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Experimental analysis of Thermostatic expansion valve, Constant expansion device & Cap tube on vapour compression refrigeration system

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Abstract

This paper is concerned with the overview of the project based on the experimental analysis and verification of thermostatic expansion valve, constant expansion valve and capillary tube on vapour compression refrigeration system with refrigerant R134a. For the purpose of analysis, the experimental set up with three expansion devices is manufactured. Thermal Expansion Valve in the system was selected as per load requirement and type of refrigerant. Capillary and constant expansion device is selected as per the compressor specification.

TXV were found to produce and control degree of superheat of refrigerant, higher efficiency than constant expansion valve and capillary tubes across the entire range of operating conditions.

Keywords: *Capillary tube, constant expansion valve, thermostatic expansion valve.*

1. Introduction

Out of all refrigeration systems, the vapour compression refrigeration system is the most important system from the view point of commercial and domestic utility. It is most practical form of refrigeration. In this system the working medium is a vapour which evaporates and condenses alternately between vapour and liquid phases without leaving the refrigerating plant. During evaporation working medium absorbs heat from the cold body, this heat is used as its latent heat for converting it from the vapour to liquid. During condensation, working medium rejects heat to external body, so the cooling effect is produced. The basic functions of an expansion device used in refrigeration systems are to:

1. Reduce pressure from condenser pressure to evaporator pressure, and
2. Regulate the refrigerant flow from the high-pressure liquid line into the evaporator at a rate equal to the evaporation rate in the evaporator

1.1 Capillary Tube:

A capillary tube is a long, narrow tube of constant diameter. The word “capillary” is a misnomer since surface tension is not important in refrigeration application of capillary tubes. Typical tube diameters of refrigerant capillary tubes range from 0.5 mm to 3 mm and the length ranges from 1.0 m to 6 m. Several combinations of length and bore are available for the same mass flow rate and pressure drop.

1.2 Thermostatic Expansion Valve:

Thermostatic expansion valve is the most versatile expansion valve and is most commonly used in refrigeration systems. A thermostatic expansion valve maintains a constant degree of superheat at the exit of evaporator; hence it is most effective for dry evaporators in preventing the slugging of the compressors since it does not allow the liquid refrigerant to enter the compressor. This consists of a feeler bulb that is attached to the evaporator exit tube so that it senses the temperature at the exit of evaporator. The feeler bulb is connected to the top of the bellows by a capillary tube. The feeler bulb and the narrow tube contain some fluid that is called power fluid. The power fluid may be the same as the refrigerant in the refrigeration system, or it may be different. In case it is different from the refrigerant, then the TEV is called TEV with cross charge.

1.3 Constant Expansion Valve:

The use of constant pressure expansion valves as expansion device in vapour compression refrigeration offer functional advantages which result in initial and operating cost benefits to the manufacturers and users of air conditioning equipment. Operating performance is improved at typical application and power consumption is reduced during peak summer time demand periods.

1.4 Experimental setup

Set up is manufactured for the analysis purpose. Three expansion devices namely thermostatic expansion valve, constant expansion valve and capillary tube are placed in the vapour compressor refrigeration system in parallel with hand shut off valves for the purpose of analysis individually.
Compressor specification are:

Model Number	**THK9414YGS**
Displacement (CC)	6.90
Power (Watts)	**230**
Current (Amp)	1.60
LRA (Amp)	15.0
Circuit	CSIR

Table 1: Compressor Specification

Sr. No.	Parameter	Description
1	Type	Test Rig
2	Refrigerant	R134a
3	Capacity	
4	Compressor	Hermetically Sealed, Single cylinder, reciprocating.
5	Condenser	Air Cooled, Finned Coil.
6	Expansion Device	TEV, Constant Exp. Valve, Capillary Tube.
7	Evaporator	Coil Type

Table 2: Test Rig Parameters

2. Literature Review

Dhumal et. al. [1] studied the effect of R407C refrigerant which is HFC refrigerant on vapour compression refrigeration system with different expansion devices. Thermostatic expansion valve requires 50% more work input at all loads load than the capillary tube but the average increase in compressor work with increase in load is 14% which is much lesser than the capillary tube where it is 75%. The TEV shows 43% low refrigerant flow rate as compared to capillary tubes and it decreases with increase of load on the system. The capillary with Dia. 0.50” shows higher mass flow rate of refrigerant and it increases with increase of load on the system. Capillary with Dia. 0.55” shows steady increase in mass flow rate with load. The increase in refrigerant mass flow rate in TEV is 12% where as 90% in capillary tube with Dia. 0.50”. The TEV gives higher refrigeration effect as compared to other two expansion devices and its performance increases by 86% at higher loads. The refrigeration effect is increased by only 50% in capillary tube with increase in load. The rate of heat extraction of the Thermostatic expansion valve is much better than the capillary tubes. Thermostatic expansion valve shows only 12% increase in refrigerant mass flow rate for 86% increase in refrigeration effect whereas capillary shows 90% increase in refrigerant mass flow rate for 50% increase in refrigeration effect.

Mutalubi Akintunde [3] studied the effect of pitch of coiled cap tube on VCR system with R134a. They examined the two configurations of capillary tubes i.e. Helical and Serpentine coils. As per their results of performance testing, variations in pitch of coil do not have any significant effect on performance but the diameter of capillary tube coil has effect on performance for helical cap tube.

Amol Gawali et. al. [2] has performed the experiment on vapour compression refrigeration system of 0.33 TR and refrigerant used was R12. He used thermostatic expansion valve and Capillary tube for analysis with R12. The analysis focuses on Coefficient of Performance for both (Capillary tube and Thermostatic expansion valve). The Carnot, Theoretical and Actual Coefficient of Performance was checked. The results of Coefficient of Performance obtained are plotted in the form of bars:

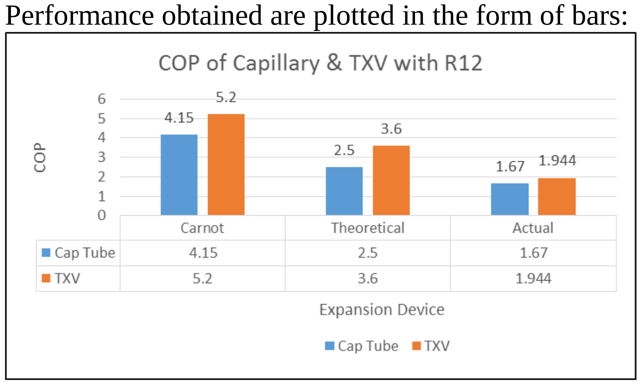

Figure 1. COP of Capillary & TXV with R12 [2]

Krzysztof banasiak et. al. [9] studied the multi ejector expansion system for R744 vapour compression units on system rated for 70kW at 35 degree Celsius outlet temperature of gas cooler and -3 degree Celsius of evaporator temperature for four cartridge sized for ejectors system and this system was analyzed & verified experimentally. Multi ejector block system retains the dynamic operational characteristics and precise control of discharge pressure with load variations and atmospheric conditions.

3. Calculations

3.1 Readings for TEV, Const Exp & Cap tube.

Valve	Unit	TEV	Const Exp	Cap tube
T_{CI}	^0C	66.5	58.2	66.7
T_{CO}	^0C	31.3	29.3	30.4
T_{EI}	^0C	16.4	13.7	10.6
T_{EO}	^0C	30.1	32.6	36.1
T_{bath}	^0C	18.0	18.0	18.0
P_1	Bar	2.8	1.8	2.1
P_2	Bar	18.2	15.5	16.8
$V_{compressor}$	Volt	226	223	227
$I_{compressor}$	Amp	2.05	2.1	2.1
$V_{evaporator}$	Volt	185	168	172
$I_{evaporator}$	Amp	4.3	4.1	3.7

Table 3: Observation Table

3.2 Calculations

3.2.1 TEV

From the property table of R134a and with interpolation & formulations, the values of enthalpies are:

h_1=397.96 KJ/Kg
h_2=436.87 KJ/Kg
h_3=293.04 KJ/Kg
h_4=293.04 KJ/Kg
T_L= 271.77 K
T_H= 336.37 K

$COP_{Carnot} = (T_L) / (T_H-T_L)$
$= 4.20$

$COP_{Theoretical} = (h_1-h_4) / (h_2-h_1)$
$= 2.69$

$COP_{Actual} = (V_{evap.} \times I_{evap.}) / (V_{comp.} \times I_{comp.})$
$= 1.72.$

Power required by compressor

$P_{Comp} = V_{comp.} \times I_{comp}$
$= 226 \times 2.05$
$= 463.3$ Watts

Power required by evaporator (Refrigerating Effect)

$P_{Evap} = V_{comp.} \times I_{comp}$
$= 223 \times 2.1$
$= 795.5$Watts

3.2.2 Constant Expansion Device

From the property table of R134a and with interpolation & formulations, the values of enthalpies are:

h_1=389.89 KJ/Kg
h_2=436.25 KJ/Kg
h_3=281.97 KJ/Kg
h_4=281.97 KJ/Kg
T_L= 260.29 K
T_H= 329.58 K

$COP_{Carnot} = (T_L) / (T_H-T_L)$
$= 3.76$

$COP_{Theoretical} = (h_1-h_4) / (h_2-h_1)$
$= 2.33$

$COP_{Actual} = (V_{evap.} \times I_{evap.}) / (V_{comp.} \times I_{comp.})$
$= 1.47.$

Power required by compressor

$P_{Comp} = V_{comp.} \times I_{comp}$
$= 223 \times 2.1$
$= 468.3$ Watts

Power required by evaporator (Refrigerating Effect)

$P_{Evap} = V_{comp.} \times I_{comp}$
$= 168 \times 4.1$
$= 688.8$ Watts

3.2.3 Capillary Tube

From the property table of R134a and with interpolation & formulations, the values of enthalpies are:

h_1=393.47 KJ/Kg
h_2=446.9 KJ/Kg
h_3=287.43 KJ/Kg
h_4=287.43 KJ/Kg
T_L=264.21 K
T_H=332.96 K

COP_{Carnot} = $(T_L) / (T_H-T_L)$
= 3.84.

$COP_{Theoretical}$ = $(h_1-h_4) / (h_2-h_1)$
= 1.98.

COP_{Actual} = $(V_{evap.} \times I_{evap.}) / (V_{comp.} \times I_{comp.})$
= 1.34.

Power required by compressor

P_{Comp} = $V_{comp.} \times I_{comp}$
= 227 x 2.1
= 476.7 Watts

Power required by evaporator (Refrigerating Effect)

P_{Evap} = $V_{comp.} \times I_{comp}$
= 172 x 3.7
= 636.4 Watts

Carnot, Theoretical and Actual Coefficient of performance are found by above formulations and these are plotted in the form of bar graph.
The power required by compressor and refrigerating effect for obtaining constant bath temperature is also compared and plotted in graphical format.

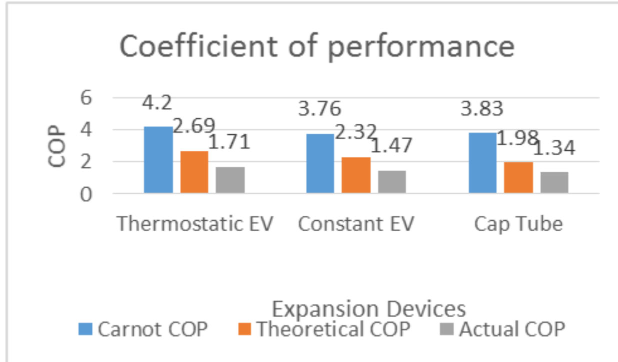

Figure 2: Comparison of COP

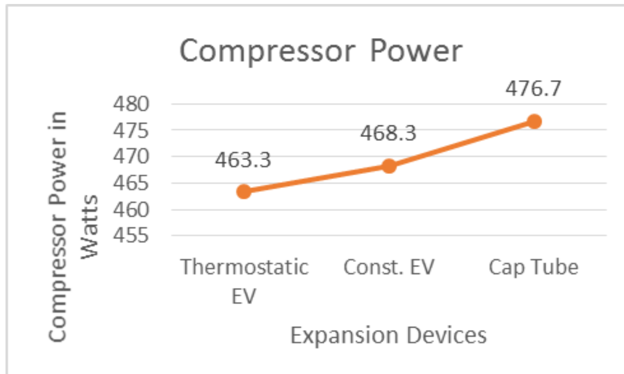

Figure 3: Comparison of Compressor Power

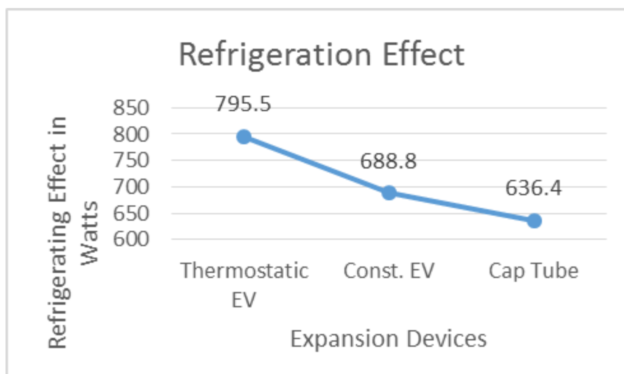

Figure 4: Comparison of Compressor Power

4. Conclusions

1. Coefficient of performance of vapour compression refrigeration system is calculated for Thermostatic expansion valve, constant expansion valve and

capillary. Carnot, theoretical and actual COP of thermostatic expansion valve is more than constant expansion & capillary tube.

2. Fixed expansion devices, such as capillary tubes & constant expansion valve, work at one present level and have no ability to compensate for load changes
3. Thermostatic expansion valve provides maximum efficiency over a wide temperature and load range, it gives improved refrigerant return to the compressor assures better cooling at high temperatures and reduces the possibility of liquid slugging which can destroy the compressor.
4. At same operating conditions, the refrigerating effect produced by using thermostatic expansion valve is 13% more than constant expansion valve 20% more than capillary tube.
5. The overall performance of the Thermostatic expansion valve is reasonably good as compared to capillary tube.

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