Influence of Electronic Expansion Valve on the Performance of Window Air Conditioner Retrofitted With R407C

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***Abstract*: The object of this experimental study is to investigate the effects of the expansion devices on the performance of a one TR window air conditioner retrofitted with eco friendly alternative refrigerant R-407C. The widow air conditioner applying the expansion devices of a capillary tube, thermostatic expansion valve and electronic expansion valve is tested by varying changing condenser temperature from 40^0C to 55^0C, while maintaining evaporator temperature at 6^0C. The R 22 capillary tube system is utilized as baseline unit for the performance comparison with the R-407C system. The capacity for the R407C EEV system is higher by 10.1% at full charge condition than that for the R22 capillary tube system. The capacity for the R407C EEV system is higher by 10.2% at full charge condition than that for the R407C TEV system. The COP of R407C EEV system is higher by 15.4% and 12.3% than that of R407C capillary tube and thermostatic expansion valve respectively. The final result show an overall better performance of the electronic expansion valve compared with the thermostatic expansion valve and capillary tube.**

***Keywords*: Window air conditioner; Capillary tube; Thermostatic expansion valve; Electronic expansion valve; R-407C.**

Nomenclature

COP	-	Coefficient of performance.
TEV	-	Thermostatic expansion valve.
EEV	-	Electronic expansion valve.
TR	-	Tonne of refrigeration.
BIS	-	Bureau of Indian Standard.

I. INTRODUCTION

CFC (chlorofluorocarbon) and HCFC (hydrochlorofluorocarbon) refrigerants as refrigerants in a vapor compression refrigeration system are known to be the principal cause of ozone depletion and global warming, production and use of these refrigerants have hence been restricted [1].As a result, a search for alternative refrigerants that fit the requirements in an air-conditioner or a heat pump has been underway. Refrigerant mixtures which are composed of HFC (hydrofluorocarbon) refrigerants having zero ODP (ozone depletion potential) are now being suggested as drop-in or mid-term replacement. An air-conditioning system based on these new alternative refrigerants must be modified or redesigned because thermophysical properties of these alternative refrigerants differ from those of conventional refrigerants. In order to maintain or improve the performance of the cycle, the operating characteristics of individual components of the cycle should be redefined with these new alternative refrigerants. It has been reported that R407C is a close match to R22 with respect to energy efficiency. The thermo physical properties of R22 and R407C are shown in tab.1. The type an electronic expansion valve (EEV) considered is a solenoid valve linked to an electronic controller. The operation of electronic controller is based on four temperatures, the refrigerant at inlet and outlet of evaporator and on the air inlet and outlet of air cooled evaporator measured by means of thermoresistances. An EEV is a variable area expansion device, which is commonly used in small refrigeration and air conditioning systems. The flow inside EEV is very complex and pressure drop through the EEV has a strong influence on the performance of the whole system.

Table 1- Thermo- physical properties of selected refrigerants

Properties		Refrigerants	
		R-22	R-407C
Molecular weight	[g/mol]	86.5	86.2
Normal boiling point	[ºC]	-40.9	-43.6
Critical temperature	[ºC]	96.2	86.7
Critical pressure	[bar]	50.5	46.2

Latent heat	at 25 ºC [kJ/kg]	180.3	185.8
Bubble pressure	at 25 ºC [bar]	10.4	12.0
Saturated liquid density	at 25 ºC [kg/m^3]	1191	1140
Saturated vapour density	at 25 ºC [kg/m^3]	44.8	43.2
Temperature glide	at 1 atm[K]	0.0	6.0
Saturated liquid specific heat	at 10ºC [kJ/kgK]	1.29	1.54
	at 50ºC [kJ/kgK]	1.46	1.79

II. EXPERIMENTAL TEST FACILITY

An experimental setup is designed to measure the performance of the window air conditioner under variable operating conditions. The T-S diagram of vapour compression system is shown in fig.1. The test rig includes the capillary, thermostatic and electronic expansion valve is shown in fig.2. The nominal cooling capacity of the window air conditioner is 3.5 kW using R22 and R-407C as a working fluid. The window air conditioner consists of a hermetic type compressor, two heat exchangers (condenser and evaporator), an expansion devices and environmental chambers to simulate the indoor and outdoor conditions and the necessary instrumentation. It is modified to accommodate various sensors and mass flow meter. The arrangement is done in such a way that any component can be replaced without refrigerant loss. The detailed specifications of the major components of the tested window air conditioner are given in Table 2.

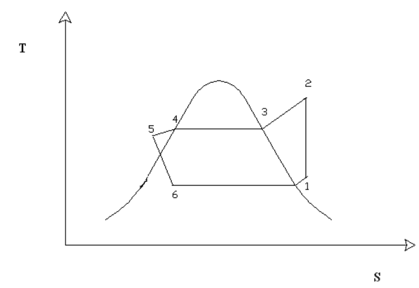

Fig.1. T-S diagram of vapour compression system

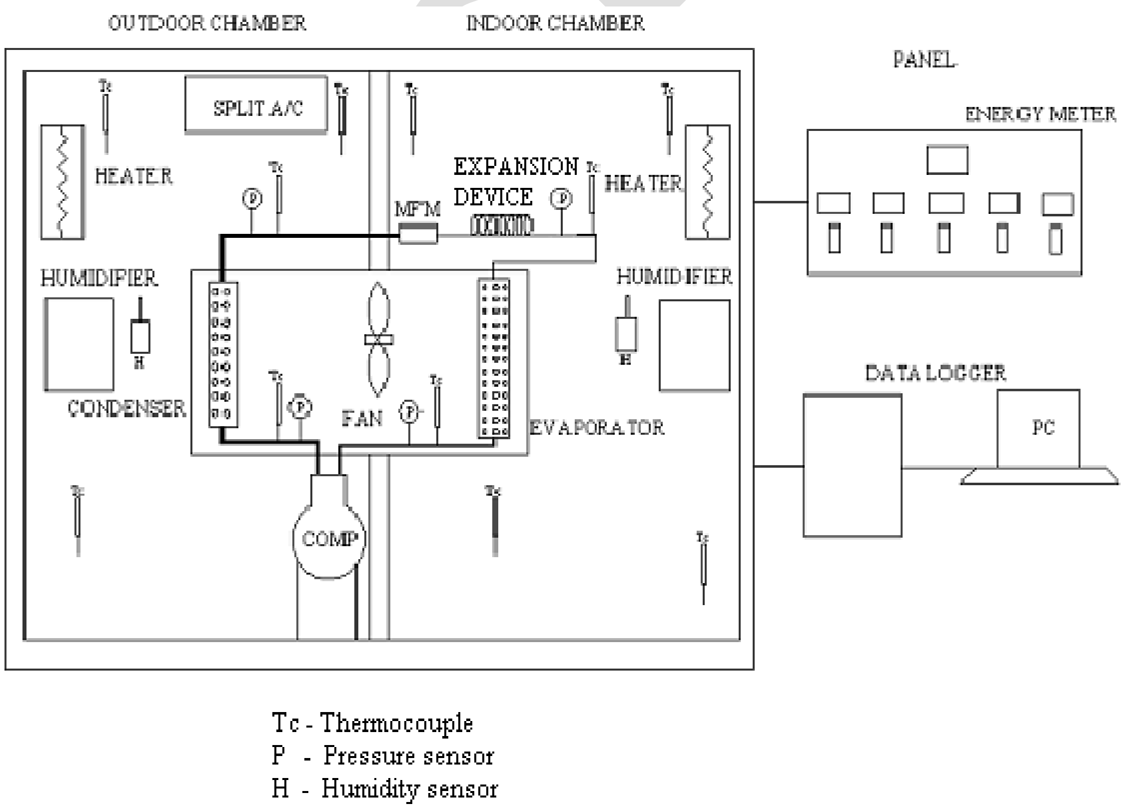

Fig.2. Schematic diagram of the test facility.

Table 2: Specifications of the main components of the system

Components	**Specifications**
Compressor	Manufacturer : Kirloskar Model No. : AHR 13 Type : Hermetic (Scroll) Rated capacity (kW) : 3.5 kW
Capillary tube	Diameter (mm) : 1.63 Length (mm) : 1860
Thermostatic expansion valve	Manufacturer : Danfoss Orifice diameter (mm) : 1.2 Orifice length (mm) : 2.5
EEV	Manufacturer : Danfoss Step (pulse) : 0-480 Orifice diameter (mm) : 1.4 Orifice length (mm) : 3

2.1. Environmental Chambers

The indoor and out door simulation chambers are made of double skin PUF insulators walls and the dimensions are chosen as per BIS: 1391 – 1992 [7]. The heat load is provided by a 3000 Watts heater placed in the indoor chamber which is controlled by a variac. There is a Wattmeter of ± 0.5 % accuracy provided to measure the power supplied to the heater. To ensure uniform temperature distribution within the chambers air circulating fans are provided. A 2 TR split air conditioner is provided in the out door chamber to dissipate the heat from condenser. Humidifiers are provided in the both the chambers to maintain the required relative humidity.

2.3. Instrumentation

The mass flow rate of refrigerant is measured using a corialis type flow meter of accuracy ±0.25%. To measure the compressor power, a digital Wattmeter of accuracy ± 0.5 % is provided. Pressure transducers with ±0.25 % accuracy and J-type thermocouples with ±0.1% accuracy are provided to measure the respective refrigerant pressures and temperatures at salient points. Thermocouples are also placed inside the chambers to measure the average room temperatures. The relative humidity is measured using humidity sensor of accuracy ±0.1 %. All sensors are connected to a computerized data acquisition system (AGILENT 34970 A).

III. EXPERIMENTATION

The first step of the test procedure is to determine full charge under a standard condition, condenser temperature at 50^0C and evaporator temperature 6^0C. The full charge condition is selected to have a maximum COP. For the window air conditioner with the capillary tube using R22 and R407C (called as ‘‘the R22 capillary tube system’’ and ‘‘the R407C capillary tube system’’, respectively). In order to determine full charge amount of the refrigerant, which is added into the window air conditioner in a 50 g increment until the maximum COP is obtained for each system. In this study, the tests for the window air conditioner with the EEV using R407C (called as ‘‘the R407C EEV system’’) are performed by setting the same full charge as the capillary tube system in order to compare characteristics of R407C EEV at the same basis of different condenser temperatures. During the tests, the EEV opening is manually changed to maximize the COP at each operating condition and charge amount. Since the window air conditioner is normally charged in the cooling mode [2], the tests in this study are carried out in the cooling mode only. Refrigerant temperature entering the evaporator is kept at 6 ^{0}C, and that entering the condenser is varied at 40 ^{0}C, 45 ^{0}C, 50 ^{0}C, and 55 ^{0}C. Temperature, pressure are monitored using a data acquisition system. The test data are recorded continuously for 40 min with 2-s intervals. Refrigerant capacity, compressor exit temperature, compressor power and COP are calculated from obtained parameters. Cooling capacity is calculated by using refrigerant flow rate and enthalpy difference between evaporator inlet and outlet [3, 4].

IV. RESULTS AND DISCUSSIONS

By varying the condenser temperatures the experiments are carried out, for both the refrigerants R-22 and R-407C. The performance parameters such as capacity, compressor exit temperature, compressor power and COP are compared between R-22 and R-407C with capillary tube, thermostatic expansion valve and electronic expansion valve. Figures 3 to 6 show the variation of COP, capacity, compressor discharge temperature and compressor power for R22 capillary, R407C TEV and R407C EEV as a function of different condenser temperature. The capacity of the R407C EEV system is higher by 10.1% than that for the R22 capillary tube system. The COP of the R407C EEV system is higher by 13.08% than that for the R22 capillary tube system.

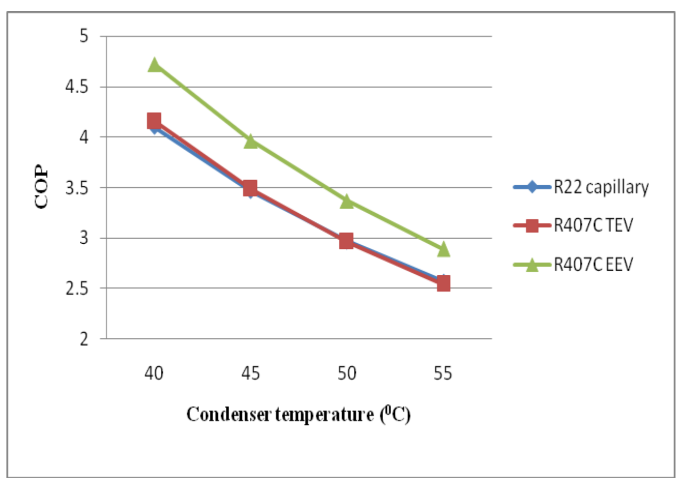

Fig 3: COP variations of R22 capillary,R407C TEV and R407C EEV at various condensing temperatures.

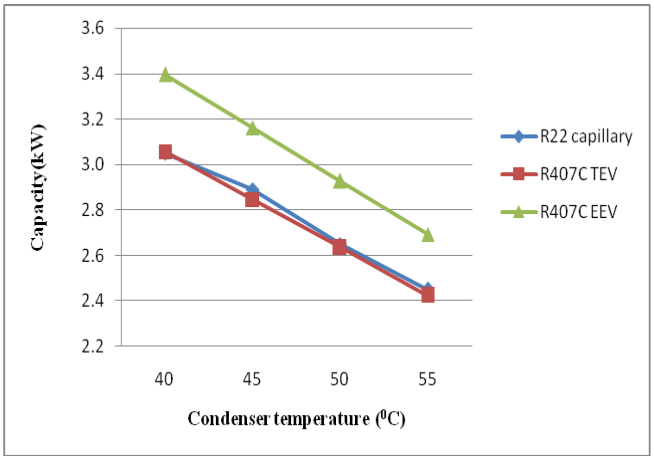

Fig 4: Capacity variations of R22 capillary,R407C TEV and R407C EEV at various condensing temperatures.

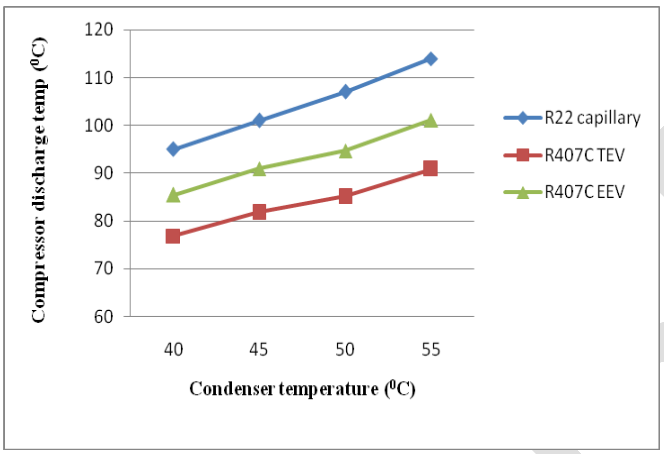

Fig 5: Compressor discahrge temperature variations of R22 capillary,R407C TEV and R407C EEV at various condensing temperatures.

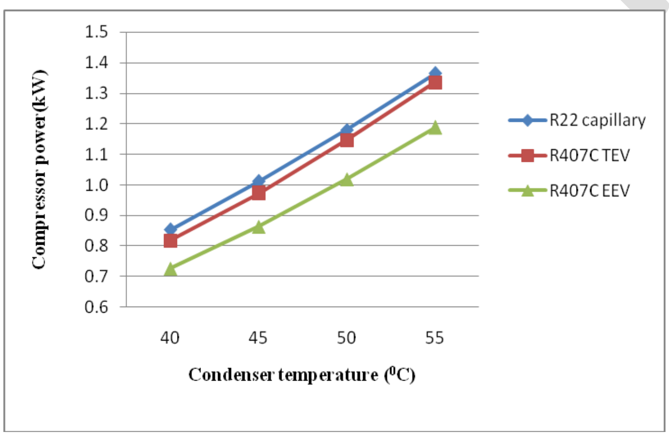

Fig 6: Compressor power variations of R22 capillary,R407C TEV and R407C EEV at various condensing temperatures.

Figures 7 to 10 show the variation of COP, capacity, compressor discharge temperature and compressor power for R407C capillary, R407C TEV and R407C EEV as a function of different condenser temperature. The result shows that R407C EEV performance is better than R407C TEV and R407C capillary. The COP of R407C EEV system is higher by 15.4% and 12.3 % than that of R407C capillary tube and thermostatic expansion valve respectively. The capacity for the R407C EEV system is higher by 10.2% and 17.1% than that for the R407C TEV system and R407C capillary.

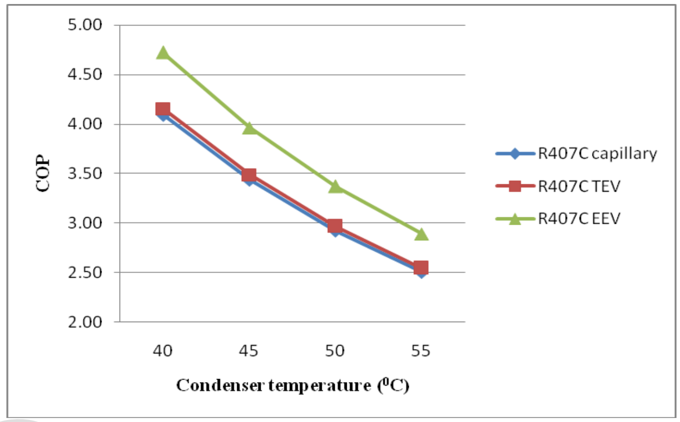

Fig 7: COP variations of R407C capillary,R407C TEV and R407C EEV at various condensing temperatures.

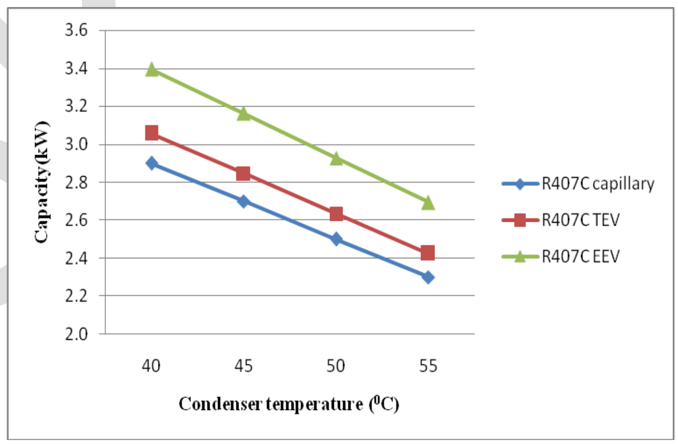

Fig 8: Capacity variations of R407C capillary,R407C TE and R407C EEV at various condensing temperatures.

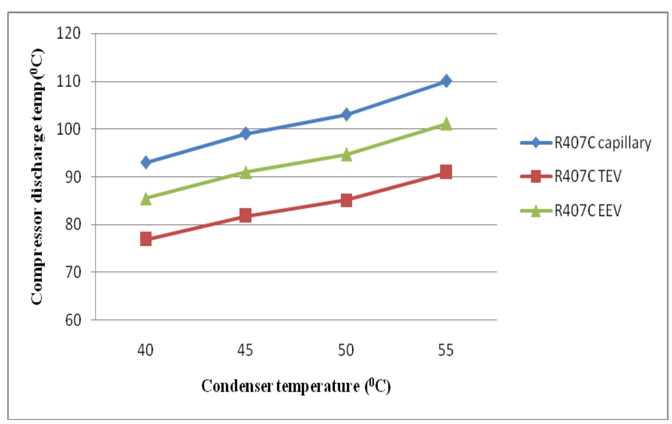

Fig 9: Compressor discharge temperature variations of R407C capillary, R407C TEV and R407C EEV at various condensing temperatures.

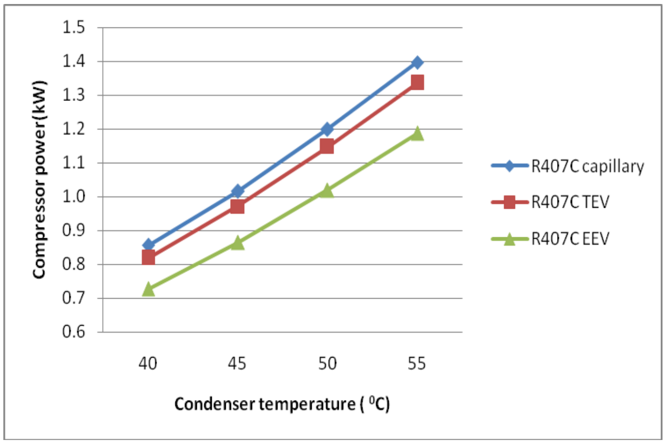

Fig 10: Compressor power variations of R407C capillary,R407C TEV and R407C EEV

IV. CONCLUSIONS

The effects of the expansion devices on the performance of a one TR window air conditioner using refrigerants R22 and R-407C have been determined through experimental set up. The R22 capillary tube system is utilized as a baseline unit for the performance comparison with the R407C system. An experimental study reveals that cooling capacity, COP, compressor discharge temperature and compressor power of window air conditioner using electronic expansion valve is better than those of thermostatic expansion valve and capillary tube. The final result shows an overall better performance of the electronic expansion valve compared with the thermostatic expansion valve and capillary tube.

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