

# **DRY VACUUM SOLUTIONS**

## **for Chemical and Pharmaceutical Applications**



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# Dry Vacuum Solutions – for Chemical and Pharmaceutical Applications

Throughout the years, many different technologies have been used to provide vacuum for chemical and pharmaceutical processes. Some examples of these include steam jet ejector systems utilizing the venturi effect to draw a vacuum, liquid ring vacuum pumps utilizing water as a sealant, and rotary vane vacuum pumps utilizing a once-through sealing system. Each of these technologies continue to have a place in chemical and pharmaceutical applications, but dry screw technology has become the technology of choice for most applications.

Dry screw vacuum technology is preferred in most chemical and pharmaceutical applications since no operating fluid is required to compress the process gas. In a screw vacuum pump, two interlocking screw-shaped rotors rotate in opposite directions (Figure 1 and Figure 2). The process vapors are drawn in, trapped between the cylinder and screw chambers, compressed, and transported to the gas outlet. During the compression process the screw rotors do not contact each other or the cylinder. Precise manufacturing and minimal clearance between the

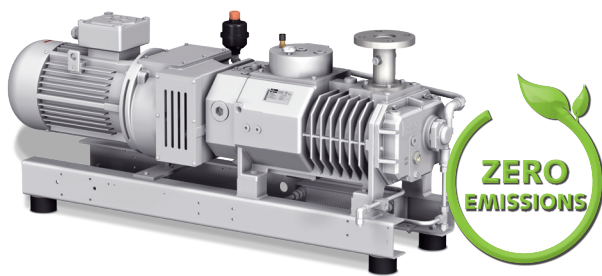


Figure 1: COBRA NC dry screw vacuum pump

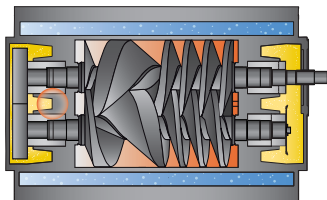


Figure 2: Cross-sectional view of a COBRA dry screw vacuum pump

moving parts enable this and guarantee an ultimate pressure of < 0.1 Torr. The dry screw vacuum pumps were originally introduced in the early 1990's utilized constant pitch screws. With constant pitch screws, the gas is transported through the pump without any compression, then is compressed to atmospheric pressure at the exhaust port. With virtually all the compression occurring at this location, the heat of compression is concentrated, causing very high gas temperatures which in some cases can lead to vapor decomposition and can exceed the auto-ignition temperature of the process gases. Modern screw vacuum pumps have a variable pitch screw which results in compression of the process gas across the entire length of the screw. This has the advantage of ensuring a more consistent temperature throughout the entire compression chamber, which can easily be monitored and controlled.

Screw vacuum pumps utilize a cooling jacket which ensures an even temperature distribution, and provides greater thermal efficiency and stability throughout the pump body. Generally, dry screw vacuum pumps operate at temperatures warm enough to prevent condensation of the process gas, preventing corrosion due to process liquids attacking the pump, but cool enough to prevent potential issues such as vapor decomposition or auto-ignition. Since there is no seal fluid in the pumping chamber, the process vapors exit the pump without contamination. This allows for the condensation of the process vapors for recycle or downstream use, should the financial returns be beneficial.

Ductile iron is the standard material used for process wetted parts in contact with the pumped medium. The metal is produced with a Teflon impregnated 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 important to warm the vacuum pump up prior to process operation and to purge the pump with an inert non-condensable gas (generally nitrogen) to remove the process vapor prior to shut down. In some applications, it is helpful to flush the vacuum pump with a suitable cleaning fluid to avoid deposits of process material forming as the pump cools.

Dry screw vacuum pumps are also amenable to the use of variable speed drives to control the operating pressure and to match the pumping speed to the required process flow. Variable speed drives give the added benefit of optimizing the energy usage of the vacuum pump. With different compression systems, various coatings and appropriate accessories, screw vacuum pumps from Busch can be configured to be compatible with virtually any chemical.

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#### **Advantages of dry screw vacuum pumps:**

- Dry compression, no contamination or reaction possible between process gas and operating fluid
- Excellent ultimate vacuum
- 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

Dry screw vacuum pumps should not be confused with oil-lubricated screw vacuum pumps. While oil-lubricated screw vacuum pumps utilize the same principle of two interlocking screw rotors rotating to move the gas through the pump, and are “dry” in the sense that they do not utilize water as a sealant, they still use oil as a recirculating operating fluid/sealant in the pumping chamber and therefore have the same potential issues in chemical applications that other pumps utilizing operating fluids/sealants (recirculating oil-sealed rotary vane, liquid ring, etc.) have. These issues include contamination of the process vapors with the sealant, contamination of the sealant with process material due to condensation, absorption, reaction, etc. This leads to reduced capacity and vacuum capability as well as oil breakdown/degradation. Since dry screw vacuum pumps do not use any sealant in the pumping chamber, they do not experience these issues.

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## **Systems and Accessories**

Dry screw vacuum pumps are frequently integrated into customized vacuum systems. These systems can be designed to provide additional capacity beyond what the pump itself can achieve, minimize the capacity requirement by removing a portion of the process stream to be pumped, protect the vacuum pump and system components, and/or control and optimize the operation of the vacuum pump and system components. The components frequently used are discussed below:

#### **Vacuum Boosters**

Chemical and pharmaceutical applications involve high flow rates at deep pressures, which lead to a capacity requirement higher than what a single vacuum pump can handle. Typically, the most economical solution is to use a roots blower as a vacuum booster in combination with the vacuum pump to “supercharge” the pump. The vacuum booster is used to partially compress the process vapors to the pressure where the vacuum pump has

sufficient capacity to handle them. The vacuum booster, like the dry screw pump, does not use an operating fluid so the pumping solution remains a “dry” technology. In cases of very high flow requirements, multiple vacuum boosters may be used in series to provide the required capacity.

#### **Condensers**

Condensers may be utilized on the inlet of the vacuum system, between a vacuum booster and pump, or on the exhaust of the vacuum pump. In processes where a high condensable load at elevated temperatures is to be handled, a condenser is often utilized to remove a portion of the vapor stream, reducing the load handled by the pump since only the uncondensed vapor passes to the remainder of the vacuum system. In cases where the operating pressure is too low to allow condensation on the system inlet, a vacuum booster may be used to partially compress the vapor stream to a pressure that will allow condensation between the vacuum booster and vacuum pump. This is still advantageous because, while the booster must pump the full vapor load, the vacuum pump only pumps the uncondensed vapor load exiting the condenser, reducing the vacuum pump size. Condensers are also frequently used on the vacuum pump exhaust to condense the process vapors for vapor recovery. This is a major advantage of the dry screw pump – since there is no operating fluid in the pumping chamber, the process vapors exhaust the pump without contamination, allowing condensation and reuse of the process vapors, or minimize the amount of effluent to be disposed of.

#### **Inlet Filters**

Dry screw vacuum pumps are frequently used on particulate dryers, especially in the pharmaceutical industry. While dry screw vacuum pumps can tolerate ingestion of some particulates, it is good practice to take measures to protect them from regular particulate ingestion. Many types of filters are available to match the process materials, including:

- Single-stage with 5-10 micron retention
- Two-stage with 10 micron and 0.3 micron elements
- Bag-In/Bag-Out HEPA filter
- High-Volume Bag-Type incorporating a self-cleaning filter bag

#### **Knock-out Pots**

Like particulates, dry screw vacuum pumps can tolerate ingestion of liquid, but it is good practice to take measures to protect them from regular liquid ingestion. Liquid can be present in the inlet process stream due to carryover from process vessels, aspiration from condensers or condensation that occurs as the process vapors pass through the inlet piping. Knock-out pots are liquid separators which utilize several stages of separation, including a demister pad, to remove any entrained liquid from the inlet stream. If required, knock-out pots can also be provided with

integrated filter elements to eliminate the need for a separate inlet filter assembly.

### Automatic Start/Purge Packages

As stated previously, dry screw vacuum pumps are intended to operate at a temperature warm enough to prevent the process vapors from condensing in the vacuum pump. However, it is critical when handling condensable vapors to allow the vacuum pump to reach that operating temperature prior to being put on process. This prevents condensation from occurring as hot vapors are drawn into a pump that is not yet up to operating temperature. Likewise, it is important to purge the process vapors from the pump prior to shutdown to prevent condensation in the pump as the pump cools to prevent corrosion or other detrimental effects. To achieve this, an automatic start/purge package can be used to bring the pump up to operating temperature during start-up, and on shutdown to sweep the process vapors from the pump. The automatic start/purge package consists of an actuated valve to isolate the vacuum pump from the process and a solenoid valve for nitrogen bleed. Sequencing of the valves can be performed by a skidmounted control panel or the customer's control system.

### Automatic Flushing Packages

In some applications, it is inevitable that process material will collect in the pump despite attempts to prevent it. In these cases, an automatic flushing package can be utilized to remove any accumulation of material in the pump. Flushing consists of injecting a small amount of a solvent into the vacuum pump while it is running to remove the process build-up. As the solvent passes through the pump it dissolves the build-up and carries it out the exhaust. Flushing is always performed prior to shutdown to clean the pump, and may also be performed periodically during the process run. Flushing can also be incorporated into the customer's clean-in-place procedure to prevent cross-contamination in multi-purpose process units.

### Control Panels

Control panels can be supplied to provide virtually any degree of control required, from simple motor control to a complex PLC based control system for monitoring of transmitters, sequencing of valves, sequencing of a number of pumps and/or vacuum boosters, first-out failure indication, communication with the customer's control system, etc.

### Variable Frequency Drives (VFD)

As stated above, dry screw vacuum pumps are very amenable to operation on variable frequency drives. Typically, a VFD is utilized in combination with a pressure transmitter in place of a control valve to control the vacuum pump inlet pressure by varying the pump speed to match the pump capacity to the process flow requirement. They can also be programmed to provide pressure ramping functions as needed by the process conditions. In the event a vacuum booster is used with a dry screw vacuum pump,

the vacuum booster can also be controlled by a VFD. If an automatic flushing package is included in the vacuum system, a VFD can be used to slow the pump to a minimal speed during the flushing cycle to allow the pump to run cooler, minimizing flashing of the flush solvent.

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## Summary

Historically, the choice of vacuum technology has been driven by many influences including rising energy costs, environmental regulations, and increasing costs of water treatment and contaminated/hazardous waste disposal. As a result, the market has been driven to seek vacuum technologies that provide high efficiency while minimizing the waste streams generated. Based on these criteria, dry screw vacuum pumps are the logical choice in that they provide high efficiency while eliminating any additional waste streams through the elimination of operating fluids, whether they be steam, water or oil.

As stated above, dry screw pumps are frequently integrated into customdesigned vacuum systems incorporating components to optimize the operation and capability of the vacuum pump with regard to flow capacity and vacuum level, and to protect the pump and components. Selection and design of the proper accessories, and integration of those accessories into a turn-key system, requires technical expertise that Busch systems engineers can uniquely provide. With Busch vacuum systems (Figure 3 and Figure 4), all components are specifically designed for their purpose in vacuum applications and matched to the other components in the system. If the customer has preferred vendors Busch will work with them to provide the appropriate products for the application and purpose. A Busch vacuum system minimizes customer installation requirements and provides the user peace-of-mind knowing the system has the proper components for long-term reliability and is fit-for-purpose.

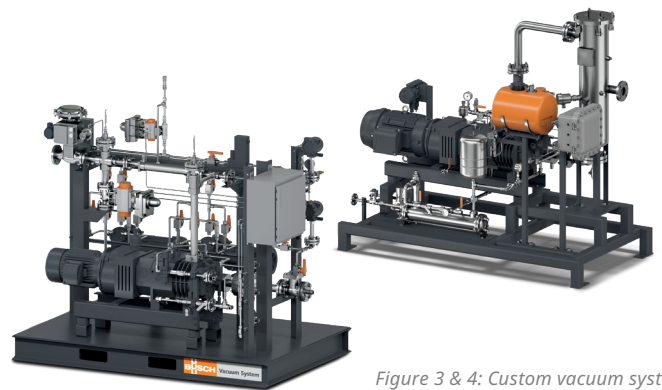


Figure 3 & 4: Custom vacuum systems