SUPERMARKET REFRIGERATION

THE TECHNOLOGY KEEPS IMPROVING

Supermarkets can experience dramatic energy savings by incorporating the latest in liquid pressure amplification (LPA)™ and suppression.

BY JOHN TOMCZYK

Liquid pressure amplification (LPA)™ technology has boosted refrigeration system capacity while saving electrical energy.

Using LPA, liquid refrigerant entering the liquid line is pressurized with a small centrifugal pump (Figure 1). The amount is equal to the pressure loss between the condenser outlet and the TXV inlet on receiverless systems, or the receiver and the TXV inlet on TXV and receiver systems. The LPA system is shown in Figure 2, along with a normal system, Figure 3.

By increasing the pressure of the liquid refrigerant, the associated saturation temperature is raised because of the pressure increase, while the actual liquid temperature remains the same. The liquid becomes subcooled and will not flash if exposed to pressure drops in the liquid line.

The liquid centrifugal pump motor is external to the refrigeration system, and the impeller is driven by a revolving magnetic field. The motor adds negligible energy and heat to the system, pressurizing the liquid. Because there is no drive shaft protruding from the motor through the pump casing, the system is completely sealed. The LPA centrifugal pump can increase the pressure of the liquid by approximately 8 to 20 psi.

AMBIENT SUBCOOLING

Subcooling exists in any liquid below its saturation temperature for a given pressure. One method of subcooling is to sensibly cool the liquid in the bottom of the condenser. This sensible heat reduction will prevent flashing from liquid line pressure drops.

The drawback to this method is that the subcooled liquid on the bottom will take up valuable condenser volume. This will cause higher head pressures and compression ratios, resulting in lower efficiencies. If we consider only the subcooling of the liquid without regard to decreasing condenser surface area, we will see a gain of $\frac{1}{2}$% of capacity for every degree of liquid subcooling.

FIGURE 1: A small centrifugal pump pressurizes liquid refrigerant entering the liquid line. *(All figures courtesy of Hy-Save, Inc., except as indicated.)*

In addition, 7°F of ambient subcooling costs .167 brake horsepower (bhp) per ton because of elevated head pressures. However, if we consider the reduction of condenser surface area due to the liquid subcooling, there is a net loss in capacity due to increased condensing pressures and temperatures.

This type of subcooling, often called *ambient subcooling,* has been practiced for years and has always been thought of as a "free" method of subcooling. This is simply not the case. Ambient subcooling is usually accomplished at the cost of increased head pressures. It has been used in refrigeration systems as a liquid seal in the condenser bottom and to prevent liquid line flash gas, by keeping a solid column of liquid supplied to the metering device.

Ambient subcooling cannot be maintained at a given level with air-side controls only. Condensing pressures are directly related to the temperature of the condenser cooling medium and the useful condensing area in the condenser. Useful, or effective, condensing area is the total condensing area minus the area used for desuperheating and the area used for subcooling. In other words, the formula is:

Total condenser area
- Condenser area used for
desuperheating and subcooling
= Useful or effective
condensing area

The more desuperheating and liquid subcooling that is done by the condenser, the less useful condenser area there will be. This will raise condensing pressures and compression ratios and cause inefficiencies with higher power draws.

ALTERNATE METHOD OF SUBCOOLING

A more efficient way to subcool liquid is to increase the pressure of the liquid without raising the temperature. This will cause the liquid to be at a higher pressure, with a higher associated saturation temperature; however, the actual temperature will not change. This liquid is subcooled in an amount equal to the difference between the associated saturation temperature, and the actual temperature of the liquid. Liquid is now below its saturation temperature for that new pressure.

By increasing the pressure of the subcooled liquid to overcome any pressure losses that occur in the liquid line, condensing pressures can be allowed to fall to their lowest attainable pressures. Another term for attaining the lowest possible head pressure is *floating the head pressure*. Condensing temperatures of 20°F are not uncommon in low-temperature systems incorporating liquid pressure amplification.

However, try to float the head pressure with the ambient, and the lower head pressures will require more subcooling for the same pressure drops in the liquid line to prevent flashing. This phenomenon reflects the pressure/temperature graph of refrigerants which is non-linear; it is much flatter at the lower pressures. This means that the same amount of liquid subcooling is needed to overcome a smaller pressure drop at these lower pressures and temperatures (Figure 4).

This is one of the reasons why LPA is incorporated in the system when the head pressure is floated with the ambient. It subcools the liquid by increasing its pressure and forces the liquid to have a new higher associated saturation temperature. Thus, flash gas is prevented when head pressures are allowed to float, because LPA ensures that the liquid line pressure (and associated saturation temperature) is always higher than the actual liquid temperature.

When head pressure is reduced without LPA, the liquid experiences the same pressure drop through the liquid line as it did at the higher condensing pressures. The flash gas will occupy more volume in the liquid line because of the higher specific volume of the flashed vapors. The TXV will begin to hunt, starve the evaporator, and system capacity will be reduced.

AN EXAMPLE

Consider the curve for an HCFC refrigerant (Figure 5). As the pressure in the liquid line drops, more liquid will flash into vapor to cool the remaining liquid to the saturation temperature, corresponding to the progressively lower pressure.

With an 8 psi pressure drop, the flash gas, by weight, will be 2% with a 100°F condensing temperature (214 psig). The vapor bubbles in the liquid line will become compressed and occupy only 20% of the volume in the liquid line. However, reduce the pressure to 97 psig (50°F), and the flashing vapor will occupy 38% of the liquid line volume. This vapor will reduce the flow through the expansion valve, have little refrigeration effect, and need to be recompressed after doing work. Again, system capacity will suffer, the evaporator will starve, and the TXV will begin to hunt.

This is the primary value of the LPA system — to ensure solid liquid to the TXV, so the TXV can supply adequate liquid to the evaporator.

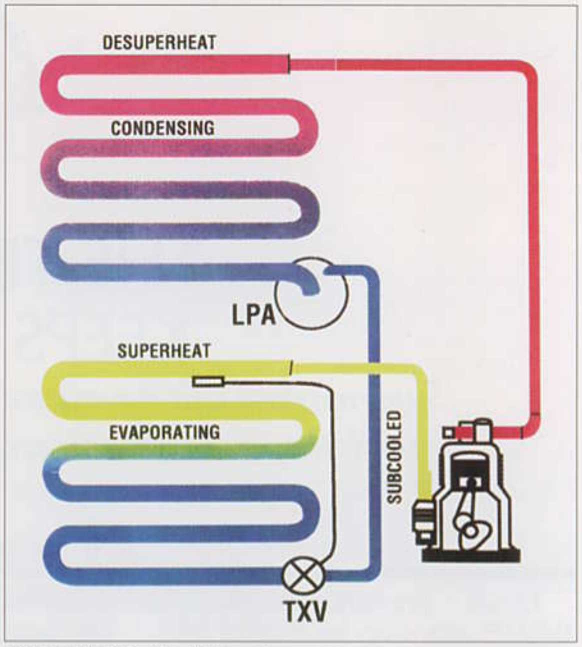

FIGURE 2: The LPA system.

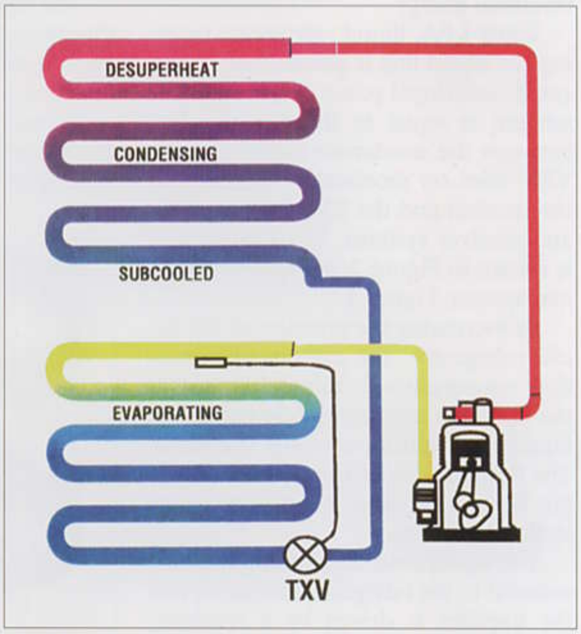

FIGURE 3: A "normal" system, without LPA.

A BETTER WAY TO DESIGN A SYSTEM

In the past, air conditioning and refrigeration system designers picked an outdoor design condition for the system. This outdoor design condition typically was a temperature that would not be reached any more than 2% of the time during the life of the system. And, when the design condition would actually be reached, it would only last for a few hours. The selection of the condenser was usually made, however, based on this seldom-reached condition.

Many years ago when energy was much cheaper, designers would select condensing temperatures at 20° to 30°F above the ambient. This was done because it was thought the higher condensing temperatures and pressures would enhance the flow through the

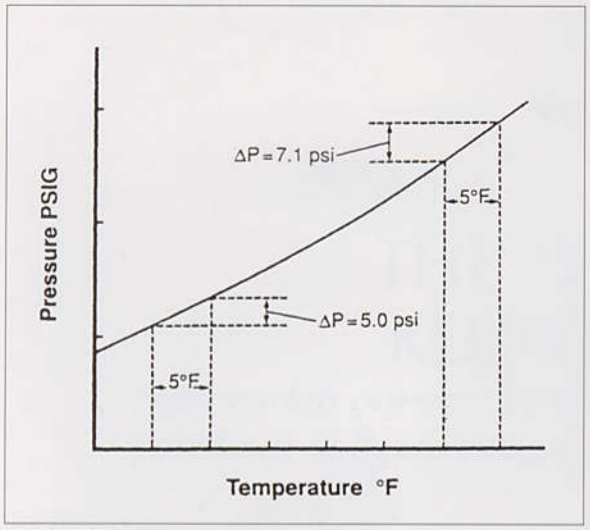

FIGURE 4: R-22 pressure-temperature curve.

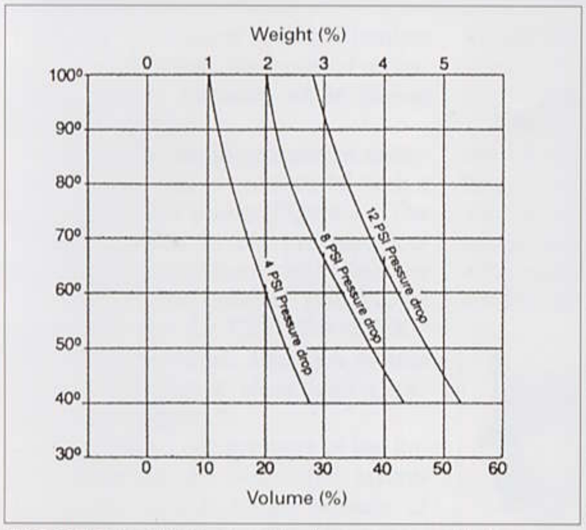

FIGURE 5: Effects of condensing pressure on flash gas.

metering device to outweigh any inefficiencies from the high compression ratios. This would force condensing temperatures and pressures higher, causing high compression ratios, and lower efficiencies.

With today's escalating energy costs, designers are specifying larger condensers with condensing temperatures 10° to 15°F above the ambient. The significant energy savings from lower compression ratios and possibly increased subcooling of liquid negates the higher costs of the larger condenser.

METERING DEVICES

After much research, metering valve suppliers found that TXVs would work with a much lower pressure drop than expected in the past — as long as pure liquid was supplied to them. The balanced port TXV design today is noted for its low-pressure drop performance.

With this new knowledge, condensing pressures and temperatures were allowed to "float" downward with the ambient temperature. In fact, a majority of the outdoor temperatures in the USA are below 70°F most of the time. The compressor capacity increases about 6% for every 10°F drop in condensing temperature.

However, pressure drops across the expansion valve of less than 30 psi should be avoided for proper evaporator feeding of liquid. For an evaporator to operate at peak efficiency, it must operate with as high a percentage of liquid to vapor ratio as possible entering the evaporator. To accomplish this, the expansion valve must allow liquid refrigerant to enter the evaporator at the same rate that it evaporates.

With an LPA pump, more constant subcooling and pressure can be maintained at the metering device. Overfeeding and underfeeding by the expansion valve, which dramatically affect the efficiency of the evaporator, will be minimized.

Historically, high head pressures and temperatures were artificially maintained in a refrigeration system, so it would function well at low outdoor temperatures. These higher pressures were considered necessary in order for the TXV to feed the evaporator adequately. This resulted in a large consumption of energy and lower efficiency. Today, however, inefficiency is an unacceptable part of a company's overhead. LPA allows a lower head pressure and reduced power consumption along with higher efficiencies.

The advantages of an LPA system include:

- Elimination of liquid line flashing by overcoming line pressure losses;
- Reduction in energy costs, because pumping liquid refrigerant is up to 40 times more efficient than using head pressure from the compressor to do the same work;
- Increased evaporator capacity along with the net refrigeration effect; and
- Lower compression ratios and less stress on compressors, meaning longer compressor life.

Like it or not, the days of the fixed elevated head pressures are fading. No longer are consumers willing to pay for inefficiencies. Today's customers are looking at life cycle costs (equipment costs plus the operational costs for the life of the equipment).

SUPERHEAT SUPPRESSION

Superheat suppression can be used in conjunction with liquid pressure amplification. The superheat suppression process injects liquid refrigerant into the compressor's discharge line or inlet of the condenser (Figure 6). This liquid usually comes from the same cen-

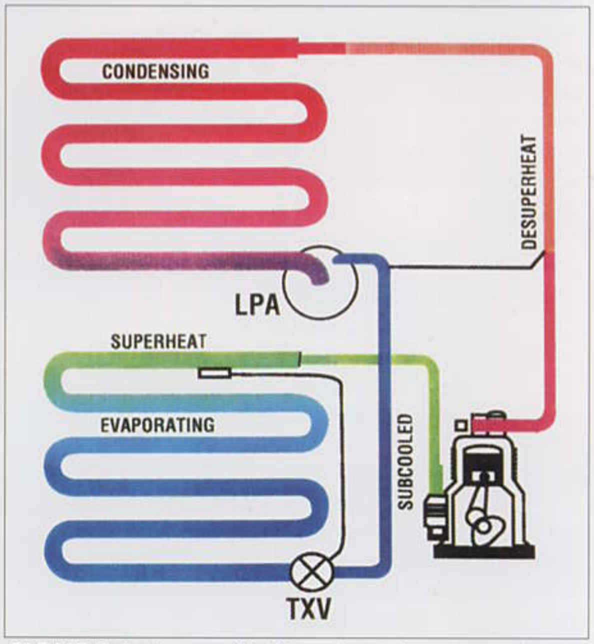

FIGURE 6: System with LPA and superheat suppression.

trifugal pump used in the LPA process.

The liquid flashes to a vapor while cooling the superheated discharge gas closer to its condensing temperature. As a result, less surface is required for desuperheating. This leaves a more efficient condenser because of the increase in useful condensing surface area. A more efficient condenser increases the overall performance of the system. Savings from 6% to 12% can be realized with superheat suppression.

Superheat suppression processes have been used in large ammonia plants for years; however, the process was not generally feasible on smaller systems. This spurred the use of LPA and superheat suppression in the same system. A small portion of the pressurized liquid refrigerant provided by the LPA's centrifugal pump can be diverted to the compressor's discharge line to cool the superheated vapors coming from the compressor. Reduced superheat of the gas entering the condenser means higher condenser efficiency, lower condensing temperature, and greater compressor efficiency. Although some efficiency gains will be seen at low ambients, the greatest gain with superheat suppression is realized at the higher ambient temperatures.

One of the less obvious advantages of superheat suppression through liquid injection is less fouling of evaporative condenser coils on the water side. As the discharge and condensing temperatures decrease, the ability of water to hold minerals in solution increases. Because of this quality, water is said to have reverse solubility. Evaporative condenser coils remain clean and scale free because of the decreased heat intensity from superheat suppression. This leads to less chemical treatment in most applications.

The main advantages of suppression or cooling of superheated vapors in a refrigeration system are:

- Reduction in the heat intensity (temperature) of superheated vapor; pressure and volume of these superheated vapors will decrease;
- Faster saturation of superheated vapors, resulting in quicker condensing;
- Condensing of the vapors will occur closer to the inlet of the condenser, resulting in lower condensing temperatures and possibly more ambient subcooling;
- Higher overall condenser heat transfer because of the increased liquid/vapor mixture heat transfer and increased effective condensing area; and
- Less fouling of evaporative condenser piping because of the reduced heat intensity of discharge and condensing gases.

SUBCOOLING/REHEAT COIL

In an air conditioning system, the evaporator removes moisture from the air. Therefore, it would seem reasonable that if the efficiency of the evaporator were increased, more moisture could be removed. The apparatus dewpoint temperature (ADP) is actually lowered, which increases the cooling coils moisture removal ability. As air is passed through an air conditioner's evaporator, it reaches dewpoint and condenses into a liquid. The liquid is then removed as condensate. This process is called dehumidification.

Another part of the conditioning process is reheating the air as it comes out of the evaporator, causing the air to become warmer and expand. This warmer, expanded air now has more ability to hold moisture and thus will have a lower relative humidity (% rh). The air is said to be less dense per cubic foot, or have a higher specific volume. The trick is to reheat the air efficiently to an acceptable delivery level with the proper amount of warmth and relative humidity. Accomplishing both of these functions greatly enhances the desired operation.

Figure 7 shows a system that reheats the air being discharged by the evaporator's air handler. The air actually comes in contact with a liquid subcooling coil connected to the discharge of an LPA pump. The liquid subcooling coil is located downstream of the liquid receiver. The liquid line is modified to allow liquid flow through this custom coil and then to the air conditioning direct expansion coil. Remember that liquid line pressure drop is not a real concern when an LPA pump is employed. The subcooling /reheat coil can be custom built and only employs one pass with about 4 fins per in., so fan power does not have to be increased (Figure 8).

Depending on the size of the coil, the liquid can be subcooled to within 8°F of the air temperature leaving the evaporator. With 60°F leaving air temperature, the liquid should be subcooled to approximately 68°F. The more subcooling there is, the closer the

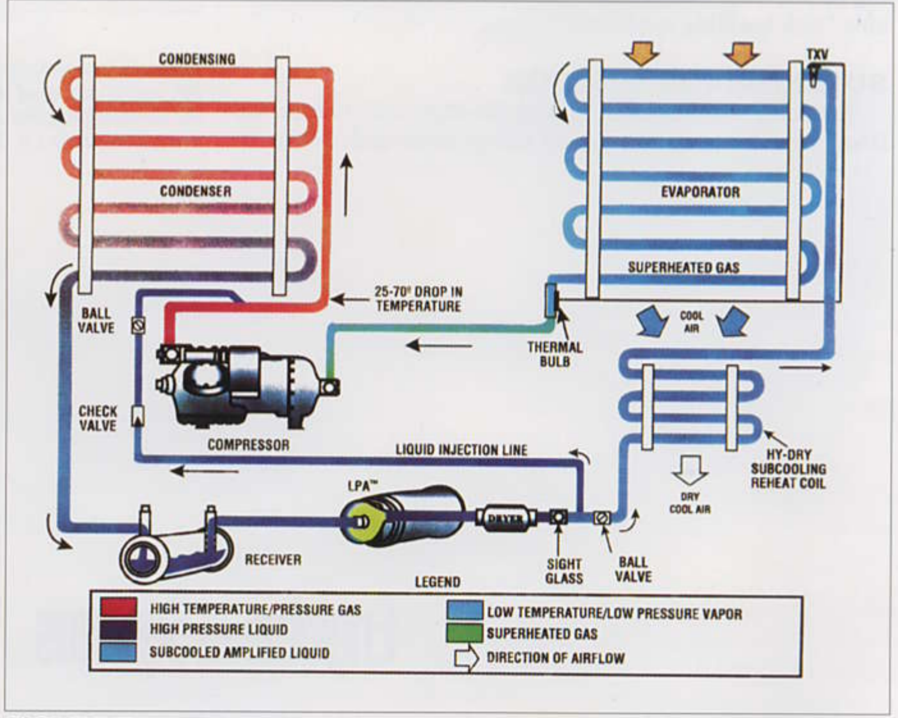

FIGURE 7: This system reheats the air being discharged by the evaporator's air handler.

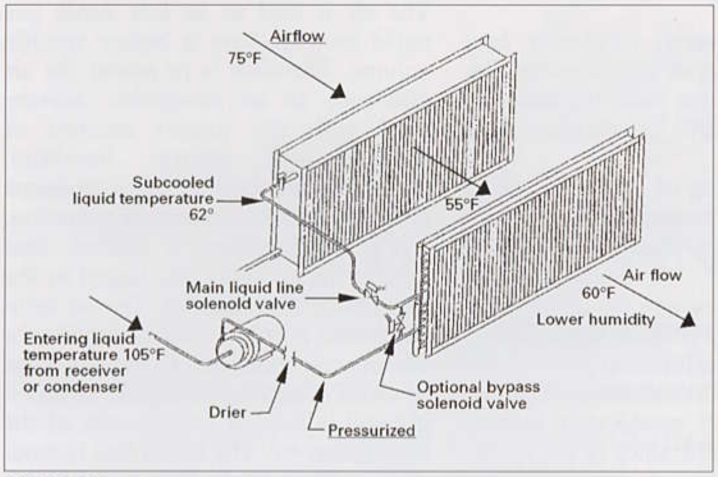

FIGURE 8: The subcooling/reheat coil can be custom built.

liquid temperature comes to the evaporating temperature. This increases the net refrigeration effect (NRE).

This subcooling coil allows liquid in the coil to be further subcooled by the colder air being discharged by the evaporator's air handler, while at the same time providing reheat to the air leaving the evaporator. Thus, the percent relative humidity (% rh) of the discharged air is lowered, the liquid in the subcooling coil is being subcooled further, and the air is being reheated to an acceptable level for the occupants.

The subcooling/reheat coil can subcool the refrigerant entering the cooling coil by as much as 50°F, resulting in a 50% increase in evaporator capacity. This can allow the evaporator to wring out up to 75% more moisture from the air. A lower relative humidity of discharge air is then experienced through the ductwork system. This abates the building of airborne molds and bacteria that cause the undesirable "sick building syndrome."

SUPERMARKET SAVINGS

Reducing the humidity in supermarkets will reduce the latent heat loads on the store's refrigeration and air conditioning equipment. Actual LPA installations have proven energy savings of as much as 13% of energy used.

High humidity in supermarkets causes excessive frost on evaporator coils in the refrigeration cases. This frost buildup reduces heat transfer and the efficiency of the system. Not only does the frost buildup consume energy, it takes energy to get rid of the frost by longer defrost periods. When used in conjunction with a dewpoint controller, mullion heater loads can be reduced with lowered relative humidity in the supermarket. Mullion heaters simply keep the surfaces of the refrigeration cases above dewpoint so condensate will not form. Equipment for this moisture control has been expensive to buy and to maintain, but this system will reduce the energy usage on both the air conditioning and refrigeration systems.

One of the key benefits of this system is the use of the internal energy of the system to accomplish reheating the air. No external heat, neither gas nor liquid, is used for reheat. Subcooling is also accomplished without any external energy source.

SUMMARY

With the rapid transition to alternative refrigerants and escalating energy costs facing the refrigeration and air conditioning industry today, more attention is being paid to operating costs and system efficiencies. Inattention to system pressures and the amount of liquid subcooling can make systems very inefficient. Because of this, it is very important that every engineer and/or technician understands the principles behind subcooling and system pressures. In today's competitive service market, who can afford not to pay attention to system efficiencies? **ES**

Tomczyk is a professor of hvac at Ferris State University, Big Rapids, MI, and is author of the book, "Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems," published by Business News Publishing Co. To order, call 1-800-837-1037.

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