

Experimental study of ejectors at chest freezer installation to increase the COP and reduce electricity consumption

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Abstract. This paper shows the results of experiments comparing basic refrigeration system (BRS) with ejector dual-evaporator refrigeration system (EDRS) in a chest freezer. Chest freezers using capillary pipes are modified using an ejector and divide the evaporator into two parts, the primary evaporator and the secondary evaporator. Experimental data is obtained using data logger and laptop. The results are processed using the EES (engineering Equation Solver) program. The results of the EDRS experiment showed a reduced power consumption of 23 percent, the increase of EDRS COP (coefficient of Performance) by 21 percent. But the final result is less satisfactory EDRS at a box temperature never reaches a temperature below zero degrees.

1. Introduction

The current refrigeration system provides a great influence on improving the quality of human life. Worldwide human dependence on refrigeration systems from year to year continues to increase, ranging from small scale (e.g. refrigerator) to storing kitchen materials that we often meet in almost every home and restaurant, from small scale to large scale such as in the marine processing industries and fruit and vegetable industries. Even the means of transportation has also been a long time to use the refrigeration system to keep the quality of the transported material.

Freezers use Vapor compression cycle technology that works using vapor compression cycles and uses capillary pipes as expansion valves. Existing theories on the installation of expansion valves (capillary pipes, TXV valves, etc.) in the cooling system are expansion valves that function to regulate refrigerant mass flow and reduce the pressure from condenser pressure to Evaporator pressure Occurs under the condition of the constant enthalpy process.

One of disadvantage of thermodynamics of vapour compression cycles is the process of isenthalpic expansion occurring in the expansion valve. While the isenthalpic process will reduce cooling capacity in the Evaporator due to the loss of energy in the process of throttling in the expansion process. Capillary pipes are also known to have weaknesses due to the friction flow of refrigerant along the pipe walls as well as changes in velocity along the capillary pipeline will cause considerable energy losses. To overcome such energy loss isentropic process is required. Ejector can be used to generate a constant entropy in the throttling process. The concept of using a two-phase ejector to reduce losses from the throttling process in the cooling system was first offered by Gay N H [1].

Some researchers who have tried the proper Ejector device on the cooling system also stated the upgrade of the COP from such systems: air conditioning systems and modified heat pump applications



with Single-phase Ejector resulted in an increase of COP between 7% to 9% [2]. In addition, the two-phase Ejector flow has no moving parts, low cost, simple construction, and low maintenance requirements that make modifications to the system very promising [3].

Chunnanond K *et al.* called the cooling system, the use of a two-phase flow ejector as an expansion tool, called Ejector Expansion Refrigeration System (EERS) [4]. Using a two-phase flow ejector, not a conventional expansion device is one of the efficient techniques for enhancing system performance not only by restoring the loss of the expansion process by producing an isentropic expansion process but Also by increasing the system cooling capacity and reducing the compressor power [5].

While the category of two-phase flow becomes two types based on the position of pattern nozzle; A constant pressure ejector and a constant area ejector [6]. Ejector, which is grouped into constant pressure ejector, is an ejector with a nozzle motif that exits the aircraft located in suction Nozzle prior to the ejector constant area where as ejector the outlet field of the airplane out nozzles motifs in Ejector area constant is categorized as a constant area projection that is retrieved from the report [7]. At the same operating temperature using a constant area of the COP and EER ejectors are higher than the system using the constant pressure Ejector as reported [8]. Bilir and Ersoy also reported theoretical studies using R134A [9]. In off-Design conditions, the system indicates a higher COP value than the conventional system and by using the constant COP the Ejector area can be increased by 22.3% depending on the operating conditions.

2. Experimental setup

This project the researchers tried to modify the chest freezer by adding an ejector and dividing the evaporator into two parts, the primary evaporator and the secondary evaporator. Performance of the existing chest freezer will be compared with the modified results. The results of this modification are expected to get better performance. Existing chest freezer installation as in Figure 1.

In this system refrigerant that has absorbed the heat of the evaporator changed the form of low-pressure fluid to vapor and low pressure. By the refrigerant vapor compressor is compressed so that high pressure with relatively high temperature. In the condenser occurs the process of drainage of the heat into the open air, so that a gas-tangible refrigerant, transformed into a high-pressure liquid. By the expansion valve, a high-pressure refrigerant is expanded into a low-pressure refrigerant in the expansion valve to facilitate heat-absorbing refrigerant in the evaporator. In the evaporator re-refrigerant absorbs heat and transforms into a high temperature gas. Thus, the process lasts continuously.

Installation refrigeration system of vapour compression with the ejectors on is like done is like Figure 2. The addition of the system is an ejector and liquid-vapor separator, which serves to separate the liquid and gas refrigerant. Liquid intangibles will go directly to the compressor, while the liquid will go to the evaporator.

While the modification we did is remove the liquid-vapor separator and divide the evaporator into two parts, namely, primary evaporator and secondary evaporator. The primary Evaporator receives a refrigerant that exits directly from the ejector, while the secondary Evaporator receives the refrigerant from the expansion valve and outputs it towards the secondary input of the ejector.

With the installation as in Figure 3. It is expected that the refrigerant effect will be more maximized than the ejector system in Figure 2. While the effect of decline in electricity consumption we will still get. The ejector created is like Figure 4. Ejector made of brass.

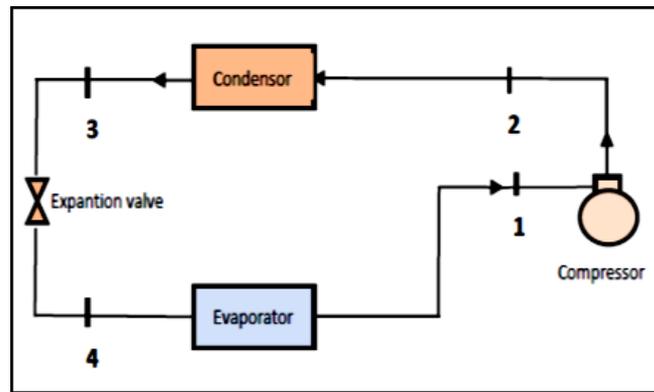


Figure 1. Schematic diagram of the existing steam compression refrigeration system.

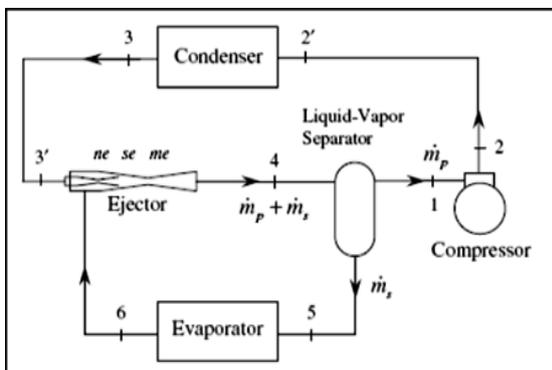


Figure 2. Schematic diagram of steam compression refrigeration system with ejectors [10].

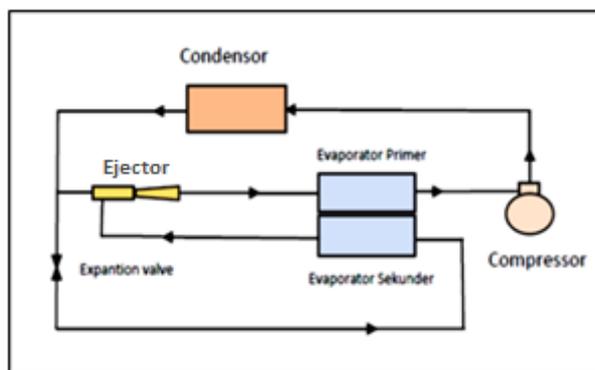


Figure 3. Schematic diagram of ejector dual-evaporator refrigeration system.

The schematic Diagram of the two-phase ejector as shown in Figure 4, is designed in three main parts: Nozzle motif, suction chamber, and mixing chamber with Diffuser. Nozzles's throat Area is designed according to the model Henry and Fauske [11]. The dimension of the ejector included the length of each section and different convergence and angles, based on recommendations from the ASHRAE Handbook [12] and from Nakagawa and Takeuchi [13]. Brass is used as an ingredient for Ejector. Three main parts of the ejector are connected using threads. Three o rings, as shown in Figure 4, are used to prevent refrigerant leakage.

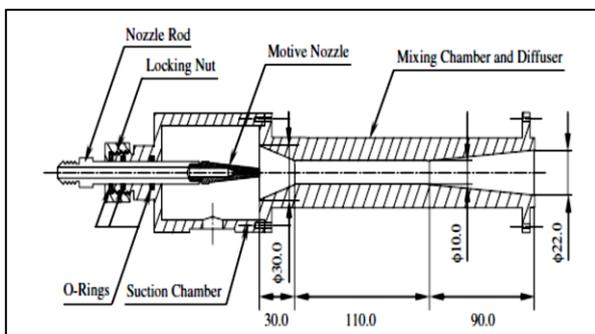


Figure 4. Schematics of the ejector diagram [10]



Figure 5. Assembly of the ejector made

3. Results and discussion

In this paper, the results of experiments that perform from Basic Refrigeration System (BRS) compared with the BRS modification performance to the dual-evaporator system ejectors. Data is collected using data acquisition and stored in the laptop. The results were later processed using the EES program (equation Engineering Solver). The scheme and P-H diagram of the BRS illustrated in Figure 6. While the two-evaporator refrigeration system (EDRS) ejectors are illustrated in Figure 7.

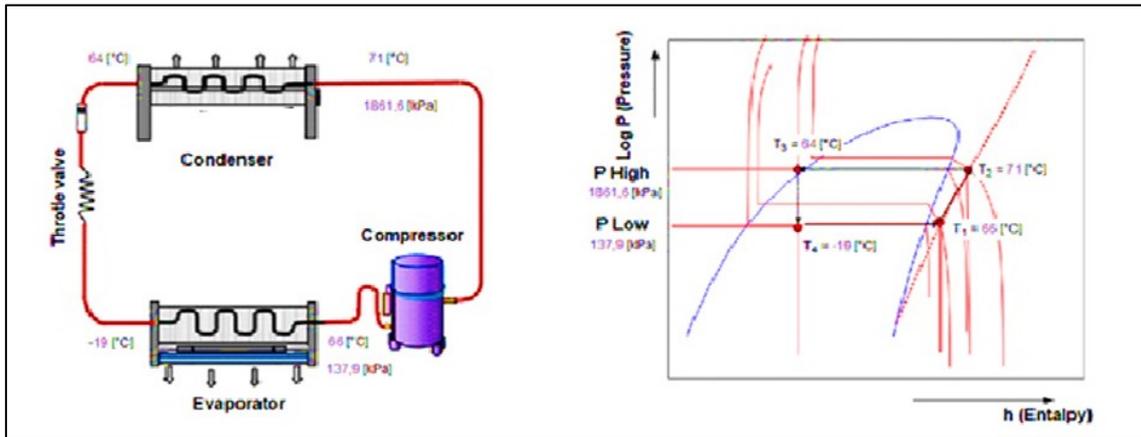


Figure 6. Schematic and P-h diagram of BRS from EES.

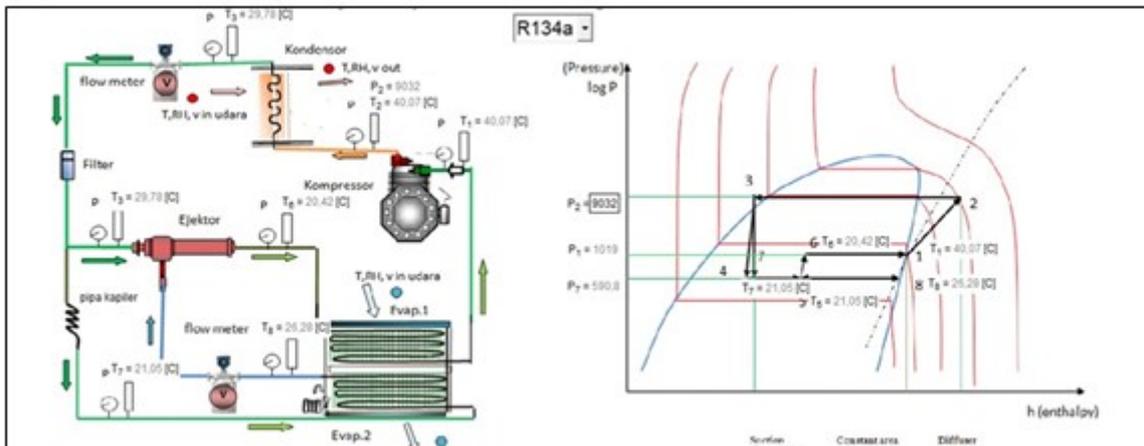


Figure 7. Schematic and P-h diagram of EDRS from EES.

From the results of the test conducted, where the first one tested is BRS, indicating the electric current that occurs is an average of 1.14 Ampere, while at EDRS showed 0.88 Ampere. Or the use of an average electricity energy of 0.224 kW, while at an average EDRS of 0.173 kW. There is a decrease in electricity consumption by 23% as shown in the Figure 7.

COP is a comparison of the effect of refrigeration or cooling effect compared to compressor work. Formulated with the Equation (1).

$$COP = \frac{Refrigeration\ Efeck}{Work\ Compressor} \tag{1}$$

For BRS, the average COP value is 1.86. Meanwhile, for EDRS, the average COP value increase by 2.43. It increases the COP value by 21%. Figure 8 shows the value of each system.

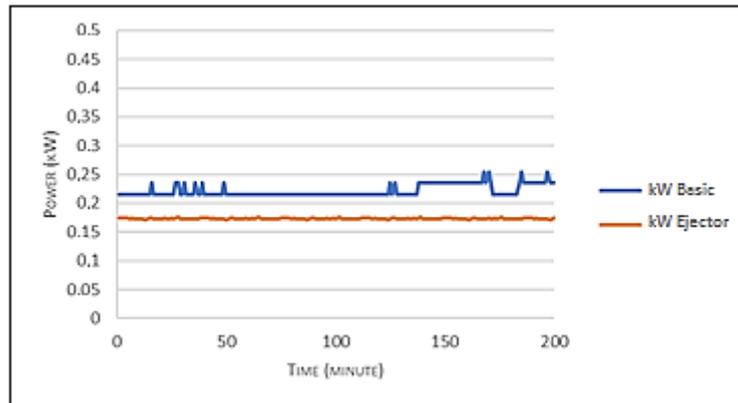


Figure 8. Power consumed on both systems.

The decrease in electricity consumption and the increase in the value of the COP in the dual evaporator ejector system did not show satisfactory results in the box that became the purpose of refrigeration system applications. The aim of the refrigeration system in chest freezer is to cool the room temperature (box) to below 0°C (some chest freezer products can reach -28°C). In the EDRS application, the box temperature only reaches about 1 degree Celsius, never touching the value below 0 degrees Celsius. Ilustasi temperature box in Figure 9.

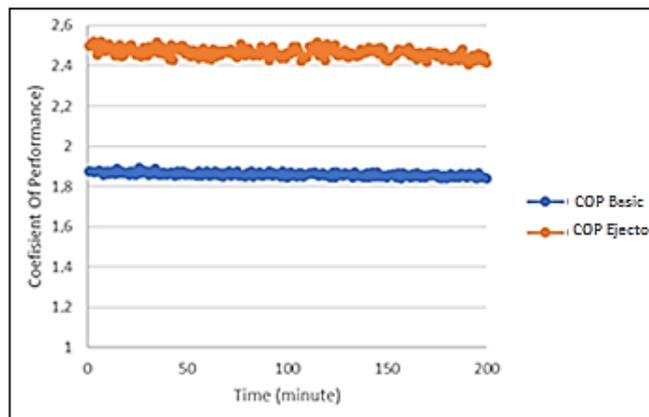


Figure 9. Coefficient of performance of each system.

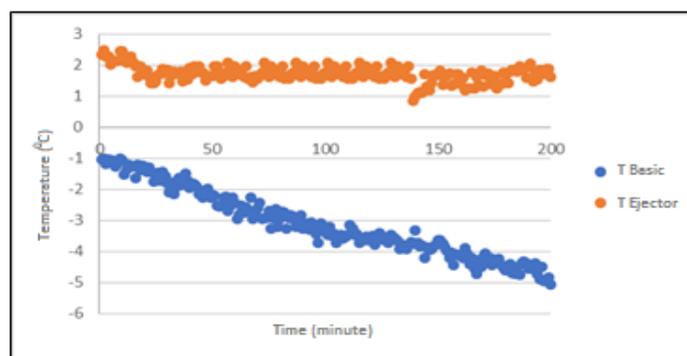


Figure 10. The box temperature of each refrigerated system.

Although the box temperature with EDRS shows less satisfactory results, but satisfactory results in the use of electricity and the increase in the COP in the EDRS compared to BRS, it is still an opportunity to do further research to Get really satisfying results on all sides.

4. Conclusions

Test results on one side showed quite satisfactory results, but on the output side is less satisfactory. Further research should be done, with some changes to the size of the ejectors adjusted to the size of the refrigeration system where the ejector will be applied.

5. References

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