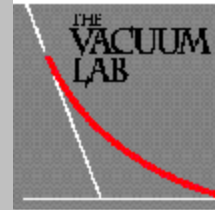


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## How To Choose a Roughing/Backing Pump for the Turbo and Drag Family

The process of choosing the right high vacuum pump to suit any particular application is often a time-consuming and difficult exercise with any number of product comparisons and usually a series of performance vs. economy trade-offs. By the time the choosing process has been finally completed, having to make a choice of a roughing/backing pump to go with it is often seen as anticlimactic and of secondary importance. This can be a mistake. Using the wrong roughing/backing pump can easily negate all the careful work that went into choosing the high vacuum pump by causing it to operate outside its maximum performance envelope. The continued difficulty in choosing a roughing/backing pump is not aided by many of the high vacuum pump manufacturers because their literature focuses on their pump with often little apparent concern with the backing pump's required operating parameters. Since both pumps are required to work together to produce a pumpdown cycle that meets the process's requirements, it is imperative that the roughing/backing pump be matched to the high vacuum pump and the process with both care and diligence.

The term roughing/backing pump is used because the pump is required to perform two fairly distinct operations. The pump has to, first, rough pump the chamber from atmospheric pressure to a low enough pressure to allow the high vacuum pump to operate, and then it has to revert to a secondary position where it supports the high vacuum pump by providing a low enough pressure at the high vacuum pump's outlet or exhaust. Probably the most significant consideration is in its backing role. a turbo, turbo/drag, or drag pump will only operate within a particular pressure envelope. The pump's inlet pressure must be low enough that the pumping arrays, be they rotor/stator as in a turbo pump or drum or disc as in a drag pump, can impart motion to the gas molecules to be pumped. Those molecules are then to be compressed through the pump and exhausted at some other reduced pressure where the backing pump removes them into the atmosphere. This exhaust pressure, usually called foreline pressure, must be low enough that the high vacuum pump can compress the gas entering the inlet to its rated efficiency. There is a wide variation of both inlet and exhaust pressure parameters from type-to-type and individual designs within a given type. This requires careful checking of the operating parameters and requirements listed in the manufacturers' literature. This means that

it is an important consideration that the backing pump must be able to maintain a low enough backing pressure during pumpdown and meeting any process gas load.

The roughing role is probably the simplest and most straightforward to think about. The term “roughing” is a historical leftover from the days when vacuum practitioners talked about “rough” and “fine” vacuums. Since, at that time, they also talked about a “perfect” vacuum, it’s easy to see just how old the term is. Roughing down the chamber to the operating inlet of the turbo or drag pump can be done in two ways. The roughing pump can be connected to the chamber through a separate pumping line and valve and the chamber pumped down to the specified pressure before the valve is closed to terminate the roughing part of the pumpdown process. At this time, a valve is opened to the high vacuum pump’s inlet and the roughing/backing pump’s inlet is valved into a line on the high vacuum pump’s exhaust. This provides an efficient roughing process since the roughing line can be optimized, but it has the disadvantage of requiring a complex set of plumbing and valving. One advantage of using turbo or drag pumps is that they can be used as part of the roughing line itself. That is, the roughing process can be carried out directly through the high vacuum pump and no valves are required. With today’s pump designs, this is the most common type of installation.

### Glossary

**Backing:** The support Role of a pump used to maintain a specified pressure at the exhaust of a momentum transfer high-vacuum pump.

**Compression ratio:** The ability of a momentum transfer high-vacuum pump to compress a gas, which is often stated as outlet pressure/inlet pressure.

**Exhaust pressure:** The pressure at the outlet fitting of a momentum transfer high-vacuum pump.

**Foreline:** The tubulation between the outlet fitting of a momentum transfer high-vacuum pump and the backing pump supporting it.

**Free air displacement:** The volume of air per unit time passing through a pump with the inlet and outlet both at atmospheric pressure.

**Gas ballast:** A small amount of gas allowed to bleed directly into a pump to help carry away condensed gases, such as water or volatile solvents.

**Inlet pressure:** The pressure at the inlet fitting of a momentum transfer high-vacuum pump.

**Momentum transfer pump:** A pump that compresses gases by imparting motion to the gas molecules to be pumped by striking them with a moving object, such as a rotating blade or surface.

**Roughing:** The first part of a pumpdown from atmospheric pressure intended to produce only a "rough" vacuum.

Roughing directly through the turbo or drag pump can be simple in terms of hardware simplicity, but it can also present some performance problems. None of these pumps are open tubes in terms of gas conductance. The inside of the pump’s housing is literally filled with either rotor/stator pairs or drag arrays, and this provides a sometimes severe constriction to gas flow. This can result in any advantage expected from a very large roughing pump, in terms of producing a faster roughing cycle, can be lost due to restriction losses alone. This can be a difficult design/choice problem since manufacturers’ literature never seems to address this problem by providing a conductance parameter for roughing. This is borne out by the common

observation, in the field, of a 17 CFM (free air displacement) roughing pump backing a turbo pump that has only enough conductance for 5-7 CFM effective pumping speed. This restriction problem is sometimes dealt with by providing a secondary line and valve so that the roughing can be carried out both through the turbo or drag pump and the secondary line at the same time in a bypass mode. Although the secondary line's valve can be manually operated, it is usually provided with a simple pressure switch to close a solenoid or electropneumatic valve when the pressure is low enough to operate the turbo or drag pump. If the secondary line is properly designed in terms of length and diameter, the full pumping speed of the roughing pump can be achieved.

Backing performance is usually much more important in terms of choosing the right pump than is roughing performance. When the roughing part of the pumpdown is completed, the roughing/backing pump's role changes drastically. Since it is now operating in back of the turbo or drag pump, the term "backing" is obvious. Both pumps are now operating together in series, and although the backing pump is now in a secondary position, its performance is almost as important as the high vacuum pump. Misuse of the term "backing" has led to a misunderstanding of the pump's importance. In the application of capture pumps such as sputter-ion, getter, and cryogenic pumps that require a chamber to be roughed before they are used, the roughing pump is often erroneously referred to as a backing pump. This misuse of terminology tends to produce a feeling that the backing pump, when the term is correctly used, is of peripheral importance. Not so! The backing pump must provide enough pumping speed and throughput to maintain the required foreline pressure to assure that the high vacuum pump meets its performance requirements. Any of the turbo or drag pumps on the market have a compression ratio between the inlet and exhaust that can be achieved only if the exhaust pressure is maintained at or below a specified pressure for that particular pump. This means that a careful perusal of the backing pump's pressure vs. pumping speed curve is required.

In the days when the only roughing pumps available were oil-sealed mechanical pumps, the pumping speed specifications for their use as backing pumps was a great deal simpler. All that was required was to look at the pumping speed specification on the data sheet. Since this was given in free air displacement, it was relatively straightforward since all oil-sealed mechanical pumps had roughly the same performance curves. With the proliferation of various types of oil-free pumps in recent years, the choice of pump, in terms of pumping speed, has become more complex. Since all roughing/backing pumps drop off in pumping speed as the pressure drops, the actual shape of the pressure vs. pumping speed curve becomes important. Each type of pump will usually have a different curve even though the free air displacement might be the same. The important factor is to be sure that there is enough pumping speed and throughput at the specified exhaust pressure to maintain that pressure. The flip side of this observation also comes into play in that although a tiny diaphragm pump might well have enough speed to maintain the required pressure for backing when the gas load from a chamber at

high vacuum is presented to it from the high vacuum pump's exhaust, it might not have enough high pressure pumping speed to rough out that same chamber in an acceptable time. This means that the whole curve needs to be taken into account when making a choice.

The oil-sealed or oil-free choice is also an important consideration. Oil-sealed mechanical pumps have been used successfully in roughing/backing applications for turbo and drag pumps. They are reliable and generally less expensive than oil-free pumps, but they are a potential source of hydrocarbon contamination. Mechanical pump oil, backstreaming from the pump into the process chamber, can be a process killer for many stringent applications. In such cases, prudence often dictates that oil be entirely excluded even though there are techniques to help avoid oil contamination. For example, a system that might seem to require a magnetically levitated turbo, to avoid any possible oil coming from oil-lubricated turbo bearings, would probably exclude the use of an oil-sealed backing pump when the initial requirements were specified. Obviously, in such cases, an oil-free roughing/backing pump would be a better choice. The choosing process immediately becomes more complex due to the number of oil-free pump types now commercially available. The actual choice of pump type isn't as important as it is to match performance through careful study of the pumps' pressure vs. pumping speed curves. As long as enough speed and throughput are available, the pump type isn't as important as it's performance. Other considerations such as price, reliability, and general market acceptance are important but must be viewed in a different context than the performance requirements under discussion here.

One other consideration that is sometimes discussed in manufacturer's literature is the effects of water vapor and how to deal with it. Any vacuum pump is also a compressor, and compressing gases containing condensable gases such as water vapor causes condensation of those gases within the pump. Since ambient air always contains some water vapor, the roughing/backing pump will condense a certain amount of water vapor or other condensable gases within it as the pumped gases flow through and are compressed. The effect of the presence of these condensed gases is often seen as a pressure rise, or limit, in the pump's inlet due to re-evaporation due to heat from the pump's mechanical action. This can result in a pressure that is too high for the turbo or drag pump's exhaust to tolerate to achieve full performance. If a backing pump, then, has just enough pumping speed available to support the turbo or drag pump, it will not be able to support it when an additional pressure from condensed water vapor is added to the mix. This can be especially true when a system is subjected to short cycle times as might be seen with a load lock where a large number of pumpdown cycles will be performed and the water vapor from each pumpdown will add its load to the pump. The roughing/backing pump must either have a reservoir of low pressure pumping speed or be provided with a gas ballast to strip water vapor from the pump.

The choice of the right roughing/backing pump can be difficult when it must be matched to the turbo or drag pump as well as the application. A systematic consideration of the pump's performance characteristics and a reasonable amount of care can allow a successful installation that takes advantage of the entire pumping system's performance.

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