WITH TWO PHASE CONDENSING EJECTOR

Working principle of two phase ejector has been discussed in above presented diagrams as well as assumptions. Now here explain the principle under working refrigeration cycle which is represented in block diagram a shown below Fig. Refrigerant vapour enters the compressor and mechanically compressed up to 4/5 of final pressure and further remaining compressed by two phase ejector i.e. 1/5 of the final pressure. This additional non-mechanical work done by ejector significantly save power. System details as:-

1-main piping connection, 1-2 evaporator, 3-compressor, 4-two phase condensing ejector, 5-condensor, 6-refrigerant separator, 7-8 capillary tube, 9-drier filter, 10-secondary flow into the two phase ejector, 11-heat absorbed from the refrigerated space by refrigerant,12-heat delivered to the atmosphere from the refrigerant by the condenser.

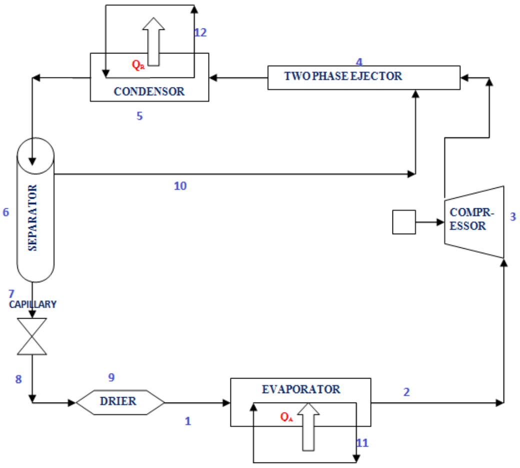


FIG.4 SCHEMATIC OF THE REFRIGERATION SYSTEM WITH THE CONDENSING EJECTOR AS A SECOND-STAGE COMPRESSOR

III. PRESSURE ENTHALPY DIAGRAM FOR TWO PHASE EJECTOR REFRIGRATION SYSTEM

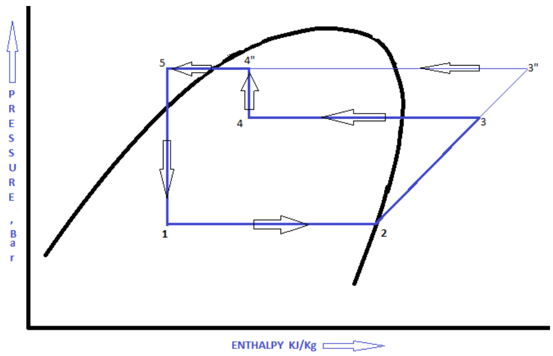


FIG.5 COMPARISON OF P-H DIAGRAMS OF THE NEW REFRIGERATION CYCLE WITH A TWO-PHASE EJECTOR AND TRADITIONAL CYCLE

Diagram show thermodynamic states of refrigerant which flow under the two phase condensing ejector system as well shown comparison between traditional cycle and new develop cycle along with saving energy. Cycle 1-2-3-4-4”-5-1 represents novel two phase ejector refrigeration system and Cycle 1-2-3-3”-4”-5-1 represents traditional refrigeration system. Here from the P-H diagram it is clear that new cycle save the energy for the same amount of refrigerating effect produce. Part of diagram 3-3”-4”-4-3 represent amount of work save by the two phase condensing ejector and hence improve COP of refrigeration system.

IV. LAVORATOTRY EXPERIMETAL SETUP

This setup has been fabricated in the Heat-Engine laboratory at BIT, SINDRI. This is possible as study of the basic schematic diagram shown above Fig.4 and with observing basic principles of design and assembly of refrigeration systems. Its overall view is shown in Fig.6.The laboratory experiments were then carried out with two main objectives: the first being to investigate the possibility of the pressure jump on the ejector and the second to determine the energy savings for the cycle with the ejector vs. traditional cycle with single step compression.

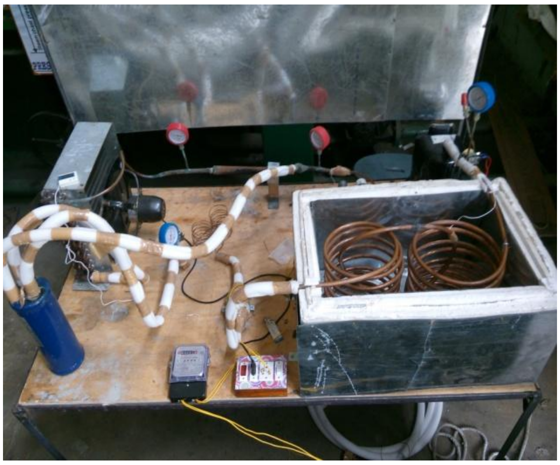


FIG.6

V. CALCULATION AND RESULTS OF LABORATORY EXPERIMENT

Data obtained from experiment with working fluid as R-134a (Refrigerant) and some needed data evaluated by properties table &P-H diagram of R-134a as:-

- Inlet condition of compressor Pressure = 0.6 bar, Temperature = -2 °C, Enthalpy (h1) =395 KJ/kg
- Outlet condition of compressor Pressure =10 bar, Temperature = 55 °C, Enthalpy (h2) = 431 KJ/kg
- Raised pressure after two phase ejector = 11.3 bar
- Outlet condition of condenser Pressure = 11.28 bar, Temperature = 43 °C, Enthalpy (h3) = 262 KJ/kg
- Inlet condition of evaporator We know Enthalpy (h4) = Enthalpy (h3) = 262 KJ/kg

(a) Coefficient of performance of two phase refrigeration cycle with two phase ejector

$$COP = \frac{\text{useful cooling}}{\text{useful work}}$$

$$COP = \frac{h1-h4}{h2-h1} = \frac{395-262}{431-395} = \mathbf{3.69}$$

(b) Coefficient of performance of two phase refrigeration cycle without two phase ejector

We know that if two phase ejector not placed here then total work in compression is done by main compressor, then at pressure 11.28 bar and temperature 55°C enthalpy (h_2) be 438KJ/kg

$$COP = \frac{\text{useful cooling}}{\text{useful work}}$$

$$\text{COP} = \frac{h1-h4}{h2-h1} = \frac{395-262}{438-395} = \mathbf{3.09}$$

Percentage increment of COP of novel cycle with respect to tradition cycle is about 19%

VI. CONCLUSION

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 19% 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.

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