Refrigeration Service Engineers Society
1666 Rand Road
Des Plaines, Illinois 60016

THERMOSTATIC EXPANSION VALVES
Part 2

Revised by Loren Shuck, CMS

INTRODUCTION

The previous chapter dealt briefly with the development of the thermostatic expansion valve (TEV), its function, and the basic principles of its operation. Knowing how to apply, install, and service TEVs properly is equally important. These procedures determine the success or failure of an otherwise well-designed system.

APPLICATION FACTORS

Five main factors determine the correct type and size of TEV:

- pressure drop across the valve
- load requirements of the system in Btuh (often expressed as "tons load")
- temperature of the liquid entering the valve
- evaporator temperature
- refrigerant type.

Do not assume that the pressure drop across the valve will equal the difference between discharge and suction pressures at the compressor. If you do, you will select an incorrect valve.

Pressure at the valve outlet will be higher than suction pressure read at the compressor. This is because suction pressure reflects friction losses through evaporator tubes, suction-line fittings, hand valves, etc. Likewise, pressure at the valve inlet will be lower than discharge pressure at the compressor. Again, there are friction losses imposed by liquid-line length, fittings, and hand valves. Vertical lift, if present, also has an effect. Such losses are a factor in selecting the properly sized valve. This is true except when the valve location is much lower than the receiver, in which case the static head built up may be enough to offset frictional losses.

LIQUID LINE SIZE

Adequate liquid line size is of the utmost importance. In order to determine the correct size, consider the required length plus the "additional length" created by various fittings, hand valves, etc.

When vertical lift is specified, there is an additional pressure drop because of static head loss in the vertical section of the liquid line. This loss is due to the weight of the liquid refrigerant column. Table 1 translates this weight into pressure loss in pounds per square inch for some common refrigerants.

In a distributor-type evaporator, there is a pressure drop across the distributor. Table 2 at the top of the next page shows the average pressure drop across the distributor for some common refrigerants.

	Vertical lift (ft)				
	20	40	60	80	100
Refrigerant	Static pressure loss (psi)				
12	11	22	33	44	55
22	10	20	30	40	50
500	10	19	29	39	49
502	10	21	31	41	52
717 (Ammonia)	5	10	15	20	25

ALCO CONTROLS

Table 1. Vertical lift converted to pressure loss (in pounds per square inch)

This document is a revision of prior publication 620-74.

Refrigerant	Average pressure drop across distributor (psi)
12	25
22	35
500	25
502	35
717 (Ammonia)	40

Table 2. Average pressure drop across a distributor (in pounds per square inch)

Friction loss occurs as refrigerant flows through the valves and fittings used in typical installations. The term "equivalent length" is used to describe this loss. It compares friction loss through a valve or fitting with that in a given length of straight pipe. Use Table 3 to convert friction loss in common valves and fittings into equivalent linear feet of pipe or tubing.

TYPICAL SELECTION PROCEDURES

Valve manufacturers publish information that will help you select the proper type and size of valve for almost any application. Before selecting a TEV for a particular application, the following elements that determine type and size must be established:

1. The Btuh requirement of the system should already be established. The second element to calculate is the pressure drop across the valve:

   a. Subtract the evaporating pressure from the condensing pressure.

   b. From (a) above, subtract all other pressure losses. This results in the *net pressure drop across the valve*. Consider all of the following possible sources of pressure loss:

      - friction losses through refrigerant lines, including the evaporator and condenser

Line size (in. IPS)	Ferrous valves and fittings[1, 2]															
	Globe valve		Angle valve		Short-radius ell			Long-radius ell			Tee, line flow			Tee, branch flow		
	S[3]	F[3]	S	F	S	F	W[3]	S	F	W	S	F	W	S	F	W
½	29		16		4.1						1.8			4.7		
¾	31		16		4.7			2.5			2.5			5.6		
1	35	57	16	19	5.3	1.6	1.8	2.8	1.5	1.2	3.4	1.0	1.6	6.8	3.8	5.2
1¼	46	69	19	22	7.1	2.2	2.3	3.3	2.0	1.6	4.9	1.3	2.0	9.2	4.9	7.1
1½	51	76	19	22	7.0	2.6	2.6	3.4	2.2	1.8	5.9	1.4	2.0	9.9	5.8	8.4
2	63	89	20	25	9.0	3.2	3.4	3.6	2.7	2.3	8.1	1.7	2.5	12.6	7.2	10.5
2½		101		28		3.8	4.2		3.0	2.7		1.9	2.9		8.4	13.0
3		123		36		4.9	5.3		3.7	3.4		2.4	3.6		11.0	16.0
4		155		48		6.2	7.2		4.5	4.5		2.9	4.5		14.0	22.0
5		190		63		8.1	9.2		5.4	5.7		3.5	5.1		17.0	27.0
6		227		78		9.5	11.0		6.1	6.8		4.1	6.1		20.0	33.0
8		295		110		13.0	15.0		7.1	9.0		4.7	7.1		27.0	44.0
10		370		142		16.0	18.0		8.7	11.0		5.6	8.7		32.0	56.0
12		465		173		19.0	22.0		10.0	14.0		6.2	10.0		39.0	68.0

Table 3. Equivalent lengths of valves and fittings (equivalent length = K(D/f)

- pressure drop across strainers, solenoid valves, hand valves, filters, driers, etc.
- pressure drop due to vertical lift of liquid line (static pressure loss), as shown in Table 1
- pressure drop across the distributor, as shown in Table 2.

2. Select a valve from the manufacturers' data according to design evaporating temperature and available pressure drop.
3. Consider the liquid temperature of the refrigerant entering the valve. (If the liquid temperature is other than 100°F for R-12, R-22, R-500, and R-502, or other than 86°F for R-717, apply the factors given in the specific manufacturer's Refrigerant Liquid Temperature Correction Factor Tables for each refrigerant.)
4. Find the nominal capacity of the correct valve from the appropriate capacity table.
5. Decide if an external equalizer type is to be used. It should be used when either of the following conditions exist:
   a. The pressure drop between the valve outlet and the remote bulb location exceeds the values shown in Table 4 on the next page.
   b. The evaporator uses a refrigerant distributor.

Line size (in. OD)	Nonferrous valves and fittings[1]											
	Globe valve		Angle valve		Short-radius ell		Long-radius ell		Tee, line flow		Tee, branch flow	
	S	O[4]	S	O	S	O	S	O	S	O	S	O
½	40	70	21	24	4.7	4.7		3.2	1.9	1.7	5.1	6.6
⅝	39	72	22	25	5.4	5.7		3.9	2.3	2.3	6.2	8.2
¾	39	75	23	25	6.2	6.5	2.9	4.5	2.9	2.9	7.1	9.7
⅞	45	78	23	28	7.0	7.8	3.7	5.3	3.7	3.7	8.2	12.0
1⅛	54	87	25	29	8.1	2.7	4.2	1.9	5.2	2.5	11.0	8.0
1⅜	64	102	27	33	9.9	3.2	4.6	2.2	6.9	2.7	13.0	10.0
1⅝	75	115	28	34	12.0	3.8	5.0	2.6	8.7	3.0	14.0	12.0
2⅛	95	141	30	39	14.0	5.2	5.4	3.4	12.0	3.8	19.0	16.0
2⅝		159		44		6.5		4.2		4.6		20.0
3⅛		185		53		8.0		5.1		5.4		25.0
3⅝		216		66		10.0		6.3		6.6		30.0
4⅛		248		76		12.0		7.3		7.3		35.0
5⅛		292		96		14.0		8.8		7.9		42.0
6⅛		346		119		17.0		10.0		9.3		50.0

[1] Friction factors (*f*) determined at "practical" Reynolds numbers based on 40°F suction line with pressure drop of 1.8 psi/100 ft
[2] Based on Schedule 40 pipe
[3] S = screwed, F = flanged, W = welded
[4] O = other (flare, sweat, flanged, etc., and based on Type L copper tubing)

Table 3. Equivalent lengths of valves and fittings (continued)

	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 4. Greater evaporator pressure drop requires external equalizer

Note: There is no operational disadvantage in using an external equalizer, even if the evaporator has a low pressure drop.

TEV capacity ratings for R-12, R-22, R-500, and R-502 are generally based on vapor-free (subcooled) 100°F liquid refrigerant entering the valve, a maximum superheat change of 7°F, and a standard factory air test superheat setting. A specific application may differ greatly from these operational values. If so, get further details on the capacity from the valve manufacturer.

INSTALLATION

For maximum evaporator performance, the TEV must be located as close to the evaporator as possible. However, the location should not sacrifice accessibility for adjustment or service. On pressure drop and centrifugal-type distributors, locate the valve close to the distributor, as shown in Figure 1. *There can be no restriction between the valve and the evaporator*. A hand valve may be needed between the expansion valve and the evaporator. If so, its port size *must be equal to the evaporator inlet size.* If a gas-charged valve is specified, then take care that the remote bulb is in a colder location than the valve body. This will minimize the loss of refrigerant flow control.

Valve body temperature is even more critical with a sweat-type valve. Carefully direct the torch flame away from the valve body. You do not want to subject the valve diaphragm to excessive heat. For added protection, put a damp cloth around the diaphragm when soldering.

When an evaporator must be located *above* the receiver in a system, there will be static pressure loss in the liquid line. With enough vertical lift, flash gas or vapor may form in the liquid line. This could cause a major reduction in the capacity of the TEV.

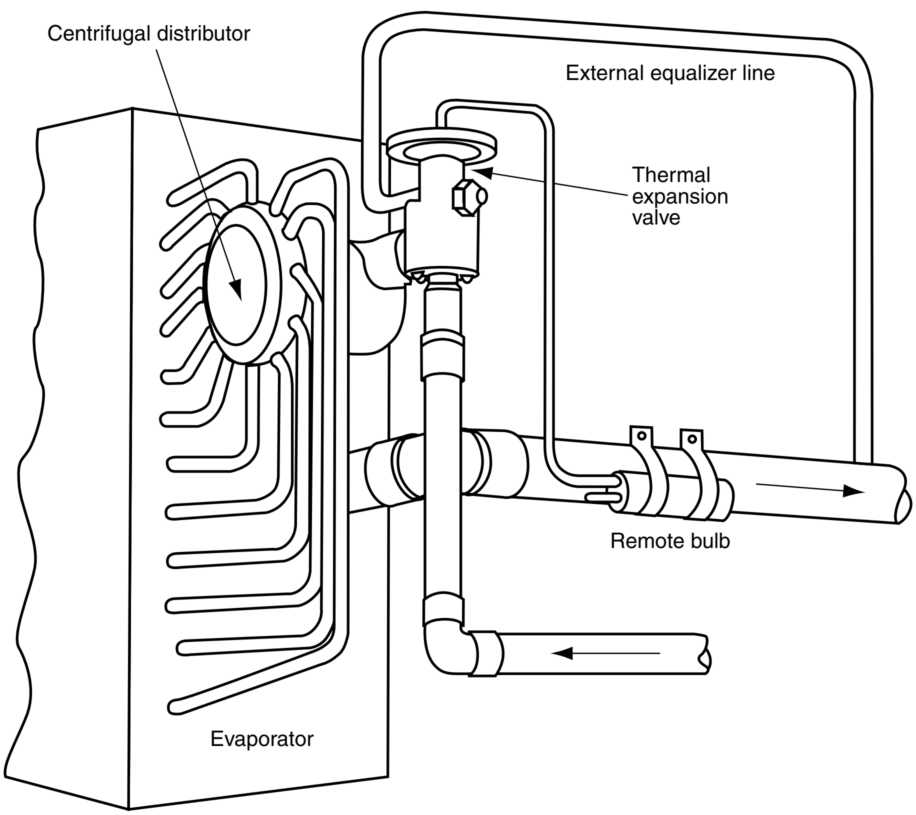


Figure 1. Typical TEV application with centrifugal distributor

Perhaps you cannot avoid the high lift. If so, prevent liquid-line vapor and add subcooling to the liquid refrigerant. Subcooling can take place either in the condenser or downstream from the receiver.

Table 5 shows required amounts of subcooling for common refrigerants. To use Table 5, you first must know total static pressure loss. Refer to Tables 1 and 3.

Typical methods of providing liquid subcooling include the use of:

- the condenser
- a suction-line heat exchanger, as shown in Figure 2 on the next page
- specially designed equipment (when required).

Subcooling in the condenser is usually adequate when only moderate liquid-line pressure drop occurs. When you use a suction-line heat exchanger, the amount of subcooling depends largely on its design and size, and on system operating pressures. Subcooling from 18 to 20°F is the maximum for most air conditioning systems with normal load pressures.

Excessive vertical lift requires more sophisticated devices to provide subcooling. These include:

- a water coil/liquid-line heat exchanger
- a heat exchanger that uses a separate refrigeration system
- a heat exchanger that uses system refrigerant to subcool the liquid line.

The last method is the most common.

A suction liquid heat exchanger may be used primarily to prevent the formation of flash gas in a vertical liquid line. In this case, the heat exchanger should be installed at the bottom of the vertical column near the receiver—*not* near the evaporator, as is ordinarily the case. It is important to provide subcooling for this purpose *before* the lift occurs. If subcooled below ambient temperature, the liquid line must be insulated as well as the suction line to reduce heat gain.

100°F condensing temperature

	Pressure loss (psi)					
	5	**10**	**20**	**30**	**40**	**50**
Refrigerant	**Required subcooling (°F)**					
12	3	6	12	18	25	33
22	2	4	8	11	15	19
500	3	5	10	15	21	27
502	2	3	7	10	14	18
717 (Ammonia)	2	4	7	10	14	17

130°F condensing temperature

	Pressure loss (psi)					
	5	**10**	**20**	**30**	**40**	**50**
Refrigerant	**Required subcooling (°F)**					
12	3	5	9	14	18	23
22	2	4	6	9	12	14
500	2	4	8	11	15	19
502	1	3	5	8	11	13
717 (Ammonia)	2	3	5	7	10	12

Table 5. Subcooling requirements based on static pressure loss

Regardless of the method used to eliminate the formation of vapor or flash gas in the liquid line, be sure that the steps taken do not compromise the existence of adequate pressure drop across the TEV.

Remote bulb location

Remote bulb location is important. It is often a major factor in system efficiency. The proper location is on the suction line at the outlet of the evaporator, but still within the refrigerated area where the difference

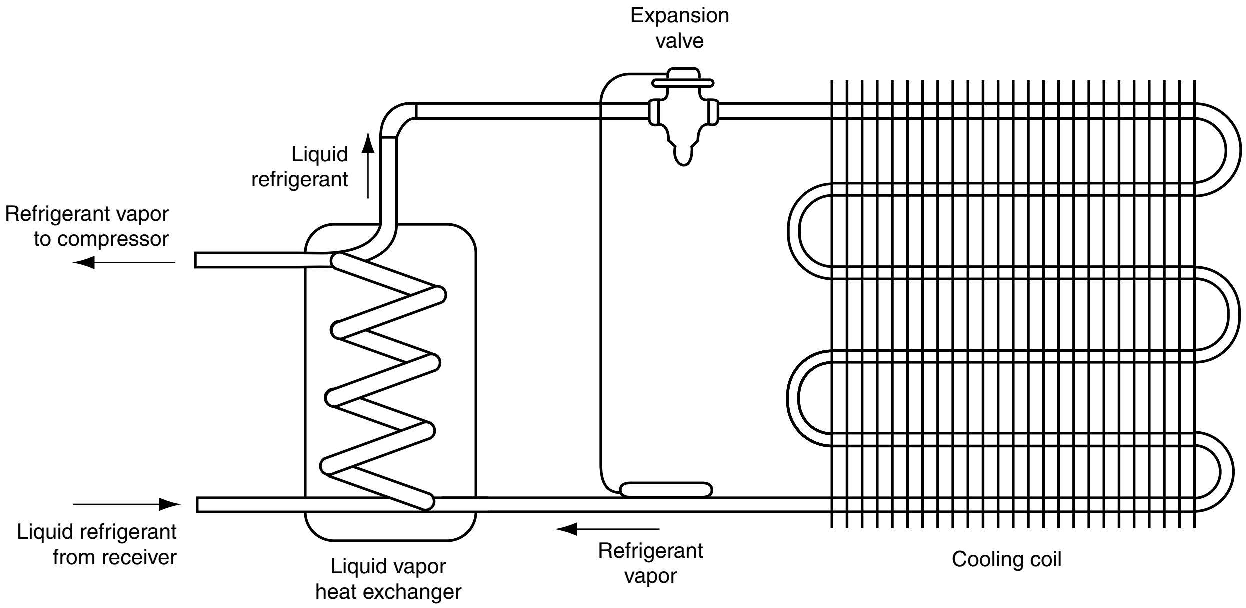


Figure 2. Typical suction-line heat exchanger

between suction-line and ambient temperatures is as close as possible. This is because the power element control is in response to refrigerant gas temperature at the suction-line location of the remote bulb.

Another aspect to consider when installing the remote bulb is its proximity to the point where the suction line leaves the refrigerated area. The bulb should be positioned at least 18 in. from this point. Examples of correct and incorrect locations are shown in Figure 3 below. The correct location prevents the opening of the valve during the OFF cycle. Such an action would produce suction-line flooding to the compressor.

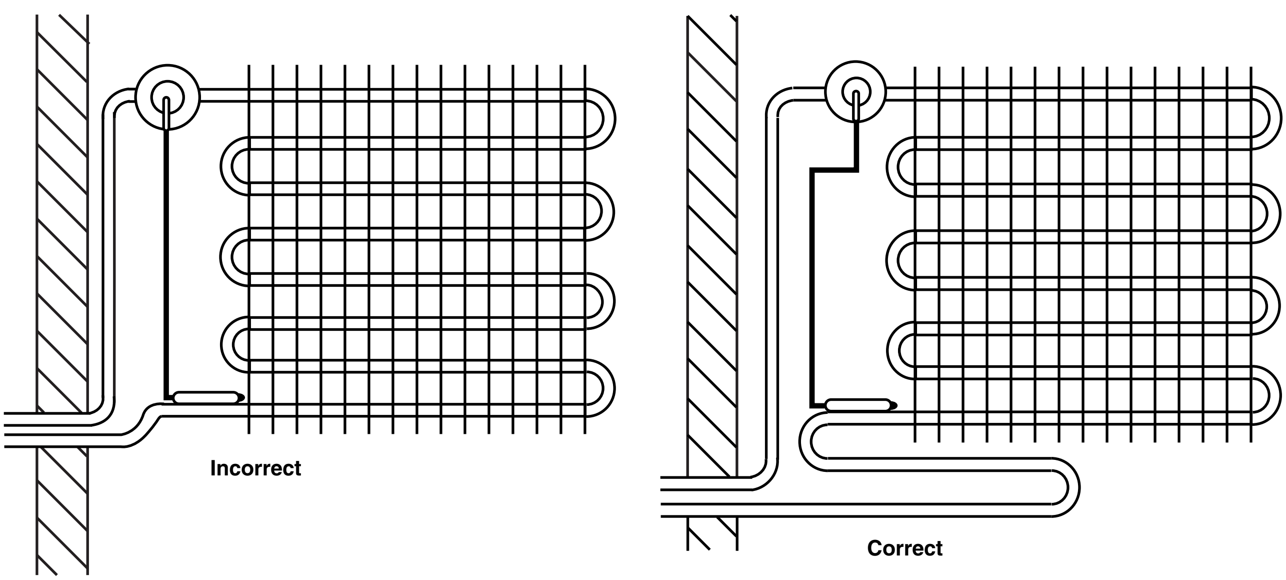


Figure 3. Remote bulb located away from exit from refrigerated space

The remote bulb should *never* be located on the evaporator suction header. In this position, the bulb cannot sense the overall distribution of refrigerant. This condition could result in suction-line flooding. It is also unwise to locate the remote bulb on a vertical riser in the suction line, where the bulb could be influenced by liquid refrigerant passing from the trap. However, location on a vertical riser may be absolutely necessary. If this is the case, erratic valve operation can be avoided to some extent if the bulb is installed with the capillary tube at the top.

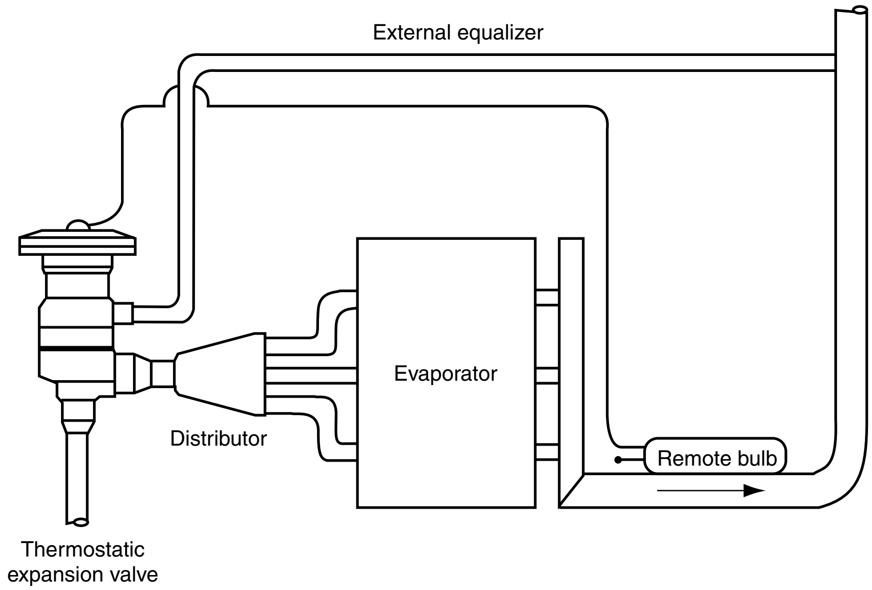


Figure 4. Remote bulb in trapped location

Never locate the remote bulb at a point where the suction line is trapped. Figure 4 shows such a location. Trapped liquid refrigerant produces extreme fluctuations in superheat of suction gas. Refrigerant and oil boiling out of the trap will cause the bulb to function erratically, resulting in inefficient refrigerant control.

Proper evaporator suction-line piping

Proper piping can overcome many of the problems that contribute to the erratic operation of a remote bulb and TEV. The following are examples of correct piping of the suction line leaving the evaporator:

- The suction line leaving the evaporator should be on a horizontal plane, but pitching down slightly.

- If necessary to convert to a vertical riser, you can install a short trap at the bottom of the riser, as shown in Figure 5. A trap of this kind accumulates liquid refrigerant and/or oil, so that they cannot influence bulb temperatures.

- When the compressor is located below the evaporator and the system incorporates a "pump-down" control, the suction-line piping is simplified, as shown in Figure 6 on the next page.

- When the compressor is located below the evaporator and the system design does *not* employ a "pump-down" control, a trap and vertical riser equaling evaporator height must be installed. Figure 6 also shows this piping method. The short vertical riser keeps liquid refrigerant from draining to the compressor during an OFF-cycle period.

Install suction-line piping on multiple-evaporator systems so that the remote bulb of any valve will not be influenced by refrigerant flow through another valve. Figure 7 on the next page shows correct suction-line

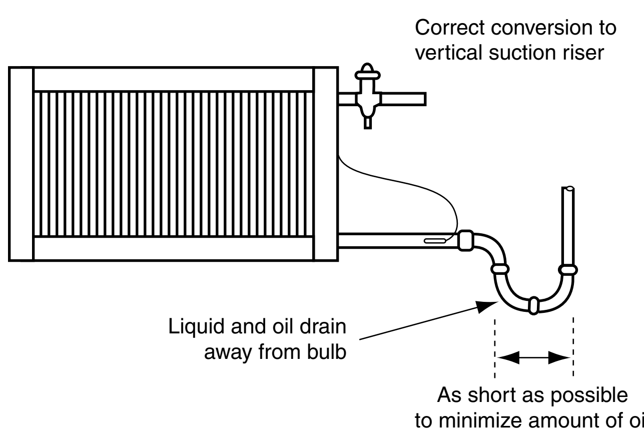


Figure 5. Compressor above evaporator

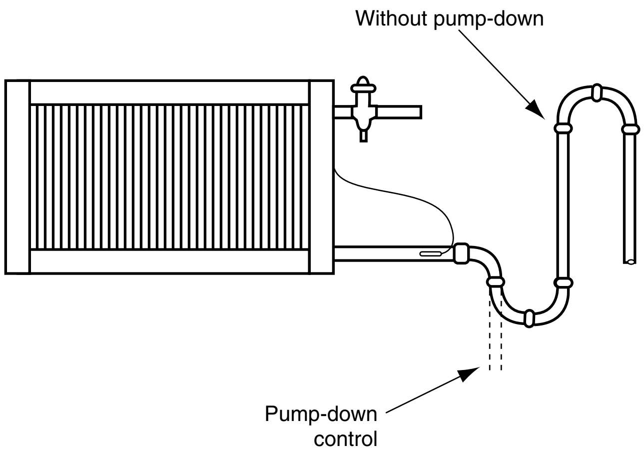


Figure 6. Compressor below evaporator

piping to multiple evaporators, both above and below the main suction line. It also shows the proper location of traps to prevent erratic operation of individual valves.

Several factors dictate suction-line piping methods on multiple-evaporator installations:

- compressor location
- system operation, with or without pump-down cycle
- solenoid valve control of individual evaporators
- capacity modulation.

When multiple evaporators are located above the level of the compressor and a pump-down control is not provided, the piping method shown in Figure 8 is recommended.

Figure 9 shows a system in which each evaporator is controlled by a solenoid valve (not shown) in its liquid line. All are connected to a common suction main. Figure 9 shows correct piping to keep refrigerant and oil from entering idle evaporators.

Evaporators may be located below the suction main. The piping arrangements shown in Figures 10 and 11 on the following pages are examples of good workmanship in this case. The double riser in Figure 11

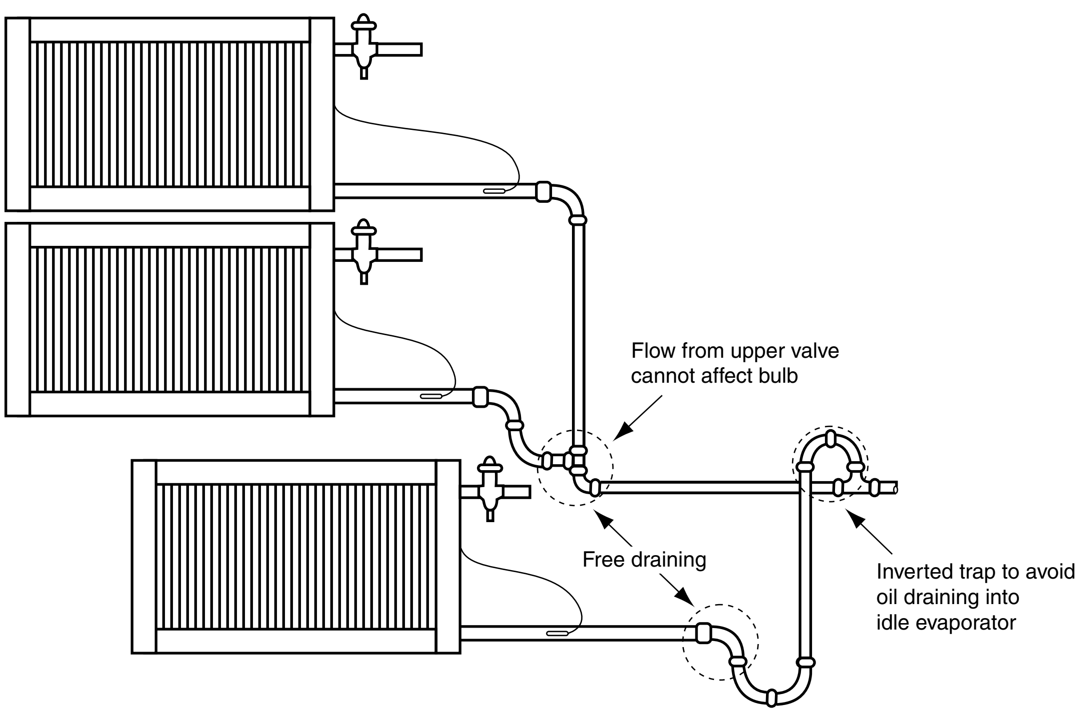


Figure 7. Multiple evaporators (above and below main suction line)

correctly deals with the capacity modulation factor previously noted.

Remote bulb installation

The location of the remote bulb in the refrigerated area is important to efficient valve operation. Much more critical is the point of bulb contact with the suction line. For effective refrigerant control, good thermal contact between the bulb and suction pipe or tubing is absolutely essential. Never install a remote bulb on a fitting, or use tape in place of a clamp. Liquid flooding and compressor damage is sure to result. Figure 12 on page 12 shows the correct installation methods for surface-mounted remote bulbs.

When the outside diameter (OD) of a suction line is $3/8$ to $5/8$ in., you can locate the remote bulb at almost

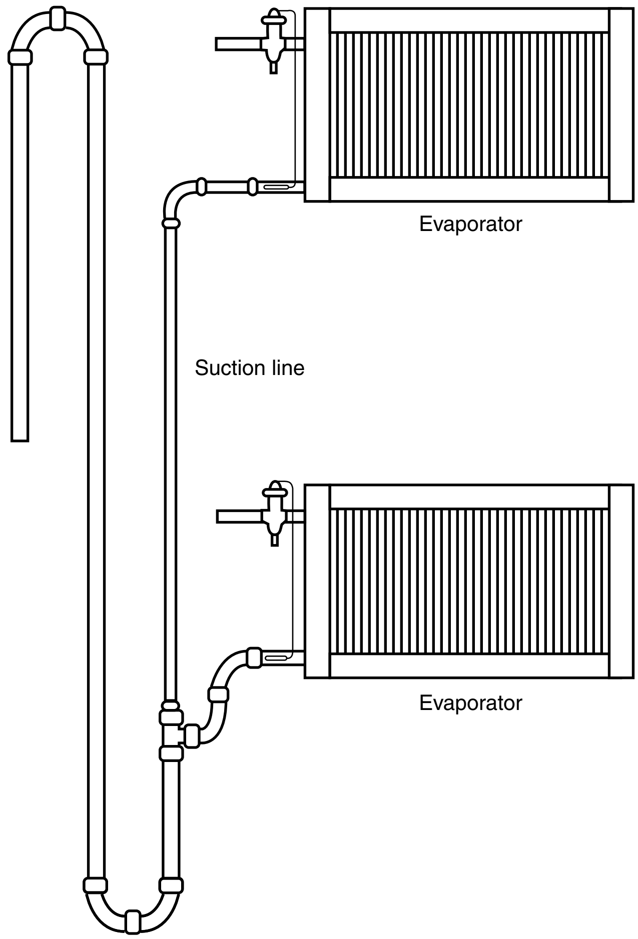


Figure 8. Correct suction-line piping without pump-down cycle

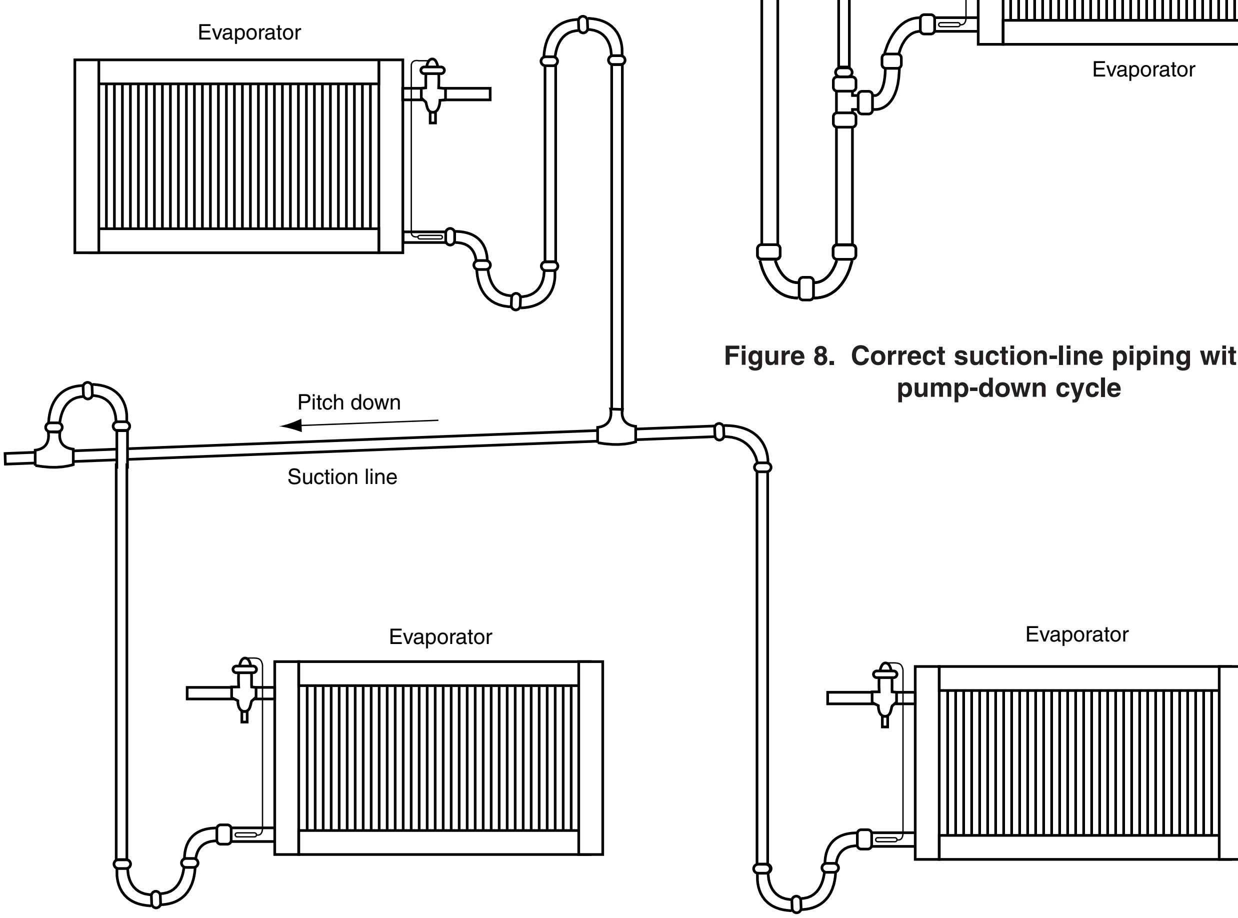


Figure 9. Correct piping for a system in which each evaporator has a solenoid valve (not shown)

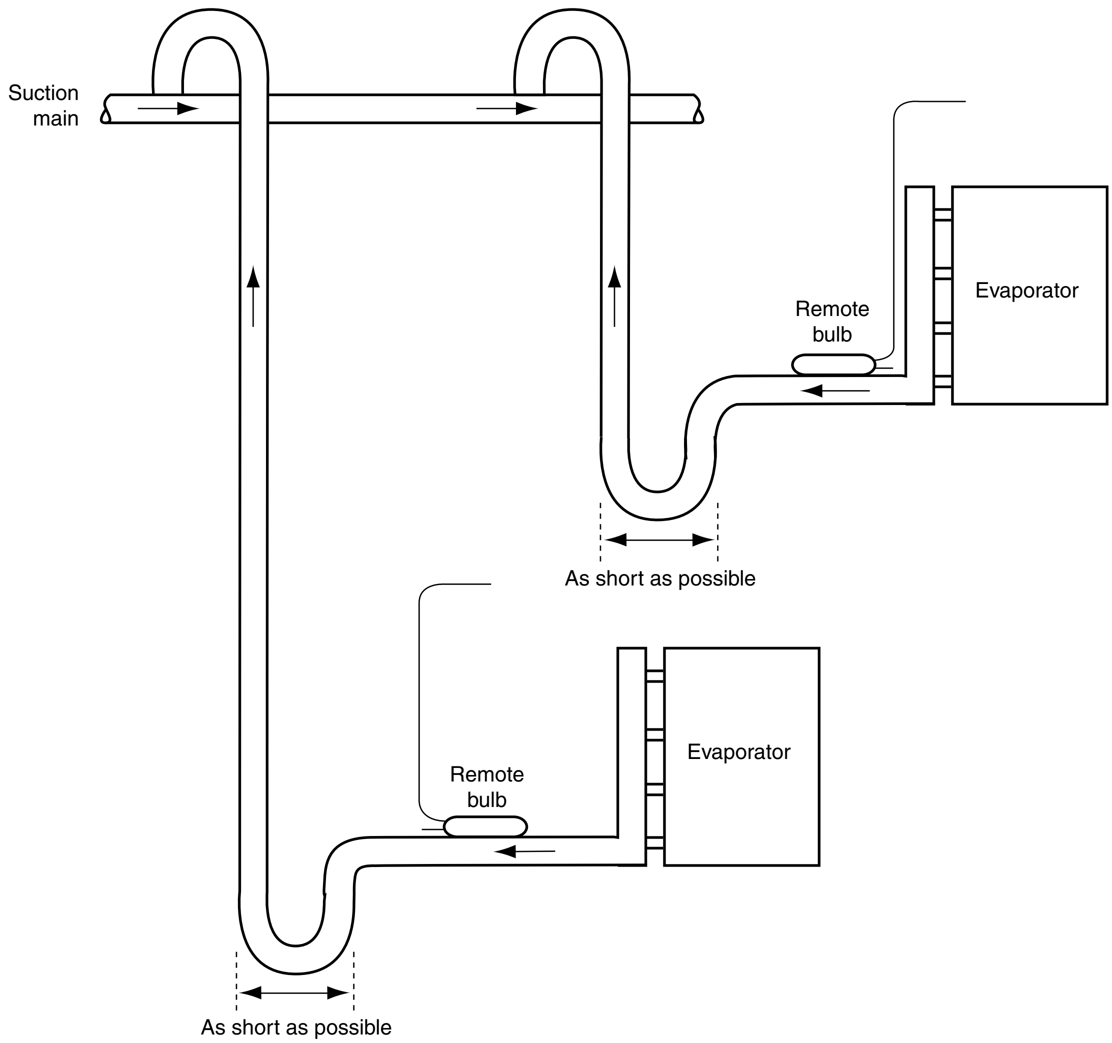


Figure 10. Branch piping should enter top of suction main

any point in the line's circumference. The one exception is at the bottom, where a mixture of refrigerant and oil might be present. The top mounting shown in Figure 12 is usually satisfactory.

Surface temperature will fluctuate slightly around the circumference of a suction line with an OD of ⅞ in. and greater. For these larger line sizes, install the remote bulb 45° below the horizontal center of the line, as shown in Figure 12.

An application in which the location of the remote bulb is extremely critical is a low-temperature installation with a cross-charged valve that must close tightly when the compressor stops. Attach the remote bulb to the suction line at a point where bulb and evaporator temperatures will stay the same during OFF cycles. In order to prevent water freeze-up at the bulb when operating below 32°F, any insulation must not absorb water. It may be that you cannot locate the remote bulb where such a temperature relationship can be maintained during OFF cycles. If so, install a solenoid valve, ported the same size as the liquid line, directly ahead of the expansion valve. It should be wired to close when the compressor is de-energized.

It is often desirable and recommended to locate the remote bulb in a well in the suction line. This often applies if the line size is 2⅛ in. OD or larger. This works very well in packaged units where low superheat is a factor in evaporator operation, or where fluctuating heat loads affect evaporators.

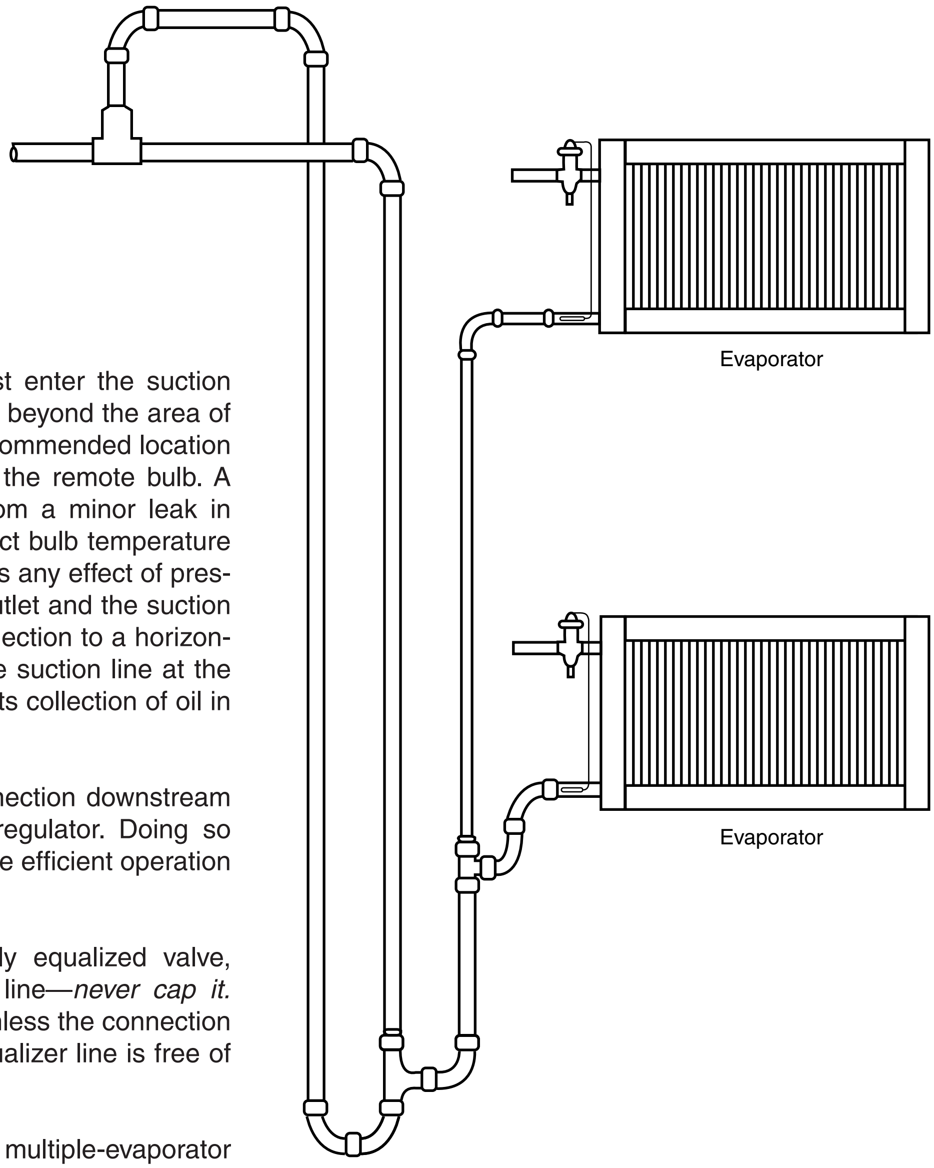


Figure 11. Use double riser when compressor exhibits capacity modulation

Equalizer line installation

An external equalizer line must enter the suction line at a point determined to be beyond the area of greatest pressure drop. The recommended location is immediately downstream of the remote bulb. A small amount of refrigerant from a minor leak in push-rod packing does not affect bulb temperature at this point. This location avoids any effect of pressure drop between the valve outlet and the suction line. An external equalizer connection to a horizontal suction line should enter the suction line at the 12 o'clock position. This prevents collection of oil in the equalizer line.

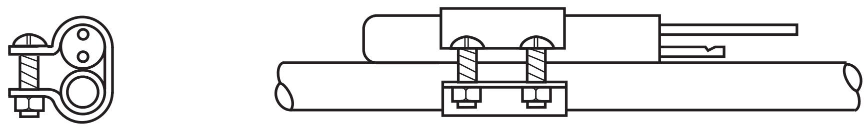
Never locate an equalizer connection downstream from any type of evaporator regulator. Doing so would seriously interfere with the efficient operation of the TEV.

When you install an externally equalized valve, *always* connect the equalizer line—*never cap it.* Such a valve will not operate unless the connection is made. Take care that the equalizer line is free of kinks or excess solder.

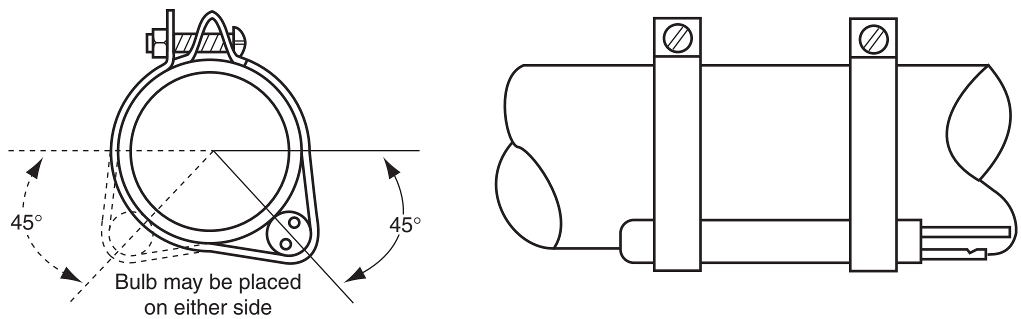
Two or more evaporators in a multiple-evaporator system may be fed by individual TEVs. If so, locate the external equalizer lines from each valve so that they are not affected by the pressure change in other evaporators. Never join equalizer lines together in a common connection to the main suction line. When suction lines from individual evaporator outlets to common suction lines are short, make external equalizer connections into the individual evaporator suction headers.

There is one possible exception to the above requirement. It applies when compressor capacity reduction is incorporated in a system. In such an application, external equalizer lines from two or more TEVs may be connected, as shown in Figure 13 on page 13. The illustration shows two independent evaporators (as far as refrigerant circuiting is concerned). Each is fed with a separate TEV and refrigerant distributor.

Each evaporator shares one-half of the total common load. The liquid-line solenoid valves ahead of each TEV are electrically connected to the compressor capacity modulation system. One of the solenoid



External bulb on small suction line



External bulb on large suction line

Figure 12. Remote bulbs correctly positioned

valves is de-energized when the compressor capacity is reduced to 50%. The solenoid valve closes, stopping the flow of refrigerant to one TEV. The other TEV remains in operation. Its capacity is approximately equal to the compressor capacity operating 50% unloaded.

A number of various combinations and adaptations are possible with this basic method. They depend on the number and size of evaporators, and on the percent of capacity reduction. Evaporator sections may have parallel flow, as shown, or may be in series. If in series, consider that the upstream section will carry a greater load per row. The selection of solenoid valves, TEVs, and refrigerant distributors must reflect this.

A factory-assembled unit may have the external equalizer connected at the evaporator inlet or in a return bend in the center of the coil. This is done if operational tests show that this position gives more efficient valve control. It applies particularly in a system with both a TEV and an evaporator pressure regulator. This arrangement is the result of design engineering. Do not attempt it in the installation of a field-assembled system. Remember, when any type of control valve is installed in the suction line, the efficient operation of an externally equalized expansion valve dictates that the equalizer line must enter the suction line on the evaporator side of the existing control valve.

VALVE ADJUSTMENT AND TROUBLESHOOTING

Assume that the correct TEV is installed in a balanced system. The liquid and suction lines are adequately sized and correctly assembled. You might think that there can be no obstacles to efficient operation. However, this is not always the case. Adjustment is sometimes required. Before attempting valve adjustment, consider the function of the TEV. The name of this device may give the impression that it directly controls temperature. This misconception has caused service technicians to make adjustments in an attempt to control refrigerated space temperature directly.

In operation, the thermostatic expansion valve actually has one simple function. It meters sufficient liquid refrigerant to the evaporator to satisfy load conditions. It does *not* directly control temperature, humidity, pressure, or compressor running time.

You cannot analyze valve performance by measuring suction pressure or by noting the extent of frost on the suction line. First measure the superheat to find out if a valve is performing its function.

Measuring superheat

There are four simple steps to calculate superheat:

1. Check the temperature of the suction gas at the bulb location.

2. Measure the suction pressure.

3. Convert the suction pressure to the saturation temperature.

4. Subtract the saturation temperature (Step 3) from the suction gas temperature (Step 1). The answer is superheat.

These four steps are not difficult. To find suction gas temperature, clean an area of the suction line close to the remote bulb. Tape either a thermocouple sensing unit or an accurate thermometer to the line at the cleaned area. Insulate the thermocouple or thermometer to avoid influence by ambient temperature. The reading you get is suction gas temperature.

You can measure suction pressure directly at the evaporator outlet if there is a gauge fitting. If not, connect an accurate gauge into the external equalizer line with a line-piercing valve.

You also may measure suction pressure at the compressor suction valve port on packaged or other close-connected installations. If you do, and if the compressor is more remote from the evaporator, there is another factor to be considered in your calculation of superheat. If the refrigerant is R-22, for example, you should know that its normal pressure drop is about 2 psi per 100 ft of line. Assume that the suction gas temperature at the bulb location is 51°F, and that the suction pressure read at compressor is 66 psi. Then the estimated suction-line pressure drop

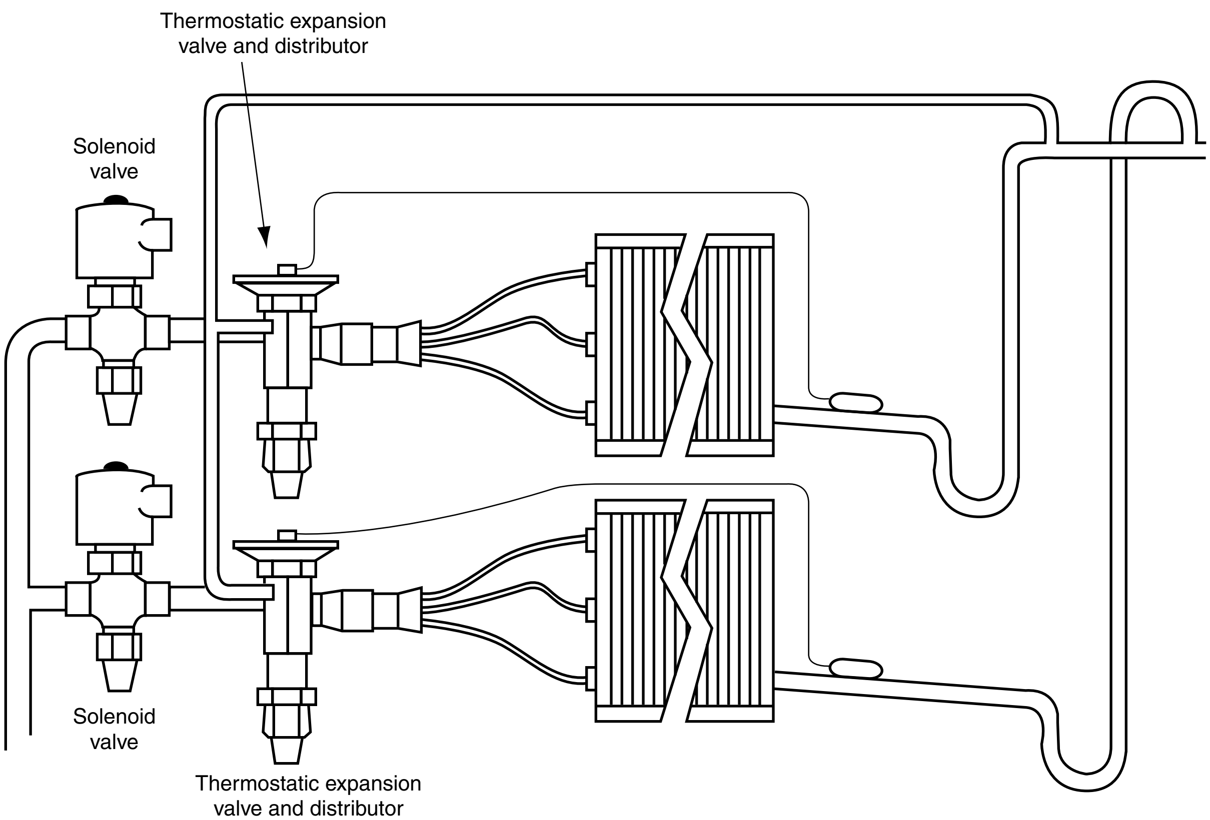


Figure 13. Capacity reduction results when two or more evaporator sections handle the same load

for R-22 of 2 psi must be added to the 66 psi, for a total of 68 psi back at the evaporator. Now you must convert 68 psi to temperature. You find that 68 psi is equivalent to 40°F saturation temperature. Subtract this 40°F from the 51°F suction gas temperature. The superheat is 11°F.

Finding the actual superheat is an important first step in troubleshooting many refrigerant flow problems. Remember that the problem may or may not involve the TEV itself. The next step is to check valve data to learn how much superheat is normal. Superheat of 10 to 15°F is about normal for air conditioning systems. About 5 to 10°F is average for low-temperature applications. If the actual superheat is too high, the problem is insufficient refrigerant flow into evaporator. If the actual superheat is too low, the reverse will be the problem—that is, too much refrigerant is being fed to the evaporator.

Both of these conditions could be the fault of the TEV. Yet, experience will tell you that the real trouble is often elsewhere in the system. Many TEVs are needlessly replaced before further troubleshooting finds the source of the real problem. In projecting your troubleshooting techniques, make two assumptions:

- first, that all equipment was checked and found satisfactory at system start-up
- second, that the system has functioned properly for an extended period of time before the call for service.

These assumptions rule out such factors as an undersized compressor, poor refrigerant distribution, incorrectly installed external equalizer, etc. In troubleshooting, the ratio of time spent is often 90% for locating the malfunction to 10% for correcting it. Accordingly, a system of checkpoints will always prove of value.

Use the troubleshooting checkpoints described in the following paragraphs as major guidelines. However, always consider other factors that could contribute to high or low superheat—leaking compressor discharge valves, an oil-logged evaporator, etc.

Let's look at a hypothetical example. You calculate a superheat of 20°F. The normal rating for the TEV is 12°F. As a result of excessive superheat, there is not enough refrigerant being supplied to the evaporator to keep up with the existing heat load. Having diagnosed the problem, you now can use troubleshooting techniques to locate the cause or causes. Study the following troubleshooting guidelines:

Guideline 1. Check for possible restrictions in the liquid line. Look for accumulated scale, loose drier material, solder, or thread-sealing compound at the strainer or solenoid valve. Spot-check along the liquid line, feeling for a possible difference in temperature, which would indicate pressure drop caused by an obstruction. Check all of the hand valves between the compressor and the TEV. Be sure that they are open and are not restricting refrigerant flow. Do not overlook compressor service valves or the solenoid valve, if one is used.

Guideline 2. Check the refrigerant charge. If the system is undercharged, superheat at the remote bulb will be excessively high. There may be a sight glass in the liquid line. If so, it will be a good indicator of refrigerant supply conditions, depending on its location. Bubbles in a sight glass at the receiver are a better indicator of refrigerant undercharge than in one at the TEV. There, the bubbles could indicate a restriction upstream in the liquid line, causing liquid-line vapor. A shortage of refrigerant will sometimes cause a whistling noise at the TEV. Other indicators of refrigerant shortage are low compressor power consumption, reduction in cooling capacity, and lengthened compressor running time.

Guideline 3. Test for insufficient pressure drop across the TEV. This condition will reduce refrigerant flow and valve capacity. A certain pressure drop must exist between the valve inlet and outlet. This mandatory pressure drop is determined by the difference between condensing and evaporating pressures. Anything that contributes to a lessening of this drop causes a loss of valve capacity. If condensing pressure is low, the usual result is reduced pressure drop across the expansion valve.

Assume that the condensing pressure is found to be satisfactory. If so, check these other areas:

- excessive liquid-line pressure losses due to high vertical lift

- inadequate subcooling
- a liquid line that is too small
- an undersized evaporator distributor, distributor nozzle, or even the distributor tubes themselves.

Guideline 4. A common source of trouble, especially in a low-temperature system, is the presence of water, or a mixture of water and oil. It will freeze in the TEV, because the valve is the first cold spot in the liquid line. The frozen material can cause the valve to remain fixed in position. It may be open, closed, or in any in-between position. If the port is restricted by the freeze-up, superheat will be higher than normal.

The existence of moisture freeze-up in the valve will be confirmed by a sudden increase in suction pressure after the system has been de-energized and has warmed up. To correct valve freeze-up temporarily, warm up the body with a hot cloth or heat lamp. After doing so, install a liquid-line filter-drier, if none exists. If one already exists, it is inefficient and should be replaced. Once you observe moisture in a system, never allow it to remain. In time, it will have an adverse effect on all other system components, whether it affects evaporator temperature or not.

Certain refrigerant oils are prone to form wax at very low temperatures. It will most likely form at the first cold spot encountered by the liquid refrigerant/oil mixture. This, of course, is the TEV. Wax formation affects the valve in the same way as frozen moisture. However, this problem cannot be corrected as easily. First, take the necessary steps to remove moisture. If the condition continues, then send a sample of system oil to the refrigerant oil supplier for testing and recommendations.

Guideline 5. It was noted previously that refrigerant flow problems are often not related to the TEV. Guidelines 1 through 4 above should tell you if there are any problems that are not valve-related. If none is found, it is time to examine the valve components. The easiest to check out is the remote bulb. If the remote bulb has lost its charge, the valve will close and stay closed. Identify a defective remote bulb in the following order:

- Shut down the compressor.
- Remove the bulb from the suction line and place it in a container of ice water.
- Start up the compressor.
- Remove the bulb from the ice water. Warm it up by holding it between your hands.
- Observe the suction line for any rapid drop in temperature. If this occurs, the bulb is OK.

If there is no rapid temperature drop, the bulb could be the problem. If the bulb is liquid-charged, it may have lost part or all of its charge. If the bulb is gas-charged, it may have lost its control. As previously noted, the remote bulb of a gas-charged valve must be kept at a lower temperature than the valve diaphragm. If it is not, the charge may condense in the diaphragm case, causing the valve to throttle. Warming the diaphragm case with hot water may increase refrigerant flow and reduce superheat to a normal level. If it does, gas-charge condensation in the diaphragm case is the cause. Correct this by relocating the remote bulb to a point on the suction line, which will maintain a lower bulb temperature.

Gas-charge condensation may also result from insufficient pressure drop between the valve outlet and the bulb location. This could be caused by system condensate dripping on the diaphragm case, the valve being located in a cold spot, or possibly an oversized distributor.

Still another cause of gas-charge condensation is found within the valve itself. There have been rare occasions when a push-rod packing leak allowed enough refrigerant to enter the equalizer line to refrigerate the diaphragm case. Consider this diagnosis only after careful checking. If correct, remove the power element and tighten the push-rod packing nuts.

Guideline 6. In the final analysis, a superheat that is too high could prove to be the result of an incorrect setting. If you have not found a solution using the above techniques, check out this possibility before assuming that the valve is defective. It has been firmly established that superheat is the controlling factor in TEV operation. Excessive superheat seriously reduces evaporator efficiency. And the reverse condition—low superheat—also affects system efficiency. It can permit liquid refrigerant to return to the compressor via the suction line. This condition can contribute to irreparable damage to the compressor. Examples include broken compressor valves and/or a bound-up compressor.

For further discussion of troubleshooting, consider the following situation. Assume that superheat is found to be 3°F. The valve specifications indicate that it should be 9°F. Obviously, superheat is exceptionally low. As a result, too much liquid refrigerant is being fed to the evaporator. It could be enough to fill the suction line back to the compressor. This condition, like high superheat, can be caused by a malfunctioning valve or compressor, or by factors that are not valve-related.

A common cause of low superheat is leakage at the TEV seat. This can be detected by a gurgling sound at the valve after the compressor has stopped running. Another indicator is bubbles that continue to show in a sight glass after the system is idle. But note that these tests are not conclusive if the system includes a permanent bleed-type valve built for use on systems with permanent split-capacitor, hermetically sealed compressors. Also, make certain that the sight glass indication is not reflecting downflow in a vertical liquid line.

Dirt, scale, drier material, frozen moisture, and wax formation can contribute to a low superheat. They can cause the TEV to be held open beyond the point required for normal operation. If this occurs, liquid refrigerant may flood all the way back to the compressor. As noted before, this can cause serious compressor damage.

Check for the existence of these conditions if there is low superheat. Use the same procedures as when the problem is high superheat. Take corrective measures, if required. You may find that the problem is not a result of these common causes. If so, make a final check to see if the superheat adjustment at the valve is set too low before replacing the valve.

Superheat adjustment procedures

TEVs are factory-adjusted to the setting best-suited to most of the applications within the operational range for which they are to be used. They generally require no further adjustment on your part. There are times, however, when you may have to adjust a valve in the field to get proper superheat. For example, the system in which it is installed may require a different superheat setting than the one that was set at the factory. Or, troubleshooting procedures may show that the correct setting has been changed. Most TEVs currently manufactured have external superheat adjustments. However, you may find one in which the superheat adjustment is in the outlet. In this case, you must remove the valve and make the adjustment with an Allen wrench. With another type of internally adjustable TEV, you must remove and disassemble the valve, and then rotate an adjusting nut in the valve cage assembly. Figure 14 shows an internally adjustable TEV.

With externally adjusted valves, no major disassembly or removal is necessary. Figure 15 shows a typical example of an externally adjustable TEV. Remove the seal cap covering the adjustment mechanism to change the superheat setting. Then, place the appropriate wrench on the adjusting stem. Turn the stem *clockwise* to increase superheat, or *counterclockwise* to lower it. Adjust the valve in increments of one turn. Then observe the change in superheat closely. This procedure prevents going beyond the desired setting. Do not expect immediate results. It may take 20 minutes or more after the adjustment to reach the new level.

If there is more than one evaporator, adjust one valve at a time. Allow ample time after each adjustment to check results. Don't forget to replace and tighten the seal caps on the valves.

On gas-charged or vapor cross-charged valves, be aware that a change in superheat also changes the maximum operating pressure (MOP) of the system in which they are installed. Increasing superheat from the existing level lowers the MOP. Lowering the initial setting raises the MOP.

The superheat adjustment for some valves with a liquid cross charge must be set at the lowest temperature that will be required of the operator. This is because superheat for this type of valve decreases as evaporator temperature decreases. Any adjustment should be rechecked at the point of the heaviest load. Do this to ensure that system capacity is not impaired by the increase in superheat present at that level of unit operation.

Also, note that changes in the evaporator temperature have little or no effect on the superheat setting of vapor cross-charged valves.

Consult the equipment manufacturer if you are not sure about the proper superheat setting for a TEV in a particular system. This applies particularly if the complete system is factory-assembled and tested. Some producers base adjustment on superheat directly. Others adjust the valve for a specific suction pressure at nominal operating conditions or for maintaining a frost line within certain limits.

ALCO CONTROLS

Figure 14. Internally adjustable TEV

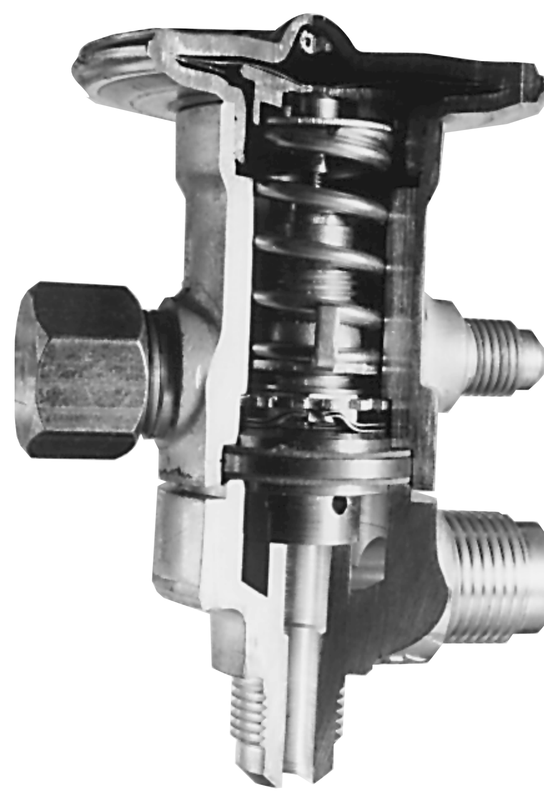
FIELD ASSEMBLY INSTRUCTIONS

With field-serviceable TEVs, you may have to remove internal parts for inspection, cleaning, or possible replacement. Most valves are easy to disassemble. During reassembly, extreme care is needed if the valve is to function properly when placed in operation. The several manufacturers of TEVs always provide disassembly and reassembly instructions. Follow them to the letter.

CONVERTING R-12 AND R-502 SYSTEMS TO ALTERNATIVE REFRIGERANTS

Because the refrigerant being used plays an important part in your selection of the proper TEV for a particular application, it is necessary to look more closely at the refrigerants themselves. As you know, the federal government enacted legislation prohibiting the production of chlorofluorocarbon (CFC) refrigerants after January 1, 1996, including azeotropes using CFCs (R-500 and R-502, for example). The production of hydrochlorofluorocarbon (HCFC) refrigerants must be phased out by the year 2030 (except for R-22, which will be phased out by 2020). Many refrigerant manufacturers have committed to accelerating the phaseout of CFCs.

Fortunately, hydrofluorocarbon (HFC) replacement refrigerants exist for both R-12 and R-502. They lack



ALCO CONTROLS

Figure 15. Externally adjustable TEV

the chlorine molecule that causes ozone reduction in the upper atmosphere. Also, a number of HCFC refrigerants have been developed as interim or service replacements for R-12 and R-502. Table 6 lists the major replacement refrigerants. R-22 is also a viable replacement in many R-12 or R-502 systems, provided certain issues are addressed. R-22 remains a proven refrigerant. The Clean Air Act allows its continued interim use while developing ozone-safe refrigerants.

REPLACEMENT REFRIGERANTS

When developing refrigerants as replacements for R-12 and R-502, manufacturers must consider three problems. First, the new refrigerants must be safe—i.e., nonflammable and nontoxic. Second, their thermodynamic properties, including their pressure-temperature (P-T) curves, must come relatively close to matching those of the refrigerants that are being replaced. Otherwise, system components such as TEVs would need to be replaced. Third, the refrigerants must be compatible with materials normally used in a refrigeration system.

Azeotropes, zeotropes, and temperature glide

Developing replacements for R-12 and R-502 requires refrigerant manufacturers to consider *blends*, or mixtures of more than one refrigerant. A desirable characteristic for a blend is a near-constant boiling temperature at a constant pressure. An *azeotrope* is a blend with a constant boiling temperature at a constant pressure. A *zeotrope* is a blend without a constant boiling temperature at a constant pressure.

CFC refrigerant	Replacement refrigerant	
	HFC	HCFC
12	134a	401A 401B
502	404A 507	402A

Table 6. Major replacement refrigerants for R-12 and R-502

Single-component refrigerants, such as R-12 and R-22, or azeotropic mixtures, such as R-502, boil at a constant temperature at a constant pressure. The refrigerant remains at a constant temperature as it changes, first from a saturated liquid to a two-phase (liquid and vapor) mixture, and finally to a saturated vapor.

This is not the case with zeotropic mixtures, such as R-401A and R-401B. Temperatures of the saturated liquid and the saturated vapor for a given pressure are not the same. The saturated liquid and vapor temperatures are often referred to as *bubble point* and *dew point*, respectively.

At a constant pressure, dew point temperature is greater than bubble point temperature. The difference in these temperatures is known as *temperature glide.* You must understand this concept in order to calculate subcooling and superheat properly with these refrigerants. You use dew point temperature to calculate superheat. You use bubble point temperature to calculate subcooling.

Zeotropes with a temperature glide less than 10°F are called *near-azeotropes*. ASHRAE designates zeotropes and near-azeotropes with a 400-series number. Letter suffixes identify blends with the same components, but in different proportions. For example, both R-401A and R-401B consist of R-22, R-152a, and R-124, but in different proportions.

REPLACEMENT REFRIGERANTS FOR R-12 AND R-502

Figure 16 shows the P-T curves for R-12, R-502, their replacement refrigerants, and R-22. The dew point curves are shown for the blends. Since the dew point curve is used to calculate superheat, it is the curve of interest when considering TEV operation.

The P-T curves of R-502 and its replacement refrigerants are very similar. They are higher-pressure refrigerants than the others listed in Table 6. The P-T curves of R-12 and its replacements are also similar. The P-T curve of R-22 falls between these two groups.

All of these refrigerants have roughly the same liquid density—about 70 lb/ft^3 at 100°F. Therefore, pressure

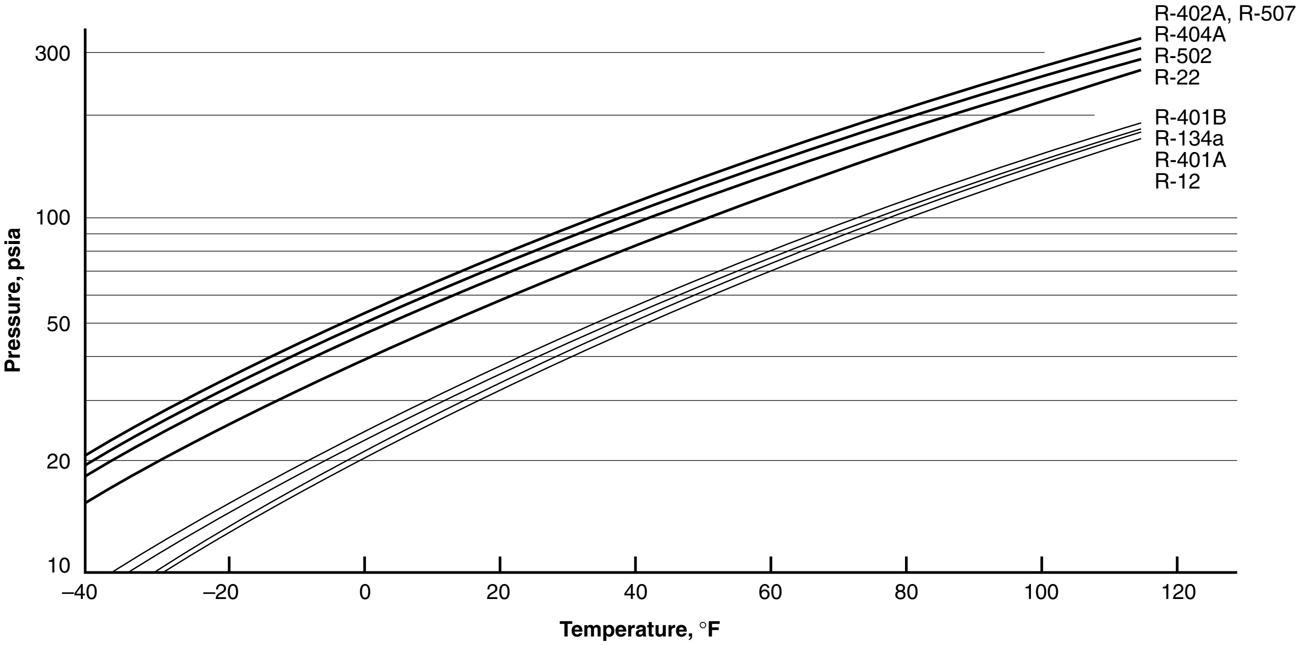


Figure 16. Saturation curves

drop due to liquid-line vertical lift is also similar for all of these refrigerants. It is about 0.5 psi per vertical foot.

Net refrigerating effect

One important characteristic of refrigerants is the amount of heat that they can absorb. This is known as the *net refrigerating effect (NRE).* This concept can be explained by determining the flow rate required to obtain an evaporator rating. Assume that you have two 18,000-Btuh refrigerated cases. One is a medium-temperature case with a 20°F evaporator. The other is a low-temperature case operating a –20°F evaporator. Table 7 shows the flow rates required of each refrigerant for rated case capacity. These data have been gathered from ASHRAE, DuPont, and Allied Signal.

The rates given assume a 90°F liquid refrigerant temperature entering the TEV that feeds the cases. Note that the flow rates for R-502 and its replacement refrigerants are similar. This indicates that the thermodynamic properties of these refrigerants also are quite similar. The required flow rates of the R-12 replacements, however, are much lower than R-12. As you can see, the listed R-12 replacements are more like R-22 in this respect. This is because of their greater net refrigerating effect. In other words, the R-12 replacement refrigerants listed absorb more heat than R-12.

	Flow rate (lb/min)	
Refrigerant	**20°F case**	**–20°F case**
12	5.9	6.4
134a	4.7	5.1
401A	4.3	4.7
401B	4.3	4.6
502	6.6	7.3
402A	6.1	6.9
404A	5.8	6.5
507	6.1	6.9
22	4.3	4.5

Table 7. Flow rates required for different refrigerants

The lower the required flow rate, the less refrigerant the compressor needs to pump to achieve evaporator capacity. Lower flow rates tend to lower refrigerant velocities. This may lead to oil return problems in a system being converted.

Lower required flow rates will also increase the capacities of the system's valves. For example, the capacity of an R-12 TEV increases about 20% when used with R-134a. The increase is about 30% when used with R-401A or R-401B. Valves that are oversized for the application are more of a concern with the listed R-12 replacement refrigerants.

Discharge temperatures

Another important factor in converting a system is the effect that the replacement refrigerant has on the compressor discharge temperature. Because of its thermodynamic properties, R-22 causes compressors to operate at higher discharge temperatures than the other refrigerants listed in Table 6. R-401A and R-401B, however, cause discharge temperature to increase above that of R-12 operation. This temperature must not reach the point where oil begins to break down.

Table 8 lists estimated discharge temperatures for the refrigeration systems discussed above. The values shown assume the following:

- a 110°F condensing temperature
- a 25°F superheat at the compressor
- a discharge temperature 80°F above *isentropic* (ideal) compression.

These values are based on the data cited earlier from ASHRAE, DuPont, and Allied Signal.

When are discharge temperatures excessive, and how can they be prevented?

Consult the compressor manufacturer for maximum discharge temperature and the method of measuring it. Generally, discharge temperatures over 300°F will break down oil.

Discharge temperatures increase when:

	Discharge temperature (°F)	
Refrigerant	**20°F case**	**–20°F case**
12	228	241
134a	223	233
401A	252	274
401B	255	279
502	226	236
402A	231	240
404A	223	229
507	218	224
22	258	287

Table 8. Estimated discharge temperatures

- suction pressure decreases
- superheat at the compressor inlet increases
- condensing temperature increases.

Use the general guidelines below to deal with these conditions:

- Do not allow the system to operate at suction pressures lower than needed to maintain product temperature.
- Insulate the suction line properly and be sure that the TEV is set properly.
- Be sure that the condenser coil is of adequate size and that it is clean.

Do *not* set the TEV by measuring discharge temperature. Set it by measuring superheat at the sensing bulb location. A TEV set to a flood (zero superheat) to reduce discharge temperatures is not able to control flow properly. Floodback will probably result.

Following these guidelines may not always solve the problem of excessive discharge temperatures. If so, use some means to cool the discharge vapor. Perhaps the simplest method is to use a *desuperheating* TEV.

This device is actually a small-capacity TEV, which feeds refrigerant directly into the suction line. Its sensing bulb is located on the suction line to control superheat at the compressor. The valve reduces superheat at the compressor, and thus reduces compressor discharge temperature. The valve may or may not use a special thermostatic charge in its sensing bulb.

Selecting the proper TEV for desuperheating is slightly more difficult than TEV selection for normal applications. Contact the TEV manufacturer or the compressor manufacturer if you need assistance in this area. A good rule of thumb for sizing a desuperheating TEV is to size it at 5 to 10% of compressor capacity.

Sporlan Valve Company also makes a temperature response expansion valve (TREV) for the purpose of desuperheating. The advantage of this valve is that it controls discharge temperature directly. The sensing bulb is placed on the discharge line. The valve feeds refrigerant into the suction when needed to keep bulb temperature at the valve setting. TREV sizing and application information may be obtained from the manufacturer.

CONVERSION CONSIDERATIONS

What needs to be done?

The replacement refrigerants considered here are listed in Table 6. There are other available HFC and HCFC refrigerants designed to replace R-12 and R-502. Consult the appropriate manufacturer about application of equipment with other replacement refrigerants.

The following text covers in general the procedure for converting an R-502 system to a replacement refrigerant listed in Table 6. Before replacing the R-502 refrigerant, change the refrigerant oil to the recommended mixture ratio of mineral and polyolester oils. Ask the compressor manufacturer for recommendations on the refrigerant oil to use and how to change out the existing oil.

As a good service practice, you should change external seals (tetraseals, O-rings, and gaskets) whenever possible. This includes seals in various components such as solenoid valves, pressure-regulating valves, filter-driers, etc. Consult service and installation bulletins on how to change seals and reassemble components. It is always a good practice to change the filter-drier anytime the system is opened.

The R-502 replacement refrigerants listed in Table 6 are similar thermodynamically to R-502. This similarity is close enough that system components should not have to be changed. Check and adjust the TEV and the pressure-regulating valve settings if necessary when operating with the new refrigerant. Also, identify the system as having a new refrigerant. One way is to paint the tops of the TEVs with the color of the refrigerant.

Look at the saturation curves of refrigerants R-402A and R-507. They run 5 to 8 psi above the curve of R-502 in the medium temperature range (10 to 30°F). This tends to cause an R-502 TEV to starve. If the valve is not undersized for the application, you should be able to readjust it to the proper superheat if needed. If the valve does not have sufficient adjustment range, replace the thermostatic element (power head) with one designed for these refrigerants.

The procedure for converting an R-12 system to one of the R-12 replacement refrigerants listed in Table 6 is identical to converting an R-502 system. Note, however, that the R-12 replacement refrigerants have a much greater influence on valve capacities. Refrigerants R-134a, R-401A, and R-401B increase valve capacities 20 to 30% over those of the R-12 capacity. With properly sized valves, this additional capacity may present no problems other than some re-adjustment. You may have to downsize them if they are too oversized for proper control.

Thermostatic expansion valves

Carefully review the TEVs when you convert R-12 and R-502 systems to R-22. An R-12 TEV used on an R-22 system will starve. In contrast, an R-502 TEV may overfeed on an R-22 system.

The best approach is to replace the TEV. You would normally replace it with an R-22 TEV with the same nominal rating. It is a good practice, however, to check the valve sizing when converting a system to R-22.

Refrigerant distributors

Refrigerant distributors require a pressure drop in order to distribute the refrigerant equally to each circuit. Refrigerant normally enters the distributor as a two-phase (liquid and vapor) mixture. The pressure drop keeps the liquid portion of the mixture entrained. An insufficient pressure drop allows the liquid portion to separate from the flow. This condition causes the lower circuits in the distributor to be overfed. This is especially true when the distributor is not mounted vertically.

Some distributors use an inlet nozzle to focus two-phase flow onto a dispersion cone. It divides the flow equally. This nozzle is frequently replaceable, and can be changed if necessary when converting to R-22.

As noted, less refrigerant flows through the system when it is properly converted to R-22. Thus, you must reduce the size of the distributor nozzle to maintain pressure drop across the distributor.

If the nozzle is easily replaceable, change the nozzle for one of the proper size. The distributor may have a nonreplaceable nozzle, however, or one that is not easy to remove. In such cases, you may have to change out the distributor.

CONCLUSION

When converting R-12 and R-502 systems to a replacement refrigerant or to R-22, you should carefully evaluate each system component in addition to and in relation to the TEV. If further questions arise, always consult the appropriate system or component manufacturer. *Note:* The material regarding the conversion of R-12 and R-502 systems to alternative refrigerants, contained on pages 17–22 in this document, was adapted with permission from Sporlan Valve Company Bulletin 10-125.

Refrigeration Service Engineers Society
1666 Rand Road Des Plaines, IL 60016 847-297-6464