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Sorting Out the Turbo, Drag, and Turbo/Drag Pump Family

A great deal of innovative progress has been achieved, in recent years, in the pumping technology associated with turbomolecular-type pumps. As with all periods of rapid technological advance, confusion tends to become endemic since it takes a finite period of time for new categories and terminology to become established. Manufacturers' literature doesn't always make it clear which type is offered on a given data sheet or catalog page. Additionally, there are variations in terminology and nomenclature that add to the confusion.

At present, there are two distinct pump types and one combination of the two that need to be clearly differentiated, both one from another and in general. These pumps can be grouped as a family. Since their performance characteristics are not the same, the application of the wrong pump in a given application or process can easily lead to a relative disaster.

The three pump types that make up the family are:

1. Turbomolecular Pumps,
2. Molecular Drag Pumps, and
3. Turbo/Drag (AKA hybrid or compound) Pumps.

There are several points to keep in mind while comparing and differentiating these pumps. First and foremost, they should all be considered to be compressors, but compressors that operate only within a set of parameters consisting of permissible inlet and outlet pressures. This means that both the pump's inlet and outlet must be below a certain pressure to operate. These conditions require that an auxiliary pump be provided to first, lower the inlet and exhaust pressure to the point where the primary pump can operate, and secondly, to maintain a low enough exhaust pressure for the primary pump to operate efficiently once the inlet pressure is low enough. Since the pump is compressing the gas that flows into the inlet, it becomes concentrated at the exhaust. This is usually done by plumbing a roughing/backing pump to the primary pump's exhaust and then pumping (roughing) the chamber initially through the primary pump until the pressure is low enough for the primary pump to operate. At this point the auxiliary pump takes on a support pumping (backing) role.

One important point that is often ignored is that the pumping arrays within the body of the pump fill most of the space and act as constriction to high pressure gas flow during the roughing period. The degree of flow constriction has the obvious effect of slowing the roughing period to an extent that depends upon the particular and specific pump design. This information is seldom given in the manufacturers' literature, if it is given at all. The degree of constriction will have a significant effect upon the total pumpdown time to high vacuum.

The reason for belaboring these points is that each type of pump will have different requirements for roughing/backing pumps. The same considerations will come into play when evaluating their varying abilities to handle process gas loads in addition to the simple requirement of pumping a chamber down from atmospheric pressure.

The other points to keep in mind are the actual compression ratios of the pumps for the various gases encountered in a particular application. Compression ratio can be defined as the ratio of inlet to exhaust pressure, and this varies with pump type.

One source of confusion in the differences of these pumps is that they tend to look alike from the outside. The inside, though, is where the crucial differences reside. Here's the difference.

Turbomolecular Pumps

The turbomolecular pump has been available for many years and is classified along with diffusion pumps as momentum transfer pumps. In its simplest form, the turbo pump is a rotating circular disk with a number of angled blades machined into it. As the disk rotates, the blades impact the incoming gas molecules and transfer the mechanical energy of the blades into gas molecule momentum that is directed from the inlet through a fixed stator with gas transfer holes. In a practical pump, there are a number of alternating rotor, stator, rotor, etc., stages arranged along a drive shaft rotating at speeds up to 90,000 rpm.

The gas is then compressed from stage to stage through the pump to the exhaust port, where it is drawn off by the backing pump which is tasked with maintaining a particular exhaust pressure. In general, this pressure must be below 100 millitorr with 10-20 millitorr as common averages. Turbomolecular pumps are easily capable of pumping into the 10^{-10} torr range on a suitable system.

Molecular Drag Pumps

Molecular drag pumps vary from turbo pumps in that the momentum transfer from mechanical motion to gas motion is not by impact but by imparting the motion of a rapidly rotating solid surface to the gas molecules between a fixed and rotating surface. One can say that the molecules being pumped are literally dragged along the surface, hence the term, molecular drag pump. These surfaces can take the form of a rotating spiraled drum (Holweck) or slotted rotor discs (Gaede). Both types are commercially available at this time.

A particular performance difference between molecular drag pumps and turbo pumps is that a drag pump will start pumping at a higher inlet pressure (several torr) and does not require as low a backing pressure (3-25 torr) for full operation. In general, commercially available molecular drag pumps will only reach an ultimate pressure of 10^{-6} torr or slightly below due to the practical impossibility of providing even smaller and closer clearances between the moving and fixed surfaces. Additionally, molecular drag pumps will have a much lower pumping speed (roughly 1/8-1/3) than a turbomolecular pump with equivalent inlet dimensions.

Turbo/Drag Pumps

Turbo/drag pumps are an elegant design compromise between turbomolecular and molecular drag pumps. Essentially, they are a combination of both turbo and drag pumping elements mounted on a single shaft and driven by a single high speed motor and a single power supply. This is really a case of attempting to get the best attributes of both types of pump at the same time and in the same package. For most applications, this is successfully achieved.

The rotor/stator arrays for the turbomolecular part of the pump are located just inside the pump's inlet while the molecular drag part is located closer to the exhaust. In operation, the molecular drag stages will begin to pump at a higher pressure than would be possible with a straight turbo pump. When the drag stages are beginning to pump, the turbo stages are doing little or no pumping. They are just waving in the breeze, but as the drag stages reduce the pressure at the inlet to below 1 torr or so, the turbo stages begin to pump. At this point in the pumpdown process, the drag stages take on more of a support role in that they provide a low backing pressure for the turbo stages even though an auxiliary backing pump is still required.

This elegant compromise plays out to provide both the turbo pump's ability to provide a low ultimate pressure along with the drag pump's ability to operate with a higher backing pressure. This allows a diaphragm or piston type oil-free roughing/backing pump to be used which solves a number of application problems in terms of both cleanliness and pump size.