A REVIEW ON DUAL PURPOSE AUTOMOTIVE AIR-CONDITIONING SYSTEM

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ABSTRACT

This application concerns an automobile air conditioning system having two evaporators and one compressor. The focus of this review paper is on the development of a multi evaporator system (2 evaporators) to maintain the different operating temperature in evaporators with a single compressor, an individual expansion device and an air cooled condenser. The system consists of simultaneously two multi-functioning Evaporators. One of them is for Air-conditioning for space cooling (car cabin) and the other cater to provide the water cooling unit facility in vehicle. The desirable temperature is 18 ^{0}C in water cooling unit and 22 ^{0}C for vehicle cabin or space cooling. An air conditioner compressor of 1 ton is used for the setup purpose with R134a refrigerant. Multi evaporator systems yields the higher value of coefficient of performance compared to single evaporator system meant for different temperatures. There is easy control of temperature by controller valve for both evaporators. Also saving in initial cost and space required are the additional advantages with single compressor multi evaporator systems. The specific temperature required for water cooling unit is takes place by the special arrangement expansion valve, flash chamber, pressure reducing valve and controller.

Index Terms: Air Conditioning System, Multi-Evaporator, Mode Switching, Beverage Can Cooler, Vapor Compression, Evaporator Design

I. INTRODUCTION

There are many applications where air-conditioning is required at different temperatures. For example, system for specific temperature required in different location of cabin of vehicle, cooling of beverages in car, etc. cold air may be required at 22^{0}C for the space cooling and 18^0 C for cooling of food products, beverages. In these cases, it is necessary that each location is cooled by separate evaporators to maintain the particular temperature and produce the required cooling load. Hence it requires different air-conditioning units with single evaporator for each location.We can use different system to cater these loads but due to high initial cost this may not be economical viable. Instead it will be beneficial to use an air-conditioning unit with multiple evaporators working at different temperatures. Therefore, it is the purpose of this paper to introduce vapor compression system which uses a single compressor and single expansion devices to provide the concurrent testing

The COP of this simple system is given by:

$$COP = \frac{Q_{e,I} + Q_{e,II}}{W_c} = \frac{m_I (h_8 - h_6) + m_{II} (h_7 - h_4)}{(m_I + m_{II})(h_2 - h_1)}$$

Where (m_I & m_{II}) are the refrigerant mass flow rates through evaporator I and II respectively. They are given by:

$$m_I = \frac{Q_{e,I}}{(h_8 - h_6)}$$

$$m_{II} = \frac{Q_{e,II}}{(h_7 - h_4)}$$

II. DUAL-EVAPORATOR SYSTEM MODELLING

In many refrigeration or air conditioning installations, different temperatures are required at various points in the plant or different compartments in Vehicle. This is true in case of food transport in large containers. So, there is requirement of space cooling in driver's cabin and other for food cooling. Similarly, in some other cases, a large number of spaces have to be maintained at almost similar temperature. This occurs in the case of air conditioning of big transporting vehicles. Depending on the system requirements, various arrangements of vapor compression system can be made that can serve that particular purpose with respect to environmental and energy conservation. A basic vapor compression system can thus be used as a building block to develop complex air conditioning and refrigeration units.

III. COMPLEX DUAL-EVAPORATOR SYSTEMS

Classification of complex air conditioning system can be done in the various ways. The evaporators can be arranged in series or parallel. There can be just a single expansion valve catering to all the evaporators or there can be an individual expansion valve for each evaporator. In the similar way, a single compressor (staged or non-staged) can cater to all the evaporators or there can be multiple compressors in the system too. In certain cases, the system can have different outdoor units also, depending on the condensing requirements. The choice of the system arrangement depends on application, initial and operational costs. The most common of these arrangements is one with multiple evaporators connected in parallel, each with an individual expansion device, a variable speed compressor or a staged set of compressors and a single outdoor or condensing unit.

In other arrangements, more commonly available in residential units, there are two air conditioning circuits, a primary and a secondary. In the primary circuit a high performance refrigerant is used to produce a certain base line cooling effort which is transferred to the secondary circuit through the other refrigerant, usually water which is circulated to the air conditioned spaces. The flow rate for secondary refrigerant is controlled separately for each of the space rather than controlling the primary cycle. Many times, it is advantageous to use dual or higher stage compressor stacks where initial cost of a variable speed / variable displacement compressor is not tolerable. It is however not particularly evident, whether, in a new design, one big compressor should serve all evaporators or there should be an individual compressor for each evaporator or there should be an intermediate number of compressors. One basic disadvantage of a single compressor catering to all evaporators is that maintenance shut down affects all refrigerated spaces. However, there are some advantages of single compressor systems that more than shadow this disadvantage. In a residential air conditioning system, a big capacity compressor can cater to large number of rooms, each having its own evaporator, thus avoiding complex high voltage electrical circuitry for more than one compressor.

Also, a multi-evaporator system with single compressor can be designed to work more efficiently than a number of single evaporator systems.

IV. PROPOSED WORK

It is proposed to develop a multi evaporator system (2evaporators) to maintain the different operating temperature in evaporators with a single compressor, an individual expansion valve and an air cooled condenser. This system is used to maintain 22 ^{0}C and 18 ^{0}C in two evaporators. An air conditioner compressor of 1 ton is used. Refrigerant R134a will be used as it is required for compressor model.

The aims of experimental work:

I. Verification of this system will be done so as to obtain the required temperature.
II. Effect on system performance and remaining evaporators due to change in load on one of the evaporator.
III. Effect on the system performance for varying the evaporator operating combinations

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V. DESIGN AND SELECTION OF COMPONENTS

5.1 Compressor

The compressor rated cooling capacity is 4900KW i.e. 1.5TR. These capacity is divided into two evaporators for experimental work in which lowest temperature evaporator i.e.) is design for experimental work. The lowest temperature evaporator (water cooler) is designed for 0.5 TR capacity and higher temperature evaporator (space cooling) is designed for 1 TR capacity. Compressor model Sanden 5H11 choose for this system which give rated condensing pressure up to 20 bar and evaporative pressure 5 bar. The power for the clutch of compressor is provided by the 12v car battery.

Specification of Compressor

Sr No.	Parameter	Description
1.	Capacity	1.5TR or 4900KW
2.	Model no.	Sanden 5H11
3.	No. of Cylinder	5
4.	Diameter of Cylinder	35
5.	Refrigerant	R134a
6.	N.W(kg)	4.7kg
7.	Size	28*25*20

8.	Suction Pressure	5 bar
9.	Discharge Pressure	20 bar

5.2 Condenser

Condenser is the nothing but the heat transfer surface which rejects the heat at constant pressure so it is selected by calculating condenser load. It is simply calculated by formula.

Condenser load = Compressor capacity × heat rejection factor

An air cooled fin type condenser having surface area 55 cm × 42.5cm, 6 rows and 17 passes is selected which is capable to reject heat absorbed in evaporators and the energy equivalent of the work of compression in compressor. Heat rejection factor is obtained from condensing and evaporating temperature of system. The condenser capacity is determine using following formula,

$Q = U_o \times A_o \times \Delta T$ (W)

Where,

U_o= Overall heat transfer coefficient based on outside area (W/m2˚C),

A_o= Outside area of tube (m2),

ΔT = L.M.T.D for condenser (°C)

VI EXPERIMENTAL SETUP

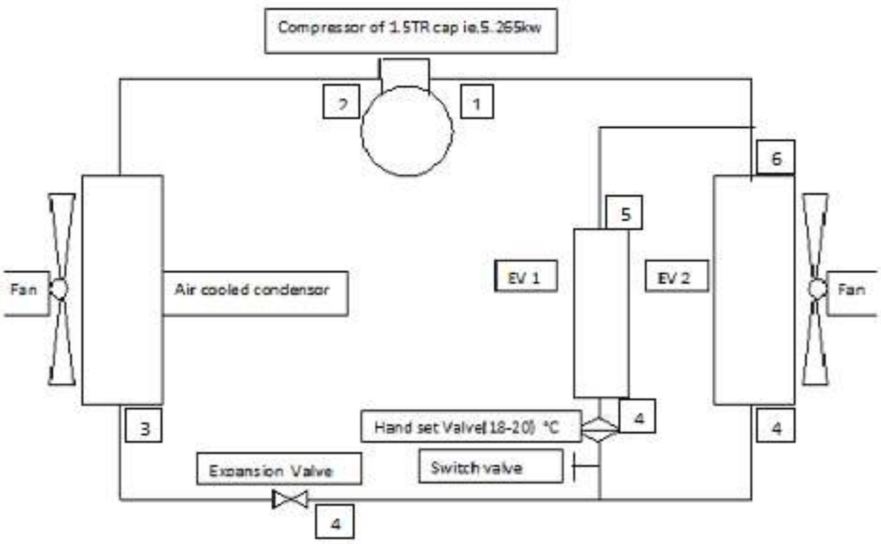

Fig: Experimental setup of Dual purpose automotive air-conditioning system

An experimental setup consists of a single compressor two evaporator system to maintain 18˚C and 22˚C in two separate compartments with cooling load. The major components of the system are compressor, condenser, fan, receiver, expansion valves, back pressure valves and evaporators. The thermocouples installed in the setup for temperature measurement at specific decided location. Pressure transducers are used for pressure measurement. A setup manufactured to experimentally investigate the performance of dual evaporator system in automobile AC system with two evaporator and refrigerant R134a.

Specifications of system

Sr. No.	Parameters	Description
1.	Type	Dual Evaporator system
2.	Refrigerant	R134a
3.	Capacity	1.5TR
4.	Compressor	Hermetically sealed, Reciprocating, five cylinders.
5.	Condenser	Finned coils, Air cooled
6.	Expansion device	Thermostatic
7.	Evaporator	Tube type

In this experimental setup four major parts i.e. compressor, condenser, expansion valves and evaporators plays an important role. All the components of the experimental setup are mounted on the metal frame

VII. REVIEW OF WORK CARRIED OUT

Jin-Long Lin et al. [1] a control strategy with flow distribution capability is proposed for multi-evaporator air-conditioners to accommodate different thermal demands in different rooms. The structure in the control strategy is based on a low-order, linear model obtained from system identification. To determine appropriate control parameters, theorems regarding stability of the closed-loop system are given. Experiments indicate that the proposed strategy can successfully regulate the indoor temperatures regardless that the reference settings for respective rooms are different and the settings are switched in the middle of the control process. It is assumed that the MEAC machine is operated in the mode that both (all) the evaporators are on throughout the control process. Although one can apply the results in the paper to design a control strategy for each of the modes, whenever a mode switching occurs, directly switching one control strategy to another could lead to discomfort to the users in the room (s) where the temperature(s) has (have) already been settle.

Abdullah A.A.A. Al-Rashed [2] R32 an optimized finned-tube evaporator with R600a (isobutane), R290 (propane), R134a, R22, for R410A is evaluated and analyzes the evaporator effect on the system coefficient of performance (COP). Results concerning the response of refrigeration system simulation software to an increase in the amount of oil flowing with the refrigerant are presented. The results of a refrigeration system simulation software to an increase in the amount of oil flowing with the refrigerant show that there are optimal values of the apparent overheat, for which either the exchanged heat or the refrigeration COP is maximized. In this study, they evaluated the performance of R600a, R134a, R290, R22, R410A, and R32, in which at critical temperatures and other thermo physical properties there is changes. The optimization is takes place for the evaporator by using non Darwinian evolutionary scheme and simulation is performed for optimized evaporator. The selection of compressor and other equipment sizing is affecting the COP of system.

Xuquan Li a et al. [3] the refrigerant flow control is improved by using electronic expansion valve (EEV) which is driven by a stepper motor in automobile air conditioning system. During the change in speed of vehicle and at the time of thermostatic on/off condition (EEV) make the quick response. The flow rate characteristic of the EEV for automobile air conditioning was presented. A microcontroller is used to receive the input signal and generate the output signal to control the opening of the EEV. Experimental results show that the new control method can feed adequate refrigerant flow into the evaporator in various operations. There is drop in the evaporator discharge temperature with 3^0 C. In conclusion, flow rate characteristic of the EEV for automobile air conditioning was presented and develop an EEV for automobile air conditioning system. By using EEV and fuzzy self-tuning control algorithm, a new refrigerant flow control method has been proposed. Under abrupt changing of the compressor's speed, the experiments showed that fuzzy self-tuning control algorithm could feed adequate refrigerant flow into the evaporator. The evaporator discharge air temperature has dropped by approximately 3^0 C.

Chen Wu a et al. [4] The suction pressure was taken as the controlled variable to modulate the speed of its compressor, and at the same time, the room air temperatures were taken to regulate the openings of individual electronic expansion valves (EEV). A self tuning fuzzy control algorithm with a modifying factor was incorporated in the controller. A controllability test was conducted with a dynamic thermodynamic model developed with a special modeling methodology. The controllability test has shown that the control strategy and algorithm are feasible and can achieve desirable control results. In this paper, a simplified lumped parameter dynamic thermodynamic model for a TEAC has been developed with a special modeling methodology. It can be concluded that such a novel control method, including the control strategy and algorithm, is feasible and valuable for MEAC product development work in practice.

Chen Lin a et al. [6] investigation was carried out for the performance of adjustable ejector used in a multi evaporator refrigeration system. The adaptability of the adjustable ejector for the system was first evaluated by the tests and the results show the adjustable ejector can efficiently deal the problem of variable primary cooling load in the system. The tests for the performance of pressure recovery were subsequently carried out. In this study, the ejector tests for a novel multi-evaporator refrigeration system with adjustable ejector were carried out in order to study the adaptability and pressure recovery performance of the adjustable ejector. The adjustable ejector can be efficient to keep the primary inlet pressure in design value when the primary flow rate varies.

D. W. Gerlach et al. [14] the performance of dual evaporator household refrigerators was studied experimentally and by numerical simulation. A serial connection where the refrigerant flows through the fresh food evaporator and then through the freezer evaporator without a pressure drop between the evaporator is considered. However, it also includes the development and validation of a complex computer model of the serial evaporator configuration.

Lee et al. [15] did work on control of a dual evaporator system using online system identification methods and their results showed good controller performance but analysis of the cycle dynamics was not presented.

VIII.CONCLUSION

We can then conclude that by using dual-evaporator system there can be reduction of energy used for different compressor and condenser for separate evaporators as well sufficient and required temperature and cooling can be maintained for different sections at the same periods, cost saving is the another benefit by utilizing multi-evaporator system.

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