Refrigeration Service Engineers Society
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THERMOSTATIC EXPANSION VALVES
Part 1

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INTRODUCTION

The *thermostatic expansion valve* (frequently abbreviated TEV or, sometimes, TXV) has played a significant role in the progress of the HVAC/R industry and its technology. Its value is based on its refrigerant control capability and its adaptability to the many and varied applications of the refrigeration cycle.

The development of many system components has been a by-product of technical evolution. This applies to the thermostatic expansion valve. In the early days of mechanical refrigeration, a hand-operated needle valve was used for refrigerant control. This device gave some measure of control in applications where the load was constant. However, it could not respond to other conditions affecting the amount of refrigerant passing through it—for example, changes in liquid pressure caused by variations in compressor head pressure. The manual expansion valve required constant supervision in locations where a varying load could produce starved evaporator or liquid refrigerant floodback conditions.

The introduction of “float”-type metering valves was a step toward automatic refrigerant flow. One type was designed to control refrigerant in the low side, and another in the high side. The float-type valve operated in the same manner as a boiler water-level control to maintain a flooded evaporator. It was highly efficient in serving that purpose—however, it could not be applied to a dry or direct-expansion evaporator system, which was gaining favor. Even so, the float-type valve did not disappear from the field. It is still used in industrial process refrigeration systems. It is also used in large water chillers, especially those with centrifugal compressors.

Efforts to overcome these inadequacies produced what is called the “automatic expansion valve.” A more accurate description would be a “constant evaporator pressure control valve.” That is, it maintains a constant outlet pressure, regardless of changes in inlet liquid pressure, in load, or in other conditions.

The automatic expansion valve was a decided improvement over the hand-operated expansion valve. It maintained temperature more evenly, and controlled the frost line of the evaporator better. Furthermore, it closed the liquid line when the compressor stopped, and prevented excessive flooding when the compressor started.

However, this device also had disadvantages and limitations. It tended to overfeed refrigerant to the evaporator when the heat load was low, as at the end of the run. It also tended to starve the evaporator when the heat load was high, as at the start of the run. Thus, its pull-down of temperature was slow. It did not take advantage of the full area and capacity of the evaporator at the start of the refrigeration cycle.

In the late 1920s, another device—the thermostatic expansion valve—was introduced. It overcame the limitations of both the hand-operated expansion valve and the automatic expansion valve. Figure 1 on the next page shows a typical example of a modern thermostatic expansion valve (sometimes also called a *thermal* expansion valve). The purpose of the TEV is to control the flow of refrigerant to an evaporator.

If the evaporator were to remain active through all variations in the heat load, it would contain only liquid and saturated vapor—no superheated vapor. In practice, this is not a desirable condition. Some of the evaporator must be used to superheat the vapor, or else there will be liquid refrigerant in the suction line, which can slug the compressor. The TEV is actually a *constant superheat valve*—a more descriptive and accurate name, though rarely used.

This document is a revision of prior publication 620-40.

SPORLAN VALVE COMPANY

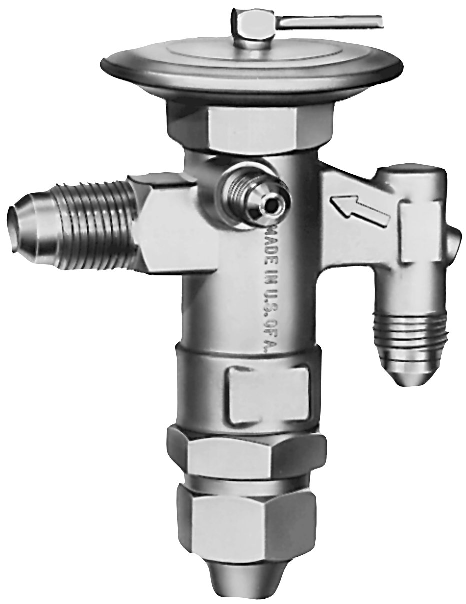


Figure 1. Typical thermostatic expansion valve (TEV)

The name of this device can give the impression that it directly controls temperature. Some service technicians mistakenly have tried to adjust a thermostatic expansion valve to control refrigerator temperature.

This chapter covers the theory of operation, proper selection, and application of thermostatic expansion valves. The control of superheat is one of the basic functions of thermostatic expansion valves. The discussion that follows will better acquaint you with the principle of superheat.

TEMPERATURE-PRESSURE RELATIONSHIPS

If you are familiar with the concept of temperature-pressure relationships already, then you should have little difficulty understanding the basic function of a thermostatic expansion valve. Figure 2 below illustrates the changes that take place in 1 lb of water at atmospheric pressure.

- Sensible heat is added. It raises the temperature from 32°F to 212°F (from the freezing point to the boiling point).
- Heat (sensible heat) is continually added until the temperature reaches 212°F. At this point, the water must absorb another 970.4 Btu/lb (latent heat of vaporization) to change completely to steam at 212°F.
- Additional sensible heat raises the temperature of the steam above 212°F.

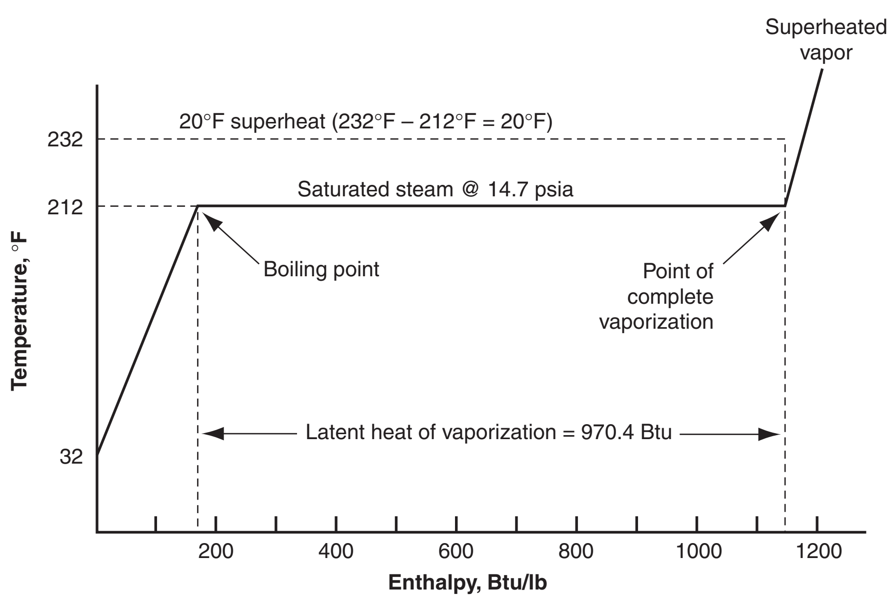


Figure 2. Water at atmospheric pressure

The temperature above 212°F is called *superheat*. It is still measured in degrees. Figure 2 shows an example. The temperature of the steam at atmospheric pressure is 232°F, which means that it has been superheated 20°F (232°F – 212°F = 20°F).

The principles are the same when you analyze the effect of superheat on a refrigerant. Figure 3 shows the effect of superheat on 1 lb of liquid R-22. At atmospheric pressure, the addition of heat makes it boil at –41°F. After all the refrigerant vaporizes, any added heat will raise its temperature above –41°F, or superheat it. Note that it takes 100 Btu (latent heat of vaporization) to vaporize the entire pound of liquid R-22. Adding more heat will superheat the vapor. If the temperature is raised to –21°F, the vapor has been superheated 20°F.

Pressure, psig	Temperature, °F
68	40
28	5
9	–22

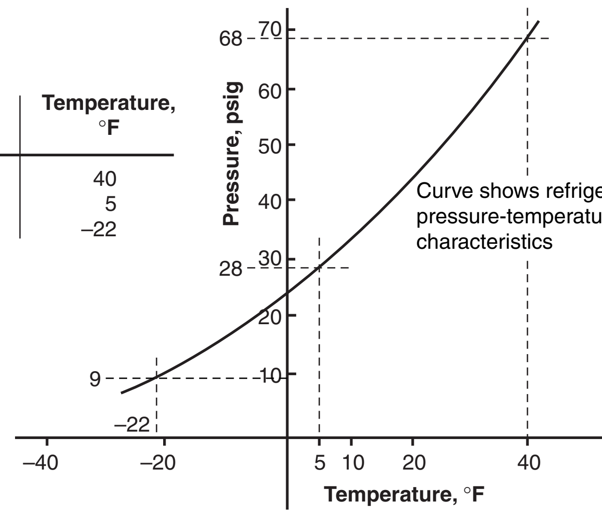
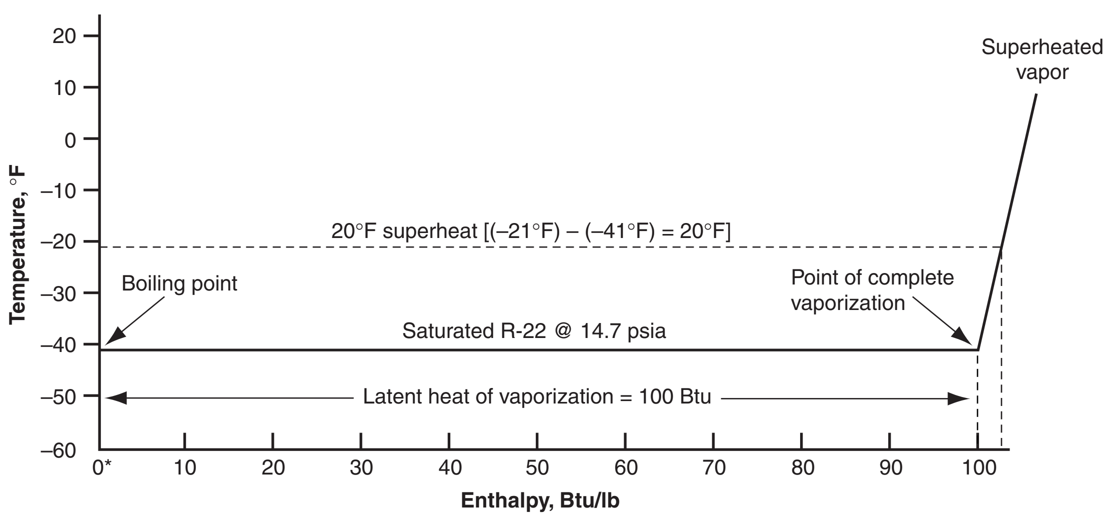


Figure 4. Boiling points of R-22 at various pressures

Figure 3 is only an example of the principle of superheat. In fact, service technicians do not work with any refrigerant at atmospheric pressure. You already know that reducing pressure on a liquid lowers its boiling point. It then takes less heat to vaporize it. Conversely, increasing the pressure on a liquid raises the boiling temperature.

Figure 4 above shows the boiling points of R-22 at various pressures. Note the curved line. It shows how the saturation or boiling temperature changes as pressure changes. As the pressure increases, it takes a higher temperature for the refrigerant to boil. The curved line also represents the R-22 pressure-temperature characteristics. The horizontal line shows the temperature in degrees Fahrenheit. The



*Based on 0 Btu for the saturated liquid at –40°F

Figure 3. R-22 at atmospheric pressure

vertical line shows pressure in psig. The dotted lines in Figure 4 show some of the coordinates on the curve at which the refrigerant will boil.

Follow this relationship up and down the pressure-temperature scale in Figure 4. You can determine a series of boiling points—for example, 40°F at 68 psig, 5°F at 28 psig, –22°F at 9 psig, etc. The curve itself is simply a line drawn through all of these points. Other refrigerants have different curves. No two refrigerants have identical pressure-temperature characteristics.

THE EFFECTS OF SUPERHEAT ON A REFRIGERATION SYSTEM

Now that the basic principle of superheat has been covered, let's relate the various factors to a simple refrigeration system. Assume that the system consists of a bare tube evaporator, compressor, condenser, and receiver. It also has the most basic of refrigerant control devices, the hand-operated expansion valve. Figure 5 shows such a basic system.

Opening the hand expansion valve slightly allows a small amount of refrigerant to enter the exposed coil. Air around the coil is at a higher temperature than the refrigerant. When the heat from the air penetrates the tubing wall, it causes the refrigerant in the coil to heat up and boil. Assume that the refrigerant flow is at a relatively slow rate. If this is the case, all the liquid boils into vapor close to the entry point. You can see an example of this at point A in Figure 5, where the temperature is 20°F.

From this point on, the boiling vapor picks up superheat. The farther the vapor travels and the longer it is exposed to heat, the greater the superheat becomes. At point B, the vapor's temperature is 30°F with 10°F superheat. At the fifth return bend, the temperature is 40°F with 20°F superheat.

Now look at point C. The difference between vapor temperature (50°F) and boiling temperature (20°F) equals 30°F of superheat. At this point, the suction pressure of the compressor is 43 psig.

Opening the hand expansion valve farther increases the flow of refrigerant. Figure 6 shows the result. The increased flow rate means that the refrigerant must reach point B before complete vaporization takes place. This reduces the evaporator coil surface that is available for building up superheat. As a result, there is only 20°F superheat at point C. Higher suction pressure results from the greater load placed on the compressor by the additional refrigerant.

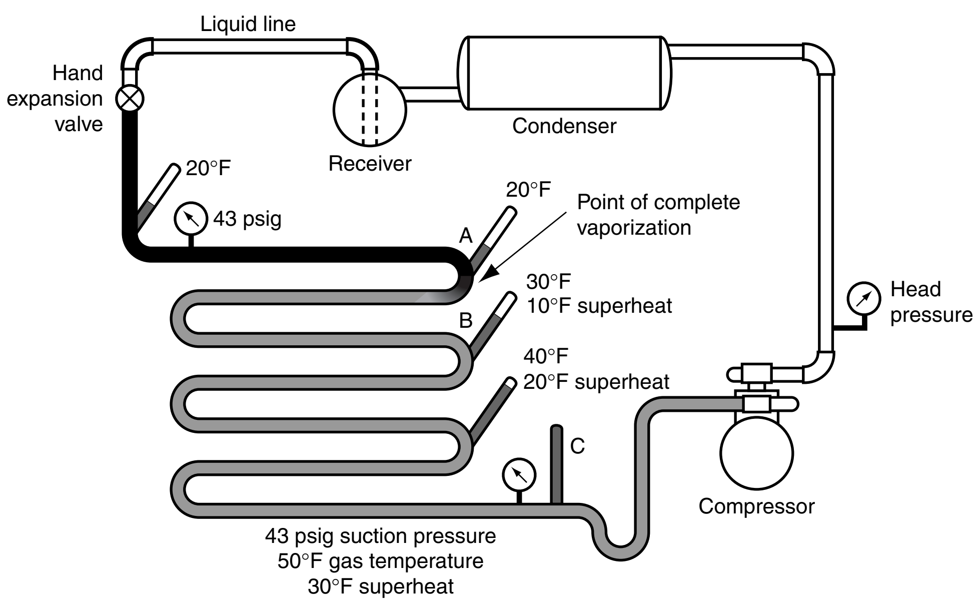


Figure 5. Simple refrigeration system

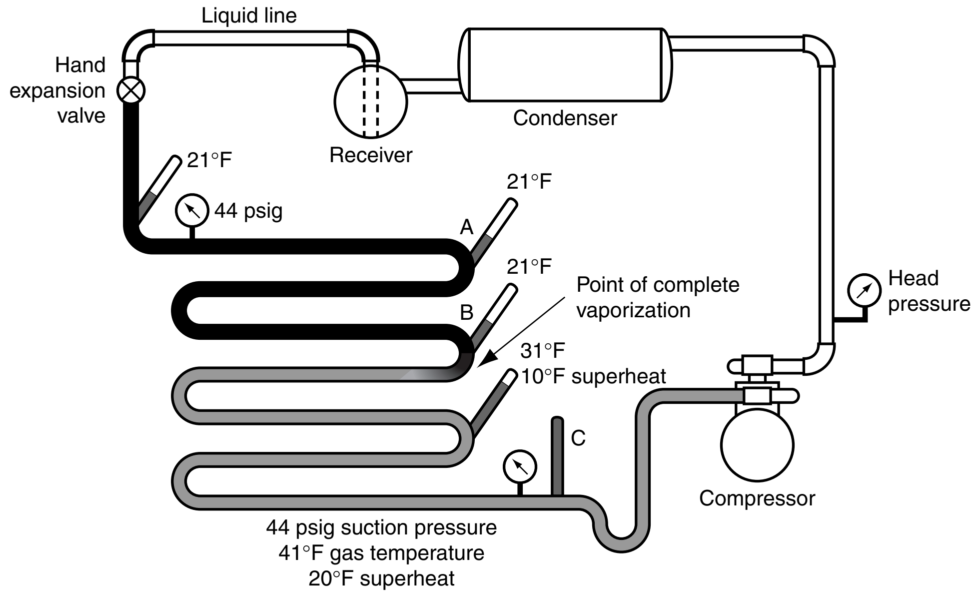


Figure 6. Additional flow reduces superheat

Now look at Figure 7. The hand expansion valve is open even farther. So much refrigerant flows that it cannot completely vaporize in the evaporator. This causes liquid to flood back to the compressor. The result is wasted refrigerant and greatly reduced compressor capacity. The greatest concern is possible damage to the compressor. The compressor is designed to compress a gas, not a liquid.

These examples demonstrate the ideal evaporator condition. The goal is to keep the point of complete vaporization at the outlet of the evaporator. Note in

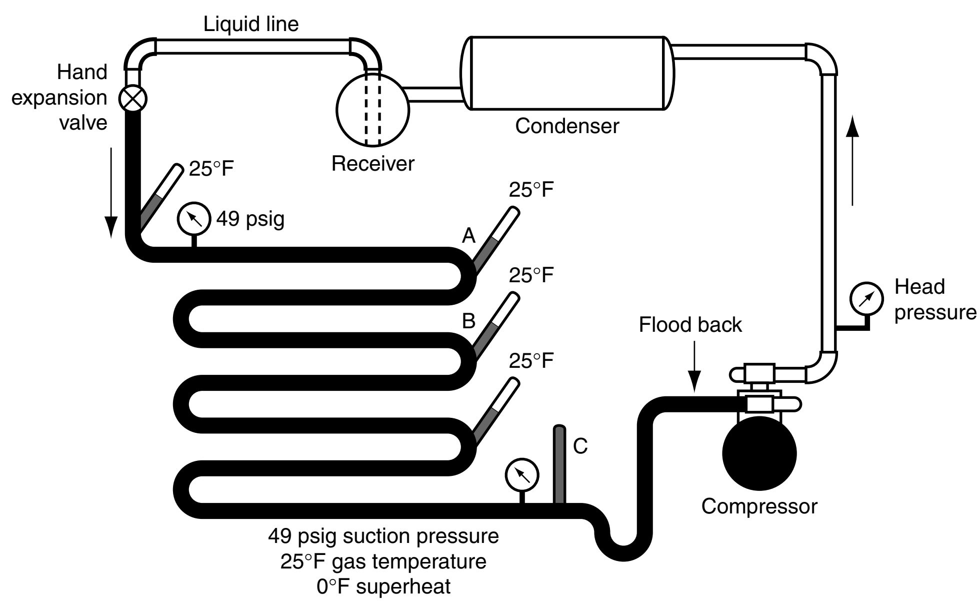


Figure 7. Too much flow produces floodback

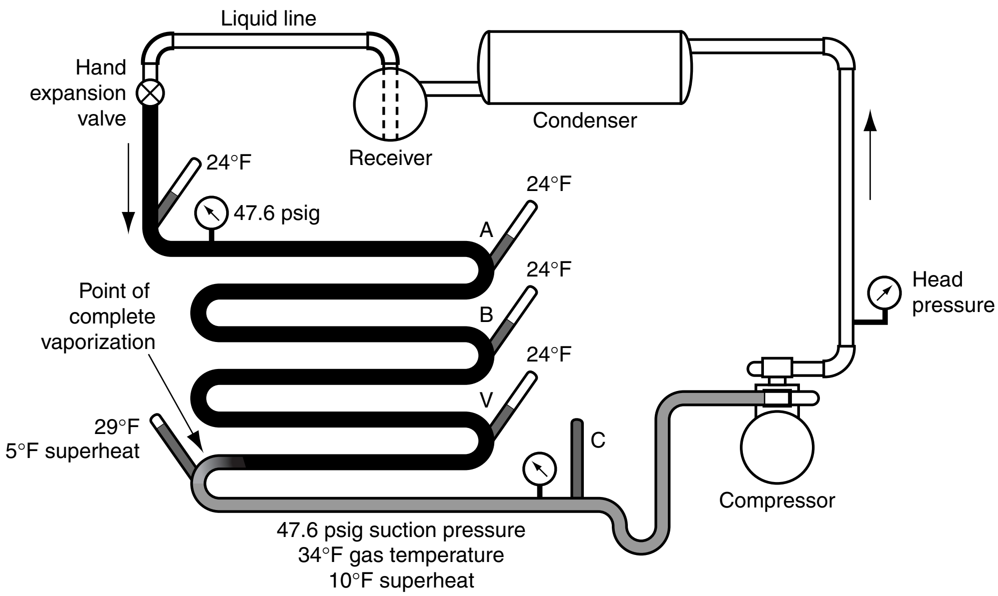


Figure 8. Proper flow results in correct superheat

Figure 8 that superheat is 0°F at point V. Ideally, the entire surface of the evaporator performs its refrigeration function. Only dry, superheated vapor reaches the compressor.

In practice, it is impossible to obtain this condition. However, the TEV allows you to reach a level close to the ideal. It takes only several degrees of superheat to open the valve. The addition of several degrees produces a steady, rated flow of refrigerant.

Figure 9 shows the level of efficiency achieved with the TEV. You have seen that low superheat at the outlet of the evaporator is desired. Thus, you place the TEV bulb at this point to measure this condition. In the proper position, its temperature will be about equal to suction gas temperature.

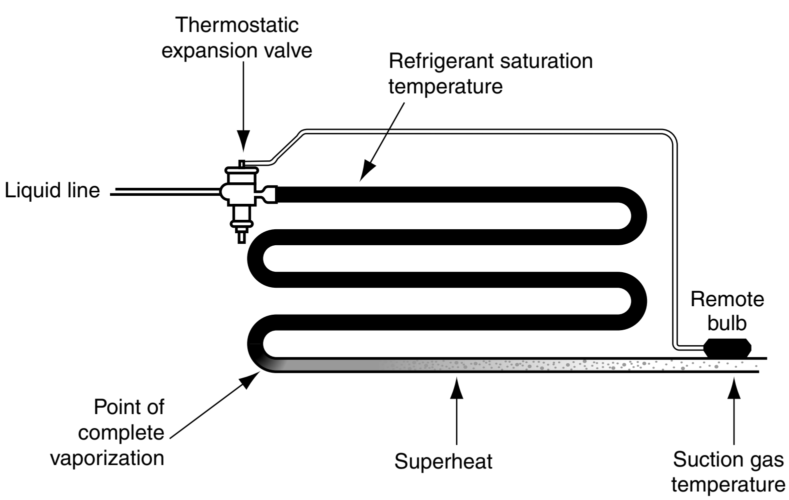


Figure 9. TEV installed at entrance to evaporator

Before examining TEV operation in depth, first review the following terms. They are closely associated with valve operation:

Liquid line. The piping that carries liquid refrigerant from the condenser to the expansion valve.

Refrigerant saturation temperature. The temperature at which refrigerant boils in the evaporator.

Complete vaporization. The point at which liquid refrigerant is entirely changed to vapor, governed by the amount of refrigerant in the evaporator.

Superheat. The heat added to vapor beyond the point of complete vaporization.

Suction gas temperature. The temperature of refrigerant vapor measured along the suction line between the evaporator and the compressor.

THERMOSTATIC EXPANSION VALVE OPERATION

Principal parts

Figure 10 shows the essential parts of a typical thermostatic expansion valve—the diaphragm case, capillary tube, bulb, seat, pin carrier, spring, spring guide, adjusting stem packing, adjusting stem, push rods, and inlet strainer.

Note that there is no direct mechanical linkage between the adjustment stem and the pin. The adjusting stem serves only to vary the spring pressure.

The diaphragm, inside its case, reacts to bulb pressure. It transmits its motion through the push rods to the top of the pin carrier. When the pin moves away from the seat, liquid refrigerant flows into the evaporator. The pin carrier is long enough to ensure straight-line movement and precise pin-seat contact. As noted, the adjusting stem serves only to control spring pressure against the pin carrier.

Operation

From the positioning of its parts, it may seem like the principle of TEV operation is bulb pressure opposing spring pressure. But this is not the case. There are three fundamental pressures that affect the opening and closing of this control device:

- bulb pressure
- spring pressure
- evaporator pressure.

Figure 11 shows the application of these three fundamental pressures. A thorough knowledge of the relationship among these three pressures is needed

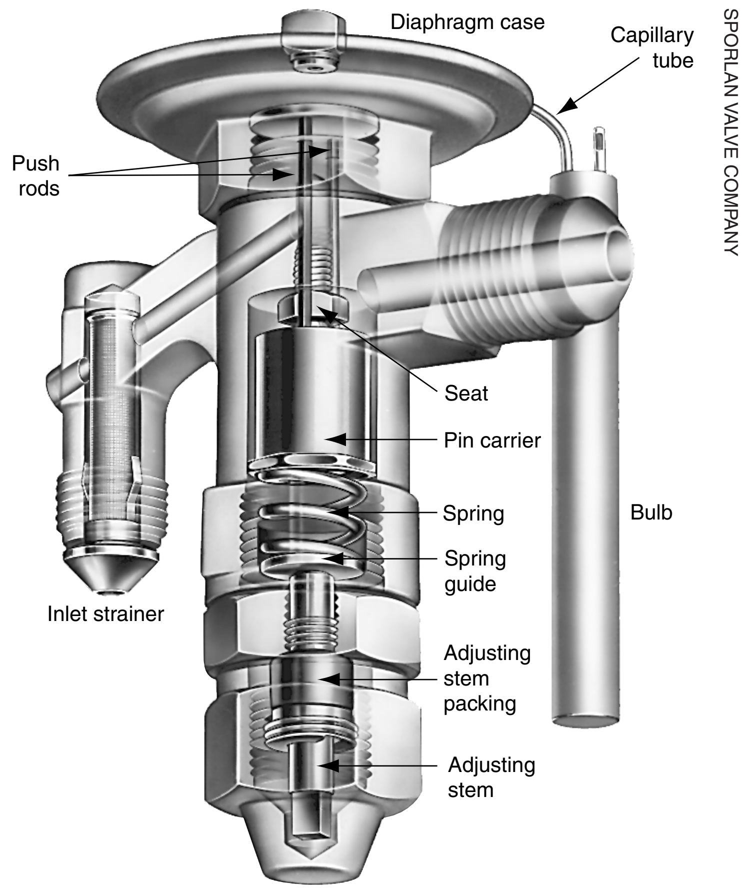


Figure 10. Essential parts of a TEV

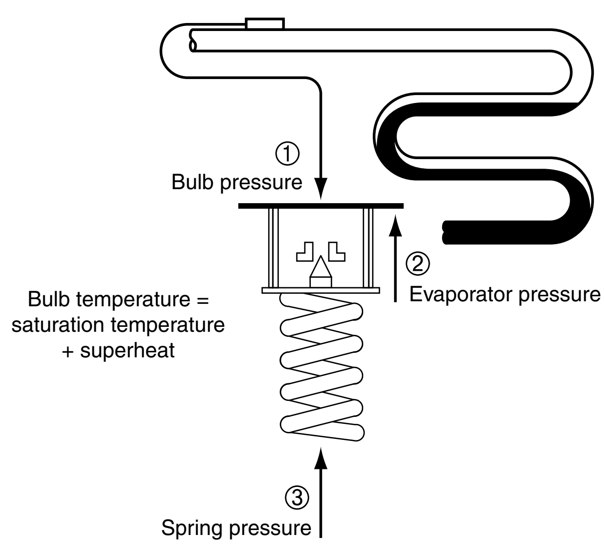


Figure 11. TEV operation

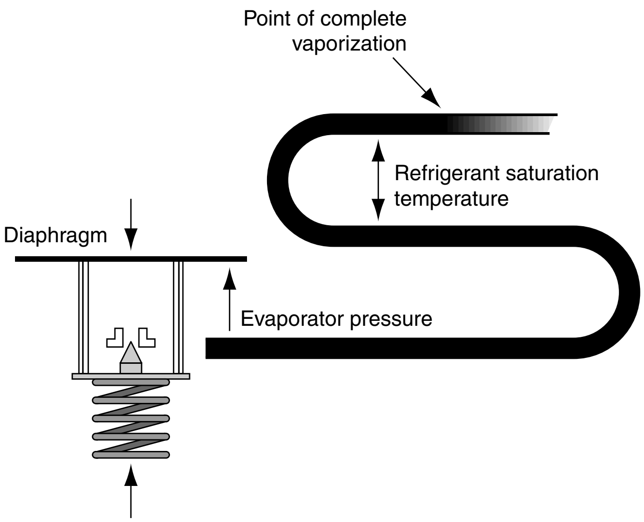


Figure 12. Evaporator pressure relates to refrigerant saturation temperature

for complete understanding of valve operation. As shown in Figure 11 on the previous page, in order for the valve to open, bulb pressure (1) must equal the sum of the evaporator pressure (2) and the spring pressure (3).

Evaporator pressure is a key factor in the operation of a thermostatic expansion valve. Unfortunately, it is often overlooked in an analysis of valve operation problems. Evaporator pressure is applied under the diaphragm in the direction of closing the valve, as shown in Figure 12 above. It is important because of its relationship to refrigerant saturation temperature. Evaporator pressure always equals the pressure corresponding to refrigerant saturation temperature. Look back at Figure 4 for a moment. It shows examples of this pressure-temperature relationship. One example is that a saturation temperature of 40°F for R-22 produces an evaporator pressure of 68 psig.

In addition, the spring transmits pressure through the top of the pin carrier and the push rods. It is also applied to the underside of the diaphragm. Thus, *spring pressure* further implements closing of the valve.

Figure 13 shows more of the evaporator. It shows the points at which superheat and suction gas temperatures can be measured. These temperatures are used to determine the final pressure—that of the bulb. *Bulb pressure* is applied through the capillary tube to the top of the valve diaphragm. This pressure opposes the sum of the evaporator pressure and the spring pressure. It acts to open the valve. When a system is operating, the bulb charge is part liquid refrigerant and part saturated vapor. Bulb temperature equals suction gas temperature. Suction gas temperature is higher than refrigerant saturation temperature. The increase is produced by superheat.

The higher bulb temperature applies more pressure to the top of the diaphragm than the opposing evaporator pressure. However, opening the valve requires enough pressure difference (increased superheat) to overcome the additional effect of spring pressure. Figure 14 provides a closer look at how the bulb pressure acts on the top of the diaphragm.

When the bulb and system are charged with the same refrigerant, both the evaporator pressure under the diaphragm and the bulb pressure on top follow the same saturation curve.

Consider the results of this relationship. Pressure on the top of the diaphragm is induced by bulb saturation temperature. Pressure on the bottom is induced

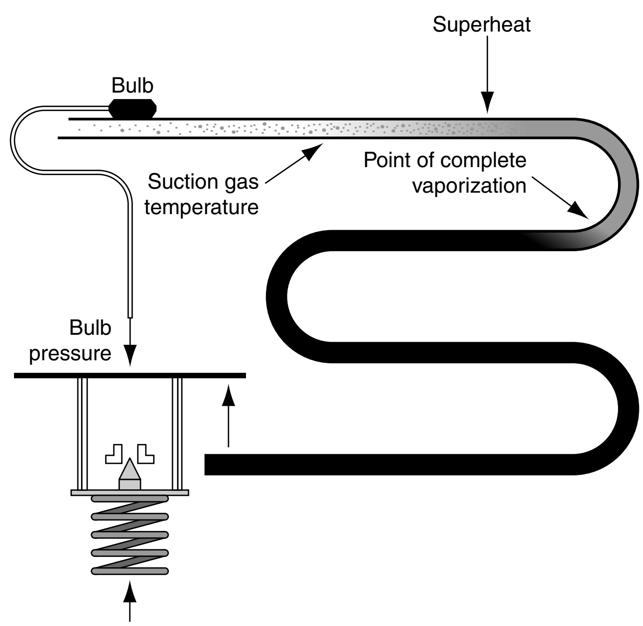


Figure 13. Bulb pressure acts to open valve

by evaporator saturation temperature. They become equal and opposing, canceling each other out. You can see, then, that pressures induced by refrigerant saturation temperature exert equal force. They act on both sides of the diaphragm. This leaves superheat and spring pressure the two factors that regulate the valve. These two opposing factors maintain a delicate pressure balance on both sides of the valve diaphragm. This permits the valve to operate over a wide range of evaporator pressures. It can handle light as well as heavy loads on the evaporator. The thermostatic expansion valve is, in effect, a superheat regulator.

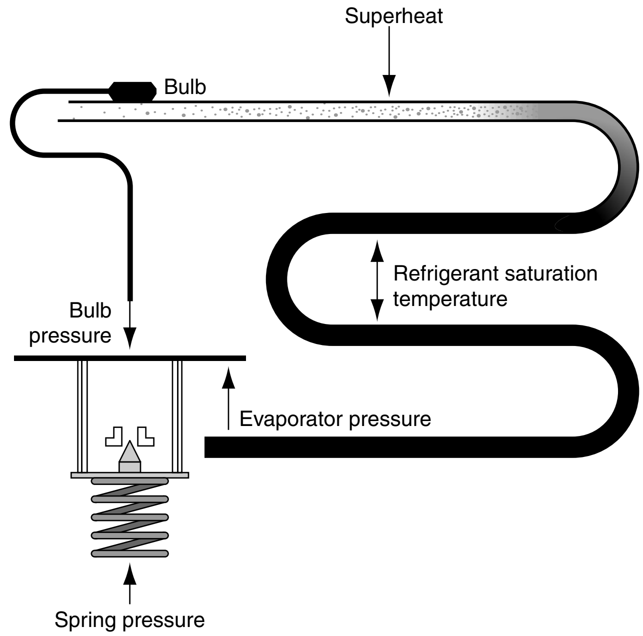


Figure 14. Bulb pressure and the effect of superheat

Occasionally you may hear a service technician say, "I opened the expansion valve" or "I closed the expansion valve." Actually, the adjustment was simply a change in spring pressure. Increased spring pressure requires more pressure induced by superheat to oppose it. The valve throttles back. On the other hand, reduced spring pressure requires less pressure induced by superheat to oppose it. The valve opens.

For any spring setting, when the load on the evaporator increases, the valve will underfeed the evaporator. As a result, suction pressure will drop or bulb temperature will increase—or both conditions may exist. In any case, the valve will open wider. If the evaporator load is reduced, the valve will overfeed the evaporator. As a result, suction pressure will increase or bulb pressure will decrease, or both. Existing spring pressure will throttle the valve to the closed position.

Figure 15 illustrates conditions in a typical system, and shows a closer relationship between theory and practice. Evaporator pressure is 52 psig, and spring pressure is 12 psig. They exert a combined closing force of 64 psig. Assume that the bulb is charged with the same refrigerant as the system. A bulb pressure of 64 psig will be required to equalize pressure on both sides of the diaphragm. At 28°F refrigerant saturation temperature, a superheat of 9°F is required to increase suction gas and bulb temperature to 37°F. This would produce the required 64 psig in the bulb.

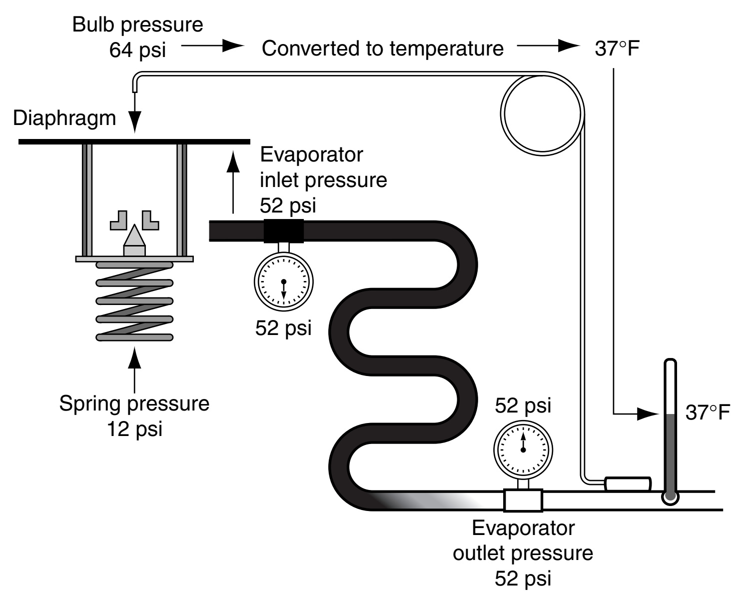


Figure 15. Superheat equals bulb temperature minus saturated evaporator temperature

In a system idle for a long period of time, pressure in the bulb and above the diaphragm will be almost enough to overcome spring pressure and open the valve. Compressor start-up will immediately lower the refrigerant pressure under the diaphragm. The bulb pressure will then be enough to oppose the spring pressure. It will force the diaphragm down and open the valve.

Liquid refrigerant will then flow through the open valve as a spray. It will fill the evaporator with wet and saturated vapor. If all of the liquid refrigerant evaporates and becomes superheated vapor before it reaches the suction line, the thermal expansion valve remains open.

The evaporator continues to absorb heat. The surrounding temperature will decrease until wet and saturated vapor extends to the point in the suction line where the capillary tube bulb is clamped. When this occurs, the reduced degree of superheat cools the suction line and bulb. As a result, vapor pressure in the bulb and above the diaphragm decreases. This permits spring pressure to close the valve, either wholly or partially.

Refrigerant flow is now stopped or reduced. It remains so until superheat at the bulb location increases vapor pressure in the bulb and above the diaphragm. When this pressure can overcome the combined evaporator pressure and spring tension below the diaphragm, the valve opens. This restores or increases refrigerant flow into the evaporator.

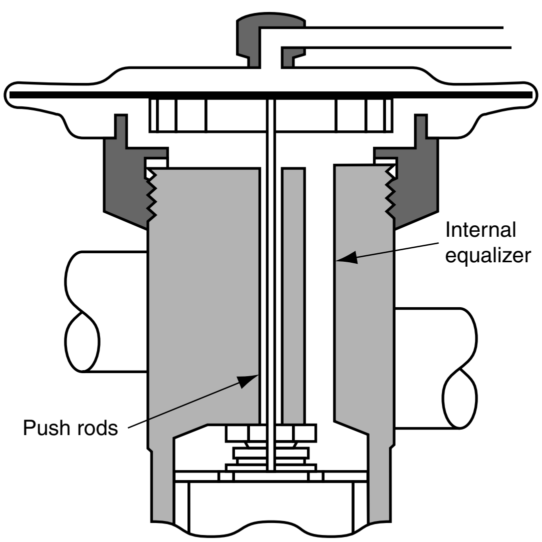


Figure 16. TEV with internal equalizer

When the system's pressure or temperature control stops the compressor, evaporator pressure immediately increases. This is because it is no longer subject to the compressor suction effect. It will increase until the combined evaporator pressure and spring tension pressure can overcome vapor pressure in the bulb and above the diaphragm. When it does, the diaphragm raises and the TEV closes.

PRESSURE DROP ACROSS THE EVAPORATOR

This discussion of TEV operation has not yet considered pressure drop through the evaporator. It was omitted for simplification. In actual system operation, however, pressure drop will exist and is a factor. To overcome the effect of pressure drop, inlet pressure is used to operate the valve.

Inlet evaporator pressure acts on the underside of the diaphragm. It feeds through a passageway from the low-pressure side of the valve. This passageway is called an "internal equalizer," shown in Figure 16. (A thermostatic expansion valve also may have an external equalizer connection, which will be covered in greater detail later in this chapter.)

By now, you should be able to form one firm conclusion. It is that the function of a thermostatic valve is to keep the refrigerating capability of the evaporator at the highest level possible under all load conditions. It is not to be confused with a suction pressure control device. Nor can it, in any way, control compressor running time.

REMOTE BULB CHARGES

The refrigeration service technician must know the correct replacement for an inoperative TEV. You may face a situation where someone else has incorrectly selected the existing valve. A major factor in valve replacement is the type of remote bulb charge.

For correct valve replacement, you must be familiar with refrigerant charges in the remote bulb and tubing of TEVs. There are three general types:

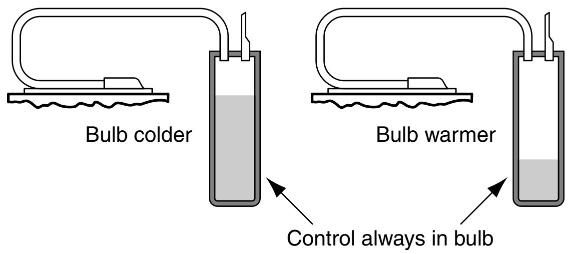


Figure 17. Bulb maintains control of power element in liquid-charged TEV

- the *liquid* charge, in which the refrigerant used in the remote bulb and tubing is the same as the refrigerant being controlled by the valve
- the *gas* charge, a limited liquid charge
- the *cross* charge, in which the refrigerant used in the remote bulb and tubing is different from the refrigerant being controlled by the valve.

The liquid charge

Figure 17 shows a conventional liquid-charged remote bulb and tube element. As you can see, the bulb is large enough and contains enough liquid so that the control point is always in the bulb. Some upper refrigerant remains liquid regardless of bulb temperature. The temperature of the diaphragm case or capillary tubing may get colder than the bulb temperature. Some of the vapor may condense in either of them. However, there will always be enough liquid refrigerant in the bulb to ensure control at that point. This becomes very important in low-temperature applications.

Look at Figure 18. Note the two curves, one on top of the other. You can see that, with the same refrigerant in both the bulb and the evaporator, pressure-temperature relationships are identical. Now apply these curves to system operation. They show that there is always a direct relationship, across the diaphragm, of bulb pressure changes to evaporator pressure changes. Thermostatic expansion valves with liquid remote bulb charges normally are used when there is a very narrow or limited evaporator temperature range. This is a condition outside the scope of other remote bulb charges.

The gas charge

A TEV with a gas-charged remote bulb contains the same refrigerant as that in the system. However, it uses a limited amount of liquid refrigerant. All of the liquid in the bulb will evaporate at a certain remote bulb temperature. The charge becomes a saturated vapor. Further increases in remote bulb temperature will not cause any substantial increase in pressure. Such temperature increases will only superheat the vapor.

Thus, in a gas-charged valve, maximum pressure on the upper surface of the diaphragm is limited by the amount of charge in the remote bulb. There is an equation that describes this relationship, which is shown in Figure 19 on the next page. Remote bulb pressure (P1) is equal to evaporator pressure (P2) plus spring pressure (P3), or P1 = P2 + P3.

This equation shows that if remote bulb pressure can be limited to a certain level while spring pressure remains constant, evaporator pressure can be limited to a certain level and no higher. When remote bulb pressure is limited, evaporator pressure is also limited. The point at which all liquid in the remote bulb is evaporated is the *maximum operating pressure* (MOP) of the valve. Look at the example shown in

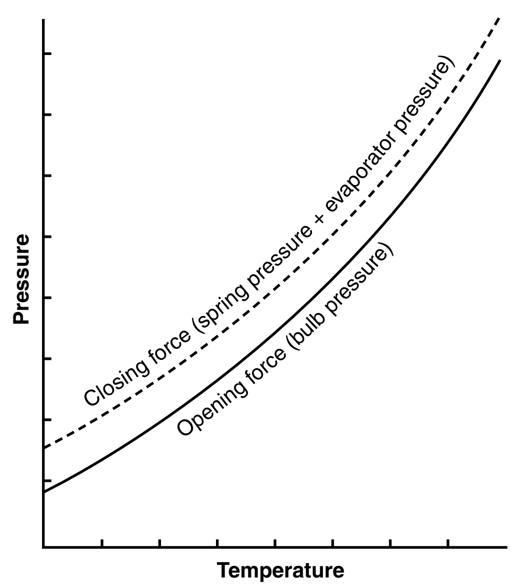


Figure 18. Conventional liquid charge

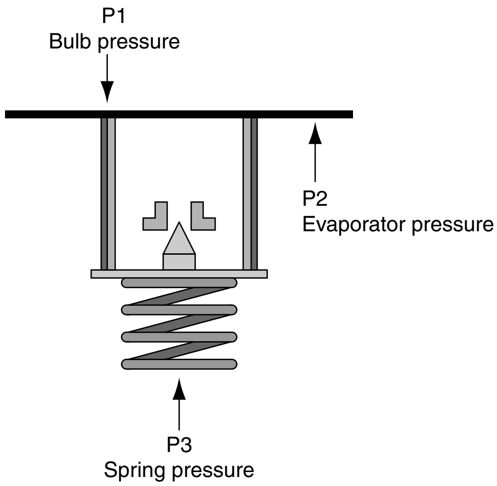


Figure 19. Evaporator pressure is limited by bulb pressure limit

Figure 20. Assume that the system pictured has an R-22 gas-charged expansion valve. It has a 100-psig maximum operating pressure and a 10°F superheat setting. Now, assume that the evaporator pressure increases to 100 psig. The total force under the diaphragm will be 100 psig plus 11.5 psig (the spring pressure setting for 10°F superheat). This equals 111.5 psig. Remember that the charge in the gas-charged remote bulb and tube is limited. When the remote bulb reaches the saturation temperature that corresponds to 111.5 psig, the entire charge has evaporated. Only vapor exists in the bulb. There will be some added superheat of refrigerant gas leaving the evaporator, but it will not produce enough pressure in the remote bulb to open the valve.

Evaporator pressure will now go down. It will drop below the MOP point of 100 psig. Only then can the remote bulb again control the valve and feed refrigerant into the evaporator. Thus, a gas-charged TEV also provides positive motor overload protection on some systems. This is because of the limiting effect of the maximum operating suction pressure. It also prevents possible floodback on start-up.

To lower maximum operating pressure, increase the superheat setting (increase spring pressure). To raise it, decrease the superheat setting (decrease spring pressure). This adjustment works because spring pressure, together with evaporator pressure, acts directly on the remote bulb pressure through the diaphragm.

You should always install a gas-charged valve in a location warmer than that of the remote bulb. The reason for this is that a gas-charged power element contains liquid up to the MOP point. It is very important for this liquid to remain in the remote bulb, as shown in Figure 21. The remote bulb tubing must never contact a surface colder than the remote bulb. If it does, the charge will condense at the coldest point and the valve will not function properly.

Generally, the application of gas-charged thermostatic expansion valves is not limited. However, they work most efficiently in such applications as water

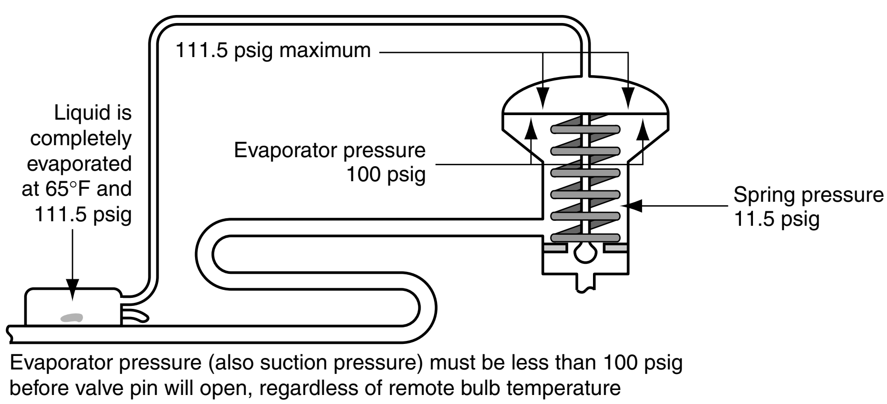


Figure 20. System with 100-psig maximum operating pressure

chillers and air conditioning units that operate in a 30°F to 50°F evaporator temperature range.

The cross charge

With a cross-charged remote bulb, the pressure-temperature curve of the refrigerant in the bulb crosses that of the refrigerant in the system.

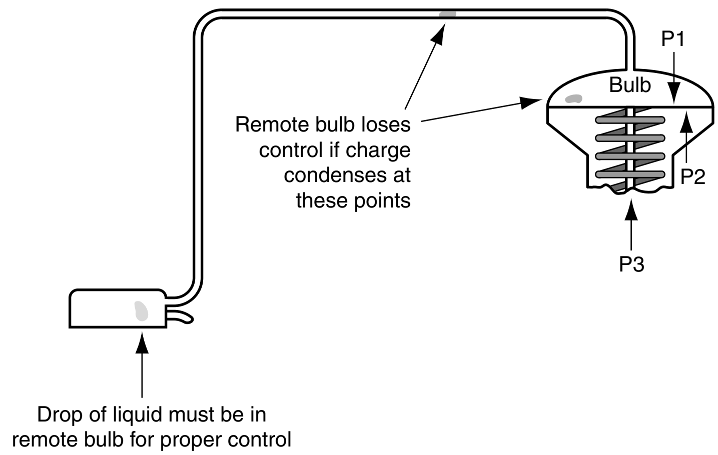


Figure 21. Control must remain in gas-charged remote bulb

When the system evaporator temperature ranges from +50°F to –100°F, the TEV in use will incorporate one of the cross charges available. This type of system often operates on what is termed a *repetitive pull-down cycle*. In this cycle, the system starts up at a high suction pressure. It shuts off when the pull-down reaches a much lower pressure. At the cutoff point, the compressor stops. Then the evaporator and remote bulb begin to warm up. The evaporator pressure rises more rapidly than the remote bulb pressure. As a result, the TEV closes quickly. It stays closed even though the bulb temperature may rise to a higher level than the evaporator temperature.

When high suction pressure exists, it takes high superheat to produce enough bulb pressure to overcome the closing pressure. The evaporator and bulb pressure curves are farther apart at high pressures. As a result, valve opening requires higher than normal superheat. This is a desirable condition. It prevents flooding and helps limit the compressor load.

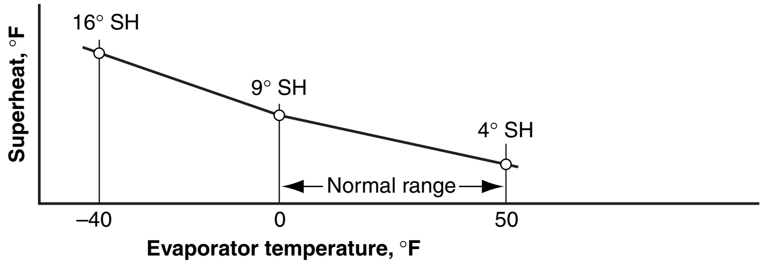
The difference between evaporator temperatures and bulb temperatures create the operating superheats of the cross-charged TEV. It is apparent, then, that a cross-charged valve must be adjusted for the best superheat setting at the lowest evaporator temperature of the system in order to prevent floodback of liquid refrigerant to the compressor.

Liquid cross charge. Cross charges may be either liquid or vapor. There are three types of *liquid* cross charges. One is designed for use in the commercial temperature range (from 40°F to 0°F). Another is for the low temperature range (from 0°F to –40°F). The third is designed for the ultra-low temperature range (from –40°F to –100°F).

Vapor cross charge. Research by TEV manufacturers has led to the development of a vapor-charged remote bulb. A *vapor* cross charge is designed for systems that operate with evaporator temperatures ranging from +50°F to –40°F. The vapor cross-charged bulb meets all the requirements for liquid-charged and gas-charged bulbs. And it meets the requirements for several of the liquid cross-charged bulbs available. A valve with this type of cross charge can replace a valve with any other type of charge if the system operates in the evaporator temperature range noted. However, it is usually necessary to readjust the superheat setting of the vapor cross-charged valve.

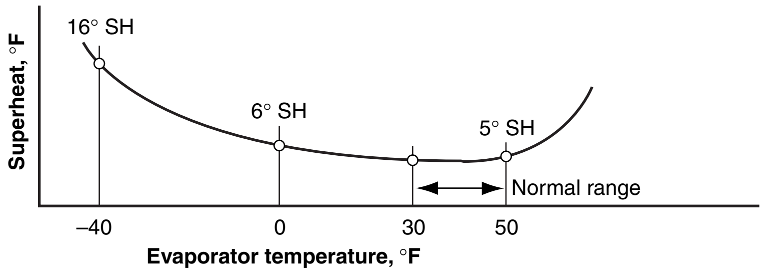
Surrounding temperature is not important to the location of a vapor cross-charged valve. This is because it cannot lose control if the valve is colder than the remote bulb.

You also can use a vapor cross-charged valve with a compressor, which requires motor overload protection. It is also available without MOP, when motor overload protection is not required. When there is no requirement for starting or overload protection, use the non pressure-limiting type. This may be the case with smaller commercial units or window air conditioners. When maximum operating pressure is required, you must consider correct MOP in selecting a replacement valve.



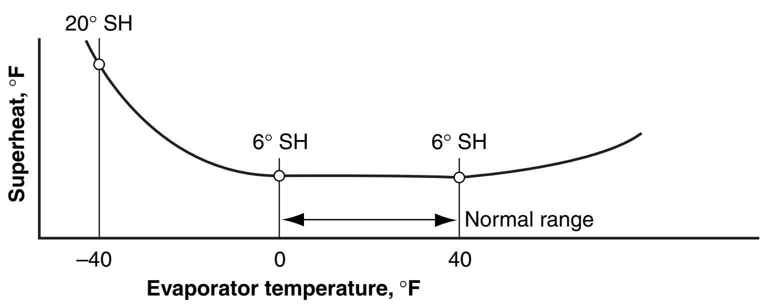
Liquid charge

1. Maintains control under cross-ambient conditions
2. Tends to allow floodback on start-up
3. MOP is not available



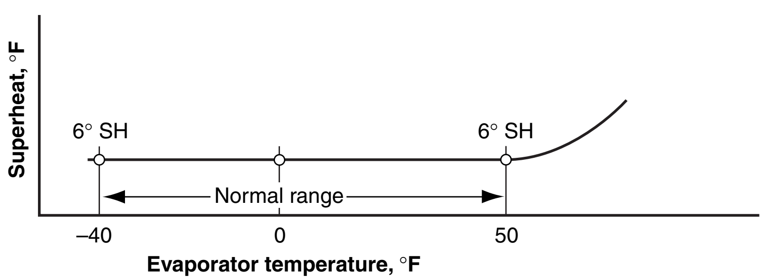
Gas charge

1. Loses control under cross-ambient conditions
2. Tends to prevent floodback on start-up
3. MOP is available



Liquid cross-charge

1. Maintains control under cross-ambient conditions
2. Tends to prevent floodback on start-up
3. MOP is not available



All-purpose vapor cross-charge

1. Maintains control under cross-ambient conditions
2. Tends to prevent floodback on start-up
3. MOP is available

Figure 22. Comparing the types of remote bulb charges

Comparing the types of remote bulb charges

Each of the four remote bulb charges discussed—the liquid charge, the gas charge, the liquid cross charge, and the vapor cross charge—has its own superheat characteristics. The curves in Figure 22 show the operating limits of each type based on a superheat of 6°F.

These curves may not reflect true values. They are presented here simply to show the general advantages and disadvantages of each. From Figure 22, you can see why the vapor cross charge is a major development. It has the potential to maintain almost constant superheat. This makes it possible to get maximum refrigeration effect from an evaporator with temperatures ranging from +50°F to –40°F. You can expect consistent superheat adjustments for the full range of evaporator operation. This eliminates concern for floodback or starving of the evaporator at the extreme ends of the temperature range.

THE EXTERNAL EQUALIZER

Look back at Figure 16, which shows a TEV with an internal equalizer. Pressure at the valve outlet to the evaporator is applied through the bottom of the diaphragm. It is applied through a hole drilled in the valve or through the space around the valve push rods. Now look at Figure 23. It shows a TEV with an *external* equalizer. Note that packing around the push rods keeps valve outlet pressure away from the evaporator side of the diaphragm.

Instead, suction pressure is applied to the evaporator side of the diaphragm through tubing. It is either soldered into an opening in the suction line near the evaporator outlet or into a reducing tee located there. This tubing is connected to the external equalizer fitting on the valve, as shown in Figure 23. The preferred tubing location in the suction line is downstream from the bulb.

Pressure drop between the valve outlet and the evaporator outlet is the most important of the low-side pressure losses that affect valve performance. Sizable pressure drops can be caused in the low side of systems by:

- undersized evaporator tubing
- extreme length of tubing per pass
- improper joints
- restrictive return bends
- distribution headers of various types.

Certain pressure drops through the evaporator are of consequence:

- above 3.0 psi in the air conditioning range
- 2.0 psi in the commercial range
- 0.75 psi in the low-temperature or food freezer range.

These pressure drops will hold a TEV in a relatively “restricted” position. This will reduce system capacity unless a valve with an external equalizer is used. The evaporator should be designed or selected for the operating conditions. The valve should be selected and applied accordingly.

The valve in Figure 24 on the next page has an internal equalizer. Pressure at the valve outlet is on the

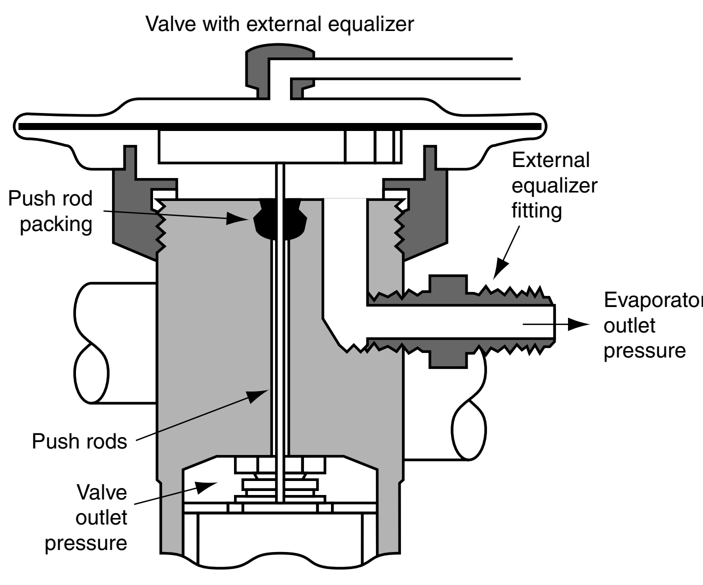


Figure 23. TEV with external equalizer

bottom of the diaphragm. It is also assumed that the evaporator shown has a negligible pressure drop. Any large pressure drop through the evaporator will cause the valve to restrict refrigerant flow unless a valve with an external equalizer is used.

To understand this, look at Figure 25, which shows an example of an evaporator fed by a TEV with an internal equalizer. As you can see, there is a sizable pressure drop of 16 psig.

The pressure at point C is 52.5 psig. This is 16 psig lower than at the valve outlet, point A. The 68.5 psig at point A is the pressure acting on the lower side of the diaphragm. The valve spring is set at a compression equal to a pressure of 15.5 psig. Thus, the required pressure above the diaphragm is 68.5 psig plus 15.5 psig, or 84 psig. This pressure corresponds to a saturation temperature of 50°F. Obviously, the refrigerant temperature at point C must be 50°F for the valve to be in equilibrium.

But the pressure at this point is only 52.5 psig. The corresponding saturation temperature is 28°F. As a result, a superheat of 22°F (50°F – 28°F = 22°F) is required to open the valve. An increase in superheat from 10°F to 22°F is needed. More of the evaporator surface must be used to produce this higher superheated refrigerant gas. This means that the amount of evaporator surface available for the absorption of latent heat of vaporization of the refrigerant is reduced. The evaporator is said to be "starved."

The thermostatic expansion valve is being held in a somewhat "restricted" position. The pressure underneath the diaphragm (at the evaporator inlet) is higher than the pressure at the remote bulb, point C. Remember that the pressure drop across the evaporator, which causes this condition, increases with the load. Thus, the "restricting" or "starving" effect is increased when the demand on the expansion valve capacity is greatest.

USING AN EXTERNAL EQUALIZER

The external equalizer type of valve must be used to compensate for an excessive pressure drop through an evaporator. The equalizer line can be connected in one of two ways:

- It can connect into the evaporator at a point beyond the greatest pressure drop.
- It can connect into the suction line at a point on the compressor side of the remote bulb.

As a general rule of thumb, the equalizer line should be connected to the suction line at the evaporator

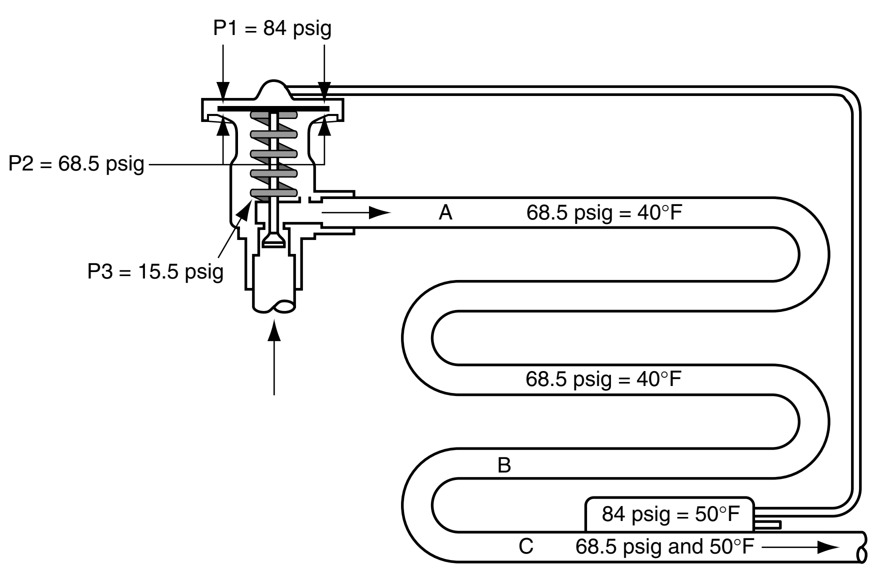


Figure 24. TEV with internal equalizer on evaporator with no pressure drop

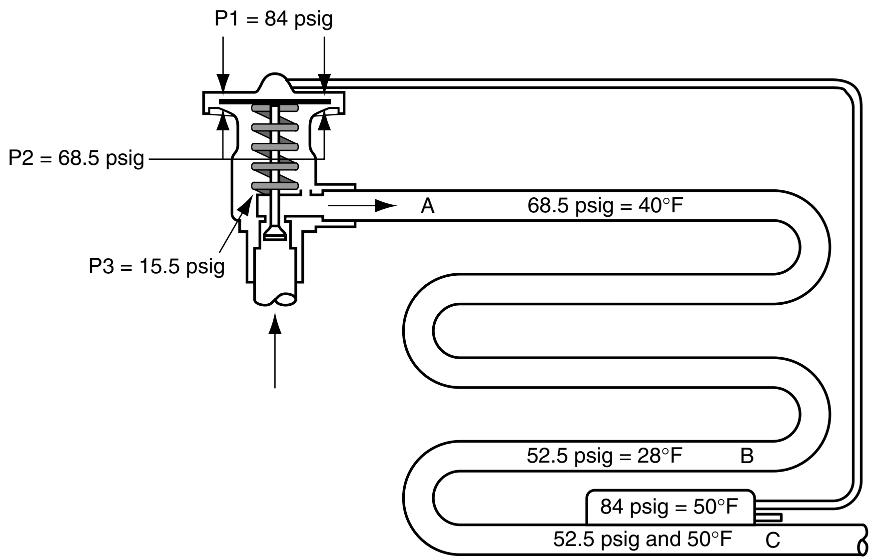


Figure 25. TEV with internal equalizer on evaporator with 16-psig pressure drop

outlet. When this arrangement is used, true evaporator outlet pressure is imposed under the valve diaphragm. Pressure drop through the evaporator does not affect operating pressures on the diaphragm. The thermostatic expansion valve will respond to the superheat of the refrigerant gas leaving the evaporator.

Look again at the system shown in Figure 25. Now assume that there are the same pressure conditions in a system using a valve with the external equalizer feature, as shown below in Figure 26. The same pressure drop still exists through the evaporator. Pressure under the diaphragm is now the same as the pressure at the end of the evaporator (point C, or

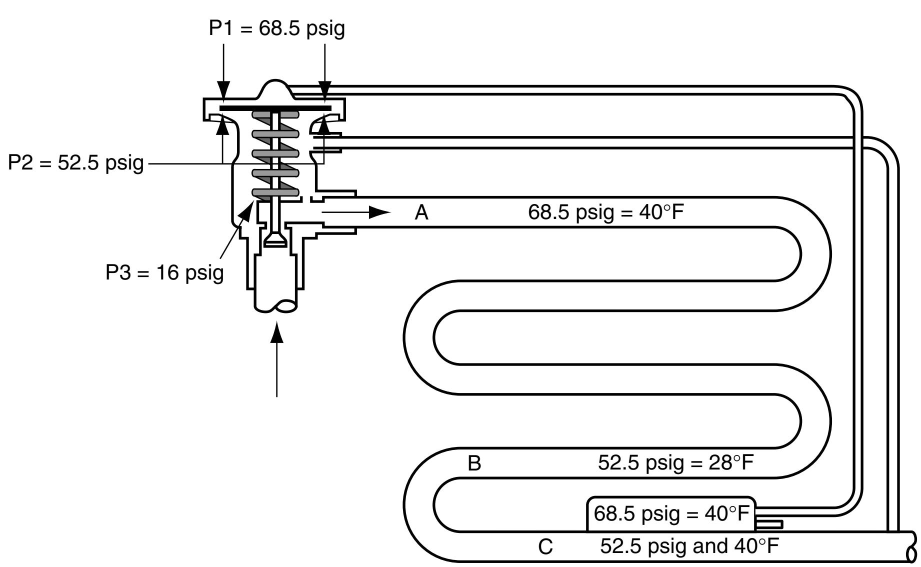


Figure 26. TEV with external equalizer on evaporator with 16-psig pressure drop

52.5 psig). The pressure required above the diaphragm for equilibrium is 52.5 psig plus 16 psig, or 68.5 psig. (Note the increase in the spring pressure—from 15.5 psig to 16 psig—needed to bring the TEV into equilibrium.) The 68.5-psig pressure corresponds to a saturation temperature of 40°F. Therefore, the superheat required is now 40°F – 28°F, or 12°F. The use of an external equalizer has reduced the superheat from 22°F to 12°F. As you can see, the operating superheat has changed from 10°F to 12°F. This is the result of the change in the pressure-temperature characteristics of R-22 at the lower suction pressure of 52.5 psig.

However, in an operating system, where more evaporator surface is made available for boiling the liquid refrigerant, the evaporator outlet pressure will increase. It will be above 52.5 psig. Thus, you can see the advantage of using a TEV with an external equalizer, as opposed to one with an internal equalizer. Capacity will increase in a system that has an evaporator with a sizable pressure drop.

A thermostatic expansion valve must be equipped with the external equalizer feature in order to provide the best performance in the following cases:

- when the pressure drop through an evaporator is in excess of the limits previously defined
- when a pressure drop type of refrigerant distributor is used at the evaporator inlet.

External equalizer application

The level of evaporator pressure drop that an internally equalized valve can cope with is determined by two factors—the evaporator temperature and the refrigerant used. Use the recommendations of valve manufacturers as guidelines. Generally speaking, a valve with an external equalizer is required when an evaporator is subject to a pressure drop of any consequence. With R-22, for example, an externally equalized valve is recommended when pressure drop exceeds the following levels:

- 3.0 psi in the comfort air conditioning evaporator temperature range
- 2.0 psi in the commercial temperature range
- over 0.75 psi in the low freezer temperature range.

The recommendations in Table 1 adequately cover the requirements for most field-installed systems. In general, install an externally equalized valve when pressure drop between the evaporator inlet and the suction-line bulb location exceeds the maximums listed in Table 1.

DUAL-DIAPHRAGM THERMOSTATIC EXPANSION VALVES

So far, this chapter has assumed that both sides of an expansion valve's diaphragm are of equal area. This is the case when the valve has a single diaphragm. However, there are valves with two diaphragms. One is subject to pressure developed in the remote valve, the other is subject to pressure developed in the evaporator and by the adjusting spring. The two diaphragms can be of different sizes, as shown in Figure 27.

There is an advantage in using two diaphragms, one acted upon by evaporator pressure and the other by remote bulb pressure. By proportioning their size, a valve can operate at the same superheat at 5°F as at 25°F. Constant superheat can be maintained. This is not possible with a single-diaphragm valve.

	Evaporating temperature, °F				
	40	20	0	–20	–40
Refrigerant	**Pressure drop, psi**				
R-12 R-500	2.0	1.5	1.0	0.75	0.5
R-22 R-717 R-502	3.0	2.0	1.5	1.0	0.75

Table 1. Greater evaporator pressure drop requires external equalizer

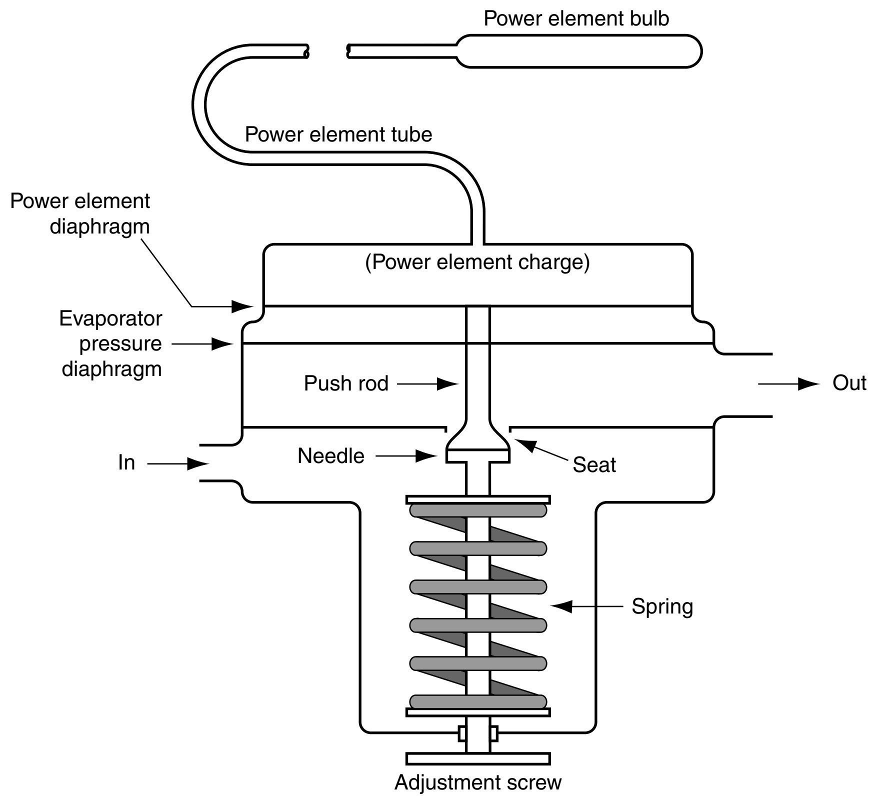


Figure 27. Dual-diaphragm TEV

PILOT-OPERATED THERMOSTATIC EXPANSION VALVES

The size of a conventional direct-operated thermostatic expansion valve, particularly the diaphragm size, is generally adequate for its design system capacity. In large-tonnage systems, however, a direct-operated valve would require a diaphragm or bellows operator of great proportions. It would not be economically or mechanically practical. For this reason, there are *pilot-operated* valves for use on large direct expansion chillers and other large-tonnage applications.

A typical application of a pilot-operated TEV is shown in Figure 28 on the next page. This assembly has a primary regulator and a conventional direct-operated valve, which acts as a pilot. The pressure and temperature of suction gas leaving the evaporator operate the pilot valve—which, in turn, modulates the primary regulator in response to changes in suction gas superheat. The primary regulator opens when pressure is exerted on top of the main piston. A small bleed orifice in the top of the piston vents this pressure to the outlet side of the primary regulator. A cage spring closes the primary regulator when the pressure supply to the top of the piston is cut off.

An *increase* in suction gas superheat reflects the need for increased refrigerant flow. In response, the pilot-operated TEV moves in an opening direction. This action supplies greater pressure to the top of the main piston. The piston moves to open the primary regulator, which provides increased refrigerant flow.

A *reduction* in suction gas superheat reflects the need for reduced refrigerant flow. In response, the pilot valve moves in a closing direction. This action reduces the pressure on top of the piston. As the piston moves to close the primary regulator, the volume of refrigerant flow is reduced. In normal operation, and in response to system load, the pilot valve and regulator assume intermediate or throttling positions.

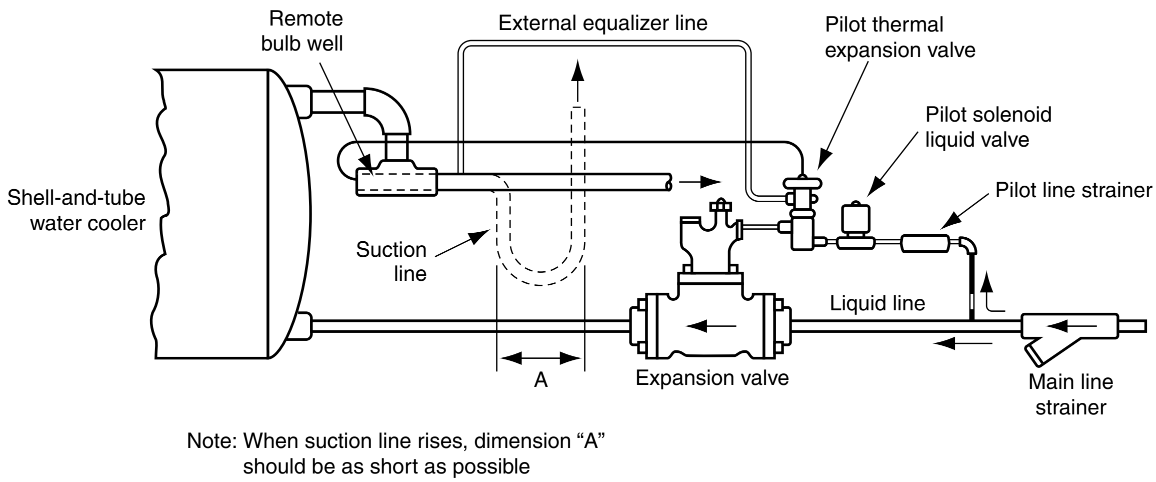


Figure 28. Typical application of pilot-operated TEV

AMMONIA EXPANSION VALVES

Thermostatic expansion valves for ammonia refrigerant operate much the same as those used with other refrigerants. Characteristics of liquid ammonia, however, differ from those of fluorocarbon refrigerants. Even small quantities of ammonia vapor have a great erosive effect on the expansion device used. High-velocity refrigerant and contaminants like dirt or scale compound this erosive effect. As with other parts of ammonia systems, valves are made of steel and steel alloys to combat the erosive effect.

EVAPORATOR LENGTH

To simplify this chapter, several assumptions have been made up to this point. When a TEV opens, refrigerant almost immediately travels through the evaporator. There, it boils and superheats to a level of, for example, 10°F. Then it proceeds to the remote bulb location on the suction line.

The subsequent increase in remote bulb temperature then develops pressure. This pressure bears against the diaphragm, opening the valve. Opening the valve allows more refrigerant to flow into the evaporator, decreasing the superheat and causing the remote bulb to become chilled. The result is total or at least partial closing of the valve.

You might be led to think that valve response to changes in bulb temperature is almost instant, so that superheat stays constant. This is not the case, however. It takes time for refrigerant to travel from the valve outlet through the evaporator to the remote bulb. There is some delay before the remote bulb reacts to any change in valve seat position. Under this condition, the valve "overshoots" on both opening and closing. This condition is called *hunting*. With an exceptionally long evaporator, this may be very undesirable. It could create alternate cycles, in which the evaporator would be overfed when there is not enough superheat, and then starved when superheat is too high.

There should be little hunting by a TEV with an evaporator that has short passes from the inlet to the outlet. Hunting will be most pronounced in evaporators with long tubes. Avoid this type of evaporator in the interest of efficient valve operation. If a large evaporator surface is required, it is better to use several short tubes in parallel than one long tube. This reduces the travel time of refrigerant. If possible, the total length of evaporator tubing should not exceed 100 ft.