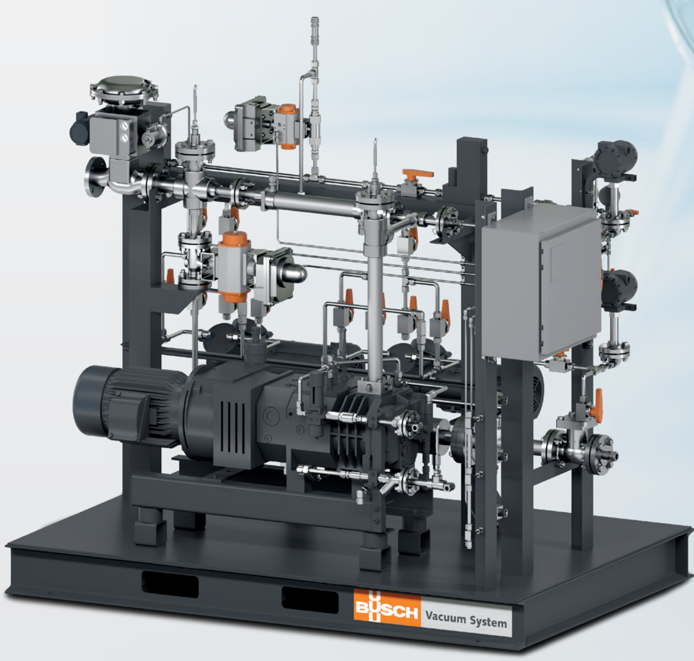
Choosing the Right Vacuum Technology
for Chemical and Pharmaceutical Processes



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BUSCH
Vacuum Pumps and Systems

Learn About "Choosing the Right Vacuum Technology for Chemical and Pharmaceutical Processes"

Selecting the right vacuum technology for chemical and pharmaceutical processing applications is often difficult. Firstly, a vacuum system must deliver the required pumping speed at operating pressure and ensure the required pump-down time. Secondly, it cannot be sensitive to process gases and must meet all requirements when it comes to CIP (clean-in-place) cleaning and gas recovery. Reliability and economic efficiency also play a significant role when deciding which vacuum technology to use.

Here, we will outline the three vacuum technologies most often used in chemical and pharmaceutical processing technologies.

- Dry screw vacuum pumps
- Liquid ring vacuum pumps
- Oil-lubricated rotary vane vacuum pumps

Dry screw vacuum pumps

Dry screw vacuum technology is widely used in the chemical and pharmaceutical industries. However, this technology is relatively new in this market compared to other technologies. In the 1990s, Busch launched the first dry screw vacuum pump for use in the chemical and pharmaceutical markets, the COBRA AC. These pumps have an advantage in this market, as dry screw vacuum pumps (Figure 1) do not require operating fluid to compress the process gas. In a screw vacuum pump, two screw-shaped rotors rotate in opposite directions (Figure 2). The pumped medium is trapped between the cylinder and screw chambers, compressed and transported to the gas outlet.

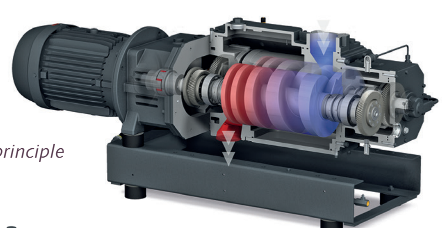

Figure 2: Modern screw vacuum pump operating principle

Figure 1: COBRA NC screw vacuum pump

During the compression process the screw rotors do not contact each other or the cylinder. Precise manufacturing and minimal clearance between the moving parts enable this operating principle and, in addition, guarantees a low ultimate pressure of <0.1 Torr.

Modern screw vacuum pumps have a variable pitch screw which results in even compression of the process gas across the entire length of the screw. This has the advantage of ensuring the same temperature throughout the entire compression chamber, which can easily be monitored and controlled. Screw vacuum pumps utilize a cooling jacket which ensures even temperature distribution, and greater thermal efficiency and stability throughout the pump body. Generally, dry screw vacuum pumps operate at temperatures sufficient to prevent condensation of the process gas. This enables the process gas to be conveyed through the vacuum pump without contamination by, or reaction with an operating fluid, as well as preventing corrosion due to process liquids attacking the pump materials. Ductile iron is the standard material used for process wetted parts that contact the pumped medium. The metal is coated with a special coating to make it resistant to nearly all chemicals. For extreme cases, other coatings are available to give additional protection. In most applications, it is recommended to warm the pump up prior to process operation and purge the pump with inert non-condensable gas (generally nitrogen) to remove the process vapor prior to shut down. In some applications, it is also recommended to flush the vacuum pump with a suitable cleaning fluid to remove process material that is in the pump prior to shut down to avoid deposits forming as the pump cools. Flushing capability is another characteristic of the dry screw pump that arises, because the pump does not utilize an operating fluid.

With different compression systems and various coatings, screw vacuum pumps from Busch can be configured to be compatible with any chemical.

Advantages of dry screw vacuum pumps:

- Dry compression, no contamination or reaction possible between process gas and operating fluid
- High vacuum level
- Energy efficient
- Can be designed for nearly all process gases thanks to material selection and temperature regulation

Disadvantages of dry screw vacuum pumps:

- Sensitive to particles entering the system
- Requires special considerations when used with process gases that tend to be reactive at high temperatures

Liquid ring vacuum pumps
Liquid ring vacuum pumps (Figure 3) are used in many applications. They are rotating positive displacement pumps with an impeller that is eccentrically placed in a cylindrical housing (Figure 4). A liquid sealant continually flows through the vacuum pump, and the rotation of the impeller creates a liquid ring on the inside of the housing that seals the spaces between the individual blades of the impeller. The gas is conveyed in the spaces between the shaft, the individual blades and the liquid ring. Due to the eccentric placement of the impeller, the volume of these spaces initially increases, drawing vapor in through the inlet. As the impeller continues to rotate, the volume of these spaces is reduced, the vapor is compressed and then discharged through the exhaust port. The liquid ring vacuum pump can be operated as a simple, continuous, sealant flow system, or a partial or total recirculation sealant system.

Over many years, these vacuum pumps have proven themselves to be robust and reliable vacuum generators in chemical processes. The operating fluid in the compression chamber continuously dissipates the compression heat, so the vacuum pump operates nearly isothermally. This means that the process gas does not heat up to a notable degree and the vacuum pump operates at relatively low temperatures. This significantly reduces the risk of unwanted reactions. Low operating temperatures also facilitate condensation of vapor, which increases the nominal pumping speed of the vacuum pump, but adds process liquid to the seal fluid. This condensed process fluid may affect the vacuum capability and/or capacity of the pump as well as generating a sealant that must be treated prior to disposal.

Water is usually used to create the liquid ring. Ethylene glycol, mineral oils or organic solvents are also often used in practice. The ultimate pressure of the vacuum pump depends on the vapor pressure of the seal liquid, and the density and viscosity of the sealant will impact the power consumption of the vacuum pump.

Figure 3: Dolphin liquid ring vacuum pump from Busch

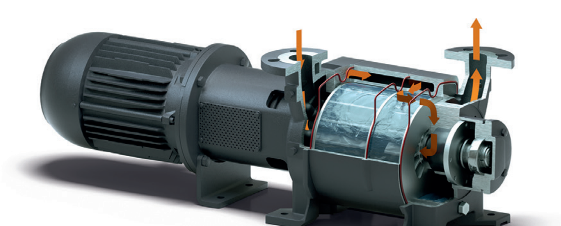

Figure 4: Two-stage liquid ring vacuum pump operating principle

Liquid ring vacuum pumps are available in different configurations and shaft seal arrangements, and they are available in many materials of construction, from simple to exotic.

Advantages of liquid ring vacuum pumps:
› Not sensitive at all to vapor or liquid entering the system
› Materials of construction can be tailored to the process gas

Disadvantages of liquid ring vacuum pumps:
› Possible contamination of the operating fluid with condensate from the process gas, affecting performance and which making it necessary to subsequently treat the operating fluid before its disposal
› High energy consumption
› Ultimate pressure depends on the vapor pressure of the operating fluid

Once-through oil-lubricated rotary vane vacuum pumps
Oil-lubricated rotary vane vacuum pumps have been successfully used in many fields for decades. Today, they are among the most widely used mechanical vacuum pumps in the chemical and pharmaceutical industry. The Huckepack is a two-stage, once-through, oil-lubricated rotary vane vacuum pump developed in the 1960s, and was specially designed for chemical and pharmaceutical processing technology. Busch constantly develops this vacuum pump, which continues to enjoy great acceptance in processing technology today, thanks to its robustness.

Huckepack rotary vane vacuum pumps (Figure 5 and Figure 6) have three significant distinguishing features when compared to other vacuum pumps that operate according to the rotary vane principle:

1. Two compression stages are stacked and connected to each other, which facilitates initial compression of the process gas in the first stage and secondary compression in the subsequent second stage. This makes it possible to achieve a lower ultimate pressure.
2. These vacuum pumps feature an oil-lubrication, which means that a defined amount of operating fluid, oil or other media-compatible fluid is injected into the compression chamber. In contrast, other rotary vane vacuum pumps use oil circulating lubrication.
3. Huckepack rotary vane vacuum pumps are water-cooled, thus allowing the operating temperature to be regulated within a certain range.

Huckepack rotary vane vacuum pumps are rotating positive displacement pumps. The vanes are placed in slots in a rotor, which rotates eccentrically in a cylindrical housing. The centrifugal force created by the rotating motion of the rotor causes the vanes to slide out to the cylinder wall. This creates spaces with different volumes, which in turn generate the suction and compression effect. As stated above, a very small amount of lubricant is continuously injected into the pumping chamber and vane slots to provide lubrication for the vanes and improve the seal. Note that the vanes do not directly contact the cylinder wall or vane slot, but rather slide on a lubricant film that is continually regenerated by the injected lubricant. This process takes place in both compression stages before the process gas is discharged together with the operating fluid via the outlet where the lubricant is collected in the silencer for draining. The continuously injected lubricant also continually flushes the vacuum pump during operation, protecting it from corrosion and deposits. Busch offers vanes made of three different materials to ensure resistance to most solvents.

Both stages utilize a water jacket for cooling. Versions with once-through water cooling and water circulation are available. The cooling jacket allows for control of the pump operating temperature to provide the optimum temperature for the specific application. The once-through water version controls the pump operating temperature by controlling the water flow through use of a temperature-controlled valve. The recirculating coolant version utilizes a thermostat to control the pump temperature.

Advantages of once-through oil-lubricated rotary vane vacuum pumps:

- High vacuum level
- Extremely robust and reliable
- Easy servicing
- Perfectly suited for conveying acid vapors and monomers or products that lead to polymerization when other vacuum technologies are used

Disadvantages:

- Operating fluids must be treated or correctly disposed of

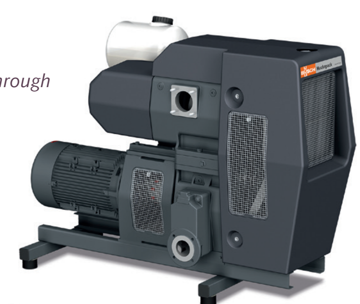

Figure 5: Huckepack once-through oil-lubricated rotary vane vacuum pump

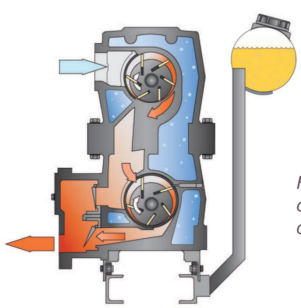

Figure 6: Huckepack once-through oil-lubricated rotary vane vacuum pump operating principle

Summary

All the vacuum technologies discussed here have advantages and disadvantages. There is no single ideal solution for all applications. It is therefore important to seek consultation from a vacuum expert and consider all important parameters in the process, starting with process conditions, process gases and integration into process control, through to economic efficiency, safety and reliability of future vacuum generation. In most cases, consideration of these factors leads to a customized vacuum system that is directly tailored to the requirements.

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