REFRIGERANT PUMP CAVITATION

When dealing with refrigerant pumps, it is important to understand that unlike pumps in other types of systems that are pumping steady state liquids like water or oil, refrigerant pumps are pumping boiling liquid. When a pump that is designed to handle liquids is supplied with a mixture of liquid and gas, it is said to cavitate. Most any pump can tolerate a certain amount of cavitation but it is detrimental if at all extreme.

To understand the complexities involved in pumping refrigerant, one must have a firm grasp of the relationship between pressure and temperature with refrigerants, and by extension, sub cooling.

Simply stated; the boiling temperature of any liquid rises and falls in direct correspondence with any increase or decrease in pressure. The often overlooked dynamic in a refrigeration system is that generally speaking, pressures can fluctuate very rapidly as a result of a compressor coming on or loading up (causing pressure to drop), or an evaporator being brought on the line (causing pressure to rise). The condition that tracks pressure fluctuations but never changes as quickly, is refrigerant temperature.

The supply of liquid for the refrigerant pumps is the pump separator, also referred to as the low pressure receiver (LPR). Under the most ideal conditions the liquid in the LPR would be saturated. This means that its actual temperature is equal to its boiling temperature; however in a working refrigeration system this would almost never be the case. Even a saturated liquid will have some gas bubbles entrained, because the slightest amount of heat will create vapor; however as vapor is released from the liquid it causes an increase in pressure which un-interfered with will raise the boiling temperature and reduce the rate of vapor generation.

Even if the liquid in the LPR is at an actual temperature lower than its boiling point, and therefore not boiling, the possibility of cavitation still exists. The liquid refrigerant must flow through a pipe to get to the pump suction. That pipe will usually be fitted with a valve, possibly a strainer, and some number of fittings, each of which will cause some amount of pressure drop.

A good pump installation incorporates the following practices to ameliorate the effect of entrained gas entering the pumps.

- The LPR and associated piping are well insulated, to limit the amount of ambient heat transmitted into the refrigerant.

- Valves and fittings are sized to create the smallest amount of pressure drop as is practicable for the expected flow rate.

- The pumps are mounted well beneath the liquid level in the LPR, to take advantage of the effect of gravity. The pressure at the inlet of the pump will increase in direct proportion to the height of the “column” of liquid above it.

A column of -40°F ammonia weighs approximately .3 PSI per vertical foot, and a column of -40°F R-22 weighs approximately .66 PSI per vertical foot. For comparison, water weighs approximately .5 PSI per vertical foot. If the centerline of the pump is 6 ft. below the liquid level in the LPR, and the refrigerant is R-22 at -40°F, then the pressure at the inlet of the pump will be approximately 4 PSI when the pump is not running, because there is no flow. As soon as the pump is turned on, flow is initiated. There *cannot* be flow without pressure drop. If the piping is well insulated, and the fittings and valves are sized correctly for minimum restriction, the pressure drop will be slight, as will the resultant boiling. This minor amount of boiling will not interfere with proper operation of the pump.

When the pressure of the refrigerant decreases, the boiling temperature (*not* the actual temperature) will decrease correspondingly. For example; if the boiling temperature of the refrigerant is -40°, and the actual temperature is also -40°, there will be no boiling. The liquid is said to be saturated. If the pressure is then lowered to a value that corresponds to a boiling temperature of -45°, the refrigerant will immediately boil, because its *actual* temperature (-40°) is 5° warmer than its *boiling* temperature (-45). A rapid decrease in pressure will result in *violent* boiling, making it more likely that cavitation will interfere with correct operation of the pump.

Cavitation will at a minimum, decrease the amount of liquid being delivered to the evaporators as it causes the pump discharge pressure to decrease. If it is severe, the rate of flow will decrease to the point where there is little or no flow of liquid through the pump. If the pump is hermetic, with a canned motor (refrigerant cooled) and refrigerant lubricated bearings, the lack of refrigerant liquid will cause damage or failure if the pump continues to operate. Most refrigerant pumps will be protected by one or more devices that will automatically stop the pump in the event of severe cavitation. The most common is a low differential pressure switch.

With the above in mind, it is important that the suction pressure never be allowed to drop at a rate that will result in the type of violent boiling described above. If the compressor is microprocessor controlled, it will likely have a ramp feature that can limit the rate at which the compressor can load in terms of pressure decrease per unit of time. The specifics of any given installation will determine the rate at which the pressure can be decreased without detrimental cavitation. Start at a conservative rate, such as 1 PSI every minute. This may sound slow, but it means that starting a system with R-22 at 50°F would require about 1 ½ hours to bring to -40°F, which is quite reasonable. It is also helpful to set controls so that compressor loading occurs gradually and unloading occurs more quickly (regardless of ramp settings). For example, set the capacity control so the compressor goes from minimum to 100% over a period of not less than 2 minutes. Set the unloading so the travel from 100% back to minimum takes one minute or less. With these or similar settings, violent boiling will be less likely to occur. When dealing with a 4 hour freeze cycle or an 8 hour chill time, adding compressor capacity slowly does not appreciably affect the refrigerating time required, and the value of the positive effect on the LPR and the refrigerant pumps cannot be overstated.