CASE STUDY

VACUUM PUMP SOLUTIONS FOR REFRIGERATION SYSTEMS

REFRIGERATION SYSTEMS PROCESS

After a refrigeration system is manufactured it requires vacuum processing to remove the air, water vapor, solvents, and other contaminants from the manufacturing process before it can be backfilled with the appropriate refrigerant and hermetically sealed. If the water vapor is not removed it can interfere with the proper functioning of the refrigeration process as well as form acidic compounds which can corrode the internals and shorten the life of the units. The most common vacuum pump used is a two stage oil sealed rotary vane or rotary piston pump. A two stage pump is preferred because of its inherent lower ultimate pressure and its higher capacity at the lower pressure range which must be attained during the evacuation processing. Two stage pumps also offer the ability to handle condensable vapors such as water vapor at a lower repeatable pressure due to its ability to operate at a lower pressure with full gas ballast flow as well as the vacuum distillation of the high vacuum oil reservoir by the rough vacuum stage continuously pumping on it which helps to keep the high vacuum oil cleaner longer.

PRESSURE RISE DETERMINATION

The normal processing procedure will include an evacuation of the refrigeration unit down to 50 to 1000 millitorr and then the unit is isolated from the vacuum pump by closing an inline isolation valve and the rate of pressure rise measured within a prescribed period of time such as less than 100 millitorr pressure rise in 30 seconds. The rate of pressure rise is based upon measurements of similar refrigeration units which have been extensively tested and which are known to perform well. The leakup rate or pressure rise is measured with a total pressure gauge located between the refrigeration unit and isolation valve and is composed of outgassing from the internal surface area, which is large in comparison to the volume, and normally consists primarily of water vapor as well as external leaks which must be small in comparison. Comparison of the leakup rate with that of similar refrigeration units that have been extensively tested and have a well determined pumpdown and leakup rate signature of pressure vs time determines if the production line units are acceptable or need to be reconditioned.

SIZING THE VACUUM PUMP

The vacuum pump size is determined by the conductance limitations due to the small diameter of the connecting tubing and the size of the tubing diameter used in the condenser and evaporator coils. During pumpdown from atmospheric pressure the orifice conductance due to the diameter of the connecting tubing predominates until the average pressure \( P_{avg} = 0.024L/D^2 \) is attained where the smaller conductance due to the tubing length begins to predominate, where \( P_{avg} = (P_1 + P_2)/2 \) is the average pressure across the tubing in torr (mm Hg A), \( L \) is the tubing length and \( D \) the tubing diameter both in inches. Pumps used on small refrigeration units of 5 tons or less are small two stage pumps such as the Kinney® models KCB or KC15. Increasing the size of the vacuum pump only reduces the pressure at the pump side of the small diameter connecting tubing without much reduction in the refrigeration side pressure due to the small conductance so that the processing time is not improved.
During the total processing run the pressure within the refrigeration unit is always > 2 x pressure at the vacuum pump with choked flow predominating. Because of the high surface area/volume ratio and low internal conductance, the leak up rate is less affected by increasing the pump capacity. Pumping in parallel on multiple portions of the refrigeration units or increasing the internal temperature to more quickly drive off the outgassing would have more of an effect on improving pumpdown and leak up rates. Because of the use of the newer HFC refrigerants replacing the banned CFC refrigerants that threatened the ozone layer, many of these require using a synthetic compressor lubricant such as POE’s (Polyol Esters) or PAG’s (Polyalkylene Glycols) which have a greater affinity for absorbing moisture compared to mineral oils and can affect the outgassing rate. If a refrigeration unit develops a problem after having been backfilled with refrigerant the vacuum pump will also need to handle the refrigerant and because of this need for compatibility Kinney offers rugged and reliable two stage KC pumps with either POE or mineral oil lubricant with compatible elastomers.

The bulk condensable load that the vacuum pump sees during evacuation is water vapor which must be removed from the internal surfaces and the compressor oil and because of the hygroscopic nature of some of the synthetic lubricants this can increase pumpdown time and require a vacuum pump with an ultimate pressure at least one order of magnitude lower than the minimum processing pressure and capable of handling water vapor with minimal degradation of performance. The Kinney KC series and KTC series for larger chiller units are ideally suited for this type application due to the following:

- Ultimate pressures two orders of magnitude below normal processing pressures
- Two-stage oil reservoir design where the high vacuum oil reservoir is continuously distilled by the second stage to remove contaminants
- Gas ballasting on the second stage to remove condensable vapors with minimum effect upon processing inlet pressure
- Rugged all cast iron rotary internals that minimize wear, reduce internal excessive localized temperatures due to better heat transfer, minimized oil degradation, and provide a robust, reliable, experience-proven pump.