the valve to open wider. The increased flow rate will result in a higher evaporator pressure (P_1) and a balanced control point will again be established. Conversely, a decrease in the heat load on the evaporator decreases the temperature of the refrigerant gas leaving the evaporator and causes the thermostatic expansion valve pin to move in a closing direction.

Under certain circumstances there may be little or no pressure response, and the thermostatic expansion valve then controls on temperature alone. This would be true if the evaporator were part of a multiple evaporator system, or if it were also controlled by an evaporator pressure regulator.

The new control point, following an increase in valve opening, is at a slightly higher superheat because of the spring rate of the diaphragm and the superheat spring. Conversely, a decrease in load results in a slightly lower superheat than the original control point.

These superheat changes in response to changes in load are best illustrated by the gradient curve of Fig. 6. Superheat at no load A, or *static superheat*, assures sufficient spring force to keep the valve closed during equipment shutdown. An increase in valve capacity or load is roughly proportional to superheat increase until the valve is fully open. The superheat gradient, represented by the distance AB, may be defined as the increase in superheat required to open the valve to the capacity at which it is intended to operate, or at which it is rated.

Capacity

The *factory superheat setting* (static superheat setting) of thermostatic expansion valves is made with the valve pin just starting to move away from the seat. Valve manufacturers establish capacity ratings on the basis of superheat gradient from 4 to 8 F deg, depending on the valve design, valve size, and application. Full-open capacities usually exceed rated capacities by 10 to 40 percent to allow a reserve, represented

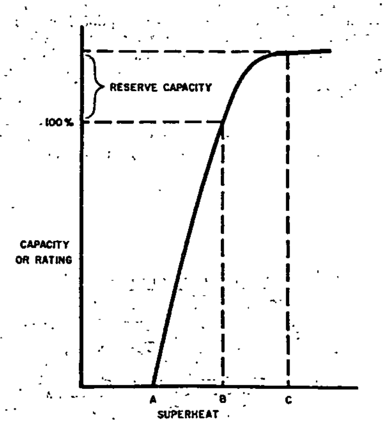

Fig. 6 .... Typical Gradient Curve for Thermostatic Expansion Valves

by the distance BC, in Fig. 6, for manufacturing tolerances and application contingencies.

System design should not be based on utilization of the reserve capacity of the thermostatic expansion valve, which is obtained only at the expense of higher superheat. The added superheat gradient may have an adverse effect on valve performance. Valve gradients used for rating purposes generally produce optimum modulation for a given valve design, and it is not wise to deviate widely from manufacturers' recommendations.

Thermostatic expansion valve capacities are normally published for various evaporator temperatures and valve pressure drops. Nominal capacities apply at 40 F evaporator temperature. Capacities are reduced at lower evaporator temperatures. These reductions in capacity are due to the change in the refrigerant pressure-temperature relationship at lower temperatures. For example, if Refrigerant 12 liquid charge is used, the change in saturated pressure between 40 F and 45 F is 4.7 psi, whereas between − 20 F and − 15 F, the change is only 1.9 psi. Although the valve responds to pressure changes, capacities are based on superheat gradients. Thus, the valve opening, and consequently the valve capacity, is less for a given superheat change at the lower evaporator temperatures.

Pressure drop across the valve port is always the net pressure drop available at the valve itself, rather than the difference between compressor discharge and compressor suction pressures.

Allowances must be made for the following:

1. *Friction loss* through condenser, liquid lines, and fittings.
2. *Liquid line accessories*, such as filters, driers, solenoid valves, etc.
3. *Static head* in a vertical liquid line. If the thermostatic expansion valve is at a higher level than the receiver, there will be a pressure loss in the liquid line due to the static head of liquid.
4. *Distributor pressure drop.*
5. *Evaporator pressure drop.*
6. *Suction line accessories*, such as evaporator regulators, solenoid valves, etc.
7. *Suction line friction losses.*

Although the mass flow rate through the valve is greater for higher pressure drops, the capacity increase is not proportional. The mass flow rate through the valve varies as the square root of the pressure drop, but, due to the greater enthalpy of the entering liquid refrigerant, a greater mass flow rate is required to obtain a given refrigerating effect. At high liquid temperatures, the capacity increase due to higher pressure drops may be completely offset by the loss in net refrigerating effect, resulting in no change in capacity.

If liquid refrigerant subcooling is increased along with the liquid pressure, the capacity changes differ from those previously discussed. Subcooling, in addition to increasing the net refrigerating effect per unit of mass flow, reduces the amount of flashing in the valve port and thereby also adds to valve capacity. Most manufacturers publish subcooling factors to be applied to valve capacity ratings.

Thermostatic expansion valve *ratings are based on vapor-free saturated liquid entering the valve.* If flash gas is present in the entering liquid, the valve capacity is substantially reduced, because the gas must be handled along with the liquid. Flashing of the liquid refrigerant may be caused by pressure drop in the liquid line due to friction losses, vertical lift, or both. If the refrigerant subcooling at the receiver outlet is not adequate to prevent the formation of flash gas, additional subcooling means must be employed to remove it. Liquid-to-suction heat exchange will provide a moderate

degree of subcooling, but, for extreme requirements, a separate liquid-cooling coil is necessary.

Thermostatic Charge

Each type of thermostatic charge has certain advantages and limitations which must be considered. The principal types of thermostatic charges and their characteristics are described here.

Gas charge. Conventional gas charges are limited liquid charges, which employ the same refrigerant in the thermostatic element as is used in the refrigeration system. The amount of charge is such that, at a predetermined temperature, all of the liquid has vaporized, and any temperature increase above this point results in virtually no increase in element pressure. Fig. 7 shows the pressure-temperature relationship of the Refrigerant 12 gas charge in the thermostatic element. Because of the characteristic pressure-limiting feature of its thermostatic element, the gas-charged valve can provide compressor motor overload protection on some systems by limiting the maximum operating suction pressure. It also helps to prevent *floodback* (the return of refrigerant liquid to the compressor through the suction line) on starting. Increasing the superheat setting will lower the maximum operating suction pressure, and decreasing the superheat setting will raise it because the superheat spring, together with the evaporator pressure, acts directly on the element pressure through the diaphragm.

Gas-charged valves must be carefully applied in order to avoid loss of control from the bulb. If either the diaphragm chamber or the capillary tube becomes colder than the bulb, the small amount of charge in the thermostatic element will condense. Control at the bulb will be lost and the valve will throttle or close. This matter is discussed further in the section, Application.

Liquid charge. Conventional liquid charges employ the same refrigerant in the thermostatic element as is used in the refrigeration system. They are termed *cross-ambient* charges because the volumes of the bulb, capillary tubing, and diaphragm chamber are proportioned so that the bulb contains some liquid under all temperature conditions. Therefore, the bulb will always control the valve operation even with a colder diaphragm chamber or capillary tube.

The characteristics of the straight liquid charge, Fig. 8, result in an increase in operating superheat as the evaporator

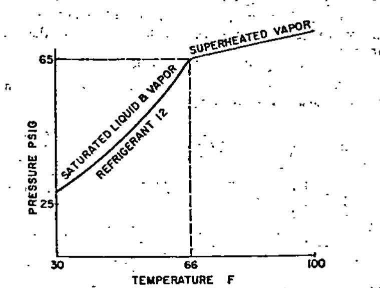

Fig. 7 .... Pressure-Temperature Relationship of Refrigerant 12 Gas Charge in Thermostatic Element

temperature decreases. This usually limits its use to moderately high evaporator temperatures. The valve setting required for a reasonable operating superheat at a low evaporator temperature may cause floodback during pulldown from normal ambient temperatures.

Liquid cross charges. The liquid cross charges are also cross-ambient charges, but, unlike the conventional liquid charges, they employ a liquid in the thermostatic element which is different from the refrigerant in the system. Cross charges have flatter pressure-temperature curves than do the system refrigerants with which they are used. Consequently, their superheat characteristics differ considerably from those of the straight liquid or gas charges.

Cross charges in the commercial temperature range generally have superheat characteristics which are nearly constant or which deviate only moderately through the evaporator temperature range. This charge, also illustrated in Fig. 8, is generally used in the evaporator temperature range of 40 F to 0 F, or slightly below.

For evaporator temperatures which are substantially below 0 F, a more extreme cross charge may be employed. At high evaporator temperatures, the valve controls at a high superheat. As the evaporator temperature is reduced to the normal operating range, the operating superheat is also reduced to normal. This characteristic prevents floodback on starting, reduces the load on the compressor motor after start-up, and permits a rapid pulldown of suction pressure. Valves with this type of charge must be set for the optimum operating superheat *at the lowest evaporator temperature expected*, in order to avoid floodback.

Mechanical pressure limiting means. While both the low temperature cross charge and the gas charge offer compressor-motor overload protection, each has its limitations. For the former, the protection offered is only partial; for the latter, application limitations restrict its universal use. Thermostatic expansion valves, equipped with a mechanical pressure limiting means to limit suction pressure, may use either the liquid or the liquid cross charge and are, therefore, not restricted by problems of charge condensation. Throttling of the valve is accomplished by a collapsible member which is operative only when the evaporator pressure exceeds a specified value. At lower evaporator pressures, there is no interference with normal valve operation.

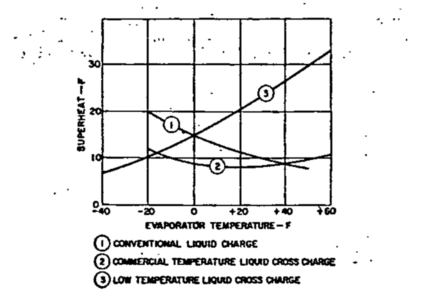

Fig. 8 .... Superheat Characteristics of Thermostatic Liquid and Liquid Cross Charges