Finding LPA's COP

Here's a look at the concept of liquid pressure amplification as it applies to air conditioning systems.

EDITOR'S NOTE: One recurring question Refrigeration Service & Contracting Magazine receives concerns the use of liquid pressure amplification on a system. Once every few years, we review the concept, each time from a different angle. What follows was prepared by HySave Inc. of Portland, OR and discusses a liquid pressure amplifier as it applies to air conditioning systems.

In air conditioning, the basic circuit is essentially the same as in refrigeration. It consists of an evaporator, a condenser, an expansion valve, and a compressor. This, however, is where the similarity ends.

In ac systems, the evaporator and condenser generally will have less surface area. The temperature difference between condensing temperature and ambient temperature (or Delta T) is usually 27 degrees with 105 degrees minimum condensing temperature, while in refrigerating it can be from 8 to 15 degrees Delta T with 86 degrees minimum condensing.

To understand how we can improve the cycle, we must first analyze the components and understand where the inefficiencies exist.

THE EVAPORATOR

The evaporator (shown in Fig. 1) is divided into two parts, consisting of the vaporizing refrigerant and the superheated vapor. Only the refrigerant changing from a liquid state to a vapor state provides refrigerating effect. The more liquid in the evaporator, the higher the efficiency. The percent of liquid to vapor can vary. Determining factors are the performance of the expansion valve, the percent of "flash gas" entering the evaporator through the valve, and the temperature of the entering liquid refrigerant.

Only the superheated vapor is entering the compressor. High superheat at the compressor inlet can add considerably to the work that must be performed by other components in the system. Ideally, the vapor entering the compressor would be at saturation, containing no superheat and no liquid refrigerant.

In most systems using a reciprocating compressor, this idea of no saturated superheat is not practical. We can, however, make considerable improvements.

THE CONDENSER

In the condenser, the refrigerant is divided into three separate stages as it is converted back to a liquid form. They are superheated vapor, condensing vapor, and subcooled liquid.

Desuperheating: The discharge temperature of the exiting vapor from the compressor consists of the superheat entering the compressor plus the heat of compression, friction, and the motor. At the entrance of the condenser, all of the refrigerant consists of superheated vapors. The portion of the condenser used to desuperheat is directly related to the temperature of superheat vapors and only after the superheat is removed can the vapors start to condense. These superheated vapors are subject to the gas laws of Boyle and Charles. When heated, they will tend to either expand (consuming more condenser area), or increase the pressure in the condenser, or a combination of both. The rejection of heat from superheated vapor will be vapor to vapor or the least effective means of heat transfer.

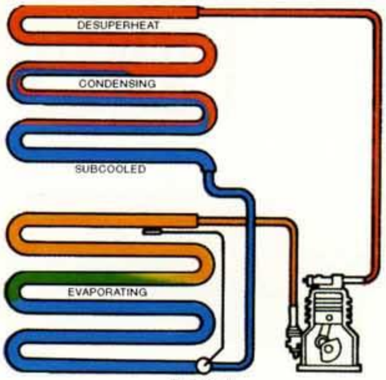

Figure 1

Condensing: As the vapor enters the condensing portion of the condenser, it is at saturation. At this stage, the further removal of latent heat will convert the vapors into the liquid state. The pressures will not change during the process. As the refrigerant starts to condense, the condensation will take place along the walls of the condenser. At this point we will have liquid to vapor heat transfer, thus a more efficient rejection of unwanted heat. The condensing pressures are influenced by the condensing area (total condensing area minus the area used for desuperheating and the area used for subcooling). The effect of superheat can be seen as both a reduction in condensing area and an increase in the overall pressure. Therefore, the less superheat, the better.

Subcooling: In an effort to suppress the formation of flash gas entering the expansion valve, many manufacturers use part of the condenser to further cool the liquid refrigerant or subcool. If we consider only the subcooling of the liquid without regards to decreased condensing surface, then we can see a gain of 1/2% capacity per degree of subcooling. If, however, we consider the reduction in condensing surface, then there is a net loss due to increased condensing temperatures, and higher head pressures due to reduced effective condensing area.

EFFECTS OF LIQUID PRESSURE AMPLIFICATION AND SUPERHEAT SUPPRESSION

From our analysis of the cycle, we find that there are numerous areas that can be improved. If we combine all of these factors we can see an improvement in the overall coefficient of performance.

A liquid pump can be installed at the outlet of the condenser on systems that do not have a receiver (Fig.2). The pump increases the pressure of the liquid refrigerant by 8 to 15 lbs. This added pressure will subcool the liquid refrigerant the same as reducing its temperature. This method of subcooling will not allow the refrigerant to flash regardless of head pressure.

Because we have eliminated the necessity to maintain the standard head pressure, minimum head pressure can be lowered to 115 lbs. on HCFC-22 air conditioning systems.

For an evaporator to operate at peak efficiency it must operate with as high a percent of liquid to vapor ratio as possible. To accomplish this, the expansion valve must allow refrigerant to enter the evaporator at the same rate that it evaporates.

The overfeeding and underfeeding of the expansion valve will dramatically effect the efficiency of the evaporator.

In a lab test (Fig. 4), the flow rate of refrigerant through the expansion valve with and without the liquid pump running is shown in the pen graph. At 131 mins., the pump was turned off. The flow rate of refrigerant entering the evaporator through the expansion valve shows a decided decrease in flow when compared to the flow when the pump is running. This reduced flow of refrigerant to the evaporator has several detrimental effects. (For example, Fig. 1 has reduced evaporator area compared to Fig. 2).

At 120 to 131 min. and 146 to 150 min., the liquid pump is running. With the pump running the flow rate is consistently higher with an even modulation of the expansion valve. It can be seen that with the