AN EXPERIMENTAL STUDY ON A VAPOR COMPRESSION REFRIGERATION CYCLE BY ADDING INTERNAL HEAT EXCHANGER

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ABSTRACT

This paper presents practical study to improve the indication COP of a vapor compression refrigeration cycle in instrumented automobile air conditioner by designing internal heat exchanger and installing it in the vapor compression refrigeration cycle.

Two cases of vapor compression refrigeration cycle were taken in this paper: the first case is that the vapor compression refrigeration cycle without internal heat exchanger and in the second case the vapor compression refrigeration cycle with heat exchanger ; in these two cases, the temperature at each point of a vapor compression refrigeration cycle, the low and the high pressure ,the indoor temperature and the outdoor temperature were measured at each time at compressor speed 1450 rpm and 2900 rpm for each blower speed 1, blower speed 2 and blower speed 3.

The refrigerant fluid was used in the vapor compression refrigeration cycle without IHE and with IHE is R134a..

KEYWORDS: Internal Heat Exchanger, R134a, vapor Compression Refrigeration Cycle.

Symbol	Description	Unit
COP	Coefficient of Performance	--------
h	Enthalpy	Kj/Kg
IHE	Internal Heat Exchanger	--------
N	Compressor Speed	rpm
P_L	Low Pressure of Vapor Compression Refrigeration	Mpa
P_H	High Pressure of Vapor Compression Refrigeration	Mpa
T_{indoor}	Indoor Temperature	C
$T_{outdoor}$	Outdoor Temperature	C
ΔQ	Energy Difference	Kj/Kg
η	Effectiveness of IHE	-------

INTRODUCTION

Over the past decades , automotive air-conditioning systems have undergoing constant improvements to achieve higher efficiency and also for addressing environmental concerns [1].

A complex scientific development and research investigations are carried out for creating and improvement of high-effective heat pipe exchangers of " gas-gas" type. These exchangers are intended to recover of ejected heat flows behind the fuel and energy using equipments. The main characteristics of the heat exchangers for different equipments and its advantages in comparison with traditional constructions are given [2].

The software is able to simulate transient operation of vapor compression cycles , predicting pressures , coefficients of performance, and condenser /evaporator liquid positions in a closed two-phase system with a fixed fluid charge. The program can also be used to size components, to estimate the impact of tolerances and other variations, and to help estimate uncertainties given limited test data [3].

The model results found that the system pressure is an important design parameter, with the COP having an optimum when the system pressure is equal to the saturation pressure of the butane refrigerant[4].

An analysis of the new algorithm for determining the heat recovery factor, and presents examples showing its performance and advantages of this model over the simple model .The electric chiller in the energy plus now has the option of having its condenser hooked up to a heat recovery loop, or what is commonly know as a double bundled chiller[5].

The aim of this work is to increase indication COP of vapor compression refrigeration cycle by adding internal heat exchanger to vapor compression refrigeration cycle of automobile air conditioner.

Identification of Instrumented Automobile Air Conditioner

Basic standard version including a complete car air conditioner fitted on a wheeled steel frame together with the driving motor ,a power supply unit with switch for motor and 12V DC output for the parts usually powered by the car circuit. The unit is composed by the following components :multi cylinder compressor with electromagnetic clutch, electric motor, forced air condenser, evaporator with multi speed fan ,liquid receiver and drier ,thermostatic expansion valve ,pressure switch and connection hoses as shown in fig(1).The lay-out of instrumented automobile air conditioner can be found as shown in fig(2).

Basic Vapor compression Refrigeration Cycle

The basic components required for mechanical refrigeration are the compressor, evaporator , condenser and the thermostatic expansion valve as shown in fig.(3).

The P-H chart is an important tool in understanding the property changes during each phase of the cycle. P-H chart are lines of constant pressure and the vertical lines are lines of constant enthalpy or heat energy[6]. The line labeled " saturated liquid line" and "saturated vapor line" are plots of the pressure-vs.-enthalpy for the saturated state of a given refrigerant. The area to the left is the sub cooled region ,to the right is the superheated region and in the middle is the wet region or mixture state. The constant temperature lines are horizontal in the mixture region indicating that the phase occurs at constant pressure as shown in fig(4). Likewise, expansion of the gas takes place at constant enthalpy.

Fundamentals of The IHE Vapor Compression Refrigeration Cycle

Consider the performance of a vapor compression cycle with IHE $a' - a - b - b' - c - d - d'$ (see Fig.(6)). Taking as a references the same cycle without IHE at the same saturation temperature in the evaporation and in the condenser a-b-c-d.

On a unit mass base, the IHE cycle incurs a cooling capacity gain $\Delta Q_{subcooling}$ $(a' - a$ enthalpy change) over basic cycle(a-b). Likewise , the IHE cycle incurs a superheating capacity gain $\Delta Q_{Superheating}$ $(b - b'$ enthalpy change) as shown in fig.(5) and the P-H diagram of vapor compression refrigeration cycle with IHE as shown in Fig.(6).

Description of IHE

The IHE was designed according to a specific measurement as shown in fig.(7); this heat exchanger contains:-

a- Cast-iron cylinder has diameter 12.5cm ,Length 34cm and thickness 3mm.

b- Two branch pipes made from brass ,each pipe has diameter 3/8 in ,first branch enters to the cylinder from the evaporator and the second branch leaves the cylinder to the compressor.

c- Coil made from brass has length 65cm and diameter 1.87cm ,this coil enters the cylinder from the condenser and leaves the cylinder to the expansion valve.

The IHE was joined with vapor compression refrigeration cycle and was recharged by R134a as shown in fig.(8).

The enthalpy was calculated at each point of vapor compression refrigeration cycle of instrumented automobile air conditioner , the low pressure and the high pressure of vapor compression refrigeration cycle were measured and the indoor temperature and outdoor temperature were measured also with heat exchanger and without heat exchanger at compressor speed 1450rpm and 2900rpm for each blower speed 1, blower speed 2 and blower speed 3 as follows:-

<u>Step 1</u>

The instrument automobile air conditioner was turned on at 23C ambient temperature in the laboratory of air-conditioning and was measured the temperature at each point a-b-c-d(without IHE) and a'- b-b'-c-d-d'(with IHE) also the indoor temperature and outdoor temperature were measured by using electronic temperature display and the low pressure and the high pressure of vapor compression refrigeration cycle were measured by using pressure gage.

Step 2

The procedure of step 1 was repeated after 5 minute to measure the temperature at each point also to measure indoor temperature and outdoor temperature and to measure the low pressure and the high pressure , this state was repeated at each 5 minute till the temperature at each node of vapor compression refrigeration cycle become constant also the low pressure and high pressure become constant.

Step 3

After measurement the temperature at each point of vapor compression refrigeration cycle and after measurement the low pressure and the high pressure ;the enthalpy at each point is calculated by using package of Computer-Aided Thermodynamic Tables 2 (CATT2), this package provides the user with a means to access various thermodynamic tables normally found in text or reference books. There is no need to interpolate values from a table.

Sample of Calculation

The indication COP of vapor compression refrigeration cycle was calculated by the law:-

$$COP_{Indication}=\frac{\text{Refrigeration Effect}}{\text{Compression Effect}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

When the vapor compression refrigeration cycle without IHE as show in fig.(4):-

$$\text{Refrigeration Effect}=h_b-h_a \ldots\ldots\ldots..(2)$$

$$\text{Compression Effect}=h_c-h_b \ldots\ldots\ldots\ldots(3)$$

When the vapor compression refrigeration cycle with IHE as shown in fig(6):-

$$\text{Refrigeration Effect}=h_b-h_{a'} \ldots\ldots\ldots..(4)$$

$$\text{Compression Effect}=h_c-h_{b'} \ldots\ldots\ldots(5)$$

$$\Delta Q_{Subcooling}=h_d-h_{d'} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$\Delta Q_{Superheating}=h_{b'}-h_b \ldots\ldots\ldots\ldots\ldots\ldots..(7)$$

The effectiveness of internal heat exchanger was calculated from the law:-

$$\eta=\frac{h_d-h_{d'}}{h_{b'}-h_b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Table (1) contains the low pressure of vapor compression refrigeration cycle ,the high pressure of vapor compression refrigeration cycle ,indoor temperature and outdoor temperature at each time with IHE & without IHE at compressor speed 1450rpm for each blower speed 1, blower speed 2 and blower speed 3.

Table (2) contains the low pressure of vapor compression refrigeration cycle ,the high pressure of vapor compression refrigeration cycle ,indoor temperature and outdoor temperature at each time with IHE & without IHE at compressor speed 2900rpm for each blower speed 1, blower speed 2 and blower speed 3.

RESULTS & DISCUSSIONS

It is found that the indication COP of the vapor compression refrigeration cycle with IHE greater than from the indication COP of the vapor compression refrigeration cycle without IHE at compressor speed 1450rpm and 2900rpm because the IHE reduces the compression effect and increases the refrigeration effect as shown in fig.(9) and fig.(10).

It is found that the indication COP for the speed of compressor 2900rpm less than the indication COP for the speed of compressor 1450rpm because of the compression effect for the COP in 2900rpm is greater than the COP in 1450rpm which due to the increase in work done by the motor on the compressor as shown in fig(11) and fig.(12).

The results show in fig.(13) and fig.(14) explain that the heat rejected from the internal heat exchanger "shown in fig.(6) d-d$'$ " approximately approach the heat absorbed at the internal heat exchanger "shown in fig.(6) b-b$'$ ".

The value of effectiveness of internal heat exchanger was around 61% -75% at compressor speed 1450 rpm and 60% -73% at compressor speed 2900 rpm.

CONCLUSIONS

It is concluded from this search that:-

1- the internal heat exchanger of vapor compression refrigeration cycle increases indication COP at the same compressor speed.

2- The $\Delta Q_{Subcooling}$ is approximately approach $\Delta Q_{Superheating}$ that it means that the amount the heat rejected from the internal heat exchanger ($\Delta Q_{Subcooling}$) absorbed at the internal heat exchanger ($\Delta Q_{Superheating}$).

3-The indication COP of vapor compression refrigeration cycle at compressor speed 1450rpm greater than the indication COP of vapor compression refrigeration cycle at compressor speed 2900rpm because that the compression effect at compressor speed 1450rpm less than the compression effect at compressor speed 2900rpm.

It may be recommended to add the effect of environment on the performance of a vapor compression refrigeration cycle.

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Table(1)

N=1450rpm ,Blower Speed 1

	Without Heat Exchanger				With Heat Exchanger			
Time(min)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)
0	0.19	1.1	21.5	25.4	0.2	0.8	21	21.4
5	0.19	1.1	16.5	24.7	0.3	0.7	13.7	18.3
10	0.19	1.1	13.7	24.3	0.19	0.9	11.8	19.6
15	0.18	1.1	12.8	24.2	0.17	0.9	11.4	20.4
20	0.18	1.1	12.3	23.9	0.2	0.85	11.3	20.8
25	0.18	1.1	12	23.1	0.2	0.9	11.2	20.8
30	0.18	1.1	12	23.2	0.2	0.9	11.2	21

N=1450rpm ,Blower Speed 2

	Without Heat Exchanger				With Heat Exchanger			
Time(min)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)
0	0.2	1	25.6	26	0.2	0.9	20.8	22.5
5	0.2	1	14.7	24.1	0.2	0.9	12	21.5
10	0.17	1.1	12	23.6	0.2	0.9	11.5	21.5
15	0.18	1.1	11.7	23.6	0.2	0.9	11.2	21.5
20	0.19	1.1	11.9	23.6	0.2	0.9	11.1	21.5
25	0.19	1.1	11.4	23.4	0.2	0.9	11.3	21.7
30	0.19	1.1	11.2	23.4	0.2	0.9	11.3	21.7

N=1450rpm ,Blower Speed 3

	Without Heat Exchanger				With Heat Exchanger			
Time(min)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)
0	0.23	1.15	25.2	26.5	0.25	0.9	16.2	23.9
5	0.2	1.15	15.6	25.8	0.22	0.9	14.6	22.3
10	0.21	1.15	15.1	25.1	0.2	0.9	12.3	22.2
15	0.21	1.15	14.3	25	0.22	0.9	11.5	22.4
20	0.21	1.2	13.8	24.9	0.22	0.9	11.4	22.4
25	0.21	1.2	13.7	24.6	0.22	0.9	10.3	17.5
30	0.21	1.2	13.9	24.7	0.2	0.9	10.3	17.2

Table(2)

N=2900rpm ,Blower Speed 1

	Without Heat Exchanger				With Heat Exchanger			
Time(min)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)
0	0.18	1.4	21.2	25.6	0.2	1	15.1	22.4
5	0.18	1.4	14.2	25.3	0.2	1	13.6	22.6
10	0.18	1.4	13	24.7	0.2	1	13	22.7
15	0.18	1.4	12.7	24.5	0.2	1	12.5	22.8
20	0.18	1.4	12.4	24.4	0.2	1	12.4	23
25	0.18	1.4	12.4	28.9	0.2	1	12.2	23.1
30	0.18	1.4	12.3	29	0.2	1	12.2	23.1

N=2900rpm ,Blower Speed 2

	Without Heat Exchanger				With Heat Exchanger			
Time(min)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)
0	0.2	1.1	20.2	25.7	0.2	1	16.2	24.5
5	0.12	1.4	16.7	25.1	0.2	1	15.3	23.4
10	0.15	1.4	13.8	24.4	0.2	1	11.8	23.5
15	0.12	1.4	12.1	24.1	0.2	1	11.7	23.5
20	0.15	1.4	11.8	24	0.2	1	11.4	23.6
25	0.15	1.4	11.6	24	0.2	1	11.3	23.6
30	0.15	1.4	11.5	24	0.2	1	11	24.4

N=2900rpm ,Blower Speed 3

	Without Heat Exchanger				With Heat Exchanger			
Time(min)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)	P_L(Mpa)	P_H(Mpa)	T_{indoor}(c)	$T_{outdoor}$(c)
0	0.25	1.2	26.5	27.8	0.25	1	15.34	25.6
5	0.15	1.4	13.6	23.7	0.23	1	16.1	24.7
10	0.15	1.45	13.2	23.8	0.23	1	13.4	24.7
15	0.15	1.45	13.4	23.7	0.22	1	12.5	24.5
20	0.15	1.45	13.1	24.4	0.22	1	12.2	24.4
25	0.15	1.45	12.7	26.2	0.22	1	12.1	24.5
30	0.16	1.48	12.3	27.9	0.22	1	12.1	24.8

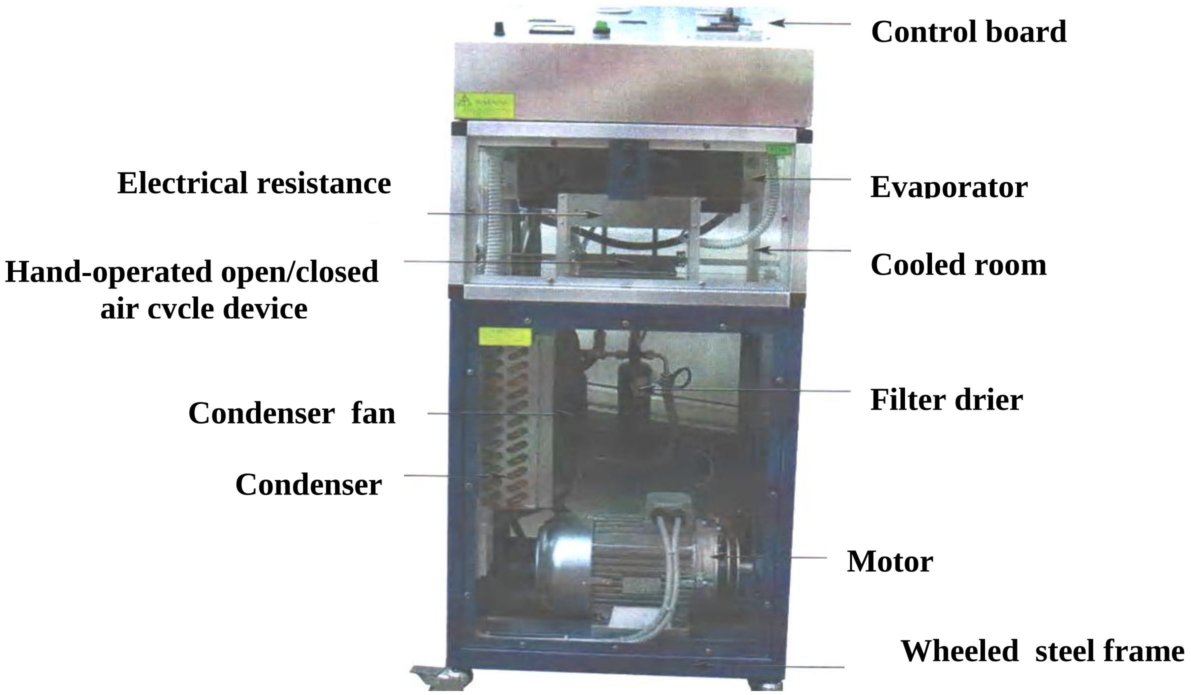

Fig.(1) Frontal View of Instrumented Automobile Air Conditioner[7]

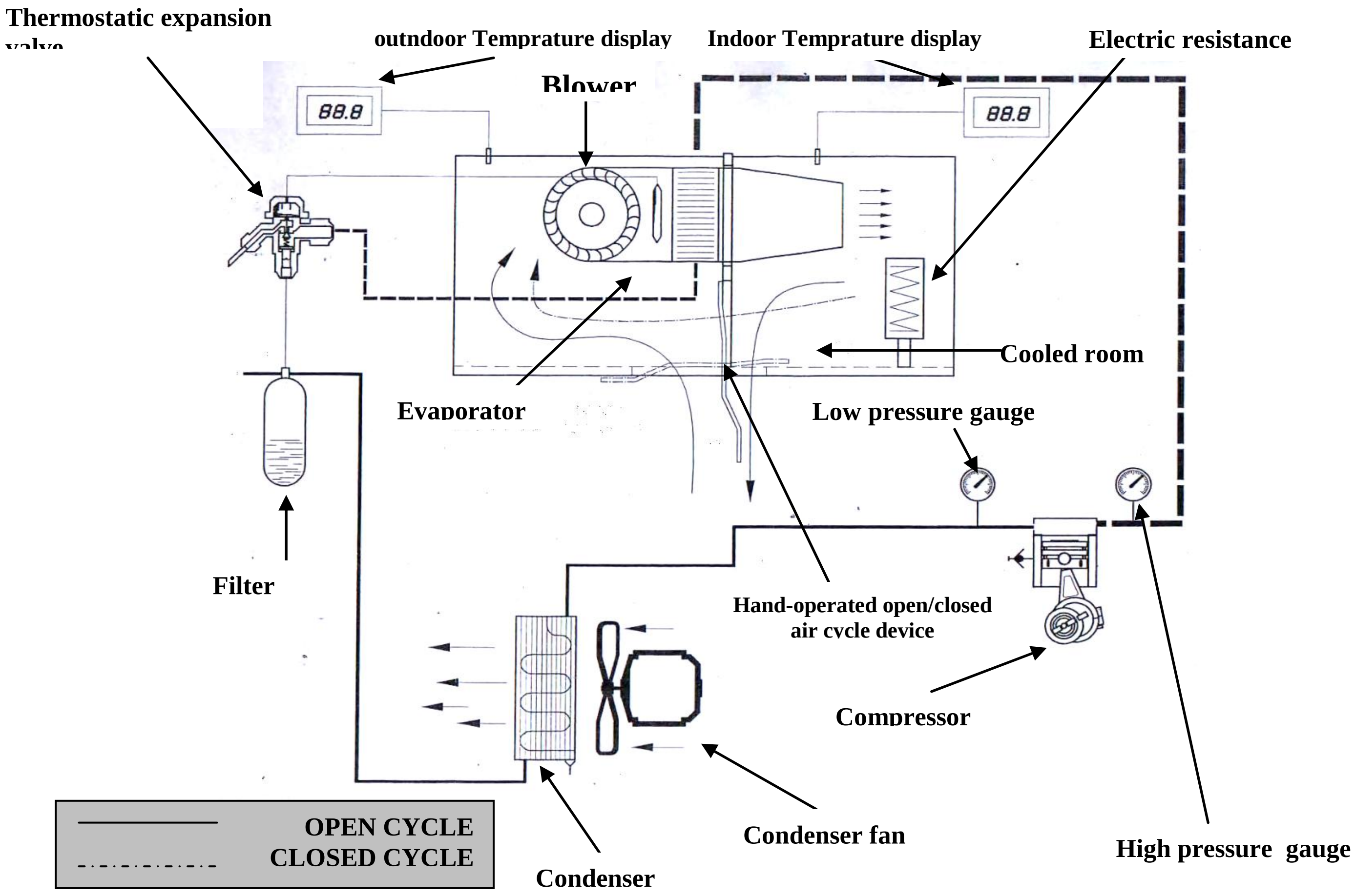

Fig.(2) The lay-out of Instrumented Automobile Air Conditioner[7]

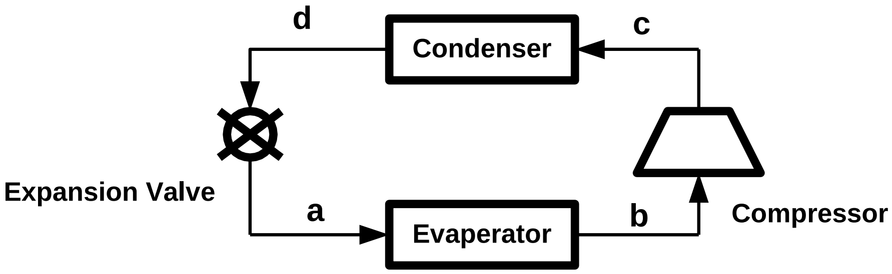

Fig.(3) Basic Vapor Compression Refrigeration Cycle[6]

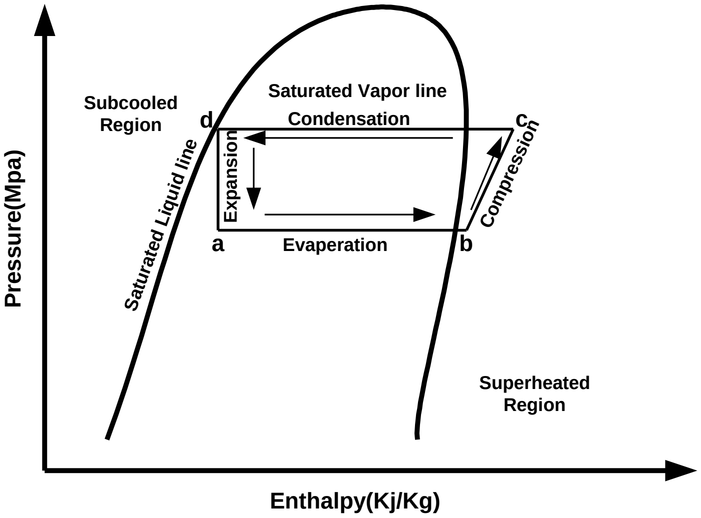

Fig.(4) P-H Diagram [6]

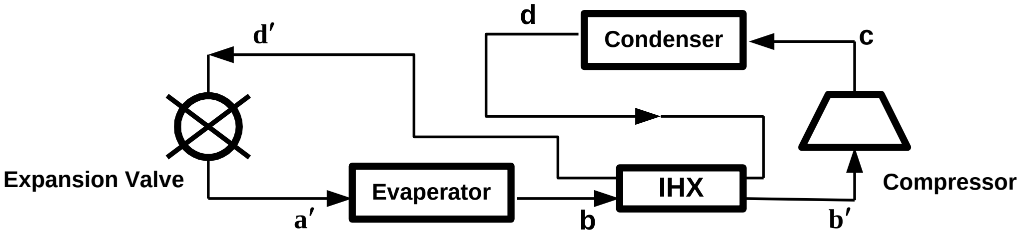

Fig.(5)Vapor Compression Refrigeration Cycle With IHX

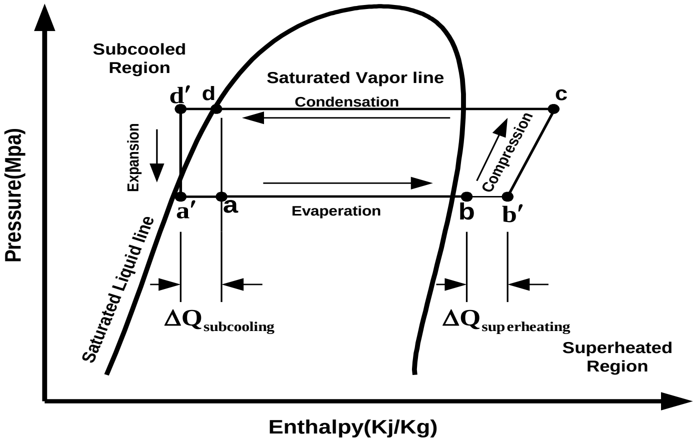

Fig.(6) P-H Diagram of The Vapor Compression Refrigeration Cycle With IHX

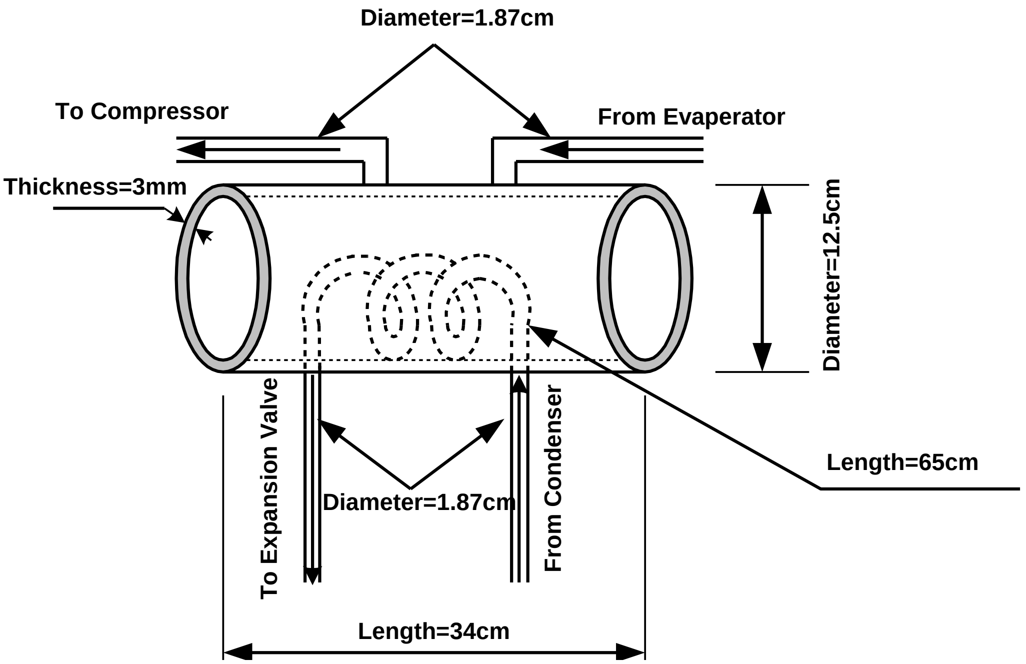

Fig.(7) Front View of Internal Heat Exchanger

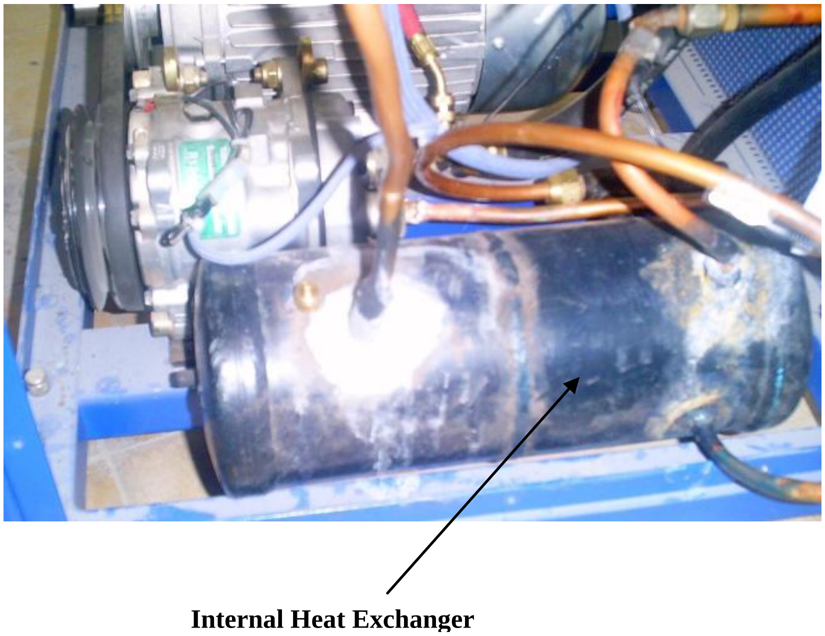

Fig.(8) IHX Joined With Vapor Compression Refrigeration Cycle in The Air Conditioner

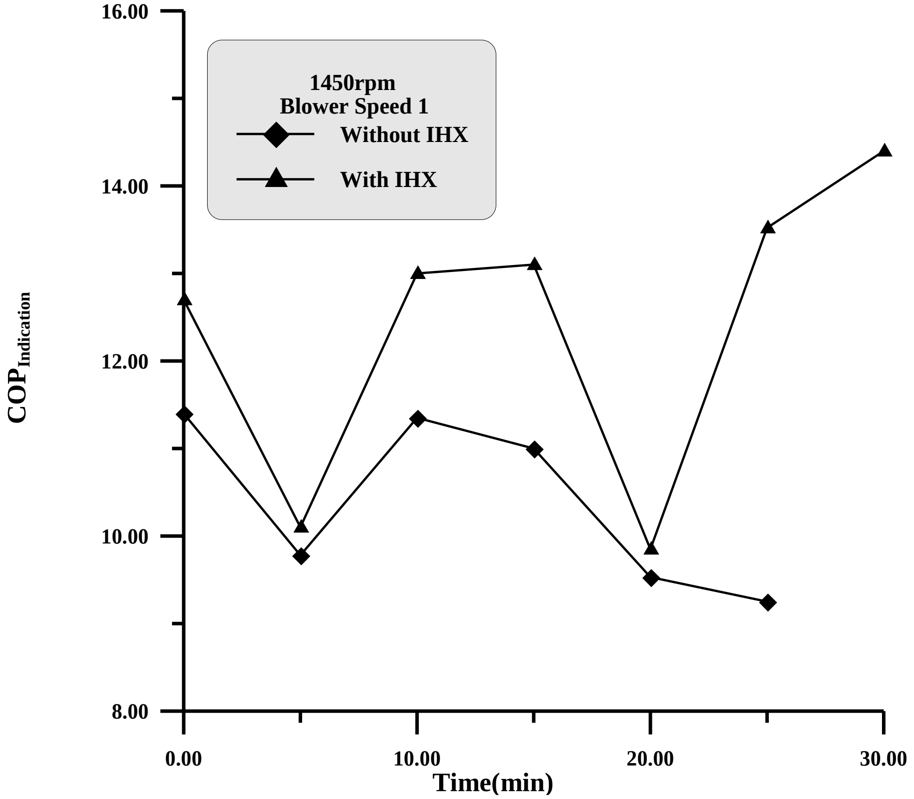

Fig.(9) The Variation of Indication COP With Time at Compressor Speed 1450rpm

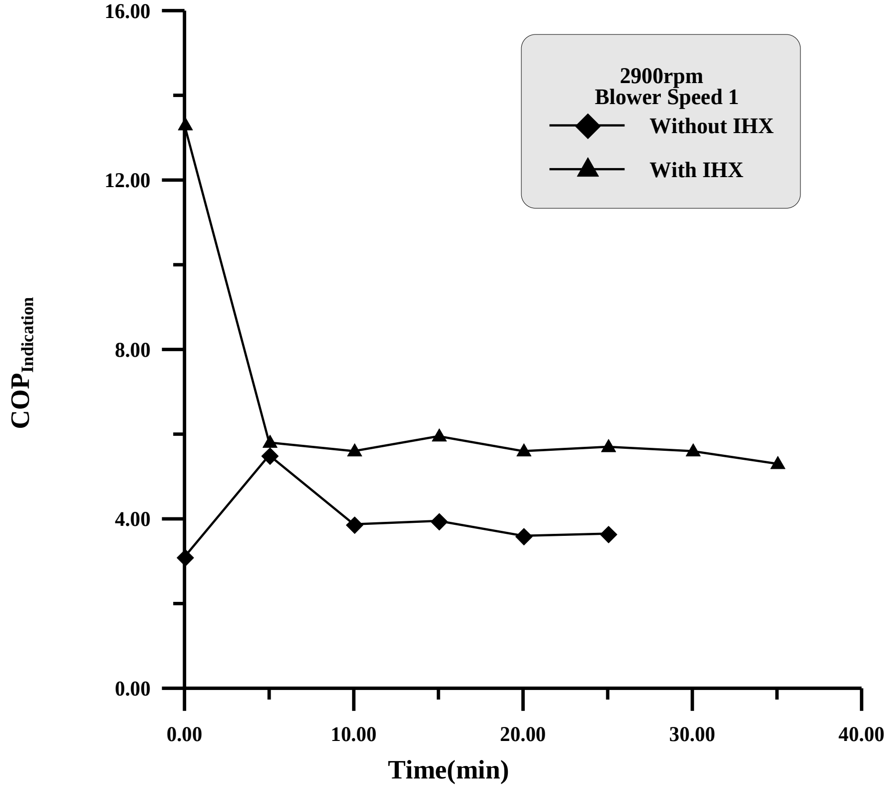

Fig.(10) The Variation of Indication COP With Time at Compressor Speed 2900rpm

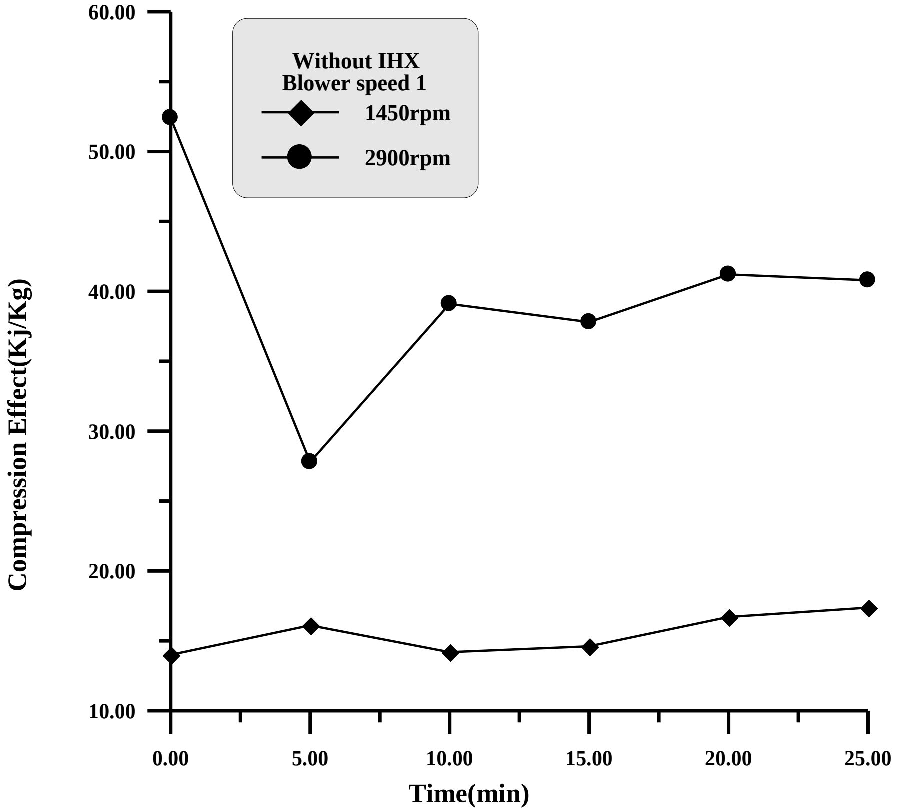

Fig.(11) The Variation of Compression Effect With Time

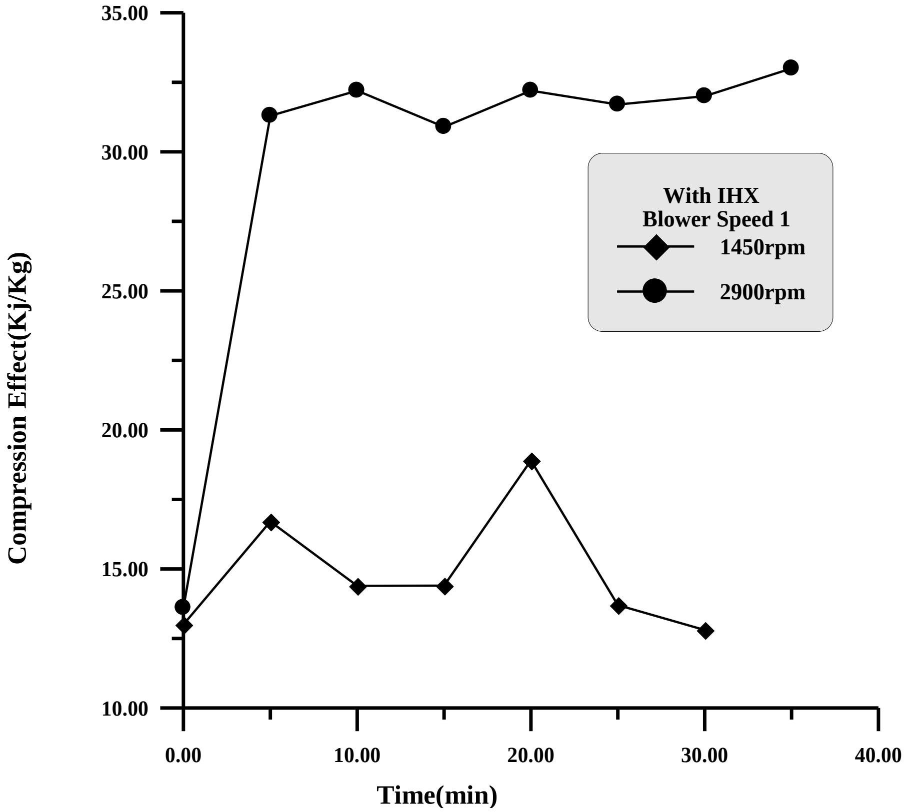

Fig.(12) The Variation of Compression Effect With Time

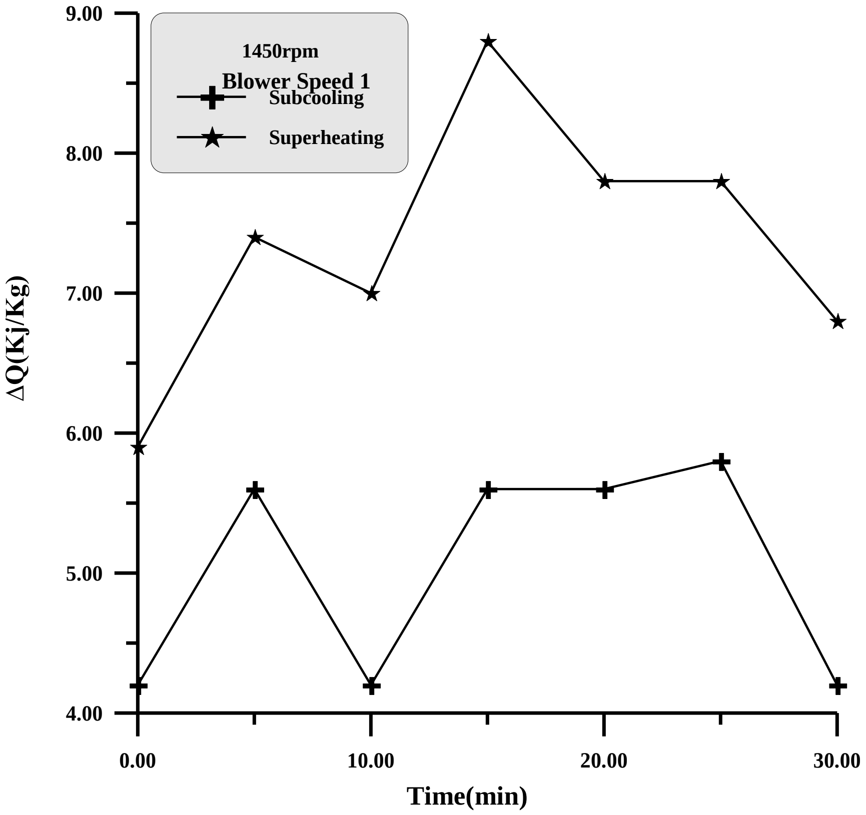

Fig.(13) The Variation of Heat Loss With Time at Compressor Speed 1450rpm

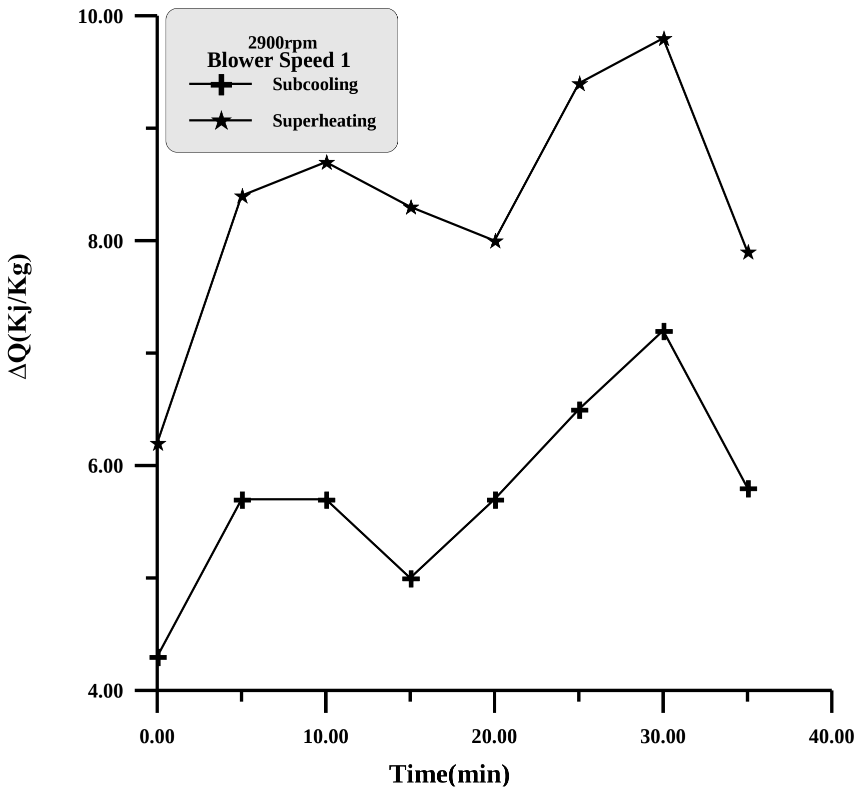

Fig.(14) The Variation of Heat Loss With Time at Compressor Speed 2900rpm

دراسة عملية لدورة التثليج الأنضغاطية بإضافة مبادل حراري داخلي

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الخلاصة

أن هذا ا البحث يقدم دراسة عملية لتحسين معامل أداء منظومة التثليج الأنضغاطبة لجهاز تكيف سيارة بتصميم مبادل حراري داخلي وتنصيبة في دورة التثليج ألأنضغاطية.

حالتان تم ألأخذ بها في دورة التثليج ألأنضغاطية، الحالة ألأولى هي دورة التثليج ألأنضغاطية بدون إضافة مبادل حراري والحالة الثانية هي دورة التثليج الأنضغاطية بإضافة مبادل حراري داخلي ; في تلك الحالتين سيتم قياس درجة الحرارة عند كل نقطة من دورة التثليج ألأنضغاطية وفي كل وقت ،الضغط العالي والضغط الواطئ سيتم قياسهم عند كل وقت، درجة الحرارة داخل الغرفة ودرجة الحرارة خارج الغرفة سيتم قياسهم عند كتل وقت أيضا عند سرعة 1450rpm و 2900rpm للكومبريسر لسرعة بلور 1 ، سرعة بلور 2 وسرعة بلور 3.

مائع التبريد المستخدم في دورة التثليج ألأنضغاطية بدون المبادل الحراري الداخلي ومع المبادل الحراري الداخلي هو R134a.

الكلمات الدالة:- مبادل حراري داخلي ، R134a، دورة التثليج ألأنضغاطية.