EXPERIMENTAL STUDY ON THE USE OF EJECTOR WITH TWO-EVAPORATOR TEMPERATURES APPLIED FOR PERFORMANCE ENHANCEMENT OF SPLIT TYPE AC SYSTEM

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***Abstract*--The study was focused on the performance of a modified split type air conditioning (AC) system that used an ejector as its expansion device. The purpose of this study was to demonstrate that replacement of accumulator device with secondary evaporator of a standard air conditioning ejector system could improve coefficient of performance (COP) of the system. The tested split air conditioning system was a non-inverter system charged with R290 refrigerant. The evaporator of the system was placed in a test chamber incorporated with electric air heater to maintain constant load to the system. The results showed that the modified ejector AC system utilizing secondary evaporator could provide significant COP enhancement of about 13% over that of the standard ejector AC system.**

Keywords: two evaporator temperature ejector system, COP enhancement, and split type AC system

1. INTRODCUTION

Split type air conditioning (AC) is a machine that applies refrigeration system with vapor compression cycle comprising a condensing unit (outdoor unit) where compressor, condenser, and expansion device to be installed and indoor unit consisting evaporator and its controller. The cycle requires heat transfer medium as working fluid which is called refrigerant. The refrigerant will absorb the heat from one location and dispose of it to another location. The current system available in the market utilizes capillary tube as the expansion device.

One thermodynamic disadvantage of a vapor compression cycle is its isenthalpic expansion process occurring in the expansion device. Isenthalpic expansion has two weaknesses on the cycle performance compared with isentropic expansion in the Carnot cycle. Its coefficient of performance (COP) decreases due to lower cooling capacity and recovery losses in the expansion process. Capillary tubes are also known to have weaknesses due to friction of the refrigerant flow along the pipe wall as well as change in velocity along the capillary pipe cancause considerable energy losses.

The loss is due to a vortex flow in the expansion device that consumes kinetic energy. Researches on the expansion device cycles that focus on energy losses of the expansion device are considerably rare. If the energy losses of the expansion process can be removed and converted into compressor power usage, it is possible to reduce power consumption of the compressor and increase system cooling capacity and finally improve its COP as well[1][2].

A two-phase flow ejector that functions as an expansion device in a refrigeration system can be applied to recover work that is otherwise lost by the isenthalpic throttling process associated with the expansion device in conventional air-conditioning cycles.

Standard two-phase ejector system generally uses liquid separator where the refrigerant vapor exit at the outlet side to suction pipe of compressor and all liquid refrigerant in the accumulator comes out on the exit side of the liquid line to the secondary channel of the ejector. The harmful effects of this mechanism if it fails to work can potentially degrade the performance of the ejector cycle in such a way that it is no longer useful. This potential danger of the liquid-vapor separator, therefore, it is necessary to consider a two-phase ejector cycle operating without separator.

2. LITERATURE REVIEW

Application for air conditioning and heat pumping systems, the utilization of single-phase ejectors could result in 7% up to 9% COP improvement [3]. Other numerical and experimental studies and analyses showed that using a two-phase ejector as an expansion device allows for COP improvement in the vapor compression cooling cycle. The analysis results showed that the COP improvement could reach above 20%, but no experimental method resulted in an increase of more than 10% [4]. These results are obtained in improved systems through modification of geometric ejector dimensions, such as the throat of the motive nozzle, suction chamber, constant area and diffuser. These kinds of research is being an interesting research topic by the majority of researchers.

Nozzle of the ejector is designed according to standard based on recommendations from the ASHRAE Handbook which also include such as the lengths of each section and the convergent and divergent angles[5]. Other experimental study reported by[6], the improvement of COP when using a two-phase ejector as an expansion device on a bus AC system was as high as 8%.

The authors have tested the AC split ejector system which was designed based on standard geometry, and could increase the COP value of AC less than 10%. However, the utilization of a standard ejector system in a split air conditioner using R22 refrigerant equipped with a liquid separator required large construction and it was found to be not practical use.

Thermodynamic simulation model[7]stated that inefficiency might occur if about 15% of the liquid and vapor mass did not exit properly on the respective ports. This would be able to decrease the COP of the standard two phase ejector cycle below that of the conventional expansion cycle. It was also noted that the ejector cycle with Condenser Outlet Split (COS) ejector cycle could achieve a COP improvement above 10% compared with conventional cycles.

This experimental study is based on a concept to possibly eliminate liquid separator device by modifying the system through utilization of secondary evaporator. By using a secondary evaporator, it is expected that the modified AC system can perform better than the standard split AC ejector system.

3. RESEARCH METHODS

The study was an experimental base investigation which focused on the causes and effects relationship of the ejector AC system after special employment given to the variables studied. The test facility was modified from air conditioning split type system used for standard ejector system experiments which was a COS ejector system.

Ejector applied in the test system was designed based on the previously mentioned [5] model as shown in Figure 1. This model required the assumption of the efficiency of the ejector component and the mixing section pressure referring to [8], a reasonable estimate was given for the input. Data were collected under steady state conditions in the COS ejector system. The speed of the air flow and the inlet temperature both on the condenser and evaporator and the speed of the compressor were kept the same for all tests unless otherwise noted. The temperature of the entering evaporator air was 28.5°C, and the air flow rate was 0.3264 kg/s. The temperature of the entering condenser air was 28.3 °C, and the air flow rate was 0.698 kg/s. R290 was used as a working fluid.

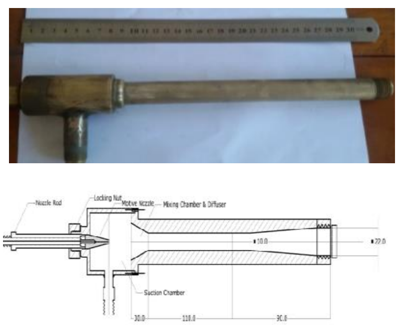

Figure 1. Ejectorconstruction and dimension

The test facility was made based on the simplified schematic diagram as shown in Figure 2. For measurement of refrigerant side used T-type thermocouple, differential and absolute pressure transducer, and power meter. To determine the theoretical mass flow rate of the refrigerant, two independent energy balances (the refrigerant and air side) are obtained for the evaporator and condenser.

The nozzles were tested with a 3 mm diameter, 110 mm long constant area mixing section. The expansion valve, shown in Figure 2, was used to control mass flow rate through the low-temperature evaporator, and data was taken at various low-temperature evaporator mass flow rates. The flow through the low-temperature evaporator was also the suction flow of the ejector; thus, varying this flow rate would also affect the performance of the ejector.

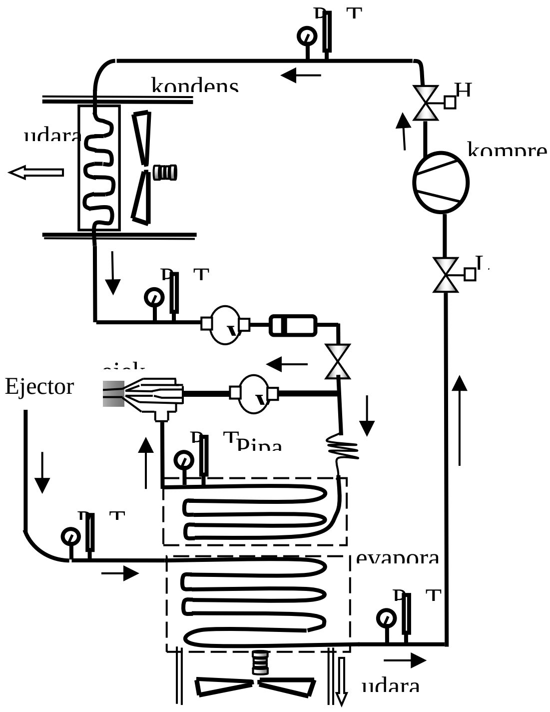

Figure 2. Schematic diagram of the test system

This study engages an ejector system and two evaporators with R-290 refrigerant. Test was conducted in a test facility where the air was conditioned and kept constant. The test results were then compared with the AC performance using standard ejector system.

Experimental facility

The construction of the test system comprises AC split system with outdoor and modified indoor with a two-temperature evaporator temperature system (Figure 2& 3). The indoor unit is installed in a test chamber which is available at the Study Program of Refrigeration and Air Conditioning, Bali State Polytechnic as shown in Figure4.

Figure 3. Split AC with ejector system design

Data recording was conducted by following the test procedure, starting from the split AC assembly in the test chamber. The test chamber was completed with air heater and thermostat controller to maintain the air temperature in the chamber constant at about 25 °C.The temperature and pressure data of the test results were collected using a data logging system. The power consumption of the system was measured by using a power analyzer.

Figure 4. Conditioned room for testing

Data analyses were performed based on real time. The pressure data (P, psig), temperature (T, °C), voltage (V, volt), current (I, Ampere), relative humidity (RH,%) and air velocity in and out of the indoor unit were recorded with Data Scan logging system and secondary data for R290 retrieved by using EES (Engineering Equation Solver) software. The obtained data were then processed numerically with the assist of the EES program to get the system cooling capacity and coefficient of performance (COP).

4. RESULTS AND DISCUSSION

The average power consumption of the test system was 503 W. It is about 23.7% lower than the power consumption of the conventional AC system using capillary tube as its expansion device. From the operational of the tested system was also found frequent on-off cycle as shown in Figure 5 and 6. From the figure, it can be analyzed that longer the off cycle of the system greater the cooling capacity and lower the power consumption.

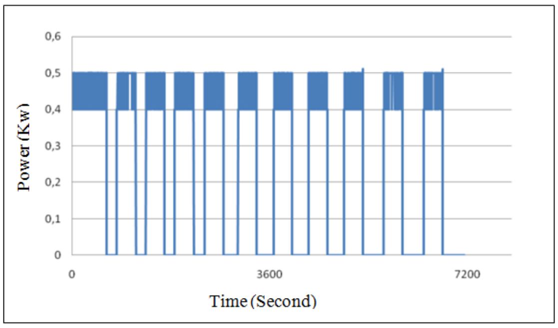

Figure 5. The on-off cycle of compressor power consumption

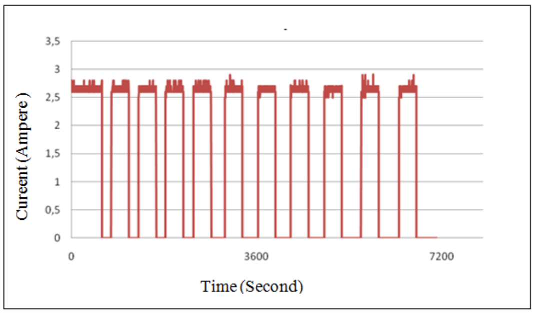

Figure 6. The on-off cycle of the ampere of thecompressor

Figure 7 shows the test results when air heater power in the test chamber was control to match the cooling capacity of the AC system as specified by its manufacturer. From the figure, it can be seen that by using the new arrangement of ejector system the chamber air temperature reduces with time and capable to reach a temperature of 18 °C rapidly of no more than 200 seconds or 3.5 minutes to lower the chamber air temperature from 28 °C.

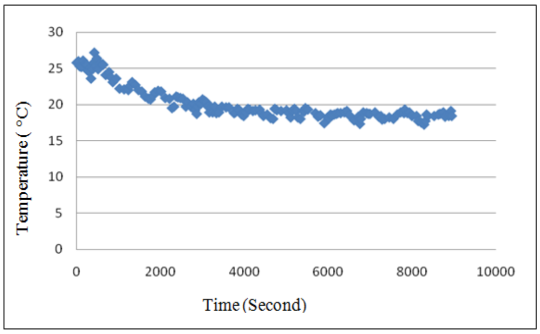

Figure 7. Cooling rate of the improvement ejector system

Figure 8 shows the test results when the system is tested at different ambient temperatures. It can be seen that the system COP decreases with temperatures. The system COP is relatively stable above 6 when the ambient temperature increases from 29 °C up to 35 °C then COP is sharply down from 6 to 5 when the ambient temperature increase from 35 °C to 40 °C.

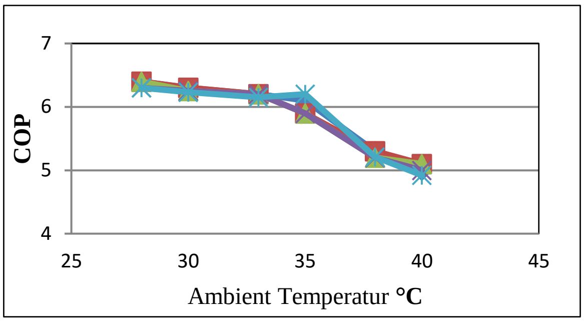

Figure 8. COP of the improvement ejector system at various ambient temperatures

For comparison analysis, Figure 9 shows the COP of the improvement ejector system, standard ejector system and conventional expansion system. The figure clearly shows that the COP of the improvement ejector system is significantly higher that other systems. The COP of improvement ejector is ranging from 6.4 down to 5 when the ambient temperature increases from 29 °C to 40 °C. While the COPs of the system with the standard ejector and expansion valve are respectively 5.7 and 5.4 at ambient temperature of 29 °C. The amount of COP improvement is 13% at temperature of 29 °C and 35% at ambient temperature of 40°C. This is in agreement with the results reported in [9] which showing the tested system has been working properly.

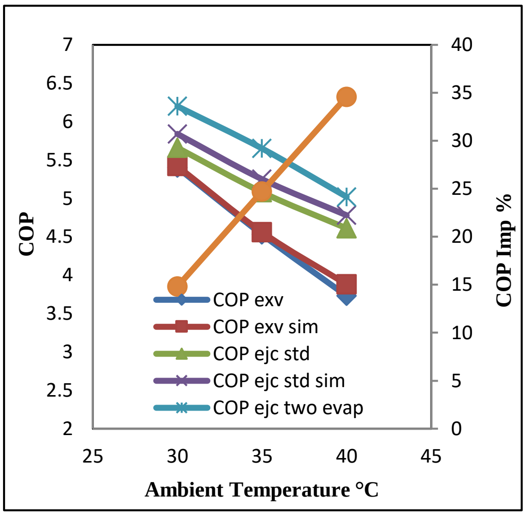

Figure 9. COP comparison between two evaporator ejector AC system and standard ejector and conventional expansion device systems at different ambient temperature.

5. CONCLUSIONS

Based on the results obtained from the study, it can be concluded that the use of ejector system in split type air conditioning utilizing two evaporator temperatures could provide system performance enhancement. Compared with the conventional expansion system, the two evaporator temperatures ejector system offer of about 23.7% power savings.While the COP could reach as high as 6.4 accounted for 13% performance improvement.

6. ACKNOWLEDGMENT

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