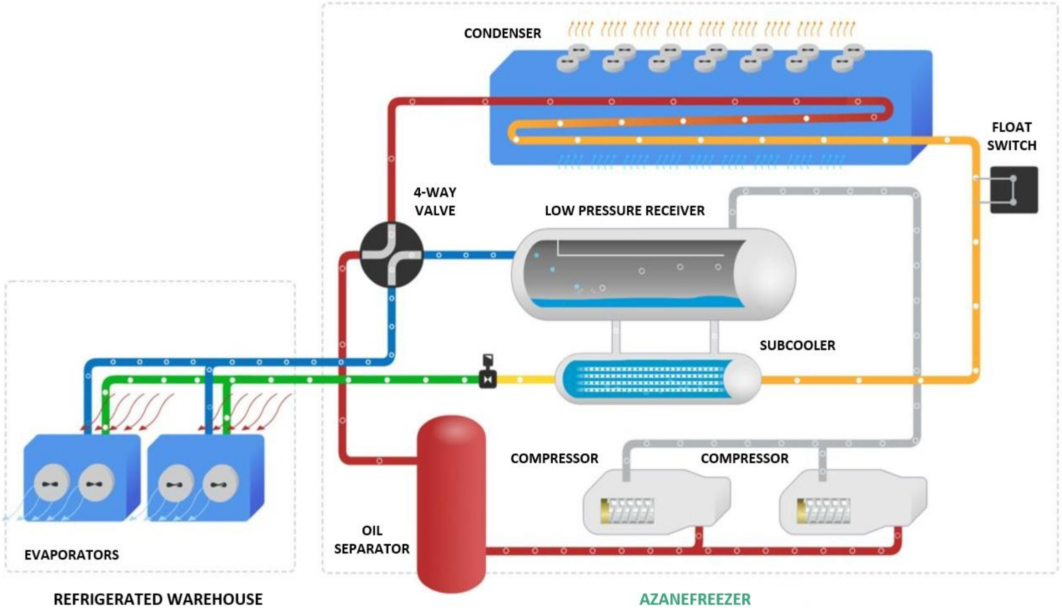
Low Pressure Receiver Technology

Low Pressure Receiver (LPR) technology was first developed and applied by Star Refrigeration in the UK in 1975. "LPR" as discussed here refers to a system arrangement whereby evaporators are flooded with an overfeed of liquid, which is driven thermodynamically (with the LPR) instead of mechanically (with a liquid pump). This type of LPR should not be confused with a simple suction line accumulator typically used in pumped liquid re-circulation systems. The original LPR systems were used with R-502, however the phase-out of this ozone-depleting refrigerant (along with others, like R-22) quickly resulted in a transition to the natural refrigerant, R717--ammonia. One key benefit to the LPR architecture is that it allows for very low overfeed rates, increasing efficiency and reducing refrigerant charge; however, operating with very low overfeed rates introduced new challenges in the shift to ammonia. Some of the properties that make ammonia an excellent refrigerant (e.g. high latent heat and low mass flow) strictly required high overfeed rates to achieve proper liquid distribution and maintain acceptable evaporator performance due to the low thermal conductivity of steel evaporator tubes. Overtime, innovation in distributor design paired with aluminum tube evaporators delivered the full benefits of the LPR system with ammonia as the refrigerant of choice. The first LPR system using ammonia, installed in 1988, was used in a traditional engine room, but applications have steadily shifted toward LPR use in distributed air-cooled packages since then. LPR technology applied in distributed systems has led to further reductions in refrigerant charge and has brought a number of other key benefits.

Principles of Operation

A simplified schematic shown below represents the basic LPR system architecture. *(It should be noted that the system normally incorporates an economizer subcooler upstream of the LPR subcooler, however this has been omitted below to simplify the figure.)* A key difference of this type of LPR system—from a standard pumped overfeed system—is that the compressor mass flow is equal to the evaporator mass flow. Normally, such a system would be considered a dry expansion system with the evaporator performing 100% of the evaporation. With the LPR system, the evaporator only does 90-95%, leaving the remaining evaporation up to the LPR subcooler.



The key to understanding how the LPR system forces an evaporator overfeed, is to understand that it works in conjunction with liquid control from the high-pressure side of the system. Since there is no high-side liquid collection, the expansion valve mass flow must equal the condenser mass flow, which also equals the compressor mass flow. Since the compressor mass flow is summed by adding the vapor returning from the evaporator and the vapor generated at the LPR subcooler, the only possible way for mass flow to balance is if liquid also returns to the LPR from the evaporator. Furthermore, the liquid returning from the evaporator must be of the same mass flow as the vapor produced in the LPR subcooler. It is in this way that the LPR subcooler heat exchanger thermodynamically overfeeds the evaporator, without a pump, and independent of gravity.

(Continued on reverse)

(Continued from reverse)

The location of liquid expansion is another important characteristic of the LPR system. After the high pressure liquid passes through the economizer and the LPR subcooler, the highly-subcooled liquid is immediately expanded to low pressure providing several unique benefits: 1) installing the expansion valve outdoors at the LPR package removes it from the indoor occupied space, reducing the risk of indoor leakage and providing safer accessibility for maintenance; 2) the liquid line carries flash gas, which displaces liquid ammonia and provides further charge reduction; 3) the system efficiency is not penalized by liquid line pressure drop and there is no operational risk of flash gas occurring upstream of the expansion valve due to pressure loss from elevation gain or pipe friction, and, 4) the liquid line feeding the evaporator is at low pressure eliminating all high-pressure ammonia pipes external to the self-contained LPR package—increasing safety further.

Reverse Cycle Defrost

The LPR system provides a unique opportunity to employ reverse cycle defrost (RCD) by using a simple and robust four-port reversing valve. With the LPR always acting as a liquid-vapor separator at the compressor suction, the 4-port valve can safely reverse the flow (and function) of the evaporator and condenser, allowing the system to operate as a heat pump to quickly and efficiently defrost evaporators. RCD eliminates valve stations and the third piping loop associated with hot gas defrost systems. RCD is therefore the preferred method over other defrost types because it performs defrost more quickly, efficiently, and effectively, and eliminates the common problem of valve stations leaking high-pressure hot gas to the low-pressure side of the system.

Benefits of RCD

- RCD is more efficient than electric defrost since the ice is melted by heating the evaporator tube directly, not by heating the external air around the ice.
- RCD is more efficient than traditional hot gas defrost because it is quicker and because hot gas flow is generated at a much higher compressor COP.
- RCD eliminates risk of hot gas leaks to the low-pressure side of the system.
- RCD cools the condenser surface during defrost, allowing for a rapid recovery.
- RCD is ideal for distributed packages with only one or two evaporators, which penalizes traditional hot gas defrost efficiency.
- RCD provides an inherent means for effective defrost termination by monitoring saturated condensing temperature in the evaporator to reliably indicate frost removal.

Benefits of the LPR System

Overall, there are many benefits of the LPR systems as described in this paper and as summarized here as compared to dry expansion and pumped recirculation systems.

Compared to DX Systems

- Enhanced efficiency
- Lower compressor discharge temperature
- Better use of evaporator surface (flooded operation)
- Good distribution in evaporator due to subcooling
- LPR can store excess refrigerant, no HPR needed
- Higher reliability and reduced risk of compressor damage
- All control valves located on the package
- Allows for reverse cycle defrost
- Improved efficiency in low ambient conditions
- Longer life and lower maintenance costs
- Minimum site work required
- Closer approach temperature in evaporator (no superheat)
- Performance not degraded by pressure drop in liquid line
- Better control under part load conditions

Compared to Pumped Recirculation Systems

- Reduced charge with the LPR (up to 85% less)
- Reduced capital cost
- Simplicity of operation
- No power required for refrigerant pumps
- Easier to maintain
- Less pressure drop in wet suction line
- Smaller suction and liquid lines
- Simpler and more efficient defrost system
- Simpler control system
- Packages built in factory so less site work
- Improved safety (fully welded, no valves or flanges indoors)
- Less chance for gas leakage from HP side to LP side