

Experimental Evaluation of an Automobile Air - Conditioning System with and without Liquid Suction Heat Exchanger

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ABSTRACT

This study involves the experimental aspects of R134a Automobile Air Conditioning (AAC) system with & without Liquid Suction Heat Exchanger (LSHX). To evaluate the performance of an Automobile Air Conditioning system, an experimental system consisting of original components from an R134a Automobile Air Conditioning system has been set up and instrumented. An additional Liquid Suction Heat Exchanger is used in conventional Automobile Air Conditioning system. Effect of evaporator temperature variation & compressor speed variation on R134a Automobile Air Conditioning system performance is evaluated.

From experimental evaluation, it is derived that there is a Coefficient of Performance (COP) improvement in Automobile Air Conditioning system with Liquid Suction Heat Exchanger compared to Automobile Air Conditioning system without Liquid Suction Heat Exchanger. Performance of an R134a Automobile Air Conditioning system degrades with increase in compressor speed. From refrigerant side, it is concluded that overall Coefficient of Performance improvement is about 2.54% with Liquid Suction Heat Exchanger with 45.83% effectiveness. From air side calculation, it is found that Coefficient of Performance improvement is about 7.51% in Automobile Air Conditioning system with Liquid Suction Heat Exchanger compared to Automobile Air Conditioning system without Liquid Suction Heat Exchanger.

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INTRODUCTION

AAC is a very competitive industry; the open literature on the performance of AAC systems is very limited. Due to the Montreal Protocol, some investigators had done the performance of AAC systems using refrigerants alternative to R12, which was the refrigerant widely used in AAC systems until 1994. Although the automobile industry has been using R134a as a standard replacement for R12 since 1994, refrigerant R134a has a very high global warming potential. Therefore, some recent studies have aimed to lower the global warming caused by the AAC systems by designing systems requiring less amounts of R134a or using CO₂ or hydrocarbons or HydroFlouroOlefin as an alternative to R134a [1].

J. Steven Brown et al [2] had concluded that R134a having a better COP than CO₂. Mahmoud Ghodbane [3] had derived that R152a and cyclopropane (RC270) exhibit superiority as refrigerants when compared to R134a. Yohan Lee et al [4] had experimented that the coefficient of performance and capacity of R1234yf are up to 2.7% and 4.0% lower than those of R134a, respectively but R1234yf can be used as a long term environmentally friendly solution in AAC system due to its excellent environmental properties with acceptable performance.

In addition to the studies on the performance of AAC systems with alternative refrigerants, some investigators had done performance on R134a AAC with Variable Capacity Compressor (VCC) and also with Internal Heat Exchanger (IHX). Alpaslan Alkan et al [1] showed that the operation with the VCC usually yields a higher COP than the operation with the Fixed Capacity Compressor (FCC) in expense of a lower cooling capacity. M. Preissner et al. [5] had created R134a automotive prototype air conditioning system and was tested in the laboratory with and without an internal heat exchanger. At a higher condenser air temperature of 40°C and a restrictive idling air flow rate of 1.0 m/s. The result was concluded that the COP and the capacity increased in the order of 5 to 10% with a suction line heat exchanger with 60% effectiveness.

Following this introduction, the focus of this investigation is to evaluate the performance of an AAC system with & without LSXH. The investigation covers following four sections: (1) To build an experimental setup made from original components of an R134a Automobile Air Conditioning system. (2) To compare the R134a AAC system performance without & with Liquid Suction Heat Exchanger experimentally. (3) To check the effect of evaporator temperature variation. (4) To check the effect of compressors speed variation.

EXPERIMENTAL SET-UP

The Schematic diagram of experimental AAC system is shown in [figure 1](#). The locations and types of the measurements are depicted in [figure 1](#). All tubing connecting main parts of AAC system and also tubing in LSHX having size of 127 mm. Amount of Refrigerant R134a charge is about 450 grams in the set-up of AAC system. The refrigerant temperatures are detected by the thermocouples which are inserted and soldered in to the tube. LSHX is insulated by asbestos material. The dry bulb temperatures and wet bulb temperature of the air streams entering and leaving the evaporator and condenser are measured. The suction and discharge pressures of the compressor were measured by Bourdon tube gauges. Neglecting the pressure drops in the evaporator and condenser as well as in the connecting lines, it is assumed that the evaporating and condensing pressures is - equal to the measured suction and discharge pressures, respectively. Here only two pressure gauges are used because of leakage issues.

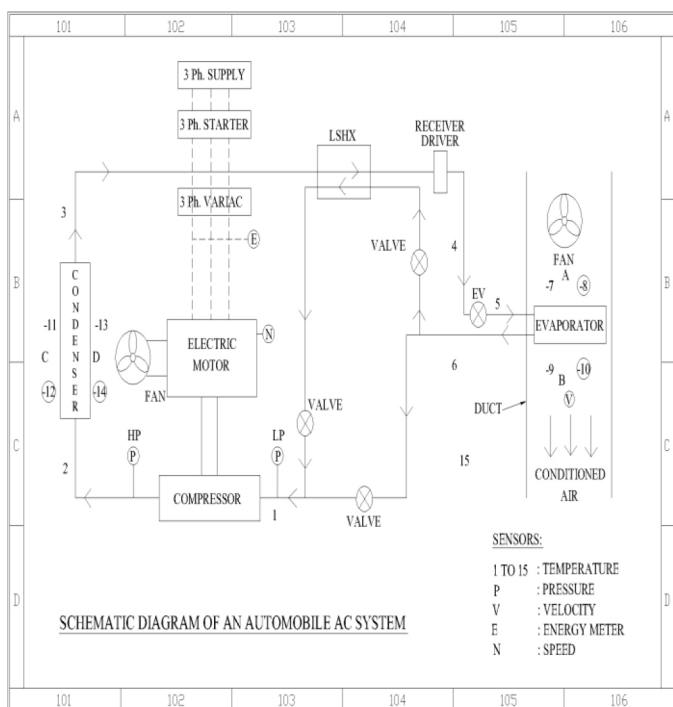


Figure 1. Schematic diagram of Experimental AAC system

The compressor speed is measured by a photoelectric tachometer. The air velocity at the outlet of the evaporator & condenser is measured by an anemometer. Then, the air mass flow rates passing through the evaporator and condenser are determined from the product of the air density by the air velocity and the flow area.

Here compressor used is fixed capacity type but with the help of three phase VARIAC (variable autotransformer), the speed of electric motor can vary & thus speed of compressor can also vary. Thus concept of variable speed of VCC can be achieved in fixed displacement compressor. Different temperature state points of refrigerant side are following as shown in [figure 1](#).

1. Compressor inlet temperature (after superheating if LSHX used)
2. Compressor outlet temperature / condenser inlet temperature
3. Condenser outlet temperature
4. Expansion Valve inlet temperature (after sub cooling if LSHX used)
5. Expansion Valve outlet temperature / Evaporator inlet temperature
6. Evaporator outlet temperature

Different temperature state points of air side are following as shown in [Figure 1](#).

7. DBT of air at evaporator inlet
8. WBT of air at evaporator inlet
9. DBT of air at evaporator outlet
10. WBT of air at evaporator outlet
11. DBT of air at condenser outlet
12. WBT of air at condenser outlet
13. DBT of air at condenser inlet
14. WBT of air at condenser inlet
15. Atmospheric temperature

The experimental Automobile AC system mainly consists of the original components from an R134a automobile air conditioning system, as shown in [figure 2](#). It requires some auxiliary equipment used for testing the system under the required conditions and some instruments were used for performing mechanical measurements.

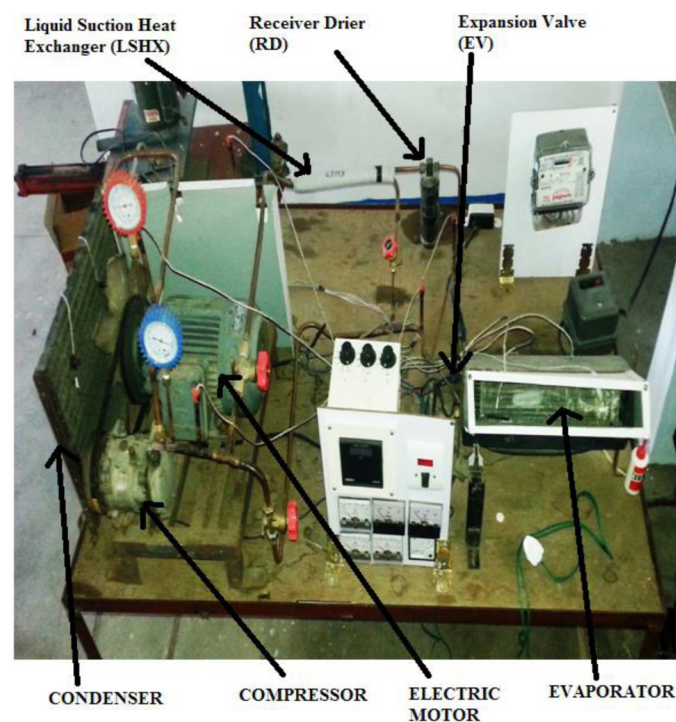


Figure 2. Set up of an Automobile AC System

Table 1. Components of an Experimental AAC system

Components :	Types :	Details :
Electric Motor	Three Phase Induction Type Motor	1.5 kW (2 HP) Power
Compressor	Reciprocating Wobble Plate Type Compressor	07 Cubic Inches displacement (114.7 cc)
Condenser	Tube Fin Type Condenser	Aluminium tubing
Liquid Suction Heat Exchanger	Tube to tube indirect contact type	Copper tubing
Receiver Drier	Tube - O' Ring Type RD	280 cm ³ net capacity
Expansion Valve	Thermostatic Expansion Valve	1 tonne capacity
Evaporator	Tube Fin Type Evaporator	Aluminium tubing

Table 2. Instrumentation of an Experimental AAC system

Measured Variable :	Instrument :	Range :
Temperature	Type K thermocouple	-50 to 100 °C
Pressure	Pressure Gauge	0 to 250 psi & 0 to 500 psi
Speed	Digital Tachometer	4 to 9999 rpm
Speed variation	Three Phase VARIAC	0-100 V & 0-30A
Velocity	Anemometer	0.1 to 15 ms ⁻¹
Power	Three phase Energy meter	(3*240) V & 3*(10-60) A

The refrigeration circuit of the system consists of compressor, condenser, receiver drier, expansion valve, evaporator & Liquid Suction Heat Exchanger (LSHX). The experimental system contains fan driven by an electric motor. The compressor in the experimental system is belt driven by an electric motor. The air flow passing through the condenser & evaporator can be achieved by fans. Table 1 and table 2 describe components and instrumentation of an experimental AAC system respectively.

EXPERIMENTAL PROCEDURE

1. Experimental Procedure Based on Varying Evaporator Temperature (Refrigerant Side)

As shown in figure 2, three phase supply is given to three phase electric motor via three phase starter, energy meter & ammeter voltmeter board. With the help of three phase starter, electric motor is started. Compressor is connected to motor via belt pulley arrangement & hence compressor pulley is also start rotating but still compressor is not started because compressor clutch is in disengaged position. Now AC blower fan regulator is turned to 1 position. Here compressor clutch is now engaged to compressor shaft & hence compressor starts rotating. Fan connected to motor starts rotating which helps to condense the refrigerant in condenser. Evaporator

blower fan is also starts rotating which helps to give conditioned air at evaporator outlet. Through valves arrangements, LSHX circuit is activated or deactivated. Voltmeter ammeter reading is measured. Motor & compressor speed is measured with help of tachometer. Air velocity at evaporator & condenser is measured with help of anemometer. After steady state condition, Temperatures from 1 to 15 points are measured with help of temperature indicator by positioning knob from 1 to 15 position one after other as shown in figure 2.

Normally Compressor clutch is disengaged when evaporator surface temperature is reached about or below 0°C in both without LSHX & with LSHX performance. After some duration, when evaporator surface temperature & evaporator air outlet temperature is going high then again compressor clutch is engaged & system starts. But for steady-state operation without interruption, evaporator surface temperature switch is deactivated.

2. Experimental Procedure Based on varying Compressor Speed (Air Side)

All procedure described above is followed in this case. In addition to this, three phase VARIAC circuit is connected for motor speed variation. Moving VARIAC knob from 0-100 V, supply voltage to three phase motor is increased from 0-415 V. Since motor is connected to compressor, variation in compressor speed is achieved. VARIAC knob is adjusted in such a way that final compressor speed achieved is in the interval of 250 rpm.

The principle of VARIAC is if voltage decreases then torque is also decreases. Hence for maintaining the same torque, slip increases i.e. speed falls [6].

The minimum compressor speed was selected as 750 rpm to avoid insufficient lubrication that might arise at lower speeds. The suction - -pressure is achieved in such a way that almost no frost appears on the evaporator surfaces under the entire range of the compressor speeds and other operating conditions.

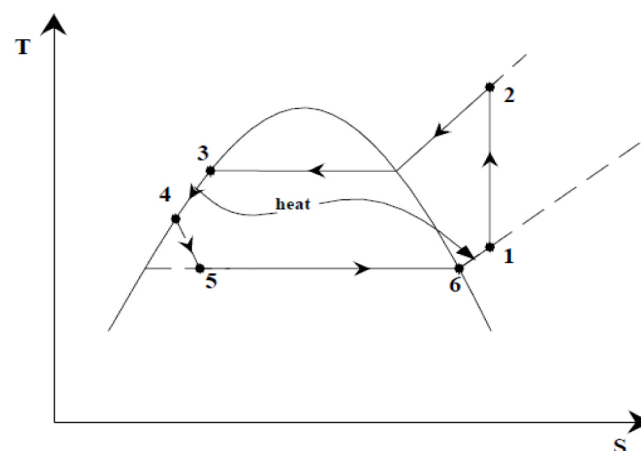


Figure 3. VCR cycle with LSHX on T-s diagram [7]