Class: Fourth Stage
Subject: Refrigeration Systems
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Chapter Four

Expansion Devices

1. Introduction

Expansion devices is the one of the basic element in the refrigerant cycle. The purpose of expansion devise is reducing the pressure of the liquid refrigerant, and regulating the flow of it to the evaporator. The common types of expansion devices are :

- The capillary tube
- The constant-pressure expansion valve
- The superheat-controlled expansion valve
- The float valve

The most commonly used are: the capillary tube, the constant expansion valve, and the superheat-controlled expansion valve.

13-1 Purpose and types of expansion devices The last of the basic elements in the vapor-compression cycle, after the compressor, condenser, and evaporator, is the expansion device. The purpose of the expansion device is twofold: it must reduce the pressure of the liquid refrigerant, and it must regulate the flow of refrigerant to the evaporator.

This chapter explains the operation of the common types of expansion devices, the *capillary tube*, the *superheat-controlled expansion valve*, the *float valve*, and the *constant-pressure expansion valve*. Operation of a refrigeration system using these devices will be discussed, with special emphasis on balanced and unbalanced flow conditions occurring between the expansion device and the compressor. The two most commonly used expansion devices, the capillary tube and the superheat-controlled expansion valve, are singled out for a more thorough study of their operating characteristics.

Let us illustrates each expansion devices

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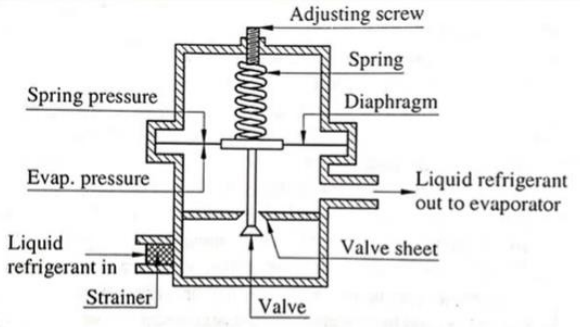
Constant-pressure expansion valve:

- The constant-pressure expansion valve maintains a constant pressure at its outlet, the entrance to the evaporator.
- It senses the evaporator pressure, and when that pressure drops below the control point, the valve opens wider. When the evaporator pressure rises above the control point, the valve partially closes

Working

Evaporator pressure increase	Evaporator pressure reduce
⬇	⬇
Diaphragm move up	Diaphragm move down
⬇	⬇
Reduce flow of refrigerant	Increase flow of refrigerant



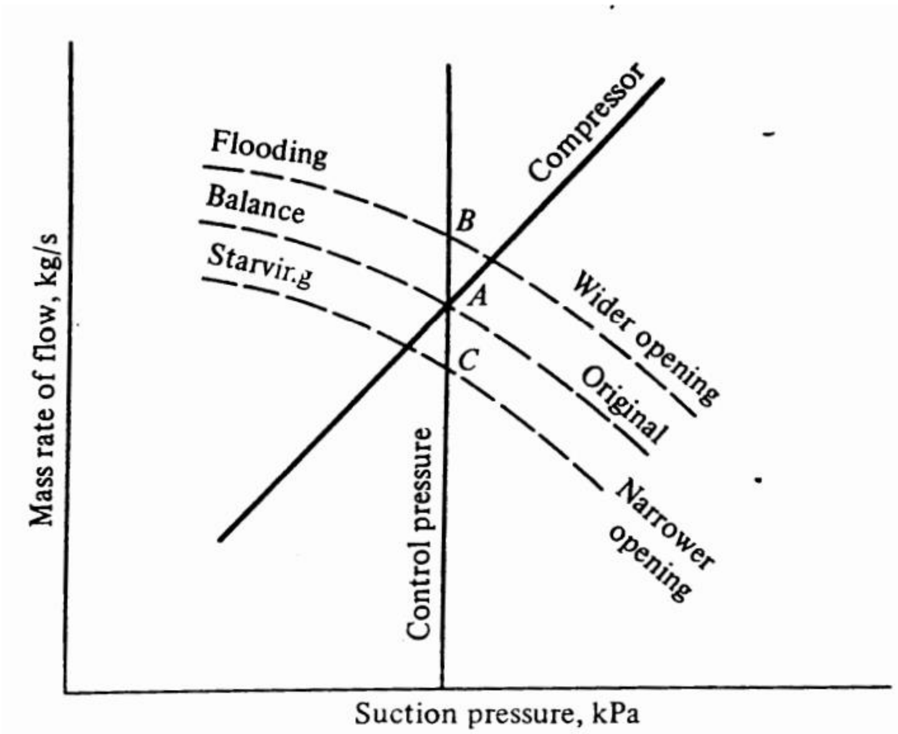


Figure 13-9 Balanced and unbalanced conditions using a constant-pressure expansion valve. The condensing pressure is constant.

The effect of the valve operation on the performance of the system is charted in Fig. 13-9. At a constant condensing pressure the compressor capacity and the feeding capacity of the expansion valve at several degrees of opening of the valve are shown. Point *A* is the balance point, where the expansion valve feeds as much as the compressor pumps from the evaporator. If the refrigeration load drops off, the suction temperature and pressure attempt to drop but the valve resists the drop in pressure by opening wider. Under the new condition the compressor capacity remains at *A*, but the feed rate of the valve changes to *B*. The evaporator will then flood under this unbalanced-flow condition. Starving of the evaporator can occur if the refrigeration load increased and the valve operated at point *C*.

Use of the constant-pressure expansion valve has been limited to systems of refrigerating capacity less than about 30 kW, in which a critical charge of refrigerant is feasible to prevent liquid from flooding out of the evaporator. Its primary use is where the evaporating temperature should be maintained at a certain point to control humidity or to prevent freezing in water coolers. The pressure-limiting characteristic can be used to advantage when protection is required against overload of the compressor due to high suction pressure.

Float valves

- The float valve is a type of expansion valve which maintains the liquid at a constant level in a vessel or an evaporator.
- A float switch which opens completely when the liquid level drops below the control point and closes completely when the level reaches the control point will give the same net performance as a modulating type of float control.
- By maintaining a constant liquid level in the evaporator the float valve always establishes balanced conditions of flow between the compressor and itself. Figure 13-10 shows an original balance point at A. If the refrigeration load should increase, the evaporating temperature and pressure rise, which momentarily allows the compressor to pump a greater rate of flow than the valve is feeding. The valve reacts to keep the level constant by widening its average opening. A new balance point occurs at point B. If the refrigeration load decreases, the suction pressure drops and the level rises, prompting the valve to close somewhat and give a balance point at C. Float valves and float-switch-solenoid combinations are used primarily in large installations. They can regulate the flow to flooded evaporators in response to the level of liquid refrigerant in the shell of the evaporator or in a chamber connected to the evaporator.

They should not be used in continuous-tube evaporators, where it is impossible to establish a level of liquid refrigerant by which they can be controlled.

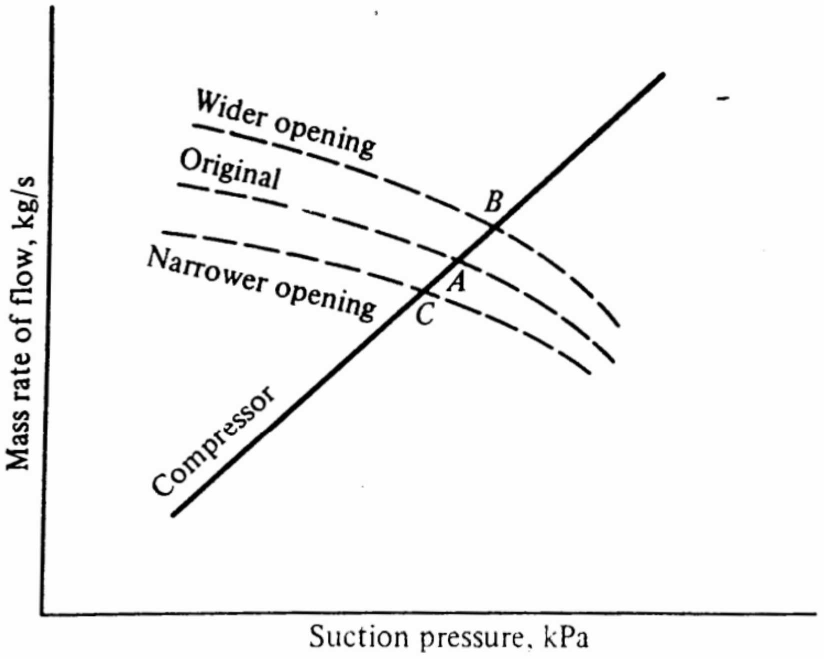


Figure 13-10 Balance points with various load conditions using a float valve. The condensing pressure is constant.

Superheat-controlled (thermostatic) expansion valve

- The most popular type of expansion device for moderate-sized refrigeration systems is the superheat-controlled valve, usually called a thermostatic expansion valve.
- The name may be misleading because control is actuated not by the temperature in the evaporator but by the magnitude of superheat of the suction gas leaving the evaporator.
- The superheat expansion valve regulates the rate of flow of liquid refrigerant in proportion to the rate of evaporation in the evaporator.
- The balances of the flow rate between the compressor and superheat-controlled expansion valve are therefore practically identical to those shown for the float valve in Fig. 13-10. Figure 13-11 is a photograph of a thermostatic expansion valve.
- The superheat of the suction gas operates the thermostatic expansion valve as follows. A feeler bulb (Fig. 13-12) is partially filled with liquid of the same refrigerant as that used in the system. The fluid in the bulb is called the power fluid. The feeler bulb is clamped to the outlet of the evaporator so that the bulb and the power fluid closely

assume the temperature of the suction gas. The pressure of the power fluid bears on the top of the diaphragm, and the evaporator pressure pushes on the bottom of the diaphragm. A slight force exerted by the spring on the valve stem keeps the valve closed until the pressure above the diaphragm overcomes the spring force plus the force of the evaporator pressure. For the pressure above the diaphragm to be higher than the pressure below the diaphragm, the power fluid must be at a temperature higher than the saturation temperature in the evaporator. The suction gas must therefore be superheated in order to bring the power fluid up to the pressure which opens the valve.

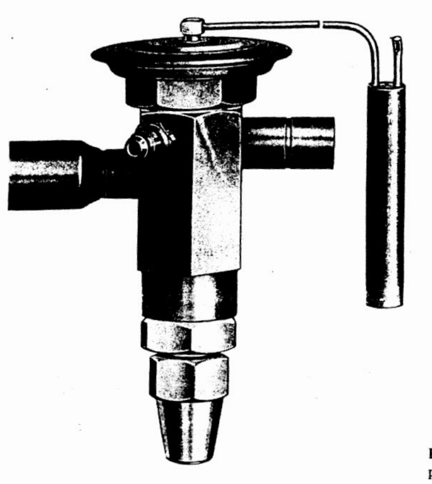


Figure 13-11 A thermostatic expansion valve. *(Sporlan Valve Co.)*

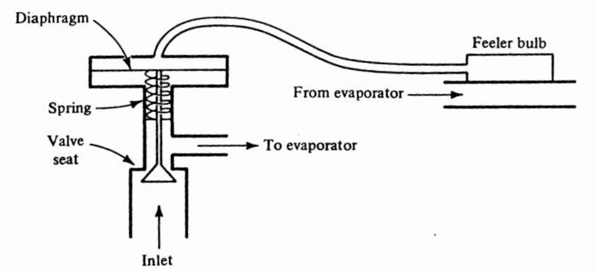
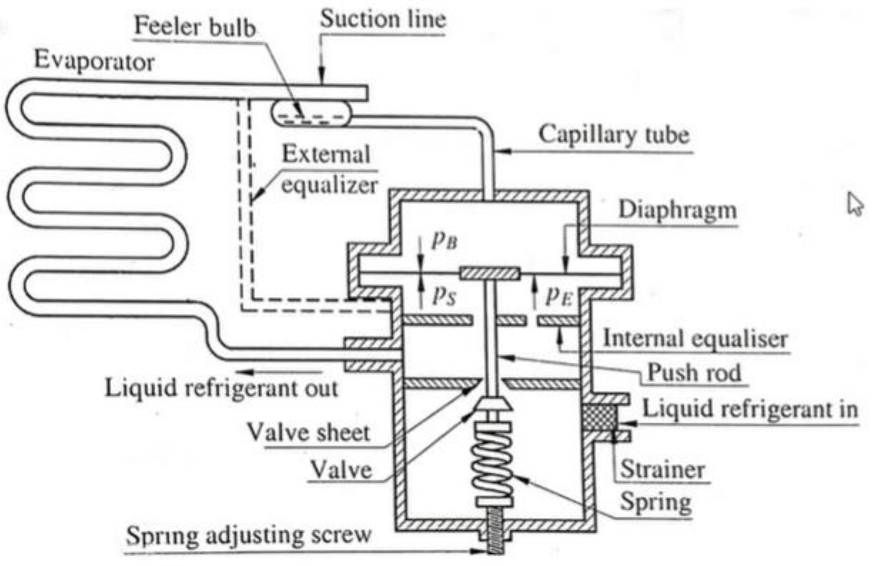


Figure 13-12 A schematic diagram of the basic superheat-controlled expansion valve.



Electric expansion valves

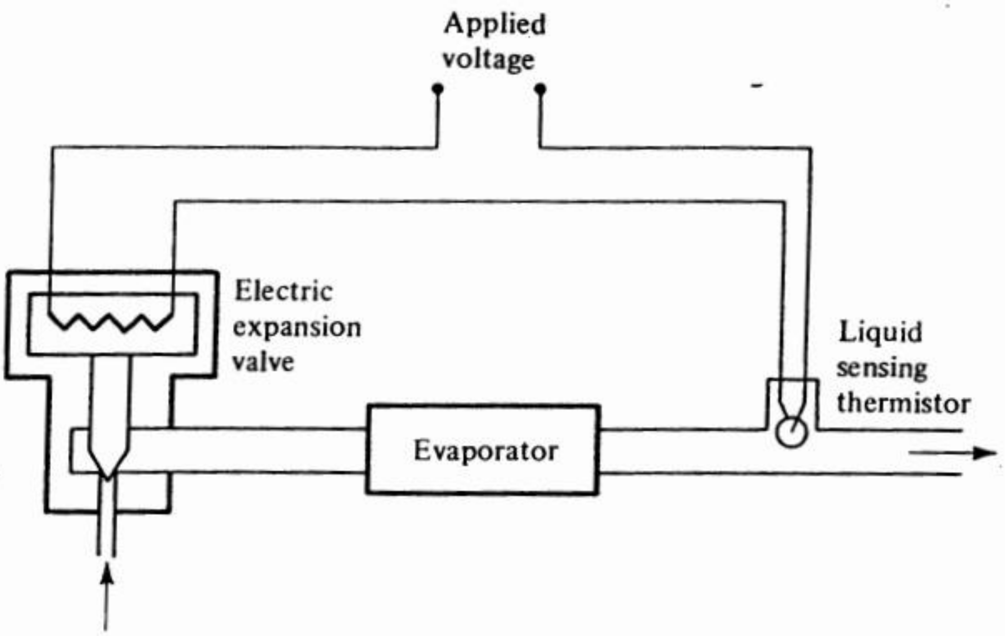


Figure 13-17 An electric expansion valve.

13-12 Electric expansion valves The electric expansion valve, shown schematically in Fig. 13-17, uses a thermistor to sense the presence of liquid in the outlet stream of the evaporator. When no liquid is present, the temperature of the thermistor increases, which drops its resistance and permits a greater current flow through the heater at the valve. The valve is thereby opened, allowing an increased refrigerant flow rate. One of the applications of the electric expansion valve is for heat pumps (Chap. 18), where the flow rate of refrigerant is reversed in order to change from heating to cooling. Since its control is independent of refrigerant pressures, the electric expansion valve can function with flow through the valve in either direction.

2. Capillary tubes

- The capillary tube serves almost all small refrigeration systems, and its application extends up to refrigerating capacities of the order of 10 kW. 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.
- Numerous combinations of bore and length are available to obtain the desired restriction. Once the capillary tube has been selected and installed, however, the tube cannot adjust to variations in discharge pressure, suction pressure, or load.
- The compressor and expansion device must arrive at suction and discharge conditions which allow the compressor to pump from the evaporator the same flow rate of refrigerant that the expansion device feeds to the evaporator. A condition of unbalanced flow between these two components must necessarily be temporary.

- For a closer look at balance points the mass rate of flow fed by the capillary tube can be plotted on the same graph as the mass rate of flow pumped by the compressor. Figure 13-1 is such a plot with the flow through the capillary tube shown in dashed lines and the pumping capacity of a reciprocating compressor shown in solid lines. At high condensing pressures the capillary tube feeds more refrigerant to the evaporator than it does at low condensing pressures because of the increase in pressure difference across the tube.
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- At a 30°C condensing temperature, for example, the compressor and capillary tube must search for a suction pressure which allows them both to pass equal mass rates of flow. This suction pressure is found at point 1, which is the balance point at a 30°C condensing temperature. Points 2 and 3 are the balance points at 40°C and 50°C condensing temperatures, respectively.

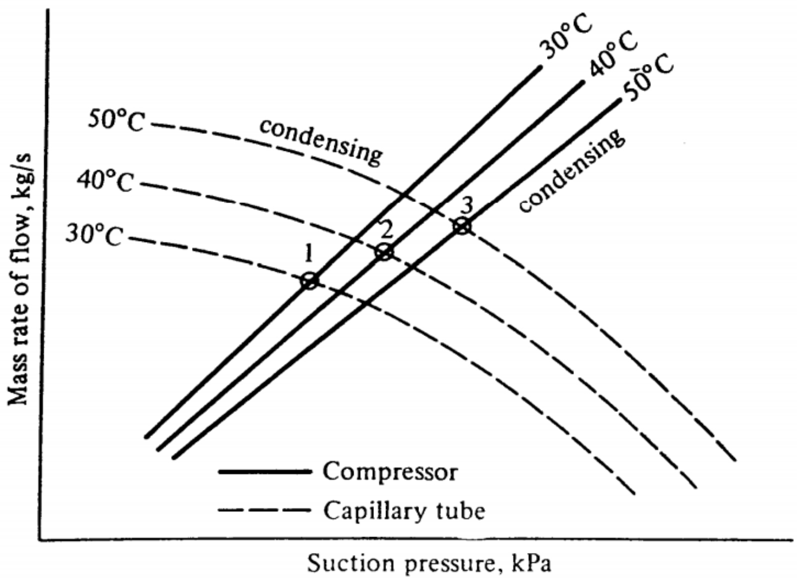

Figure 13-1 Balance points with a reciprocating compressor and capillary tube.

At suction pressure B the compressor can draw more refrigerant out of the evaporator than the capillary tube can supply, so the evaporator soon becomes short of refrigerant. Since the evaporator cannot be emptied indefinitely, something must happen to restore the balance. The corrective condition on most units without a receiver (vessel that stores liquid between the condenser and expansion device) is that liquid backs up into the condenser. The condensing area is thereby reduced and the condenser pressure raised. With the elevated condenser pressure, the compressor capacity is reduced and the capillary-tube rate of feed is increased until balance is restored. Another possibility for regaining a balanced flow rate is that the heat-transfer coefficient in the starved evaporator decreases. A greater temperature difference must develop between the fluid being chilled and the refrigerant in the evaporator, which occurs by means of the suction pressure dropping back to pressure A and restoring balanced flow.

An opposite unbalanced condition results if the refrigeration load falls off to less than the refrigeration capacity at the balance point. If the refrigeration load drops off, the suction temperature and pressure drop to some point C At suction pressure C the capillary tube can feed more refrigerant to the evaporator than the compressor can draw out. The evaporator fills with liquid and would spill over into the compressor with disastrous results were it not prevented. Slugging the compressor with liquid can be prevented by limiting the charge of refrigerant in the system. The charge is carefully measured so that there is enough refrigerant to fill the evaporator but no more. Balance of flow is restored when some gas enters the capillary tube, reducing the feed rate of the capillary tube 1 because of the high specific volume of the vapor. A new balance point is at point D in Fig. 13.2.

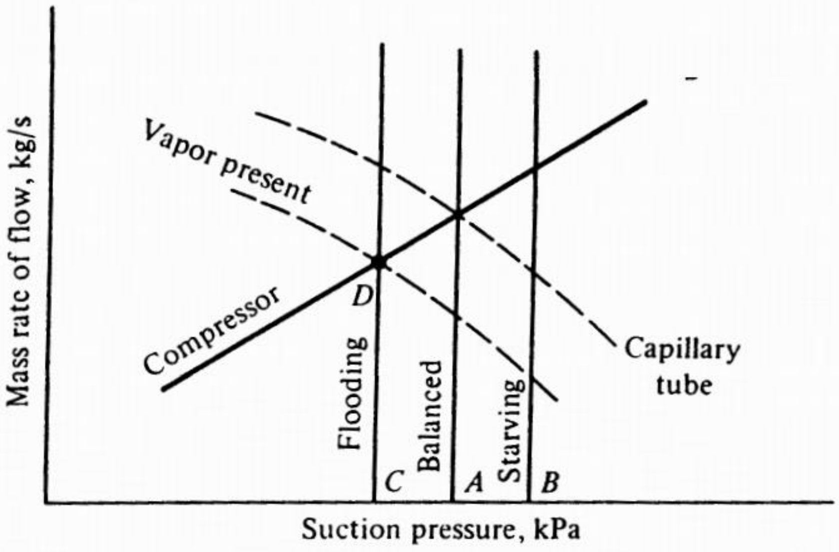

Figure 13-2 Unbalanced conditions causing starving or flooding of the evaporator. The condensing pressure is constant.

Although point *D* represents balanced flow, it is not a satisfactory condition. The state of the refrigerant entering the capillary tube shown on the pressure-enthalpy diagram in Fig. 13-3 is in the mixture region, which reduces the refrigerating effect compared with that when saturated or subcooled liquid enters the capillary tube. Each kilogram of refrigerant provides a reduced refrigerating effect in Fig. 13-3, but the work per kilogram remains unchanged.