## Diaphragm Vacuum Pumps in

# Pilot & Process Operations

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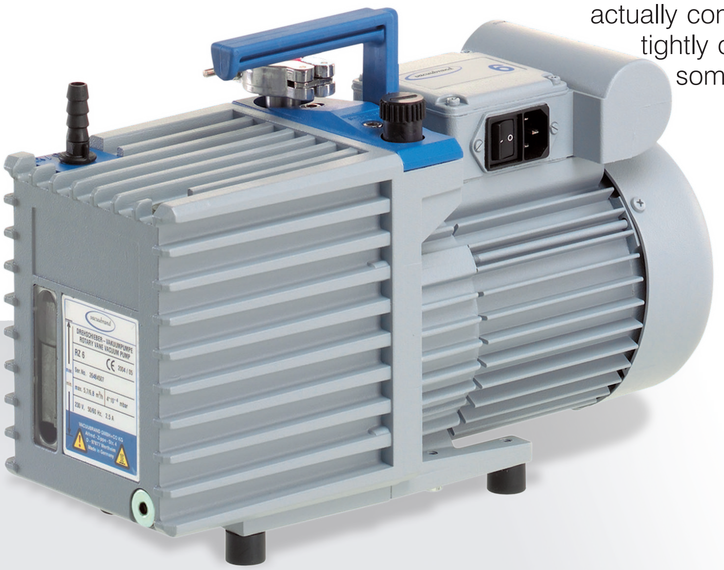
*Synopsis: Of the wide range of vacuum pump technologies used in the pharmaceutical and chemical process industries, many incorporate wetted materials that prove problematic because of poor corrosion resistance. Chemical-resistant diaphragm vacuum pumps, with their oil-free operation, can offer substantial long-term cost savings over pumps – such as oil-sealed rotary vane pumps – that are not as resistant to corrosive chemicals. Improved chemical resistance can provide cost savings through reduced maintenance, longer pump life, greater productivity, and lower operational costs. Significant advantages in process control can contribute further to operational efficiencies. This article reviews design features of diaphragm pumps which yield these benefits.*

Vacuum is a very widely used utility in the process industries – from pharmaceutical and chemical to food and biotechnology. While some applications require fairly deep vacuum – so-called "fine" vacuum – many other operations rely on vacuum in the "rough" range. These rough vacuum applications include suction operations to drive liquid movement or accelerate filtration, and evaporative applications, in which vacuum is used to dry materials or separate liquids by controlling their boiling points. Using common scales, rough vacuum is used to describe vacuum between atmospheric pressure and 1 torr (29.88 inches of mercury gauge pressure at sea level, represented as "in. Hg"). Fine vacuum refers to the range between 1 torr and 0.001 torr (29.919999 in. Hg).

## Traditional approaches

Longstanding practice has been to use oil-sealed (rotary vane) vacuum pumps for many industrial vacuum applications. The technology is fairly robust, pumps can readily be re-built when needed, pumping speeds are fairly high, and the technology is suited for continuous duty. Further, rotary vane pumps can deliver pressures in the fine vacuum range. These pumps have some important drawbacks, however; they are not particularly resistant to corrosive conditions, and so need frequent service. The service demands lead to process downtime, or the need to keep back-up capacity at the ready in order to protect against unplanned maintenance. Further, while rotary vane pumps are capable of vacuum in the fine vacuum range, many process operations are best managed in the rough vacuum range, where rotary vane pumps are less efficient, and where they may actually complicate process management with excess vacuum. In addition, tightly controlling vacuum with rotary vane pumps has historically been something of a challenge.



## Addressing the shortcomings

Diaphragm vacuum pumps can overcome these drawbacks and provide additional advantages in the many situations in which rough vacuum levels are a better fit for the process being considered.

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- **Fit to the need:** When pumps designed for deeper ("fine" vacuum are used for operations that do not require the deeper vacuum, the mismatch can cause problems. Operations in which the vacuum is intended for suction for liquid transfer, for example, can result in evaporation of process liquids when a fine vacuum rotary vane pump is used. Besides the loss of liquids, the evaporated liquids end up in the pump, contaminating the pump oil and shortening the intervals between oil changes. In an evaporative process, excess vacuum can cause "boiling retardation," or "bumping" and foaming that can lead to sample losses. With dry pumps, it is easier to select a model that delivers the more appropriate vacuum, one that is a better fit to the process and that does not risk product loss.

- **Oil-free operation:** Diaphragm pumps have no oil in the wetted path. The reciprocating drive arm moves a diaphragm that pushes gas or vapors through the pump. That means there is no oil to get contaminated with process vapors, or to break down and lose its ability to lubricate. The lack of oil changes provides an immediate savings, but also ensures that there is no contact between pump oil and process fluids or vapors. Further, by eliminating oil from the pump, there is no longer a need for the costly disposal of contaminated waste oil.

- **Long service cycles:** High quality diaphragm pumps can deliver long service intervals. Pumps from some manufacturers have recommended maintenance intervals of as much as 15,000 hours in normal fixed speed operation. Even in continuous duty, that means nearly two years without service interruption.

- **Corrosion resistance:** When pump heads, diaphragms and valves are built of chemical-resistant materials such as fluoroplastics, the pumps are exceedingly resistant to corrosion. Combined with the long maintenance intervals available with some dry diaphragm pump designs, the corrosion-resistant construction further reduces service demands.

- **Control:** Vacuum control involves a careful balancing of pumping speed, system leakage, and vapor generation. Since vapor generation is strongly influenced by temperature, the vapor pressures of the components of the evaporating mixture, and surface area, any change in any of these variables will impact the vacuum level needed to optimize conditions. Too much vacuum, and the mixture may "bump" and cause product loss, or time lost for product recovery. With too little vacuum, the process will proceed more slowly, possibly affecting productivity or production rates.

  Traditional vacuum control relies on a "two-point" method. A target vacuum level is set, and tolerances are set above and below the target vacuum pressure. When the pressure rises to the upper set point, vacuum is introduced by either turning on the pump, or opening a solenoid valve that opens the connection between a continuously operating pump and the process. If the lower set point is reached, vacuum is interrupted by shutting off the pump or closing the valve. As a result, the actual vacuum oscillates around the target vacuum, rarely settling on the optimum conditions. Also, if the system does not respond quickly enough, bumping and product loss can occur from excess vacuum – the same problem characteristic of the fine vacuum pumps described earlier. Further, turning

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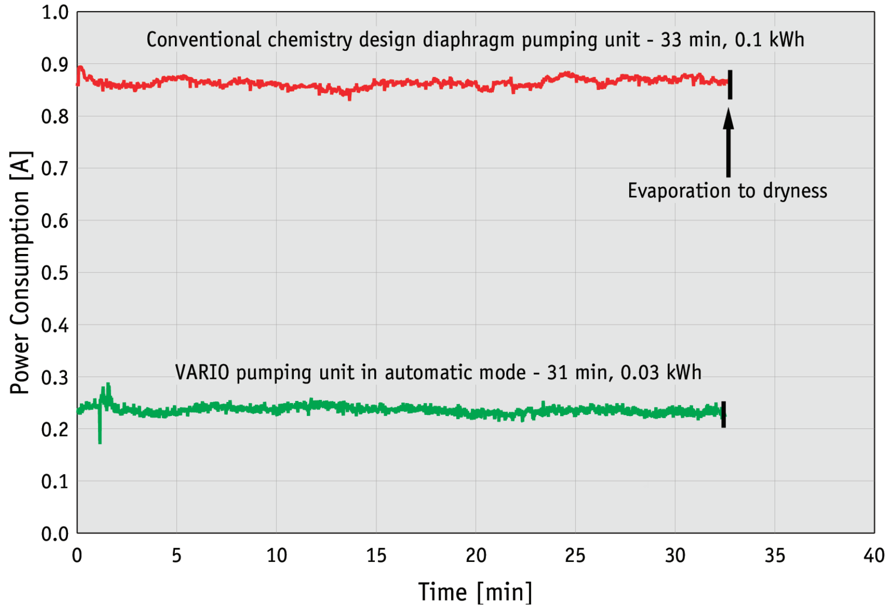
the pump on and off as a means of control can lead to premature pump failure.

Modern vacuum control of diaphragm pumps can be achieved by adjusting motor speed. Instead of relying on a solenoid to open and close, or repeatedly turning the pump on and off, the diaphragm pumps are operated at whatever fraction of maximum operating speed is needed to provide exactly the pumping needed to maintain optimum vacuum. With speed controlled vacuum, conditions can be continuously and instantaneously optimized. And unlike rotational technologies for producing vacuum, in which the ability to create vacuum collapses as the motor speed reaches some minimum point (often about half of the specified "free air displacement" speed), diaphragm pumps can effectively pump over virtually the entire range of motor speed. If 5% of maximum pumping speed is all that is needed to maintain optimum process conditions, the adjustable speed diaphragm pump can deliver just that.

The continuous optimization of vacuum provides several very positive contributions to operating economics, even beyond the inherent chemical resistance of the pump. In a pilot facility, the exacting control and computer interface can be a very efficient means to determine optimum conditions for later process operations. Lower average motor speeds further extend the service-interval advantage of diaphragm pumps, reducing maintenance interruptions and costs. The lower average motor speed also means the pumps use much less electricity – often as much as 70% less than fixed speed pumps. Continuous process optimization often results in shorter process times, further reducing run time against maintenance schedules and electricity use.

**Power consumption for evaporation of 500 ml ethanol at 50 °C in a rotary evaporator until completely dry**




The shorter process times may permit completion of more batch runs, or the use of smaller equipment, resulting in further savings. And the continuous, automatic operation may reduce staff oversight, improving facility productivity.

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## The perfect solution?

Confronted with all of these advantages, an obvious question is, “Why aren’t more industrial processes supported with diaphragm pump technology?” The answer is two-fold. First, as mentioned previously, certain operations require deeper vacuum than the diaphragm pump can provide. For these applications, reliance on alternative technologies – such as rotary vane, scroll, claw or liquid ring – may be needed. Second, the physics of the technology limits the size of diaphragm pumps, so they are not a practical way to produce vacuum for large processes needing very high pumping speeds. Maximum speed for a commercial, single-stage diaphragm pump is in the range of 12 cfm. When quadruplexed into a pumping station, speeds of up to 50 cfm can be achieved, with the full control capabilities, chemical resistance and service advantages previously described. This may be an appropriate capacity for a pilot plant, or for a specialty chemical or biotechnology facility, but may be insufficient to serve the needs of a full scale, commercial facility for pharmaceutical or chemical production.

## Summary

Chemical-resistant, diaphragm pumps offer a set of attributes that should make them a first choice for vacuum operations in pilot, scale-up and small process operations. Rugged reliability, low energy use, low service demands, and unsurpassed control capability can yield significant operating cost savings. The dry operation keeps oil out of facilities – food, biotechnology, pharmaceutical – in which cleanliness is a critical concern. At the same time, the pressure range of diaphragm vacuum pumps is an excellent match to the optimum pressure levels for many industrial vacuum processes.