GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

DETERMINATION OF CAPILLARY TUBE SIZING IN VAPOUR COMPRESSION REFRIGERATION SYSTEM FORDIFFERENT REFRIGERANTS

K. Srinivasa Reddy*[1], A Saibhargav[2], V. Mukesh Reddy[3]
[*1]Professor, Department of Mechanical Engineering, CMR Engineering College, India
[2&3]Assistant Professor, Department of Mechanical Engineering, CMR Engineering College, India

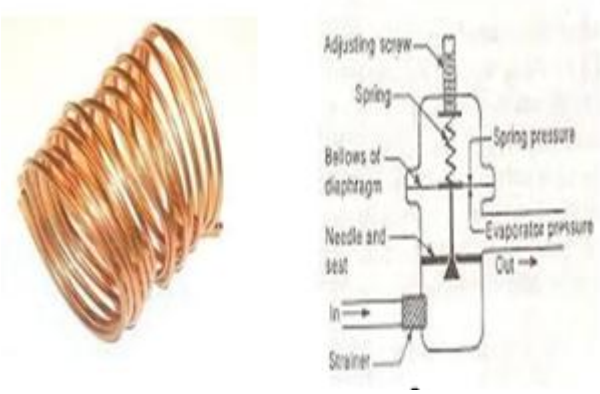
ABSTRACT

Capillary tube is one of the commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is made up of copper tube of very small internal diameter. It is of very long length and it is helically coiled to several turns so that it occupies less space. The internal diameter of the capillary tube used for the refrigeration applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). Capillary tube used as the Expansion device in the refrigerators, deep freezers, water coolers and air conditioners. The objective of this research is to determine the optimal dimensions of capillary tube in a Vapour Compression Refrigeration system (VCRS) and the Pressure drop across the capillary tube. The optimal dimensions are calculated theoretical using analytical approach.

I. INTRODUCTION

Expansion device is also known as throttling device is an important device that divides the high pressure side and the low pressure side of a refrigerating system. It is connected between the receiver and the evaporator. The expansion device performs the following function. It reduces the high pressure liquid refrigerant to low pressure liquid refrigerant before being fed to the evaporator. 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. It controls the flow of refrigerant according to the load on the evaporator. Figure 1 shows the types of expansion devices used in Vapour Compression Refrigeration System.

The expansion device 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. It controls the flow of refrigerant according to the load on the evaporator.

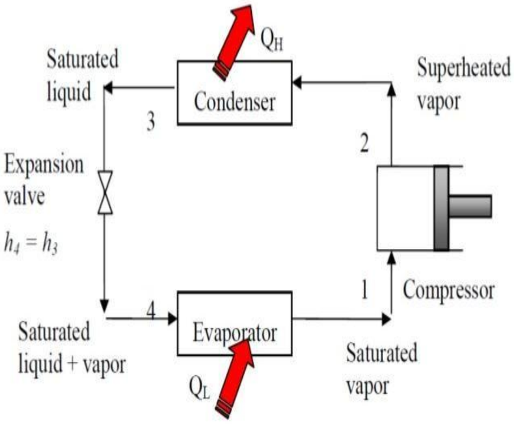


(a) Capillary tube (b) Thermostatic expansion *valve*

Figure 1: Types of expansion devices used in Vapour Compression Refrigeration System

Figure 2(a) shows four basic elements of a vapour compression refrigeration system. Quantities QH and QL are the amount of heat transferred in the condenser and evaporator respectively. Figure 2(b) shows four salient points (1-2-3-4) of a cycle on a pressure-enthalpy diagram.

The process 3-4 stands for isenthalpic expansion of refrigerant with zero degree of sub cooling at the entry to the capillary tube. Normally in an ideal VCRS, the refrigerant entering the compressor must have some degree of superheat, while at entry to capillary expansion device; it must have a few degree of sub cooling as compressor cannot handle two phase fluid while capillary cannot effectively handle two phase entry. Otherwise both units will suffer due to mal-functioning. The capillary tubes serve almost all small refrigeration systems and its applications extend up to a capacity of order of 10 kW. Numerous combinations of bore and length are available to obtain the desired restriction. Once a capillary tube has been selected and installed, the tube cannot adjust to variations in suction, discharge pressures or load. The compressor and expansion device must arrive at pressure conditions which allow the compressor to pump from the evaporator the same mass flow rate of refrigerant that the expansion device capillary feeds to the evaporator. A condition of unbalanced flow between these two components must necessarily be temporary. At high condensing pressures, the capillary tube feeds more refrigerant to the evaporator than it does at low condensing pressure because of the increase in pressure difference across the tube. The compressor and capillary tube do not have complete liberty to fix the suction pressure because the heat transfer relationships of the evaporator must also be satisfied. Figure 3 shows the variation of mass flow rate of refrigerant with suction pressure in typical VCRS .



(a) Blockdiagram

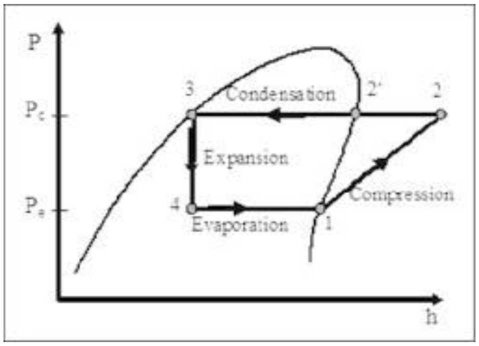


Figure 2: A Vapour Compression Refrigeration System.

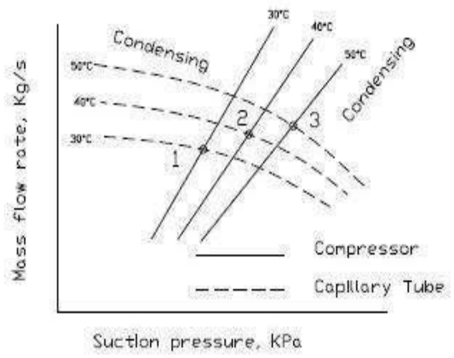


Figure 3: Variation of Mass flow rate of refrigerant with suction pressure

II. CAPILLARY TUBES

A capillary tube is 1 to 6 m long with an inside diameter generally from 0.5 to 2 mm. The name is a misnomer, since the bore is too large to permit capillary action. Liquid refrigerant enters the capillary tube, and as it flows through the tube, the pressure drops because of friction and acceleration of the refrigerant. Some of the liquid flashes into vapor as the refrigerant flows through the tube.

The disadvantages of capillary tubes are that they are not adjustable to changing load conditions, are susceptible to clogging by foreign matter, and require the mass of refrigerant charge to be held within close limits. This last feature has dictated that the capillary tube be used only on hermetically sealed systems, where there is less likelihood of the refrigerant leaking out. The capillary tube is designed for one set of operating conditions, and any change in the applied heat load or condensing temperature from design conditions represents a decrease in operating efficiency.

III. MATHEMATICAL COMPUTATION OF PRESSURE VARAIATION IN A CAPILLARY TUBE

The equation relating state and conditions at points 1and 2 in an elemental length of capillary tube as shown in Figure 4 is written as follows.

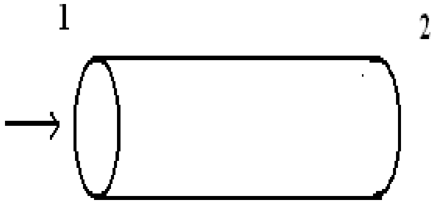


Figure 4: An elemental length of a capillary tube

The fundamental equations applicable to the control volume bounded by points 1 and 2 in Figure 4 are

1. Conservation of mass
2. Conservation of energy
3. Conservation of momentum

The equation of conservation of mass states that

$$w = \frac{V_1 A}{v_1} = \frac{V_2 A}{v_2} \qquad (1)$$

The conservation of energy gives

$$1000h_1 + 0.5 x V_1^2 = 1000h_2 + 0.5 x V_2^2 \qquad (2)$$

This assumes negligible heat transfer in and out of system. The momentum equation in words states that the difference in forces applied to the element because of drag and pressure difference on opposite ends of the element equals that is needed to accelerate the fluid.

$$\left[(P_1 - P_2) - \mathrm{f} \times \left(\frac{dL}{D}\right) \times \left(\frac{V_2}{2v}\right)\right]\mathrm{A} = \mathrm{w}\,(V_2 - V_1) \qquad (3)$$

As the refrigerant flows through the tube, its pressure and saturation temperature progressively drop and the

Fraction of vapor dryness continuously increases.

Enthalpy at any point

$$\mathrm{h} = h_f(1-x) + xh_{fg}(4)$$

$$v = v_f(1-x) + xv_{fg} \qquad (5)$$

The quantities of Eq.(4) V, v and f all change as refrigerant flows from point 1 to 2. Simplifying using eq.(2)

$$\mathrm{f} \times \left(\frac{dL}{D}\right) \times \left(\frac{V_2}{2v}\right) = \mathrm{f} \times \left(\frac{dL}{D}\right) \times \left(\frac{V}{2}\right) \times \left(\frac{w}{a}\right) \qquad (6)$$

In the calculation to follow, V used in Eq.(6) will be mean velocity

$$V_m = \frac{V_1 + V_2}{2} \qquad (7)$$

The friction factor with turbulence is

$$\mathrm{f} = \frac{0.33}{Re^{0.25}} = \frac{0.33}{\left(\frac{VD}{\mu_v}\right)^{0.25}} \qquad (8)$$

he viscosity in two phase flow is given by

$$\mu = \mu_f(1\text{-}x) + x\mu_g \qquad (9)$$

The mean friction factor f_m applicable to incremental length 1-2 is

$$f_m = \frac{f_1 + f_2}{2} \qquad (10)$$

$$f_1 = \frac{0.33}{Re_1^{0.25}}$$

$$f_2 = \frac{0.33}{Re_2^{0.25}}$$

IV. EVALUATION OF LENGTH OF CAPILLARY

The essence of the analytical calculation is to determine the length dL between points 1-2 as shown in Figure 4 for a given reduction in saturation temperature of the refrigerant. The flow rate and other conditions at point 1 are known and for a required selected temperature at point 2, the remaining conditions at point 2 and dL would be calculated as fallows

1. Temperature T_2 selected
2. P_2, $hf_2 hg_2$ and vf_2 are calculated, all being function of temperature (or pressure).
3. Conservation of energy gives the

$$1000h_2 + \frac{V_2^2}{2} \times \left(\frac{w}{A}\right)^2 = 1000h_1 + \frac{V_1^2}{2} \quad (11)$$

Substituting from Eq.4 and 5 in Eq.11

$$1000hf_2 + 1000(hg_2 - hf_2)x + \left[\frac{1}{2} \times \left\{\{Vf_2 + \{(Vf_2 - Vf_1)x\}^2\} \times \left(\frac{w}{A}\right)^2\right\}\right] = 1000hf_1 + \left(\frac{V_1^2}{2}\right) (12)$$

where x is the quality of refrigerant

4. with known values of x, h_2 and v_2, V_2 will be calculated
5. Reynolds Number is computed at point 2 using the viscosity from Eq.(9), the friction factor at point 2 from Eq.(8), and friction factor for increment length from Eq.(10)
6. Finally, substituting values from Eq.(6) and (7) dL is evaluate

V. RESULTS

Refrigerant	Capillary diameter	Length (m)	Pressure at exit	Pressure at entry
R-22	75 thou	0.62	606.38 Kpa	2127 KPa
	80 thou	1	606.38 Kpa	2127 KPa
R-407C	75 thou	0.65	713.07 KPa	2426.4 KPa
	80 thou	1.07	713.07 KPa	2426.4 KPa
R-410A	75 thou	1.47	1001.09 KPa	3362.7 KPa
	80 thou	2.17	1001.09 KPa	3362.7 KPa
R-134A	75 thou	0.55	725.05 KPa	2716.5 Kpa
	80 thou	1.12	725.05 KPa	2716.5 Kpa

VI. CONCLUSIONS

The calculation for capillary sizing is based on the same fixed refrigeration effect and capillary diameter. is observed that for same 75 thou diameter the capillary length is approximately same for R22 andR407c which is equal to 0.62 m and 0.65 m, whereas, its length is 0.855 m more for R410A than that of R22 .It is also observed that for same 80 thou diameter the capillary length is approximately same for R22 and R407 which is equal to 1m and 1.07 m, whereas, its length is 1.17m more for R410A than that ofR22.The mathematical approach is quite helpful in determining the size of capillary tube for different refrigerants.

REFERENCES

1. *Stoecker,W.F.and Jones, J.W Refrigeration & Air Conditioning, 2nd Edition, Tata McGraw Hill, New Delhi 1982.*
2. *Arora, C.P., Refrigeration and Air Conditioning, Tata-McGrawHill, New Delhi, 2003.*
3. *Akkarat Poolkrajang and Nopporn Preamjai. 2009. Optimization of capillary tube in air conditioning system. As. J. Energy Env. 10(03):165-175 .54Kim, S.G., M. S. Kim and S. T . Ro. 2002.*
4. *Experimental investigation of the performance of R22, R407C & R410A in several capillary tubes for air-conditioners, Inter. J. Refrigeration 25:521 531Pongsakorn Sarntichartsak,A., B.Veerapol Monyakul and Sirichai Thepa, C. 2007.*
5. *Modeling and experimental study on performance of inverter air conditioner with variation of capillary tube using R- 22 and R-407C. Energy Conver.Manage. 48: 344 354*
6. *Testing inverter type air conditioners for field performance. Dr. Satya Mavuri (BE MSc PhD), M.AIRAH, Vipac Engineers and Scientists Ltd.*
7. *'Performance of Window AC using Alternate Refrigerants with different configurations of capillary tube' Richa soni1,P.K.Jhinge and R.C,Gupta 2 ISSN:2347-3215 Volume 1 Number4(2013)pp 46-54*
8. *'Aluminium roll bond- a single innovative circuit for air conditioner, car radiator, refrigerator and water heater' Mr. Kasuba Sainath, Dr.Suresh Akella, 'International Journal & Magazine of Engineering, Technology, Management and Research, ISSN No.: 2348-4845, Volume-01, Issue-09 in September-2014.*
9. *'Overview of " HVAC Systems" in General Aspects' Mr. Kasuba Sainath in 'IJRASET"/International Journal for Research in Applied Science and Engineering' Paper Id No.1488,Volume-02,Issue-12,December-2014 ISSN No. 2321-0653, Page No: 558-569*
10. *'Experimental & Theoretical Analysis of Roll Bond Evaporator as Air Conditioner' Kasuba Sainath, DR.T.Kishen*
11. *Sainath, Suresh Akella, T. Kishen Kumar Reddy,Proceedings of ICETiME 1st International Conference on Emerging Trends in Mechanical Engineering (ICETiME 2016) .*