Using an LRPS to Reduce Energy Costs

A liquid refrigerant pumping system (LRPS) operates within the existing refrigeration plant to fundamentally change how liquid refrigerant moves through the system. An LRPS relieves refrigeration vapor compressors from their misapplied task of moving liquid refrigerant through the system and properly transfers it to a VFD-controlled liquid refrigerant pump.

Before examining how an LRPS works, it will be helpful to take a closer look at how conventional refrigeration systems can waste energy.

**Conventional system operation**

A conventional system's vapor compressors discharge high-pressure vapor that is used to push liquid refrigerant through the system to expansion valves that feed the cooling coils of refrigerators, freezers, air handlers, etc. This is an inherently inefficient method of moving liquid refrigerant.

A conventional system cannot take advantage of seasonally lower temperatures to save energy the way an LRPS does. Cooler temperatures make lower discharge pressures possible, but they must be kept unnecessarily high so that liquid pressures are high enough for proper expansion-valve operation. Discharge vapor pressures are always higher than liquid refrigerant pressures in a conventional refrigeration system that uses refrigerant vapor to push refrigerant liquid. An LRPS shows that it is unnecessary and costly to push liquid refrigerant with refrigerant vapor.

Conventional systems rely on vapor compressors to create the pressure difference that causes refrigerant vapor and liquid to move through the system. Low-pressure refrigerant vapor exits the refrigerated cases and moves by pressure difference to enter the vapor compressor's suction port. It is then compressed and exits the compressor through its discharge port as a high-temperature, high-pressure vapor. This vapor moves through the condenser until enough heat is rejected to change it from its vapor state to its liquid state. From this point forward, the liquid refrigerant is pushed by the high-temperature, high-pressure refrigerant vapor behind it until it passes through the refrigerant expansion devices in the refrigerated cases where its fluid form again changes, now from a liquid to a vapor as heat moves from the medium being cooled and is absorbed by the refrigerant fluid. At this point, the cycle completes and a new cycle begins.

Learn how a liquid refrigerant pumping system operates to help make a refrigeration system more energy and cost efficient.

By Bob Kolarich

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Expansion valves are positioned within refrigeration and air-conditioning systems to change high-temperature, high-pressure liquid refrigerant into low-temperature, low-pressure refrigerant vapor. It is during this change of state from liquid to vapor as the refrigerant fluid flows through the evaporator that heat is removed from refrigerated products in their respective refrigerated food cases in a supermarket, for example.

To operate at their rated capacities, expansion valves must receive 100% liquid refrigerant at pressures that remain minimally high enough throughout the year. In conventional systems, as noted above, liquid refrigerant is pushed through the system by the discharge vapor from vapor compressors until it finally reaches the expansion valves. This method commonly causes vapor, or “flash gas,” to be present where only liquid should be. Flash gas in the liquid refrigerant line leading to the expansion valve is another cause of inefficiency in many conventional systems; flash gas is eliminated with an LRPS.

How an LRPS works
An LRPS is a hardware and software package installed within the central refrigeration system to take over responsibility for moving and pressurizing liquid refrigerant. The LRPS has been designed to:

→ Improve refrigeration system efficiency;
→ Maximize refrigeration capacity;
→ Provide a liquid refrigerant pumping system that proactively prevents pump cavitation;
→ Economically reduce refrigeration energy consumption by lowering discharge vapor pressures and increasing suction vapor pressures, thereby lowering compression ratios;
→ Economically increase refrigeration capacity by lowering liquid refrigerant temperatures and increasing liquid refrigerant pressures;
→ Suppress the formation of flash gas in refrigeration systems, thereby increasing refrigeration capacity and efficiency;
→ Automatically supply refrigeration systems’ expansion valves with their specified amount of pressure drop across those devices so they operate at their rated capacities;
→ Easily retrofit to an operational refrigeration system;
→ Allow the original refrigeration system to operate properly whether the LRPS system is in operation or out of operation; and
→ Be configured for a small footprint, thereby allowing it to be installed or retrofitted into a spatially limited area.

An LRPS removes the need to send discharge vapor to the condensers at higher-than-needed pressures and temperatures. The system takes advantage of lower outdoor...
seasonal temperatures to increase refrigeration capacity, reducing the compressor workload for significant net savings.

It also utilizes an energy-efficient liquid pump controlled by a VFD to add the optimal amount of pressure to the liquid refrigerant delivered to the expansion valve. Vapor compressors are consequently only needed to move discharge vapor at lower pressures, suction vapor at higher pressures and they no longer need to push liquid refrigerant. The net result: liquid refrigerant is cooler, compressors operate at lower compression ratios, cycle on less often and net energy savings are realized, along with other hard and soft cost savings.

Figure 1 shows the main components of an LRPS, including:

1. A refrigerant receiving tank for receiving the liquid refrigerant from the condenser;
2. A liquid-monitoring tank and liquid-level probe to maintain the refrigerant level in the receiving tank at a minimum predetermined level;
3. A liquid refrigerant pump driven by an electric motor, which receives the liquid refrigerant from the refrigerant receiving tank, pressurizes the refrigerant, and discharges the refrigerant to the inlet of the refrigerant expansion device;
4. A VFD that varies the speed of the liquid pump motor to change the amount of pressure added to the liquid refrigerant; and
5. An eductor fluidly connected to the discharge from the liquid refrigerant pump, the refrigerant storage tank and the refrigerant receiving tank, which utilizes a portion of the pressurized refrigerant from the liquid refrigerant pump to continuously transfer liquid refrigerant from the "original" refrigerant storage tank to the LRPS refrigerant receiving tank.

Figure 2 shows a typical supermarket refrigeration system with an LRPS installed. While the LRPS is in operation, pressurized liquid refrigerant flows to multiple destinations. It should be noted that the liquid pump adds pressure but not heat to the liquid refrigerant, thereby subcooling the liquid refrigerant.

The first destination for liquid refrigerant from the pump is through the conduit downstream of the check valve at the outlet of the refrigerant storage tank. Liquid refrigerant discharged from the pump is at a pressure higher than the pressure within the storage tank itself. This allows liquid refrigerant to flow directly from the pump discharge to the expansion device, preventing saturated liquid to flow from the storage tank to the expansion device. An LRPS regulates the liquid flow by monitoring pressure with a pressure differential transducer. By monitoring the pressure transducer sensors, as well as the receiver tank level sensor, the VFD is used to control the operation of the pump and thereby matches demand for liquid refrigerant flow in the system, adding the proper amount of pressure to the liquid refrigerant so that the expansion device operates at its specified capacity.

Liquid refrigerant discharged from the pump is also delivered to a liquid venturi eductor. In order to move liquid from the storage tank that is now unavailable to the operating portion of the system, the eductor is used to continually move liquid refrigerant from the storage tank to the receiving and monitoring tanks, and finally to the liquid pump. Specifically, a portion of the high-pressure liquid from the discharge of the refrigerant pump flows into the venturi eductor where its velocity is increased. The high-pressure, high-velocity liquid exits the venturi eductor and is mixed with the lower-pressure refrigerant from the storage tank. As a result of pressure difference and frictional mixing, liquid refrigerant is transported from the storage tank to the LRPS receiving tank. The flow of liquid refrigerant through the liquid venturi eductor serves two functions. First, the eductor provides for a minimum flow through the liquid refrigerant pump when cooling demand is low and demand for refrigerant flow to the refrigerant evaporators are reduced or stopped. Its second function is to continually move liquid refrigerant from the storage tank to the receiving tank in order to always keep an adequate amount of liquid refrigerant in the receiving tank. The use of an overflow conduit within the receiving tank
works with the eductor to maintain an adequate liquid-level height in the receiving tank, and ensures that net positive suction head available (NPSHa) to the liquid pump exceeds the net positive suction head required (NPSHr) at all times to greatly reduce the possibility of cavitation, which is discussed later.

Within the liquid receiving tank is an overflow conduit that ensures that liquid refrigerant not flowing through the liquid pump must reach the upper terminus of the overflow conduit in order to drain into the storage tank. This piping arrangement, together with the liquid venturi eductor keeps the liquid refrigerant column height above the NPSH required by the pump manufacturer. The column height of liquid refrigerant that is available to the liquid refrigerant pump is continually in close proximity to the upper terminus of the overflow conduit.

If the LRPS liquid refrigerant pump is taken out of operation, liquid refrigerant from the condenser flows to the refrigerant storage tank and conventional refrigeration system operation is not interrupted.

**Lowering discharge pressure/temperature**

On the vapor side of the refrigeration system, low-pressure suction vapor enters the refrigeration compressors. Because the LRPS now transports and pressurizes the liquid refrigerant, the vapor compressors do not discharge refrigerant vapor at unnecessarily high pressures and temperatures. Consequently, the compression ratio and KWh consumption are significantly reduced for the largest user of energy in the system, the vapor compressor.

Additionally, a portion of the pressurized liquid refrigerant is injected into the main vapor discharge line to de-superheat the refrigerant vapor, bringing the refrigerant fluid closer to its liquid state prior to its introduction into the refrigerant condenser. Injecting a relatively small portion of the high-pressure liquid refrigerant into the main discharge line directly upstream of the condenser is another energy-saving benefit from the LRPS. Single-stage conventional systems cannot do this.

Most conventional systems operate at unnecessarily high discharge pressures and temperatures and do not take advantage of seasonally cooler outdoor temperatures. Because the LRPS operates with refrigerant vapor compressors operating at lower discharge pressures, liquid refrigerant condenses at lower pressures and temperatures, increasing system capacity while reducing compressor workload and energy consumption.

**Preventing cavitation**

A key element of the LRPS design addresses the need to prevent cavitation at the liquid pump impeller. While there have been many previous attempts to add liquid refrigerant pumps to commercial refrigeration systems, the LRPS has successfully and proactively solved the problem that was the ruin of many of those previous attempts: cavitation. Cavitation remains a leading cause of liquid pump failure.
Cavitation is defined as the sudden formation and collapse of low-pressure bubbles in liquids. For a liquid refrigerant pump, cavitation is the formation and violent collapse of refrigerant vapor bubbles when the local static pressure of the refrigerant falls below its saturation (or vapor) pressure, causing damage to the pump impeller and reducing or stopping the flow of liquid refrigerant through the pump. It is essential to be constantly attentive and responsive to preventing cavitation in liquid refrigerant pumps in conventional systems because liquid refrigerant in those systems is always very close to its saturation (vapor) pressure.

To prevent cavitation, NPSHa must exceed NPSHr by the pump. NPSHa is calculated by measuring the height of the vapor-free column of liquid refrigerant that is above the centerline of the pump inlet and subtracting all pressure losses as it travels from there to the centerline of the pump inlet. The positive pressure difference between the liquid pressure at the centerline of the pump inlet and the liquid pressure at the top of the vapor-free column of liquid refrigerant is correlated to the NPSHa. Due to the weight of the liquid refrigerant, NPSHa increases as the height of the liquid refrigerant column increases. NPSHr is supplied by the pump manufacturer. An LRPS is designed to keep NPSHa above NPSHr with a margin of safety.

Figure 3 shows how an LRPS manages NPSHa. Height X represents the height of liquid refrigerant used to calculate NPSHa to the liquid refrigerant pump. The VFD is in communication with the liquid refrigerant pump, a differential pressure transducer and the receiving tank liquid-level sensor. By means of the LRPS software program that controls the VFD, the liquid refrigerant pump will only operate when the liquid refrigerant level detected by the liquid level sensor is at a sufficient height to ensure that the liquid refrigerant pump’s NPSH requirement is covered with a margin of safety and that the differential pressure across the pump is sufficient while the pump is in operation.

Summary
With an LRPS, refrigeration system capacity increases and energy costs decrease, because:
- Compressor discharge pressures and compression ratios are reduced;
- Liquid refrigerant temperatures are reduced;
- Expansion valves are fed with optimally pressurized, 100% liquid refrigerant; and
- Seasonal outside temperatures can be used to the system’s advantage.

An LRPS increases refrigeration system capacity, extends existing refrigeration equipment life, reduces service calls and refrigerant leaks. Consequently, it may also reduce product shrinkage. An LRPS utilizes pressure difference and gravity to operate and has only one moving part, the pump impeller. An LRPS is a high-efficiency, low-energy cost solution for refrigeration and air-conditioning systems.

Cost savings using an LRPS will vary based on local energy rates, refrigeration plant equipment capacities and outdoor temperatures. These systems are also approved for energy-efficiency rebates and incentives in certain regions.

Bob Kolarich is Owner of Key Refrigeration, a refrigeration service/installation company located in Brick, NJ. Kolarich has more than 20 years of hands-on experience as a supermarket refrigeration mechanic, and 15 years of experience installing and designing liquid refrigerant pumping systems for supermarkets. He has filed a USPTO patent application for the liquid refrigerant pumping design described in this article. For more information, visit www.coolsmart.net.
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