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EXPERIMENT ANALYSIS AND PERFORMANCE TESTING OF CAPILLARY TUBE AND THERMOSTATIC EXPANSION VALVE

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ABSTRACT

This paper provide an overview of the project, the fundamental physics underlying the operation of fixed and variable expansion devices, and summarizes results of the analyses performed to compare them. This paper analyzes a broad spectrum of strategies for actively or passively controlling the inlet state of fixed-geometry expansion devices such as capillary tube and Thermostatic expansion device, to match compressor mass flow rates with minimal performance degradation in an efficient R12 refrigeration system. A TXV (Thermal Expansion Valve) system was selected as per load requirement and type of refrigerant. Results yielded insights that can be generalized to other refrigerants and systems. TXV were found to produce and control degree of superheat of refrigerant, higher efficiency than capillary tubes across the entire range of operating conditions, although the difference can be mitigated by proper choice of the latter's length and diameter.

INDEX TERMS: capillary tube; thermostatic expansion valve; fixed and variable restriction; cop;

1. INTRODUCTION

The selection of the expansion device is of particular importance to the operation of the refrigeration system because it regulates refrigerant flow into the evaporator. An expansion device which is misapplied or incorrectly sized will ordinarily result in operational difficulties and poor system performance. For example, an undersized expansion device will prevent sufficient refrigerant from flowing into the evaporator causing a reduction in the design cooling capability of the system. An oversized expansion device may allow too much refrigerant into the evaporator causing liquid refrigerant to flow back to the compressor. Capillary tubes are used to expand the refrigerant from the condenser pressure to the evaporator pressure in low capacity refrigerating machines such as domestic refrigerators and window type room air conditioners. It also balances the system pressure in the refrigeration cycle however; it has no provision to adjust the mass flow rate when load conditions changes. In spite of this fact, capillary tubes are preferred in small capacity refrigerating machines, where the load is fairly constant due to its several advantages such as simplicity, low cost, zero maintenance, and requirement of a low starting torque motor to run the compressor.Fig1 shows simple capillary tube. The thermostatic expansion valves provide an excellent solution to regulating refrigerant flow into a direct expansion type evaporator. The TEV regulates refrigerant flow by maintaining a nearly constant superheat at the evaporator outlet. Fig 2 shows thermostatic expansion valve. As superheat at the evaporator outlet rises due to increased heat load on the evaporator, the TEV increases refrigerant flow until superheat returns to the valve's setting. Conversely, the TEV will decrease refrigerant flow when superheat lowers as a result of a decreased heat load on the evaporator. The effect of this type of regulation is it allows the evaporator to remain as nearly fully active as possible under all load conditions.

2. EXPANSION DEVICE FUCTION

The basic function of expansion device used in refrigeration system (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. Under ideal conditions, the mass flow rate of refrigerant in the system should be proportional to the cooling load sometimes; the product to be cooled is such that a constant evaporator temperature has to be maintained. In other cases, it is desirable that liquid refrigerant should not enter the compressor. In such a case, the mass flow rate has to be controlled

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in such a manner that only superheated vapor leaves the evaporator. Again, an ideal refrigeration system should have the facility to control it in such a way that the energy requirement is minimum and the required criterion of temperature and cooling load are satisfied. Some additional controls to control the capacity of compressor and the space temperature may be required in addition, so as to minimize the energy consumption.

The expansion devices used in refrigeration systems can be divided into fixed opening type or variable opening type. As the name implies, in fixed opening type the flow area remains fixed, while in variable opening type the flow area changes with changing mass flow rates. Capillary tube belongs to the fixed opening type, while the thermostatic expansion valve belongs to the variable opening type.

2.1 CAPILLARY TUBE

A capillary tube is a long, narrow tube of constant diameter. 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. The pressure reduction in a capillary tube occurs due to the following two factors (1) the refrigerant has to overcome the frictional resistance offered by tube walls this leads to some pressure drop. (2) The liquid refrigerant flashes (evaporates) into mixture of liquid and vapor as its pressure reduces. The density of vapor is less than that of the liquid. Hence, the average density of refrigerant decreases as it flows in the tube. (3) The mass flow rate and tube diameter (hence area) being constant, the velocity of refrigerant increases since = ρVA. The increase in velocity or acceleration of the refrigerant also requires pressure drop

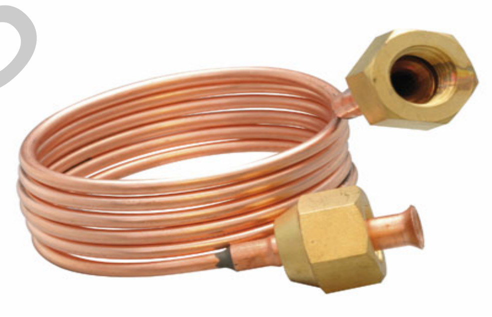

Figure 1: Capillary Tube

2.2 THERMOSTATIC EXPANSION VALVE

Thermostatic expansion valve is the most versatile expansion valve and is most commonly used in refrigeration systems. It is variable opening type expansion device. 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. The schematic diagram of the valve is given in Figure 2. 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.

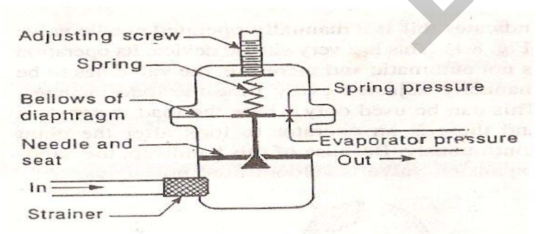

Figure 2: Thermostatic Expansion Valve

3. EXPERIMENT SET-UP

A setup manufactured to experimentally investigate the performance of capillary tube and Thermostatic Expansion valve for refrigerant R-12.Experiment setup consist of four major part of refrigeration system such as compressor, which compress refrigerant, condenser which rejects the heat from refrigerant at constant pressure .expansion device which drop down the temperature and pressure of the refrigerant. And finally evaporator which is absorbs heat from refrigerated space. All the component of the refrigeration system is displayed on portable the metallic panel. The unit consist 0.3 TR capacity compressor, condenser thermostatic Expansion Valve and capillary tube and evaporator. Here for the experiment purpose two expansion devices capillary and thermostatic expansion valve are used in system.fig 3, shows line diagram of simple vapor compression system. Evaporator coil is deep in water calorimeter to so that the water temperature lowers down due to loss of heat energy due to evaporation process. Heater is providing at the bottom of the calorimeter which offers the heat load which is balanced by the refrigeration effect produce by the system.

Calorimeter contain sufficient of water that the evaporative coils totally immersed. Temperature of water present in calorimeter is measured with the help of digital temperature indicator. Pressure gauges are attached at inlet and outlet of condenser as well as Evaporator. For safety of compressor purpose high temperature and low temperature cut off switch is provide

Table -1: Specification of Experiment Set-up

Sr. No	Parameters	Description
1	Type	Refrigeration Tutor
2	Refrigerant	R12
3	Capacity	0.33 TR
4	Compressor	Hermetically Sealed, single cylinder reciprocating
5	Condenser	Finned coils, Air cooled
6	Expansion device	Capillary tube and TXV
7	Evaporator	Bare tube type

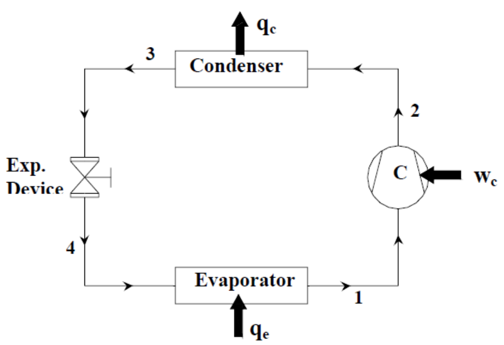

Figure 3: Vapor Compression cycle

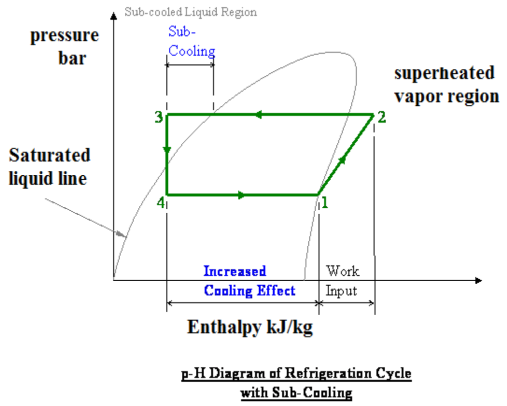

Figure 4: p-h Diagram for R-12

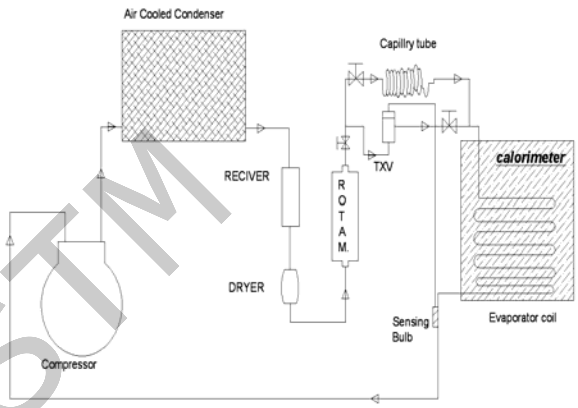

Figure 5: Actual Setup Line Diagram

4. EXPERIMENT READINGS FOR CAPILLARY

The readings for capillary tube is taken by allowing flow of refrigerant R-12 through capillary tube while refrigerant flow to TXV is restricted with the help of manual valve. This reading is use to calculate system actual, theoretical and Carnot COP.

Table -2: Capillary Tube Readings

S. No.	Parameter	Unit	Readings
1	Condenser pressure in	bar	11.5
2	Condenser pressure out	bar	11.2
3	Evaporator pressure in	bar	3.2
4	Evaporator pressure out	bar	3.0
5	Refrigerant flow rate	lph	28
6	Condenser inlet temperature	0C	53
7	Condenser outlet temperature	0C	30
8	Evaporator inlet temperature	0C	3
9	Evaporator outlet temperature	0C	12
10	Time for 10 revolution of compressor meter	sec	62
11	Time for 10 revolution of Heater (energy)meter	sec	32

4.1 CALCULATION FOR CAPILLARY TUBE

From P-h chart of R-12 shown in Figure 4.

h1 = 190 kJ/kg,

h2= 230 kJ/kg,

h3 = h4= 90 kJ/kg,

Carnot cop=4.15

Theoretical cop =2.5

Actual cop=1.67

Table -3: Thermostatic Expansion Valve Readings

S. No.	Parameter	Unit	Readings
1	Condenser pressure in	bar	10.7
2	Condenser pressure out	bar	10.5
3	Evaporator pressure in	bar	2.4
4	Evaporator pressure out	bar	2.2
5	Refrigerant flow rate	lph	16
6	Condenser inlet temperature	0C	58
7	Condenser outlet temperature	0C	34
8	Evaporator inlet temperature	0C	-3
9	Evaporator outlet temperature	0C	16
10	Time for 10 revolution of compressor meter	sec	70
11	Time for 10 revolution of Heater (energy)meter	sec	36

4.2 CALCULATION FOR THERMOSTATIC EXPANSION VALVE

From P-h chart of R-12, shown in figure 4.

h1 = 190 kJ/kg,

h2= 220kJ/kg,

h3 = h4=80 kJ/kg,

Carnot cop= 5.2

Theoretical cop =3.6

Actual cop= 1.944

4.3 FORMULAE USED FOR CALCULATION

Input given by compressor

$W_{comp,\,ip} = (N_c \times 3600) / (t_c \times 3200)$

Input given by heater

$W_{heater,ip} = (N_h \times 3600) / (t_h \times 3200)$

Carnot cop

$(COP)\ Carnot = T_L / (T_H - T_L)$

Actual cop

$(COP)\ Actual = W_{heater,\ ip} / W_{comp,\ ip}$

Theoretical cop

$(COP)_{theoretical}$ =Refrigerating effect / compressor work

$= (h_1 - h_4) / (h_2 - h_1)$

4.4 NOMENCLATURE AND SUBSCRIPTS

W=work done

h=enthalpy

Cop=coefficient of performance

Comp=compressor

ip=input

L=lower

H=higher

1, 2, 3, 4=enthalpy point value.

5. CONCLUSION

1) A TXV equipped refrigeration system provides energy saving.TXV have shown that they maintain higher level of efficiency even when refrigerant charge is lower than the manufactures specification.

2) Fixed expansion devices, such as capillary tubes, work at one preset level and have no ability to compensate for load changes

3) Variations of capacity over the ambient temperature range of 26 0C to 55 0C can cause a performance loss of 85% with a cap tube system. A well tuned expansion valve system will lose less than one half this amounts, while maintaining better compressor temperature control.

4) Thermostatic expansion valve 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

5) Carnot cop is higher than theoretical cop and actual cop in case of both thermostatic expansion valve and capillary tube.

6) Experimental results shows thermostatic expansion valve has higher Carnot,, theoretical and Actual cop than capillary tube. TXV has less compressor work than capillary tube.

7) It was found that the energy consumption of the thermostatic expansion valve system was only lower than that of the capillary tube system at higher cooling loads and at lower cooling capacities

8) During experiment it is occurs that thermostatic expansion valve able to drop down more pressure than the capillary which is produce more refrigerant effect for the system.

9) During experiment it is occurs that thermostatic expansion valve able to control degree of superheat of refrigerant which causes reduction in compressor work and energy saving of system.

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