THEORY OF THE CAP TUBE AS A REFRIGERANT CONTROL

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First and foremost, the cap tube acts as a pressure reducing device. If air or water is pressurized at the inlet, there will be a linear or equal reduction of pressure for each foot of tubing. For example, if water enters a cap tube at 50 psig, the pressure decreases at a constant rate as the water passes through the tube, as shown in Figure 1.

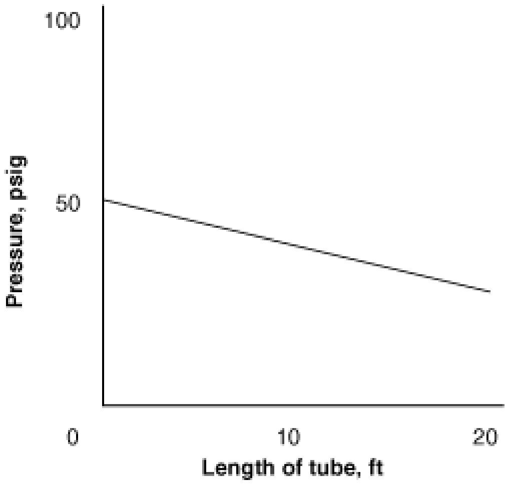

FIGURE 1 Water Pressure Drop

If refrigerant responded the same way as water, the cap tube could never be used as a refrigerant control. Why not? Because when the head pressure was low, the evaporator would be starved, and when the ambient temperature was high, the evaporator would be flooded with liquid (the flow rate would be greater than the rate of vaporization).

However, if there was a way to increase the flow rate when the head pressure was low, and decrease the flow rate at high ambient temperatures, you would have a refrigerant control. This modulating effect is exactly what happens when a cap tube is installed in a well-balanced system.

The following two principles are involved:

- Liquid refrigerant flows faster than vapor (vapor restricts the flow of liquid).
- The colder the liquid, the faster the flow.

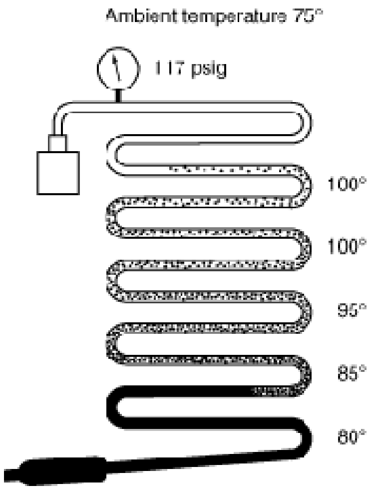

Figure 2

Condensing temperature 100°
Liquid out temperature 80°
Subcooled 20°

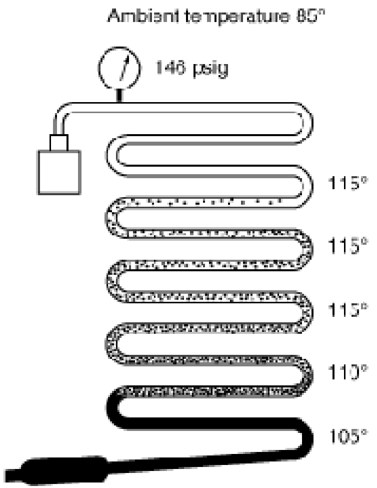

Figure 3

Condensing temperature 115°
Liquid out temperature 105°
Subcooled 10°

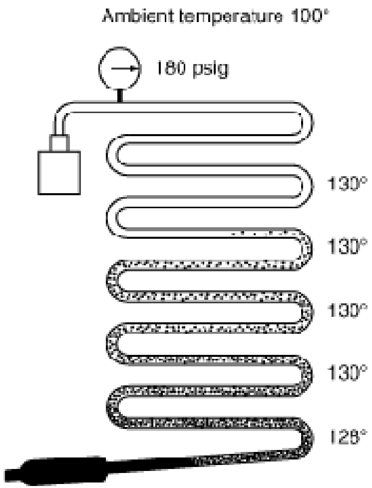

Figure 4

Condensing temperature 130°
Liquid out temperature 128°
Subcooled 2°

SATURATED PRESSURE TEMPERATURE R-12
Temperatures are indicated in degrees Fahrenheit.

PSIG	117	113	109	105	101	97	93	89	85	60	20
TEMP	100°	98°	96°	93°	91°	89°	86°	83°	80°	62°	19°

Figure 2A

PSIG	117	113	109	105	101	97	93	89	85	60	20

TEMP	80°	80°	80°	80°	80°	80°	80°	80°	80°	60°	19°
FEET	0	1	2	3	4	5	6	7	8	9	10

SATURATED PRESSURE TEMPERATURE R-12
Temperatures are indicated in degrees Fahrenheit.

PSIG	146	142	138	134	130	126	117	105	77	47	12
TEMP	115°	113°	111°	108°	107°	105°	100°	92°	75°	50°	6°

Figure 3A

PSIG	146	142	138	134	130	126	117	105	77	47	12

TEMP	105°	105°	105°	105°	105°	105°	100°	92°	75°	50°	6°
FEET	0	1	2	3	4	5	6	7	8	9	10

SATURATED PRESSURE TEMPERATURE R-12
Temperatures are indicated in degrees Fahrenheit.

PSIG	180	176	170	162	152	140	125	105	70	45	15
TEMP	130°	128°	126°	122°	118°	112°	105°	93°	70°	48°	10°

Figure 4A

PSIG	180	176	170	162	152	140	125	105	70	45	15

TEMP	128°	128°	126°	122°	118°	112°	105°	93°	70°	48°	10°
FEET	0	1	2	3	4	5	6	7	8	9	10

Figures 2, 3, and 4 show a condenser operating in three different ambient temperatures (with R-12). Note that in these figures and throughout this chapter, all temperatures are in degrees Fahrenheit and all pressures are in psig.

NOTE: The temperature of the subcooled liquid at the inlet to the strainer varies inversely with the ambient temperature. As the ambient temperature rises, the temperature of the subcooled liquid is reduced. This is the basic reason why the flow rate modulates in a cap tube. Remember that vapor restricts the flow of liquid—a fact that will become more apparent as you discover what actually happens inside a cap tube.

The 20° subcooled liquid of the condenser in Figure 2 is entering a 10 ft. cap tube, shown in Figure 2A. Notice that the liquid refrigerant is reacting the same way as water—that is, the pressure drop is constant for each foot of tubing at 4 lb./ft. until the 8 ft. mark. Also note that the temperature remains the same until the 8 ft. mark. The numbers at the top of Figure 2A are those of the saturated temperature (the pressure scale is for R-12). It is interesting to note that as the liquid refrigerant passes through the cap tube, the subcooled temperature decreases. For example, liquid enters the tube at 20° subcooled, but at the 4 ft. mark the liquid pressure is 101 lb. and at the same temperature of 80°.

However, the scale shows that R-12 at 101 lb. should be 91°, which means that the liquid is only 11° subcooled. And at the 6 ft. mark, it is only 6° subcooled. Now look at the 8 ft. mark where both the temperature and the pressure of the liquid refrigerant inside the cap tube are at the saturation point and equal to the figures in the R-12 scale.

The controlling factor (the modulating effect) occurs after the 8 ft. mark. As the pressure drops after that point, the liquid refrigerant pressure will be below its saturation level. The refrigerant will boil (cause bubbles to form) inside the cap tube, in the same way as in an ordinary evaporator. The gas pockets, or bubbles, will restrict the flow of liquid, causing a lower flow rate, which will result in more violent boiling and, in turn, more restriction.

To summarize Figure 2A: liquid refrigerant enters the cap tube at 20° subcooled. The subcooled temperature decreases with each foot of tube until the liquid reaches the 8 ft. mark, where the refrigerant is at its saturation level. At that point, the liquid has traveled a distance of 8 ft. As the liquid travels further, bubbles start to form. The remaining 2 ft. are referred to as the bubble length. As the refrigerant travels through the bubble length, both the temperature and the pressure are reduced and remain at the saturated level.

The cap tube in Figure 3A is connected to the condenser in Figure 3, operating in a warm ambient temperature of 85°. The subcooled liquid is now only 10°. The liquid in the cap tube will reach its saturated level at the 5 ft. mark, which leaves the remaining 5 ft. as the restrictive bubble length.

The cap tube in Figure 4A is connected to the condenser in Figure 4, operating in a hot ambient temperature of 100°, with a 2° subcooled liquid. The liquid has to travel only 1 ft. to reach its saturated level. This leaves a 9 ft. bubble length to restrict the flow rate.

To sum up briefly: as the ambient temperature rises and falls, the temperature of the subcooled liquid in the condenser also changes. It is this variable subcooled temperature that determines the bubble length in the cap tube—which, in turn, modulates the flow rate. This phenomenon in effect transforms the cap tube from a pressure-reducing device to a refrigerant control.

The figures that are used to show temperatures and pressures inside the cap tube are not meant to be accurate, but simply to illustrate how the modulating flow is achieved. This leads to an important point: the cap tube does in fact have an advantage over the thermostatic expansion valve (TXV) when it comes to "runaway overloads."

For example, assume that a 3 ton central air conditioning system equipped with a thermostatic expansion valve and a liquid receiver is operating in a 100°F ambient temperature with a dirt-clogged condenser. The head pressure is above its designed maximum. The inefficiency of the condenser causes the back pressure to rise, which puts an additional load on the compressor and motor. As a result, the compressor can no longer maintain the evaporator load. This in turn causes an additional load on the condenser and an even higher head pressure—and so on until the overload mechanism is energized, resulting in a complete shutdown of the entire system.

However, in a cap tube system operating under the same conditions, the overloaded condenser results in a different outcome. Because the condenser cannot fully condense all of the vapor, liquid and vapor enter the cap tube. Now the entire length of the cap tube is the bubble length, applying the brakes to the flow rate and actually reducing the overall efficiency of the entire system. Instead of a total shutdown of the entire system, the rise in evaporator temperature alerts the proprietor to call the service contractor.

In the early 1960s, a manufacturer of window air conditioners took advantage of bubbles entering a cap tube by placing a small heater around the strainer before the cap tube inlet. The thermostat was in reality a rheostat that controlled the intensity of heat to the strainer—which in turn regulated the amount of bubbles entering the cap tube. The first stage of heat to the strainer was to reduce the subcooled liquid temperature (increasing the bubble length). The second stage was to create a boiling action, in various heat intensities, to decrease the overall efficiency of the evaporator.

Before the oil and electric power crunch, the ultimate in air conditioning comfort was to run air conditioning units continuously and adjust the compressor capacity or evaporator efficiency to the heat load. This method of regulation eliminated the discomfort of temperature fluctuations when the unit cycled on the thermostat.