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NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CA 93043-4328

Liquid Pressure Amplification and Liquid Injection in Air Conditioning and Refrigeration Systems

INTRODUCTION

Liquid pressure amplification and liquid injection are two patented methods of decreasing compressor energy consumption and increasing condenser capacity in an existing reciprocating vapor compression refrigeration system. Although this 6-year-old technology has been installed on thousands of existing systems, it continues to generate controversy in engineering and utility circles.

CONVENTIONAL REFRIGERATION CYCLE

As shown in Figure 1, the basic vapor compression refrigeration system is comprised of an evaporator, a compressor, a condenser, a liquid receiver, and a thermostatic expansion valve (TEV). The cycle is a closed-loop system. Refrigerant, the working fluid, flows through each part of the system in sequence, changing phase from liquid to vapor and back again at specific locations.

- The evaporator absorbs the heat from the surrounding air which causes the low-pressure liquid refrigerant to change phase and become a low-pressure vapor.

- The compressor raises the pressure and temperature of the vapor. The refrigerant leaves the compressor as a superheated vapor so it then can be condensed by relatively warm water or air.

- The condenser rejects heat from the superheated vapor and the refrigerant condenses into a high-pressure liquid.

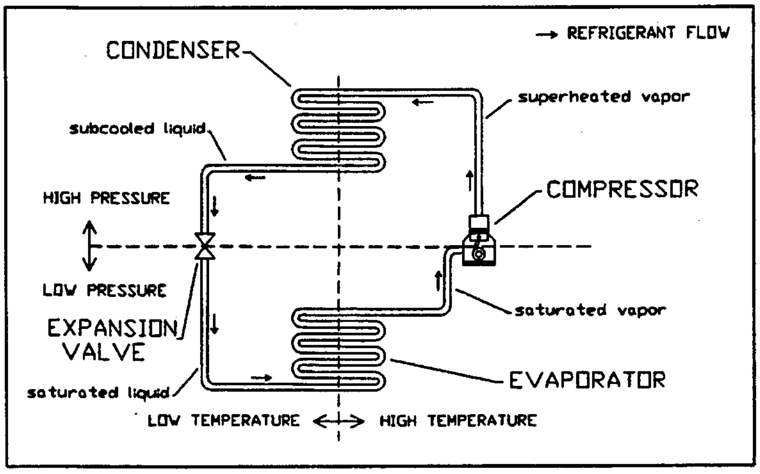

Figure 1
Conventional vapor compression cycle.

- The liquid receiver stores the high-pressure liquid, maintaining a constant supply for the TEV.

- The TEV separates the high-pressure part of the system from the low-pressure part. The TEV lowers the pressure and temperature of the liquid refrigerant so it can be evaporated again.

A conventional refrigeration system maintains a fixed refrigerant pressure as it leaves the compressor. This discharge pressure or head pressure is designed to allow condensation at high ambient conditions. Unfortunately, energy is wasted during mild and cool ambient conditions because the condenser temperature and pressure are unnecessarily high.

With floating head pressure control, the compressor discharge pressure can be lowered according to the ambient conditions. Unfortunately, the amount the compressor discharge pressure can be lowered is limited to the minimum pressure difference required across the expansion valve to maintain a liquid seal at the valve inlet and ensure stable valve operation without excessive evaporator superheat. Excessive liquid line pressure drop or a large difference in height between the condenser and the evaporator would further limit the minimum compressor discharge pressure.

LIQUID PRESSURE AMPLIFICATION

Liquid pressure amplification (LPA) requires the installation of a pump between the liquid receiver and the TEV (see Figure 2). Increasing the liquid refrigerant pressure directly before the TEV serves two purposes. By increasing the pressure of the saturated liquid from the liquid receiver, the refrigerant entering the TEV is less likely to contain flash gas. Flash gas is vapor refrigerant in the liquid line that cannot be used to absorb heat in the evaporator. The LPA pump also ensures that a minimum pressure drop across the TEV is maintained while allowing the condensing pressure to remain low. If the minimum pressure drop specific to a particular TEV is not maintained, the valve operation will become unstable and cause excessive superheat at the evaporator discharge. Excessive superheat at the evaporator discharge may cause the compressor to overheat and fail. By maintaining correct TEV operation, the evaporator capacity is also maintained while the compressor head pressure can be reduced.

LIQUID INJECTION

Liquid injection is an additional modification to a vapor compression system. A small amount of subcooled liquid created by the LPA pump is injected into the compressor discharge (see Figure 2). The subcooled liquid immediately flashes as it enters the compressor discharge and reduces the temperature of the superheated vapor.

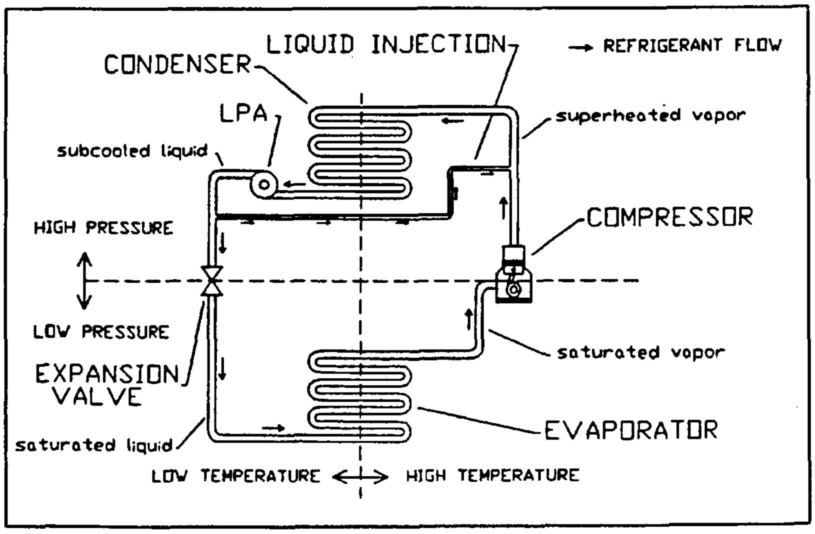

Figure 2
Vapor compression cycle with LPA and liquid injection.

Liquid injection basically desuperheats the vapor refrigerant. This increases the effective efficiency of the condenser by decreasing the overall condenser desuperheating load.

CAPITAL COST

Initial capital costs for LPA pumps are summarized in Table 1. Additional capital costs may include special controls to float the compressor head pressure.

Table 1. Initial Capital Cost for an LPA Pump

System Size (nominal tons)	LPA Pump Size (hp)	Cost ($)
3 - 10	0.13	600 - 800
10 - 35	0.40	1,400 - 1,500
60 - 140	0.75	4,400

ENERGY SAVINGS

The performance of the LPA is dependent on a number of factors:

Ambient Temperature

A low condensing temperature is required when decreasing the compressor head pressure, which is only possible during cool weather. The exact temperature at which savings will occur is site specific. The ambient temperature must be low enough to not only extract sufficient heat from the condenser coils, but also make up for increases in energy consumption by the LPA pump and condenser fans.

System Design

A system with an excessive liquid line pressure drop or a large difference in height between the condenser and evaporator will limit the allowable reduction in compressor head pressure.

System Load Profile

If the system load profile is directly related to the ambient temperature, the total energy consumption by the system will be at a minimum when maximum LPA energy savings are available. A system load profile which is independent of ambient temperatures (e.g., computer rooms and refrigeration processes) would be ideal.

Operating Hours

If the above factors can be optimized during periods of peak electrical demand, further savings may be possible.

Because of these factors, independent, third-party testing of LPA technology proving substantial energy savings over a wide range of the above variables is not readily available. ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.) Fundamentals Handbook includes a table of the general effects of condenser temperature on theoretical compressor horsepower. Based on this table, a theoretical 1.4 percent average reduction in compressor energy per Fahrenheit degree can be calculated. An LPA pump can potentially lower the working condenser temperature when the ambient air temperature is low. However, caution must be used when utilizing the theoretical 1.4 percent energy reduction per Fahrenheit degree to estimate the potential savings that can be realized by LPA technology. LPA distributors have used values between 1.1 and 1.4 to predict energy savings. This theoretical reduction is strictly for the compressor and does not include the possible increased condenser fan and LPA pump energy required to achieve the low condensing pressures. Most compressor manufacturers do not provide compressor performance data at such low condensing pressures. Unless such data is available, predicting the actual available savings from large reductions in condensing pressure is impossible.

CONCLUSION

Our experience in evaluating Navy heating, ventilating, and air conditioning systems indicates immediate energy savings are available by simply performing the required maintenance to operate systems as designed. Therefore, before considering implementing LPA, we recommend focusing on the maintenance of existing systems.

Because of the application-specific nature of this technology, it is difficult to develop general guidelines for savings resulting from LPA installations. Energy savings in the case studies from the manufacturer of this patented technology range from 6 to 60 percent. In these cases, the energy savings were not documented in detail and measurements were not carried out long enough to determine the long-term benefits of LPA. However, one test performed by an independent third party shows an increase in compressor energy consumption. Other independent evaluators have performed tests, but refuse to release any documentation of LPA testing. However, they have verbally disclosed to the Navy that their tests indicated overall energy savings much less than those claimed by the manufacturer. In our opinion, independent, controlled testing over a range of applications and conditions is needed to truly evaluate the energy savings potential of LPA and liquid injection. It is Navy policy that these independent tests be the responsibility of the manufacturer. We recommend waiting until such test results are available before considering investing in LPA technology.

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