Selecting Your Next Vacuum Pump

7 Questions to Help You Make the Right Choice

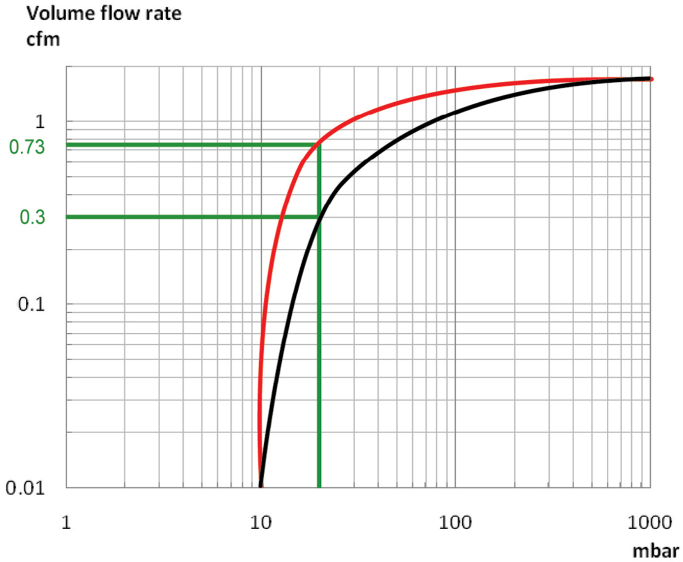
One of the most common questions we hear from our customers is, what pump do I need? The right answer depends upon a variety of factors, such as the nature of the process or application, the working pressure and/or flow rate required, the desired process time, if the pump will be exposed to aggressive chemicals, and what sort of process control is desired (manual, electronic, automated). This paper addresses each of these issues, in turn.

How much vacuum?

Step one in specifying a pump is to define how much vacuum you need. "Vacuum" in applied work simply means pressure below atmospheric pressure, so how much below atmospheric pressure is the key question, and determined by your process. Once you know the depth of vacuum needed, this will determine your technology options. Some technologies – such as diaphragm pumps – can support operations down to about 2 mbar, or about 0.2% of atmospheric pressure. This addresses common process such as filtration, degassing, drying, and many distillations, as well as roughing for many turbomolecular pumps, but is not deep enough for applications like freeze drying. Operations that require deeper vacuum will have to rely on alternative technologies such as rotary vane, screw, or scroll vacuum pumps. Vacuum for analytical instruments often demands turbomolecular pumps for their high and ultrahigh vacuum capability.

How much pumping speed?

Rated pumping speed (aka, flow rate, free air displacement), when referring to vacuum pumps, means the amount of air a pump can move *when not producing vacuum*. This last phrase is critical, because in most applications you need to move air, gases or vapors under vacuum conditions. The rated pumping speed is the maximum flow that the pump produces, which occurs when the pump generates the minimum pressure differential between its inlet and outlet. The pumping speed you need is not the one provided by the pump's specification; it's the pumping speed at the working vacuum of your application. The only way to learn that is to check the pump's performance curve, or ask your manufacturer's rep. Get this wrong and your process may take a lot longer than you anticipate.



Two pumps with identical specifications can have markedly different pumping speeds at the working vacuum of 20 mbar.

With that in mind, we have put together two different calculators to help size pumps for applications like vacuum drying or solvent stripping. Generally speaking, these applications all center on the idea of inducing a solvent or mixture of solvents to evaporate at reduced temperature by pulling a vacuum. One calculator can be used to estimate how long a process will take for a given pumping speed; the second calculator estimates what flow rate is needed to complete a process in a given period of time. Both calculators provide first-order estimates based on the ideal gas law and a few process-specific parameters.

Another common application for vacuum pumps is to simply pump down a chamber in order to establish a vacuum level, where there are no vapors being generated. This process sounds like a relatively simple calculation would be sufficient - where the flow rate would simply equal the volume that needs to be pumped out divided by time.

But it turns out that, because the volume of gas varies with pressure, the math is a little more complicated. You have to modify the "flow rate = volume / time" equation by multiplying by the natural log of the pressure ratio. To help, we have developed another calculator intended to help estimate the pumping speed needed to evacuate a vacuum chamber. Based on the volume of the vessel that is to be evacuated, the desired pump down time, and the vacuum level you want to get down to, it will calculate the pumping speed required. If you know the leakage rate of your system, you can also factor that in.

As helpful as these calculators may be, it's always best to check with the manufacturer of the pump you are considering to make sure you have enough pumping speed at your working vacuum.

What about reliability?

There are a number of more subjective issues that should also be considered when evaluating vacuum pumps. For example, the durability of the pump and its maintenance requirements have significant impact on both maintenance costs (parts, labor) and future equipment costs (pump life and subsequent replacement pumps). By virtue of their design, some pumps require regular maintenance and rebuilds whereas other types of pumps are relatively low maintenance and durable. The pump's wetted materials significantly affect the durability if the pump is exposed to aggressive gases and chemical vapors. The type of pump selected can also result in large differences in operating costs (electricity, water, disposal charges for water/oil, etc.)

Other dry pump technologies can provide deeper vacuum than diaphragm pumps, but may be more vulnerable to corrosion because the wetted surfaces are steel, and thus vulnerable to corrosion. Technologies that address this susceptibility to chemical attack with a corrosion-resistant coating may help for a time, but may require periodic recoating, which can be costly. Liquid-sealed pumps may be able to tolerate aggressive conditions, provided that they receive regular maintenance, which may be costly in itself, with the added cost of disposal of contaminated sealing liquids.

Sensitive process?

When evaluating different pumps, one step is be to be sure that the pump technologies you consider will be compatible with your process. Many processes - manufacturing of APIs, for example - are highly sensitive to contamination, whereas other processes are less so. When used in sensitive operations, liquid sealed pumps often require additional equipment to prevent back-streaming which contaminates the product. Some liquid-free pump technologies eliminate the risk of liquid back-streaming but may produce particulates, or are much more sensitive to corrosion. In contrast, a diaphragm pump allows for a relatively simple installation as no additional equipment is need to prevent backflow, and these pumps don't generate particulates.

Constant or changing conditions?

Picking the right pump for your operations also includes consideration of whether you just need the full, design vacuum level of the pump, or whether you need to set the vacuum to a different level or a range of values. Unless you are using vacuum for uncontrolled evaporation, it's important to recall: the best vacuum for your application is not the deepest vacuum; it's the right vacuum level. Vacuum that's insufficient may significantly extend process times. Vacuum that's too deep may cause foaming or bumping, or evaporate process liquids you want to collect or merely transfer. To get the right vacuum, you may need a pump with vacuum control.

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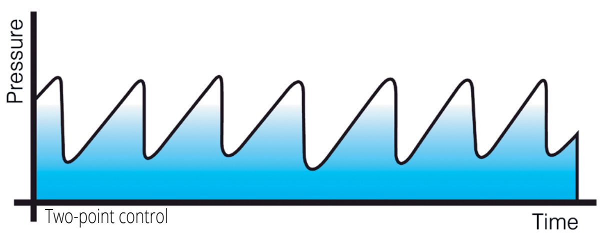
Most vacuum control is accomplished in one of two ways:

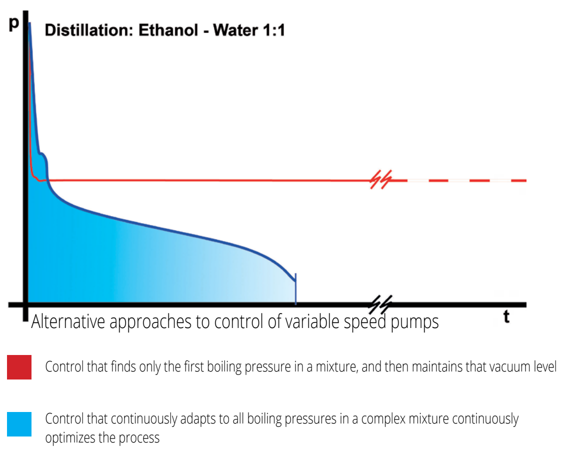
- Two point control, in which the vacuum supply is interrupted either by turning a pump on and off or using a solenoid valve to interrupt flow when the pump reaches the set vacuum level; or,
- Variable pumping speed, in which the motor speed is ramped up to pump down quickly when needed, or slowed to maintain desired conditions.

Both approaches to control can deliver the required vacuum, and even permit programmable vacuum conditions with multiple steps when needed. Two-point control sets an upper and lower bound around the target vacuum condition, and resumes pumping when the pump reaches the upper bound and discontinues pumping at the lower bound. Turning a pump on and off to control vacuum levels is often the cheapest approach to control, but can be very hard on the pump over time. Using a solenoid valve to make and break the vacuum connection as the pump operates at a fixed speed is easier on the pump, and provides a reasonable level of control for a multi-step process, or one for which the desired vacuum level is different from the ultimate vacuum rating of the pump.

Variable pumping speed can provide more precise control of vacuum, save considerable energy compared with fixed speed pumps, and virtually eliminate the hysteresis – the fluctuation between the upper and lower bounds in two-point control. For critical processes, where precise vacuum conditions are necessary to protect process materials or accomplish other process objectives, pumps with variable speed motors can be an excellent choice. Unfortunately, while this approach works exceptionally well with diaphragm pump technology, not all pumping technologies can make most effective use of variable speed control. At a certain reduced speed with some pump technologies, pumping can collapse altogether when motor speed drops below, say, 50 percent of nominal pumping speed.



Two-point control



Alternative approaches to control of variable speed pumps

Corrosive conditions?

Another aspect of process sensitivity is its corrosiveness. If your process involves corrosive vapors, a dry pump with a fluoropolymer flow path will provide much better corrosion resistance than oil-sealed or water-sealed pumps with much less maintenance, since the exposed surfaces are inherently chemical resistant. Diaphragm pumps will typically offer the best chemical compatibility, provided they can reach the vacuum depths and pumping speeds you need.

Even among dry, diaphragm pumps there are differences in chemical resistance. The thickness of the protective layer, and the support system for the fluoroplastics that provide the protection, both contribute to the durability of the pump when pumping corrosive vapors. These design differences may show up in the pump pricing, but provide the pump with much better resistance to abrasion from crystalline materials or other particulates that find their way into the gas or vapor stream being pumped. These are all aspects of the pump design you should discuss with your manufacturer should you choose diaphragm pump technology for corrosive vapors.

Significantly different thickness of chemical-resistant material (black layer) in components from two dry pumps that claim chemical resistance. The pump with the thicker layer will have better resistance to corrosion.

How noisy will it be?

Noise generated by equipment can be quite disruptive and make for a challenging working environment - especially in scale-up or lab settings. While many people think of all vacuum pumps as very noisy, some types of pumps are inherently noisier than others, and different design priorities can lead to quite different noise levels even within a pump technology group. Selecting a quieter pump that meets the performance specs can have a meaningful impact on the background noise in a facility. For example, all things being equal, a diaphragm pump will generally be quieter than an equivalent piston pump. Additionally, well-designed pumps tend to run more quietly and more efficiently. Finally, by ensuring that the pump is installed properly, and that air leakage into the vacuum lines and pump is minimized, pump noise level can be further mitigated.

Summary

Because it's often difficult for customers to gather all of this information, we strongly recommend that customers work with manufacturers to size a pump for their particular needs. As helpful as an online pump selection guide can be, sometimes there is no substitute for speaking with an expert who specializes in the technology to make sure that you get a pump for your needs. With a brief conversation or a quick email exchange, an experienced vacuum specialist can typically whittle down the options to a small group of pumps for your consideration, and guide you to the right pump.