How to make sure you select the right dry vacuum pump

By Joe Aliasso. Unlike steam jet ejectors and liquid ring vacuum pumps, dry vacuum pumps do not require any working fluids to create a vacuum. They operate by either gas compression, or a combination of gas compression and mechanical compression (volume reduction).

The definition of a dry vacuum pump is a pump that does not use any fluids to create a vacuum or contact the process gas and can also discharge to atmosphere.

All dry vacuum pumps run hot, since there are no liquids to remove the heat created by compressing the gas. They all employ a cooling jacket to help regulate the internal temperature in the pump, preventing excessive thermal growth, which would lead to failure. Timing gears with oil reservoirs and close clearances between the rotors and housing are additional attributes that make up a dry vacuum pump.

Since dry vacuum pumps run hot, they can easily handle corrosive vapours with standard iron construction, as corrosion normally occurs in the presence of moisture. Cast or ductile iron is inexpensive to manufacture in, and limits thermal growth. Dry pumps are not manufactured in stainless steel or other high alloy materials because of the excessive thermal growth characteristics associated with these materials. This would require larger clearances to allow further proper thermal growth, thus resulting in a lower efficiency (more backslippage of gas). Also, because of the increased clearances, the ultimate vacuum would be degraded. Another consideration would be the manufacturing costs due to the complex parts that make up a dry vacuum pump. Stainless steel normally is two to three times the price of iron. With the proper selection and correct operating procedure, dry vacuum pumps constructed in iron negate the use of stainless steel or other high alloy materials.

The similarities of the three types of dry vacuum pumps end here. Each manufacturer includes unique features to differentiate their pump from others. The end user should understand what features are available and then choose the dry pump that best fits the application.

Rotary lobe design

The rotary lobe style was the first dry pump used in the chemical industry. It is based on the Roots blower principal. This design, when properly selected, works well with few problems. Maintenance is typically moderate to high on this design as lip seals are employed that frequently leak, and cleanout of the last stage is required as buildup will occur here. When the lip seals leak, gas can contaminate the bearing oil. If left unattended, the bearings will fail and the rotors can make contact. Rotary lobe type pumps can employ heat exchangers to reduce the operating temperature of the pump. If condensables are handled, then these heat exchangers can condense under vacuum. This would require a barometric leg or a complex control scheme to drain out any liquid in the pump.

The rotary lobe and rotary screw type are difficult to re-time when repairing. Setting the clearances on a rotary screw type is difficult as the maintenance person will need to perform this on a curved surface. The rotary lobe type will require trained personnel to set the clearances and re-time the pump also.

Rotary screw

The rotary screw type vacuum pump can reach extremely high vacuum levels (low absolute pressures). It is in the range of 10 to 100 microns. Even though it can reach these levels, it cannot be used for every application. Because the rotary screw pumps run hot, actually the hottest of any of the designs, temperature sensitive materials and severe service applications will cause problems for this design. Polymerization can occur because of the operating temperatures.

Rotary screw pumps move the gas along the length of the screws. Gas compression and mechanical compression does not occur until the final half turn of the screws. Here, immense heat is produced. Discharge temperatures of 660°F can be produced in the pump. Temperature sensitive products and flammable gases are difficult to handle with this design. In addition, if any wear occurs on the screws, they need to be replaced in matched sets. Other dry pump designs allow for individual part replacement.

Some manufacturers offer a spray coating on the screws. The purpose of this coating is for initial fit up of the screws. This spray-on coating is extremely thin and allows for tighter clearances to produce a better ultimate pressure and higher efficiency of the pump. As the pump is operated, the spray-on coating will wear off and affect performance.

Hook and claw
There are two types of hook and claw pumps in the market, a two-stage and a three-stage. The three stage produces vacuum levels less than 1 mmHg by a combination of mechanical and gas compression. The two stage produces vacuum levels down to 5 mmHg by gas compression only.

The three stage, with a combination of mechanical and gas compression, produces discharge temperatures of 430°F or greater. One manufacturer has solved this temperature problem by offering a pump that has discharge temperatures less than 100°F.

A hook and claw type requires a larger footprint and runs slightly noisier than the rotary lobe and rotary screw type pumps.

Most types of dry vacuum pumps use lip seals with an N₂ purge. Lip seals require frequent maintenance with difficult replacement. One design comes standard with single mechanical seals. This eliminates the maintenance problems associated with lip seals and also eliminates N₂ requirements.

When handling corrosive and wet vapours, the hot running type of dry vacuum pump is desirable. This will prevent corrosion of the iron body components. Also, for handling gases that can solidify at room temperature, the hot running type is also required to prevent any product solidification inside the pump.

The cool running hook and claw vacuum pump design allows safe pumping of explosive and temperature sensitive gases.

The cool running hook and claw pump uses a unique discharge gas heat exchanger that provides for direct gas cooling. Once the inlet port is isolated and the pumping chamber is at its maximum volume, then cooled discharge gas is injected in. The gases mix and compress, increasing density (shrinking the volume). The discharge port is then opened and the compressed gas is merely swept out. No mechanical compression, by reducing the volume of the pumping chamber, occurs inside this pump.

On this design, all the discharge gas passes through a heat exchanger at atmospheric pressure where it is cooled. This heat exchanger can also act as a condenser and be used for solvent recovery. Since it operates at atmospheric pressure, simple draining of the condensed liquids is accomplished. No barometric leg or complex control scheme is required.

The two-stage and cool running hook and claw is the only dry vacuum pump that does not use mechanical compression to achieve vacuum. Because of this unique design, it can be started completely flooded with liquid. This provides a distinct advantage over other types of dry pumps. If the pump is starting to accumulate product buildup during operation, then it can be stopped and filled with a solvent to dissolve the buildup. The pump can then be started flooded, pumping out the liquids. This also reduces downtime, as the pump would not need to be taken apart and cleaned.

Handling liquid contaminants

All dry pumps have difficulty handling slugs of liquids. Knockout pots are generally required. A liquid ring pump is the only type of vacuum pump that can safely handle slugs of liquids. If the process results in the pump continuously being taken out of service for repairs, then a simple to rebuild dry pump is desired. As mentioned previously, timing, setting of clearances and replacement of lip seals requires a major effort. The manufacturer with the cool running dry pump offers simplified rebuilding. This pump can be taken apart and re-built in 2 to 4 hours, with no timing requirements. All other types usually take days to repair.

All dry pumps will be sensitive to process upsets and should be carefully selected to insure maximum run time. Inlet filters and knockout pots, along with discharge silencers are normally required for a complete operating system.

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