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IMPEDANCE METHOD FOR DETERMINING VAPOR PRESENCE AT EXPANSION VALVES INLET

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Abstract. *Refrigerant fluid generally leaves the condenser in the liquid state but, if there is significant off design occurrence in the condenser to the expansion valve line, under certain limited circumstances, vapor phase will form and the fluid will reach the expansion valve as a two-phase mixture, which negatively affects flow control.*
This work presents a study of an impedance method applied for determining vapor presence at refrigerant expansion valves inlet with the aim of furnishing an electrical signal to the refrigerant mass flow control system or to a simple bad operation alarm.
A discussion of the experimental technique, procedure as well as the cause and consequences of vapor presence at expansion valves inlet were carried out in this paper. As a goal, the work aims to furnish a possible new tool for refrigeration cycles control improvement.

Keywords: *refrigeration, void fraction, impedance sensor, expansion valve.*

1. Introduction

With an increasing automation of refrigeration systems, new technologies for specific system parts control have been developed as an effort for process operational optimization and, mainly, for energy consumption reduction. Electronically controlled refrigeration systems have the advantage of having faster control responses and avoid thermally induced failure of devices and components. One of the most important components of any refrigeration system is the expansion device that besides providing the necessary pressure drop usually has the additional function of controlling the refrigerant mass flux into evaporator, maintaining the superheat set point to adjust the refrigeration load. Obviously, the refrigerant mass flux control is an important process parameter and it needs a special attention.

Methods for producing the necessary pressure drop between the condenser and evaporation has increased over the years. Quite probably, the first technique was a simple hand valve set to a particular flow restriction and load condition. Its usefulness was limited by the fact that it had to be manually reset for each change in system load.

The capacity of capillary tubes, which generates a pressure drop by having a high internal flow friction, is limited to follow refrigeration load variation. In the same way, a fixed orifice as the pressure drop device displays poor capability to impose flow restrictions for variable refrigeration load. Advances in the area of mechanical valves led to the conception of automatic expansion valves. Automatic expansion valves maintain a pressure in the evaporator, and open in response to a drop in suction pressure. While automatic expansion valves are able to follow load oscillations better than fixed restrictors or capillary tubes, their operating characteristics are sometimes in opposition to those needed for an efficient controlling system.

An efficient expansion device for refrigerant control is the thermostatic expansion valve (TXV). The TXV works by sensing and controlling the superheat in the evaporator. Superheat is a direct measure of the work done, or heat absorbed, by the evaporator. Therefore, by controlling the superheat, a TXV regulates the proper amount of refrigerant into the evaporator under a large range of load conditions, and it still prevents backflooding from damaging the compressor. TXV`s have a sensing bulb filled with a substance, usually formed by a mixture of refrigerants, which expands when heated and actuates on a spring balanced device to open or to close the flow controlling orifice (Dossat, 1980). The idea is that the superheat modulates the valve operation as can be seen in Fig 1.

Figure 1 shows a typical diagram of the TXV capacity versus the liquid superheat. In that diagram it can be observed that the working superheating (WS) controlled by the valve is the sum of the static superheating (SS), in which the valve remains static (factory defined superheating), and the opening superheat (OS), in which the valve make the control by the nozzle area control. The nominal capacity (q_n) is associated with the working superheat (WS) while the reserve capacity (q_r) is the difference between the maximum capacity (q_{max}) and the nominal one.

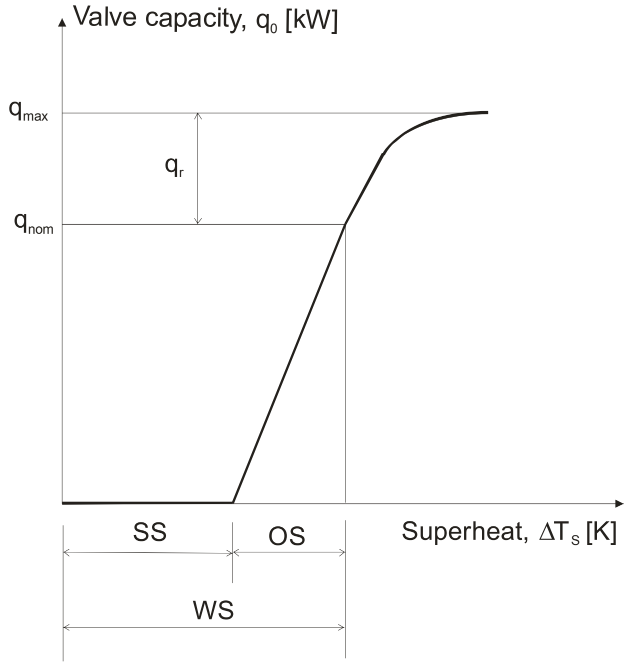

Figure 1 – TXV capacity versus superheat typical diagram (Asercom, 2005).

Electronically controlled valves (EEVs) are refrigerant control devices that have a very wide load range, are remotely set, and temperature controlled directly. There are generally two basic types of electronically controlled expansion valves: solenoid or pulse, and step motor. In this type of valve, a small motor is used to open or close the valve port. The motor that is used does not rotate continuously, but instead, rotates a fraction of a revolution for each signal sent by the controller.

The TXV is set to be passive over the SS band and controls only the OS band while the EEV can control all the WS band, with capability to change SS band accordingly to the operational need.

According to the results obtained by Mulay et al. (2005), the system stability is hardly sensitive to the bulb location, once the thermal resistance, and the two-phase heat transfer coefficient between the suction line and the bulb affects the control system dynamics. That author noted that there exists a point in the suction line at which the superheat variation is the least, or minimum stable superheat where the expansion valve bulb must be located making the valve, and consequently, the system more stable.

Although it has been confirmed that the characteristics of the expansion valve limits this useful range because of excessive pressure drop into liquid line, instability at partial loads, and low subcooling conditions, experiments need to be carried out to determine the effect of the above described parameters. Investigations must be done about the occurrence of flashing gas at valve inlet, both theoretically and experimentally, to show how much the flashing presence at expansion valve inlet reduces controlling capacity.

EEV`s respond only to the signal supplied by their controllers. Tests have shown that under most operating conditions EEVs modulate at about 30% of full open position. EEV or controller failures would most likely not lead to floodback, except immediately after a defrosting cycle. Most modern controllers used with EEVs have built-in diagnostic capabilities. Online failure diagnosis systems have been developed to monitor compression refrigeration cycles. They are generally based on a priori system symptoms and they are not completely reliable (Grimmelius et al., 1995). When a failure is experienced in the valve/controller system, the first step is to define the failure as controller related or valve related (Outtagarts et al., 1997).

This work give an overview on refrigeration cycles troubleshooting causing expansion valves malfunctions from analyzing recent works on some new techniques demanded by performance increasing and energy saving. Special attention is done to the liquid line flashing occurrence and its respective consequence on the expansion valves operational capacity reduction. The valve inlet refrigerant quality is suggested as a new controlling parameter as a technical solution, which consists in implementing an impedance sensor at the inlet expansion valve to furnish a characteristic signal for control system actuation.

2. An Overview on EEVs Performance

Although expansion device studies have been the main target of many works for evaluating a parametric influence on mass flow control, there are no in-depth analyses concerning the influence of flashing at the expansion valve inlet as a way to optimize refrigerant flow control.

Choi and Kim (2004) carried out similar investigations were the influence of the expansion valve on the performance of a heat pump using R407c under several refrigerant charges. The authors tested capillary tube and EEV performance on heat pump capacity under different refrigerant charging range from –20% to +20% of full charge and evaporation temperature of 25 ^oC. For capillary tube using R22 and R407C, it was observed a higher sensitivity to the refrigerant charge condition, and system COP reduction under refrigerant overload condition due to the higher superheating. For EEV it was observed higher system COP and capacity due to the low dependence on the refrigerant charging condition using R407C, compared to the capillary tube, concluding that electronic control leads to higher system performance and stability.

A large evaluation of TXV and EEV comparing its performances with the use of R22 and R407C was made by Aprea and Mastrullo (2002). Permanent and transitory regimes were analyzed and no COP considerable difference between EEV and XV were observed, with the use of R22 or R407C. The EEV presented fast response to the operational condition changes and more adaptability to new set superheating. The authors verified the incapacity of the TXV to the refrigerating control when variable velocity compressors are used. They observed that during dynamic operation (OS regime, see Fig.2), if the evaporation dynamic pressure decreases after compressor stop or start, a two-phase mixture could be pumped to the compressor making severe damage. For transitory operational conditions like cycle start the EEV flow control is quite linear and faster than TXV that presents non-linear control. Furthermore, the compressor power consumption is small for EEV control than TXV.

Lenger et al. (1998) used a traditional model based on force equilibrium and pressure drop on the valve diaphragm. These authors took in consideration the spring constant and the bulb time constant, and the offset temperature. They carried out a refrigerant transient flow study showing that there was a weak relationship between transient mass flow rate and superheating.

The transient effect of the suction pressure was also analyzed by McMullan e Hewitt (1995), and they concluded that superheating has a strong influence on the valve control capacity. Park et al. (2001) realized a large study of an air-conditioned system using an EEV by implementing a numerical model. The authors changed the compressor's velocity and determined the best valve lift for an optimized COP. Finally, the authors did not find any work that consider the influence of vapor presence at an expansion valve inlet, which is the paper main goal.

3. Liquid Line Flashing: Problem Characterization

Flashing or refrigerant vapor into the refrigeration cycle liquid line is a more frequently occurrence than one would like. All refrigeration cycle design theory guides on subcooling liquid refrigerant as a way to prevent the flashing problem. The use of liquid subcooling in the evaporator exit is probably the most well-known and generally accepted method of suppressing that phenomenon. The technical literature presents some of the main causes of flashing occurrence as exposed below:

- Excessive frictional pressure drop in the liquid line;
- Installation of flow restriction devices in the liquid line causing localized pressure drop;
- Excessive line lift;
- Off design refrigerant charge; and
- Thermal gains from ambient.

The first two flashing causes are directly related to the liquid line head pressure. Generally, the condensing temperature (head pressures) for air conditioning applications is about 40 ^oC and it can be as low as 30 ^oC for a refrigeration system (Stoecker & Jones, 1985). When considering the energy cost of running the compressors without addressing the generation of flashing before the liquid entering the expansion device, these condensing temperatures have been found to be the most optimum condensing ones. Due to the flow from the evaporator to the expansion device inlet, some pressure drop is expected as consequence of frictional losses and additional pressure drop may occur if any flow restriction device, such as regular valve, is installed in between. In addition, flashing can occur where a drier is installed which may cause a flow restriction.

In large refrigeration systems, many times the condenser and the evaporator are located far apart from each other and, in some cases, at different gravitational levels. Such is the case when the condenser and the other machinery are located at the ground level and the evaporator is a one or more floor above. Some pressure head reduction will occur by simple gravitational head reduction that may induce the formation of flashing. System operation may be erratic because the expansion valve will be starved at the evaporator inlet point. Another cause can be excessively long pipe runs. The pressure drop causes flashing to occur. The last situation may occur in long liquid lines where it may be exposed to a temperature above the corresponding saturation one.

Finally, flashing can also be an indication of refrigerant leakage, particularly if bubbles are known not to be present previously. Furthermore, other factors can induce flashing occurrence, such as refrigeration system malfunction, in which the low refrigerant charge is the cause of vapor bubbles presence into the liquid line and it can reduce the system performance.

Important results were obtained by Vinnicombe and Ibrahim (1991) concerning to the verification of flashing occurrence into liquid line. The main set of tests were carried out with the returning chilled water temperature and the evaporator maintained constant at 12 ^oC and 0 ^oC, respectively. The results of the tests at duty load greater than design one for the expansion valve show that they confirm the manufactures contention that the valves can operate at duties larger than the design ones. The result of the tests at full and partial load duty for each of the valves show that over all the conditions imposed, apart from at high condensing temperature and low load where valve instability was observed, the system performed most satisfactory and no practical difficulties were experienced. In fact, at the low condensing temperatures the compressor ran far more smoothly and quietly. At low condensing temperatures where the desired refrigerating capacity cannot be maintained even when the expansion valve is fully open, it can be seen that both the TXV`s behaved broadly as expected and their capacities were significantly larger than the declared capacities. It is noticeable that the extra capacity of the valve in excess of the declared capacity is very significant and it allows the system to maintain the set load condensing temperatures much lower than that predicted from the declared data. Nevertheless, further technical improvements cannot be included during the design stage because solutions are different for each operational condition and particular refrigeration system.

Bahajji et al. (2005) developed an experimental study about flashing process through expansion valve using the refrigerants R22, R290, and R410A. They evaluated the upstream and downstream expansion valve pressures, subcooling, and valve flow area on the refrigerant mass flow. Upstream pressure revealed to hardly influence the refrigerant mass flow for all refrigerants tested. Next, it was observed that the downstream pressure has little influence over refrigerant mass flow that indicates that the flashing phenomenon was well anticipated by the flow models analyzed. The next experiment indicated that the subcooling had a major influence over the refrigerant mass flow, i.e., the higher the subcooling the higher the mass flow. Finally, the flow area had a large influence over the mass flow, but the influence was clearly different for each one of the tested refrigerants due to different thermodynamic properties. In addition, flow area models were compared with the geometrical (actual) valve area assuming that the little amount of vapor present at the inlet (about 2% in volume) was negligible so that the Bernoulli equation was used also used. The central discussion on the mass flow model through nozzles is how to determinate the throttle pressure (P_i). Bahajji et al. (2005) also proposed and analyzed three hypothesis for the throttle area: the first assumed that $P_u \sim P_s$ (saturation pressure for satured liquid temperature at nozzle inlet) overestimating the flow area compared to the geometrical one. The expansion valve makers use $P_u \sim P_e$ (evaporation pressure) underestimates the flow area for the lift positions. The conventional nucleation theory based model was adopted to obtain a more precise flow area model which establishes a differential pressure between the thermodynamic saturation pressure and the minimum pressure in a depressurization process, or ($P_{sat} – P_f$), giving best predicted flow area compared to the geometrical one.

According to O´Brian (2005), The expansion valve has its capacity hardly reduced when starved of refrigerant, when not being fed by liquid. With the speculated saturated condensing pressure drop from 43 ^oC to 20 ^oC there is a reduction in available TXV pressure drop, an increase in available liquid density and a reduction in liquid enthalpy. The author presents the use of a liquid pump after the condenser and the liquid receiver as way to avoid the flash gas into liquid line. The study, showed that assuming that there is not only liquid available into liquid line, it can be estimated that the EEV capacity loss may be about 20% and the TXV capacity loss may be about 28%. Both TXV and EEV capacities is subject to available liquid quality and sufficient liquid pressure available at inlet. Some EEV manufacturers suggest the inclusion of a control characteristic to cycle condenser fans in the event of low load and/or low temperature ambient as a way to avoid liquid starvation.

Many other works have been done in order to investigate external parameter influence in refrigeration systems supplied by expansion valves as in Ibrahim (2001) that developed a theoretical model to investigate the sudden changes in external parameters over a refrigeration system with an evaporator controlled by a TXV.

Although all the problems posed before, there is no control system in the literature concerning to the possibility of to detect and indicate a possible refrigerant vapor presence at liquid line or to permit a valve control by the action of an electronic controller. In a recent work, Hrjak et al. (2001) present four methods of detecting droplets in the stream of superheated vapor at the evaporator exit of a refrigeration system. The authors show a construction technique of a thin-film resistance sensor (MEMS) to detect and measure the liquid droplets.

4. Basic Mass Flow Rate Model and Considerations

The refrigeration system performance is predicted by manufactures and this information assumes that the refrigerant enters the expansion valve in the liquid state. Invariably the refrigerant will leave the condenser in the liquid state but, as seen above, if there is a significant pressure drop in the liquid line from the condenser to the expansion valve, under certain limited circumstances, vapor will form in the refrigerant and so a two-phase mixture will enter the expansion valve. As a result of that, the mean specific volume of the refrigerant will be higher than that one of a liquid phase alone and, therefore, it is likely that the mass flow rate through the expansion valve and, consequently, the overall refrigerating capacity will be lower than that one if there were no vapor presence. The amount of refrigerant flow (mass flow) into the evaporator will determine the capacity of refrigeration and the expansion valve must be able to feed enough refrigerant to sustain any increase in capacity demand. The most significant loss of expansion valve capacity will occur if the valve is fed with a two-phase mixture. Besides that, along with the presence of vapor other factors will affect the valve capacity. Both the liquid refrigerant temperature and pressure drop across expansion valve will affect its performance but as hardly as the upstream pressure as found by Bahajji et al. (2005).

The most elementary valve model considers a thermodynamic equilibrium and the refrigerant mass flow rate through an orifice with a differential pressure is obtained from Bernoulli's equation, i.e.,

$$\dot{m}_c = C_d A\sqrt{2\rho\left(P_u - P_d\right)} \text{, and} \tag{1}$$

$$C_d = \frac{\dot{m}_A}{\dot{m}_C}, \tag{2}$$

where, $\dot{m}_C$ is the ideal refrigerant mass flow (isentropic) through expansion valve, $\dot{m}_A$ is the actual refrigerant mass flow through expansion valve, C_d is the discharge coefficient, ρ is the liquid density, P_u is the valve upstream pressure, and P_d is the valve downstream pressure.

Almost invariably, expansion devices in refrigeration systems take the form of some type of automatically adjustable orifice. In a flooded evaporator, the adjustment will be by the means of a float switch to maintain the liquid refrigerant level and, in the more common thermostatic expansion valve (TXV), the adjustment is made in response to a temperature sensor at the evaporator exit to maintain a constant refrigerant superheat.

In an expansion valve there will be a maximum size of orifice when the valve is fully open and, if the operating conditions require a larger one than that to maintain the superheat, the valve will be incapable of supply the flow demand. Consequently, there will be a superheat larger than that of the set point and a corresponding reduction in refrigerating capacity.

According to Shanwei et al. (2005), at low differential pressure the refrigerant flow is, in practice, determined by the fully open orifice size of the valve and the Eqs (1) and (2) can determine the mass flow rate. When the pressure difference is large, the flow is determined by the capacity of the compressor and the size of the orifice in the expansion valve will be reduced automatically to maintain the set superheat. Investigations like those carried out by the above cited works show that the refrigerant flow and therefore the refrigerating capacity is proportional to the differential pressure over the expansion valve implying that low condensing temperatures imply in a low mass flow rate and that is the reason put forward why the condensing temperature must be maintained high. However, Bahajii et al (2005) showed that the use of a relatively large orifice could reduce the problem, although the limit is the range of TXV operations, which may become unstable. The instability (hunting) results in a cyclic overfeeding and underfeeding of the evaporator and the most serious consequence can be a refrigerant in the liquid state entering into the compressor leading to a possible mechanical failure.

For the subcooled flow, the most applied model to predict the mass flow through nozzles are the homogeneous equilibrium model (HEM), which assumes that the two phases are flowing with the same velocity and it considers that the mixture is pseudo fluid having a thermodynamic properties averaged by the vapor quality. It was investigated by Abdul-Razzak et al. (1995a, 1995b, and 1995c). The authors investigated and compared the different models developed to the mixture density prediction for a tow-phase flow through a venturi tube and other measurement devices: homogeneous equilibrium model, separated flow density model, equivalent density model, and velocity slip ratio model. The comparison showed that each model has a specific applicability range, and the homogeneous equilibrium model revealed to have the largest applicability range. Bahajii et al. (2005), is one of the few recent works available in specific literature that investigated using the refrigerants R22, R290, and R410A.

Although the enormous amount of literature examples available, four important reviews, beyond others, present an overview of the flashing phenomenon studies evolution in the last decades: Isbin (1980), Shin and Jones (1993), and Bilnkov et al. (1993).

Many authors have purposed critical flow models and correlations in last decades like, for example, those of Fauske (1988), Crespo et al. (2001), Simões-Moreira & Bullard (2003), Boccardi et al. (2005), Shanwei et al. (2005), and Vieira and Simões-Moreira (2006) for all expansion devices including nozzles, capillary tubes, short capillary tubes, and other flow expanders.

In an important work, Brenem (1995), presents an homogeneous flow model for two component mixture flow through a nozzle, given reservoir conditions p_o and α_o as well as the polytropic index k and the liquid density (assumed constant), it is possible to know both critical gas volume fraction and dimensionless mass fraction as can be observed in Fig.2.

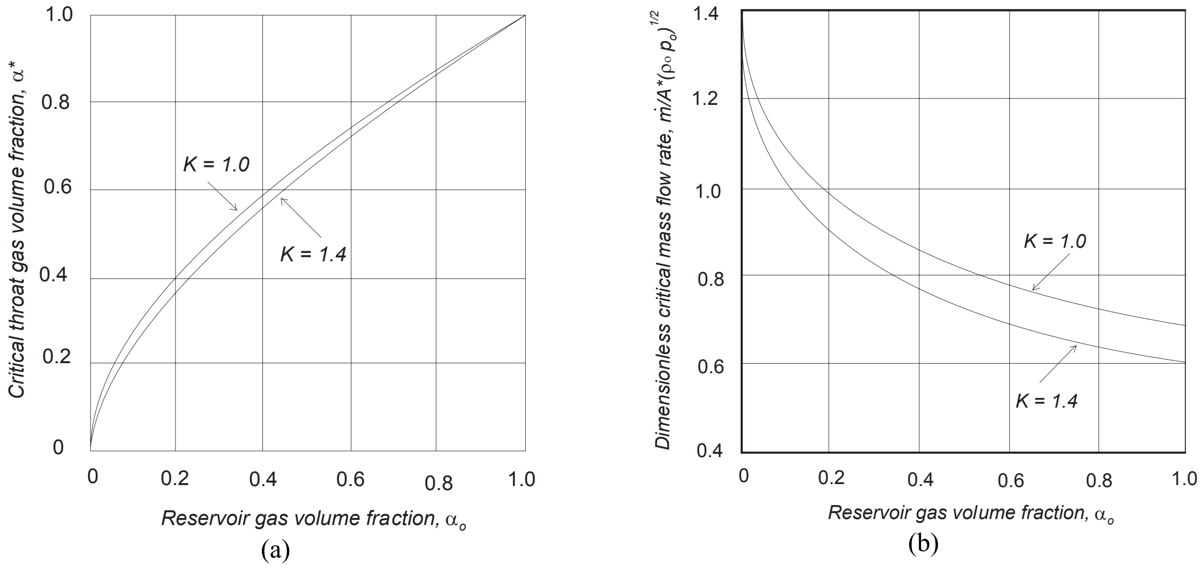

Figure 2 – Gas-liquid mixture flow through a nozzle: (a) critical throat gas volume fraction, α*, against reservoir gas volume fraction, α_o, and (b) dimensionless choked mass flow rate, $\dot{m}/A^*(p_o\rho_o)^{1/2}$, against the reservoir vapor volume fraction, α_o, (Brenem, 1995).

5. Experiments and test facility

The test facility has been conceived to be setup in the Alternative Energy Systems Laboratory (SISEA) at EPUSP and it is sketched in Fig 3. A typical refrigeration cycle was mounted for the tests and data acquisition. The design refrigeration capacity is 5.0 kW and it has an evaporator operating in the temperature range from 0 ^{o}C to 30 ^{o}C. The refrigerant R417A will be an alternative azeotropic refrigerant for R22. The evaporator is a tube into a recirculating water bath and electrical heaters installed in the to provide the cooling load. The heaters is thermostatically controlled to maintain a constant return temperature to the evaporator at full and partial load conditions. The condenser is an air-cooled heat exchanger and the compressor a regular hermetic one. The test facility was mounted according to the recommendations of the ASHRAE Handbook, Equipments (2002).

A pressure control valve introduces a pressure drop increased the liquid line from the condenser to the expansion valves. Additionally, an electrical resistance wrapped around the liquid line furnishes energy to a controlled evaporation.

A visualization section is placed immediately before the expansion valve to give a visual indication of the presence of vapor, and the impedance sensor is placed between the sight glass and the expansion valve to permit the void fraction measurement at the valve inlet.

The first set of tests to be undertaken will be to monitor system performance when the condensing temperature is progressively reduced and, at the same time, ensuring that no flashing is present at the expansion valve inlet. The obtained results will be compared to the tests in which flashing occurs.

Repeating some of the tests described above, and introducing different pressure drops in the liquid line with the aid of a pressure control valve, it is aimed to investigate the effect of flashing on EEV performance. It is expected that the liquid line pressure drop should have two effects: first, when there is a considerable subcooling after the condenser, no flashing will be generated even after the pressure drop and so there will be a reduction in flow rate only as a result of reduced pressure drop across the expansion valve.

The second effect, when flashing occurs, the flow rate reduction and other important parameters will be measured for conclusions.

The present type of sensor operates based on the difference of electrical properties of the two refrigerant phases. According to the operation frequency imposed on the signal applied between the electrodes along with the knowledge of the electrical properties of the refrigerant phases, the average dominating impedance of the two phase mixture filling in the cross section may be either resistive, or capacitive, or both. The sensor analyzed in this study will operate in the capacitive range. The elementary electrical model of the sensor and the measuring system is a parallel *RC* circuit, as discussed by Rocha and Simões-Moreira (2002).

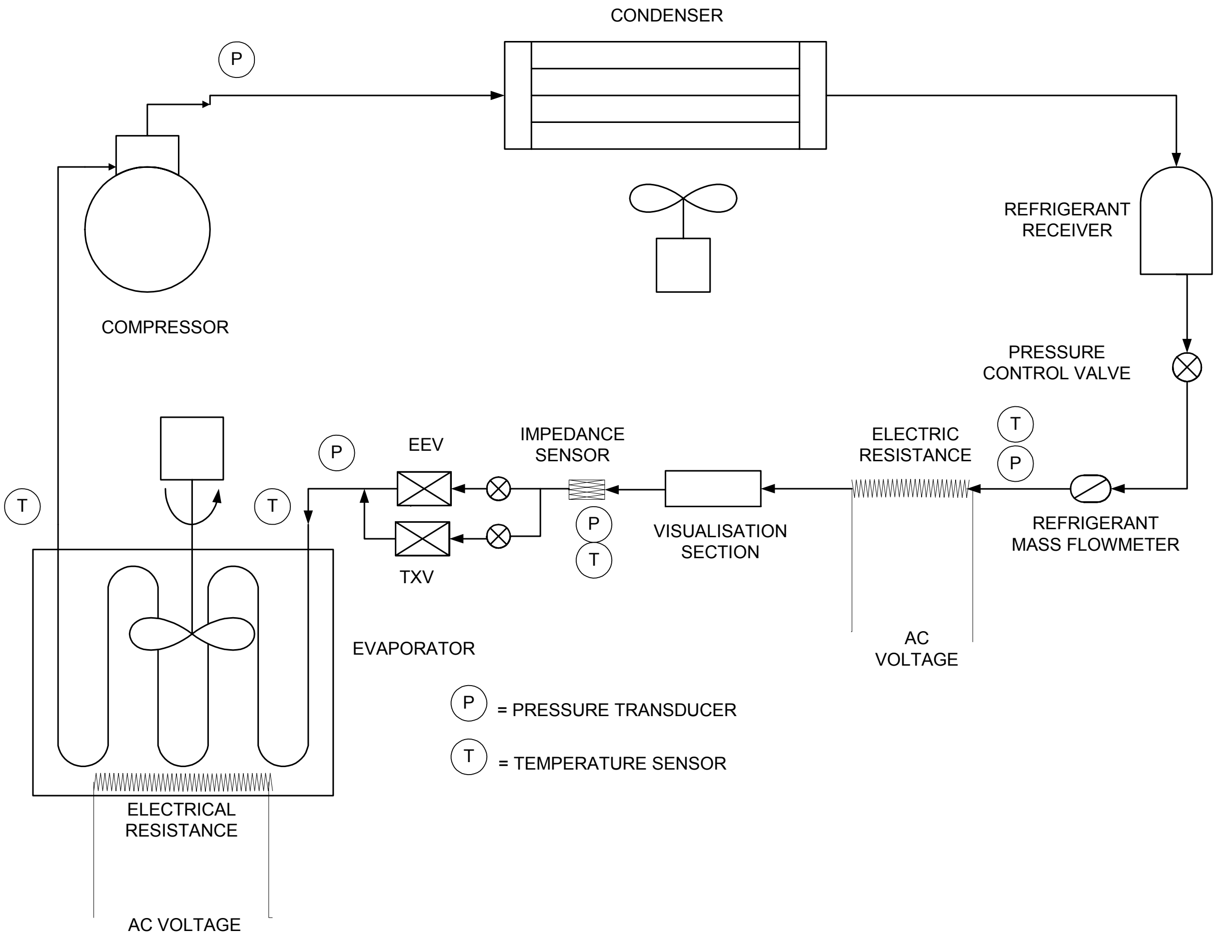

Figure 3 – Schematics of the experimental test facility.

The mentioned work shows in a simple way that, it is possible to associate the overall two-phase mixture impedance, with the phases corresponding electrical properties, as follows.

$$\left(\frac{k}{k_L}\right)_t \approx \left(\frac{V - V_V}{V_L - V_V}\right)_t , \tag{3}$$

where, the subscript "V" indicates the situation of pure vapor filling the test section, and "L" the situation of pure liquid filled between the electrodes. The subscript "t" denotes instantaneous value of the dimensionless conductivity, k/k_L. So, a time-average of the dimensionless conductivity can be expressed as:

$$\frac{k}{k_L} = \frac{1}{T}\int_T \left(\frac{k}{k_L}\right)_t dt , \tag{4}$$

where T is the total sample period of measurement.

The fluid conductivities are strongly dependent on temperature. In this way, it is necessary to use a dimensionless conductivity rather than the absolute value to avoid temperature influence over variable measurements. Therefore, for a sensor operating in the resistive range, the frequency of the applied signal is given by the condition imposed by used refrigerant electrical properties. A special electronic circuit will be designed for signal demodulation, and filtering as the same way as presented by Rocha and Simões-Moreira (2003, 2004, 2005a, and 2005b).

6. Expansion Valve Control Basics

Typical control algorithms or sets of instructions, used to control any electronic expansion valve are commented below. Just as with traditional mechanical control system, EEVs are primarily liquid superheat controlled devices. When using EEVs, the manner in which the superheat will be sensed must be determined first.

There are two basic schemes for sensing liquid superheat. Actual superheat is a pressure-temperature relationship, specific to each refrigerant. When electronically derived, pressure-temperature superheat requires the use of a pressure transducer, a temperature sensor, and a pressure-temperature table or equation. Another, simpler, but less accurate measure of superheat, is the two temperature method. In the two-temperature method the temperature is sensed at the inlet and at the outlet of the evaporator.

The difference in temperatures is assumed the superheat. Refrigerants or blends with temperature glides may affect two-temperature superheat control. A distinct advantage of two-temperature superheat is the low cost; pressure transducers are far more expensive than thermistors. Additionally, it works with any refrigerant without reprogramming. The temperature difference between the two sensors will indicate superheat no matter what the pressure-temperature relationship of the refrigerant. The main disadvantage of the two-temperature method is the uncertainty upon the inlet sensor location. For the two-temperature superheat method to be accurate, the inlet sensor must be located in a position that has saturated refrigerant present at all times. Failure to find, or use, the proper location can lead to poor control or compressor damage.

Generally as temperature rises, the voltage sent out through the signal wire also rises. The controller uses this voltage to calculate the temperature of the refrigerant with the use of a pressure-temperature table encoded in the controller itself.

Pressure-Temperature tables are familiar to the air conditioning and refrigeration industry and are available in many forms. To be useful to an electronic device, they are encoded in a “lookup table”. When a *P-T* (pressure-temperature superheat) controller is used, the lookup table for the specific refrigerant used in the system must be programmed into the controller.

Another way pressure-temperature relationships of one or more refrigerants are stored in the memory of a controller is by use of the “equation of state”. The equation of state is a mathematical description of refrigerant properties. Since EEV controllers are small computers, they have the ability to process equations efficiently and quickly. Once the pressure of the refrigerant is sensed and the lookup table is used to calculate the saturated temperature, only the real suction temperature must be sensed to determine the operating superheat. Temperature sensors detect suction temperatures.

The temperature sensors are generally simple thermistors, because of it widespread availability, reasonable price, and good accuracy. A thermistor is a device that will change electrical resistance in response to a change in temperature. The indicated temperatures are then used to generate superheat measurements, either by the pressure-temperature method or by the two-temperature method. Temperature sensors are also used to allow electric valves to directly control temperature. In systems with coils specifically designed for EEV control, or with provisions to float suction pressures, EEVs may increase control precision while saving energy.

Step motors are simple and cheap devices that actuate directly over the valve, controlling the lift, and permitting the repeatable precision valve movement needed for this application. Small increments of rotation may be useful in print head drives or for signaling purposes, but often a linear movement is more desirable. In the case of EEVs, not only a linear motion is needed, but significant linear force is also needed to close a port against high pressure.

The solution to both methods needs a Digital Linear Actuator (DLA), which are used to convert rotation to a push/pull output force. A simple gear train increases the force and may account in mechanical advantage.

Li et al. (2004), developed an automobile refrigerant system control method by using an EEV presetting the flow rate response for any operational conditions. It was proposed a new control method based on a fuzzy self-tuning algorithm, showing that it can feed adequate refrigerant flow into evaporator under abrupt changing of the compressor speed, which is a specific and hard operational condition.

In the same kind of investigation, Wu et al. (2005) present controllability tests for control strategy with fuzzy control algorithm achieving the desired control accuracy for the room air temperatures, without considerable oscillation, using EEV´s. Therefore, it was concluded that such a control method, including the control strategy and algorithm, is feasible and valuable for multi-evaporator air conditioners (MEAC) product development work in practice.

7. Summary and Conclusions

In this work, an overview of expansion valves influence and behavior on the refrigeration and air-conditioning systems were carried out. The main troubleshooting involving the use of thermostatic and electronically controlled expansion valves is the occurrence of flashing in the liquid line at the valve inlet. This paper examines this problem from an experimental point of view and a way of measuring the amount of vapor in order to provide a corresponding electronic signal for controlling purposes. To achieve that, the impedance sensor technique was proposed as an alternative tool to furnish that refrigeration control parameter.

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