ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 8, Issue 3, March 2021

Comparison of Performance on Various Metering Devices used in Open type Refrigeration System

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Abstract*:* Now-a-days majority of the refrigeration equipments works on the vapour compression system. In vapour compression refrigeration machines, the heat is removed from the cold by evaporation of the refrigerant which is given a thermal potential so that it can gravitate to a natural sink by compressing the vapour produced. The performance of the system depends on all the components of the system. Eventhough theoretical calculations can make effective new designs possible they may fail due to some real time uncertainties. Hence it is better to perform experimental investigations for optimization of certain design parameters. The paper taken up for review is concerned with the overview of the project based on the experimental analysis and verification of capillary tube, automatic expansion valve (AEV) and thermostatic expansion valve (TEV) on vapour compression refrigeration system with refrigerant R134a. An experimental set up with three metering devices is manufactured for analysis purpose. TEV was found to produce higher COP than constant expansion valve and capillary tube across the entire range of operating conditions.

Keywords: Vapour compression system, Capillary tube, Automatic expansion valve, Thermostatic expansion valve.

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I. INTRODUCTION

A vapour compression refrigeration system (VCR) is an improved type of air refrigeration system in which a suitable working substance, termed as refrigerant is used. In this system R-134a is used as refrigerant. This refrigerant is capable of readily evaporation and condensation without leaving the plant during the evaporation state it absorbs heat from heated body. This absorbed heat is used as latent heat for converting it from liquid to vapour state. In the condensation or cooling process it rejects the heat to the external body. Thus it produces a cooling effect in the working fluid. This system is the most practical form of refrigeration. This VCR system is generally used for all industrial and commercial purpose from a small refrigerator to a big airconditioning plant.

II. DESCRIPTION

Vapour compression refrigeration system consists of the following parts.

Compressor: The purpose of the compressor is to raise the temperature and pressure of the input refrigerant which has low pressure and low temperature.

Discharge line: A discharge line is used for delivering the high pressure, high temperature vapour from the discharge of the compressor to the condenser.

Condenser: The temperature of the hot refrigerant is reduced using a coolant with the help of condenser.

Receiver tank: Receiver tank is used to provide storage for a condensed liquid so that a constant supply of liquid is available to the evaporator as required.

Liquid line: A liquid line transmits the liquid refrigerant from the receiver tank to the refrigerant flow control.

Expansion valve: The proper amount of refrigerant liquid to the evaporator is controlled by the expansion valve.

Evaporator: An evaporator provides a cooling effect to the refrigerated space. The liquid refrigerant absorbs heat from the refrigerated surface and gets converted into refrigerant vapour.

Suction line: The low pressure vapour from the evaporator is transferred to the suction inlet of the compressor with the help of suction line.

III. WORKING PRINCIPLE

The vapour at low temperature and low pressure enters the compressor where it is compressed which makes the temperature and pressure to increase considerably. From the compressor the vapour enters the condenser where it is condensed to a very high pressure liquid and it is collected in a receiver tank. From the receiver tank, the refrigerant slowly passes through the expansion valve, where it is throttled down to a lower pressure. Finally it reaches the evaporator where it extracts heat from the surrounding where it is being refrigerated and vaporizes to low pressure vapour. Thus the surrounding is cooled. From the evaporator the low pressure refrigerant vapour enters the compressor. This process is repeated as a cycle.

IV. METERING DEVICE

The metering device is also known as expansion device or throttling device. It divides the high pressure side and the low pressure side of a refrigerant system. It is connected between the receiver and the evaporator.

The metering device performs the following functions:

1. It reduces the high pressure liquid refrigerant to low pressure liquid refrigerant before being fed to the evaporator.
2. It maintains the desired pressure difference between the high and low pressure side of the system, so that the liquid refrigerant vaporizes at the designed pressure in the evaporator.
3. It controls the flow of refrigerant according to the load on the evaporator.

V. CAPILLARY TUBE

It is a copper tube of small internal diameter and of varying length depending upon the application. The inside diameter of the tube used in refrigeration work is generally about 0.5mm to 2.25mm. The length varies from 0.5m to 5m. It is used as an expansion device in small capacity hermetic sealed refrigeration. It is installed in the liquid line between the condenser and the evaporator. A fine mesh screen is provided at the inlet of the tube to protect it from contaminants.

VI. THERMOSTATIC EXPANSION VALVE (TEV)

It is a refrigerant control device whose operation depends upon the increase or decrease of temperature of evaporator or suction line. This is also called a constant superheat valve because it maintains a constant superheat of the vapour refrigerant at the end of the evaporator coil by controlling the flow of liquid refrigerant through the evaporator.
It contains of a needle valve, a valve seat, a diaphragm, a fluid charged remote feeler bulb, a controlling spring and an adjusting screw. A strainer is also fitted at the entrance to the valve to prevent any foreign matter from entering it.

VII. AUTOMATIC EXPANSION VALVE (AEV)

It is a variable restriction type expansion valve. It is also called as constant pressure expansion valve since it maintains constant pressure in the evaporator. This valve consists of a needle and seat, a pressure bellows or diaphragm, spring with an adjusting screw and a strainer. It has a metallic body with inlet and outlet. A needle valve is fitted on the valve seat. It opens or closes the orifice with the help of the diaphragm fitted in the body. An adjusting screw is fitted for increasing or decreasing the entrance of the liquid in the evaporator. A strainer is fitted at the liquid inlet of the valve in order to prevent the entrance of foreign materials.

VIII. EXPERIMENTAL SETUP

The Experimental set up is manufactured for the analysis purpose. Three metering devices namely capillary tube, constant expansion valve and thermostatic expansion valve are connected in the open type refrigeration system in parallel with hand operated valves for the purpose of analysis individually.

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

Table 1 Compressor Specification

S.NO	PARAMETER	DESCRIPTION
1	Type	Test rig
2	Refrigerant	R-134A
3	Capacity	-----
4	Compressor	Hermetically sealed, single cylinder, reciprocating
5	Condenser	Air cooled, finned coil
6	Evaporator	Shell and coil type
7	Expansion device	Capillary Tube, Automatic expansion valve and Thermostatic expansion valve

Table 2 Test Rig Parameters

IX. EXPERIMENTAL PROCEDURE

- Pour measured quantity of water in the evaporator tank (20 liters).
- Note the initial temperature of water in the evaporator tank.
- Allow the unit to run for one hour.
- Note down the final temperature of water in the evaporator tank.
- Note the suction and discharge pressure.

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- Note the suction and discharge temperature.
- Note watt meter reading.
- Pump down and stop the unit.

X. OBSERVATION & TABULATION

Mass of the water in the evaporator tank : M_w (Kg)
Initial temperature of water in the evaporator tank :T_1 (^{0}C)
Final temperature of water in the evaporator tank : T_2 (^{0}C)
Specific heat of water : CP_w (KJ/Kg K)
Watt meter reading : W (KW)
Suction pressure : P_1 (Psi)
Discharge pressure : P_2 (Psi)
Suction temperature : T_1 (^{0}C)
Discharge temperature : T_2 (^{0}C)
Test duration time : t (sec)

S.NO	PARAMETER	CAP. TUBE	AEV	TEV
1	M_w (Kg)	20	20	20
2	T_1 (^{0}C)	32	32	32
3	T_2 (^{0}C)	6	4	2
4	CP_w (KJ/KgK)	4.187	4.187	4.187
5	W (KW)	0.8	0.7	0.6
6	P_1 (Psi)	18	45	41
7	P_2 (Psi)	150	120	165
8	T_1 (^{0}C)	11.4	12.5	12.1
9	T_2 (^{0}C)	44	40	41
10	t (sec)	3600	3600	3600

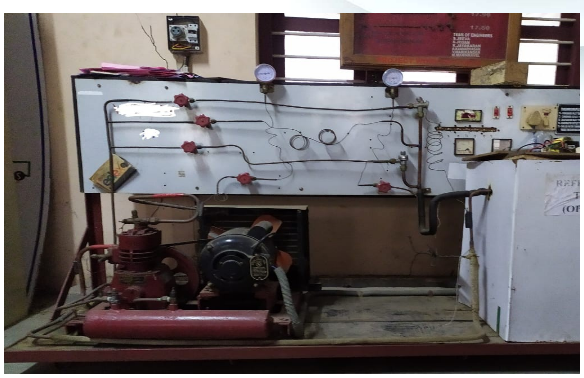

Figure 1. Experimental Set-up

Calculation for Capillary Tube:

1. Refrigeration Effect (N):

$N = M_w\ CP_w\ (T_1-T_2) / 3600$
$N = 20 \times 4.187 \times (305-279) / 3600$
$= 2177.24 / 3600$
$N = 0.6048$ KJ/Sec

2. Capacity (Q):

$Q = N / 3.5$
$= 0.6048 / 3.5$
$Q = 0.1728$ Ton

3. Coefficient of performance (COP):

COP = N / Workdone
= 0.6048 / 0.8
COP = 0.756

Calculation for Automatic Expansion Valve:

1. Refrigeration Effect (N):
$N = M_w\ CP_w\ (T_1-T_2) / 3600$
$N = 20 \times 4.187 \times (305-277) / 3600$
$= 2344.72 / 3600$
$N = 0.6513$ KJ/Sec

2. Capacity (Q):

$Q = N / 3.5$
$= 0.6513 / 3.5$
$Q = 0.1861$ Ton

3. Coefficient of performance (COP):

COP = N / Workdone
= 0.6513 / 0.8
COP = 0.9304

Calculation for Thermostatic Expansion Valve:

1. Refrigeration Effect (N):

$N = M_w\, CP_w\, (T_1 - T_2) / 3600$
$N = 20 \times 4.187 \times (305-275) / 3600$
$= 2512.2 / 3600$
$N = 0.6978$ KJ/Sec

2. Capacity (Q):

$Q = N / 3.5$
$= 0.6978 / 3.5$
$Q = 0.1994$ Ton

3. Coefficient of performance (COP):

COP = N / Workdone
= 0.6978 / 0.6
COP = 1.163

XI. CONCLUSION

Experimental studies have been carried out to evaluate the Refrigeration system performance under various operating conditions. From the investigations, the following conclusions are drawn:

- Coefficient of performance of vapour compression refrigeration system is calculated for capillary tube, automatic expansion valve and thermostatic expansion valve.
- COP of thermostatic expansion valve is more than automatic expansion valve and capillary tube.
- At same operating conditions, the refrigerating effect produced by using thermostatic expansion valve is 7% more than constant expansion valve 13% more than capillary tube.
- The overall performance of the Thermostatic expansion valve is reasonably good as compared to capillary tube.

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