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From THE VACUUM LAB

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Making the Oil-Sealed vs Oil-Free Decision

The subject of vacuum pumps is an ongoing favorite topic of discussion with vacuum practitioners. In fact, calling it a discussion is often an understatement. The topic is often replete with red faces, raised voices, and flailing arms. This is not a new phenomenon. As vacuum technology has grown, over the years, new pumps have become available and each one has required a good deal of discussion to come anywhere close to pinning down its strengths and weaknesses along with good, bad, and marginal applications. Over the last decade, the once ubiquitous oil-sealed (OS) mechanical rotary pump used for roughing and/or backing applications has come under ever increasing suspicion. Based on the concept that hydrocarbon contamination is a problem for most vacuum processes, it would seem to be a simple move to avoid the problem by doing away with the OS pump. This, seemingly obvious solution, would then indicate that the vacuum practitioner would only need to replace an OS pump with an oil-free (OF) pump to force all those pesky hydrocarbon-contamination problems to go away forever. As you might expect, it's not all that simple. Making the final decision really requires a series of decisions that will lead to the best solution for your system and your process.

First, though, we need to be clear on terminology. Sloppy nomenclature and terminology often creep into use during the early stages of a new technology. This is the situation we find ourselves in at present when we try to communicate on the subject of pumps. The terms 'dry' and "wet" tend to be used with little thought about what they really mean. If you ask around, you'll probably find that "wet" means OS and "dry" means OF. If that's the case, water-ring, water-aspirator, and steam-jet pumps would be "dry" since they are definitely OF. The point is that the subject is complex enough without compounding the communication problem with confusing nomenclature and terminology. Hence, OS and OF would seem to simplify the communication process.

Sorting Out the Pumps

Oil-Sealed Pumps

Rotary Vane	Rotary Piston

Oil-Free Pumps

Diaphragm	Blowers
Piston	Hook and Claw
Scroll	Screw
Molecular Drag with Backing	

The first major decision point is to decide whether you need to protect your process from the pump or to protect the pump from the process. Oil vapor, backstreaming from an OS pump can easily migrate into the process chamber by several mechanisms. If the amount of migrating hydrocarbon is too much for the process, it's necessary to protect the process from the pump. If, on the other hand, the process uses or generates gases that will react with the pump's oil, it's necessary to protect the pump from the process. In fact, some processes will have both problems at once to deal with. In either case, it would seem, at first blush, that the obvious solution would be to replace the OS pump with an OF pump. The decision shouldn't be taken or made that lightly. Rotary vane and rotary piston OS pumps have been on the market for decades, and their designs have been refined to the point where possible improvements are now approaching the zone of diminishing returns. The point here is that there are obvious advantages to using an OS pump if at all possible. Before making the decision to replace it with an OF pump, the application should be analyzed to determine if an OF pump is really required. In many cases, the addition of ancillary equipment or a simple change in operating technique might offer enough protection,

Protecting the pump from the process is required when the process either uses deliberately introduced gases or materials that will harm either the oil or the pumps itself. Additionally, the process might produce gases or particles that will cause harm to the pump. These considerations range from utterly simple to extremely complex. A simple situation might be a process that removes large amounts of condensable gases such as water vapor or solvents that would condense within the pump, dissolve in the oil, or physically displace the oil entirely as the gases are compressed during the pumping process. A simple cold trap, interposed between the process chamber and the pump to condense these gases might suffice to keep them out of the pump. Conversely, the best move might be to allow the gases to condense within the pump, and to use of the pump's gas ballast valve to bubble a dry gas through the oil to sweep the condensate out of the pump. The situation changes drastically if gases that might react with the pump's oil are to be pumped. The solution ot this problem might be as simple as changing to one of the inert pump oils such as Fomblin or Krytox.

Some incoming gases can be trapped before they enter the pump. In some of today's processes, condensable gases come out of the process chamber that will condense into solids at such a high rate that the condensate can literally close off the pumping line unless the line is heated. If the gas is allowed to enter an OS pump, the condensate will freeze up the pump almost instantly. A trap can be interposed between the pump and the pumping line to allow the condensate to form in the trap. Here we encounter another terminology problem because these traps are sometimes called sublimation traps. The term "sublimation" is most often used, in vacuum technology, only to describe the conversion of a solid directly to a gas without passing through the liquid state. If you shop round through enough definitions, you will occasionally find the term used to describe condensation to a solid state as well, but using it in this way in vacuum technology actually causes a good deal of confusion.

Particulate matter can be a problem if allowed to enter a pump. Traps that can be interposed between the pump and the chamber to physically trap particles are commercially available. Oil filtration systems, in many configurations, that continually filter the oil are also available. Safety considerations are also important. For example, hot pump oil and oxygen or ozone can detonate.

If an analysis of the process won't allow any of the above options to be applied, the possibility of substituting an OF pump for an OS pump needs to be seriously considered, but the disadvantages of the presence of oil should be weighed against some of the advantages of using the OS pump in the decision process.

Protecting the process from the pump is not necessarily a mutually exclusive consideration since a process that might produce harm to the pump can also be harmed by pump oil. It's more common, though, to find that oil, emanating from an OS pump, can harm a process if the oil is allowed to enter the process chamber. There are two ways in which oil can be transferred to the chamber. One is by surface creep along the inner walls of the pumping line, and the other is by oil vapor backstreaming into the chamber. If the process is sensitive to hydrocarbon contamination, there are some remedies to prevent oil transfer.

A backstreaming trap can be interposed between the pump and the chamber. Commercially available traps include cryogenic, absorption, and adsorption trapping mechanisms. The idea is to stop and hold any backstreaming oil vapor in the trap. All three types will do that effectively, but there are still concerns to deal with. A cryogenic trap will usually consist of a liquid nitrogen (L/N_2) container within a housing. The L/N_2-cooled surface will condense oil as a solid, but it will also freeze out water vapor entrained in the gas flow during pumpdown. In time, the L/N_2 surface will build up a thick enough coating of oil/water ice to touch the inside of the housing to create a thermal short condition and the coating will start to warm up and sublime. As sublimation continues, both water and oil vapors will re-enter the pumping line in both directions, and contamination with oil vapor will probably occur. The same problem can occur if the liquid level of L/N_2 is not maintained. When a cryogenic trap approaches saturation, it must be removed from the pumping line and allowed to warm up in air or contamination will occur. Absorption traps most commonly use a mesh container of molecular sieve within a housing. The backstreaming oil vapor will be easily absorbed into the pores of the molecular sieve. Molecular sieve will also absorb water vapor, and it will selectively absorb water over oil. This is not a problem until the material is approaching saturation, and the absorption of more water vapor will cause desorption of oil vapor. A built-in regeneration heater is usually provided to regenerate the sieve material, but if the heater is used while the pump is in operation, oil vapor can pass upstream toward the chamber as easily as into the pump. This means that the operator really should remove the trap from the pumping line for either regenerative heating or replacement of the sieve. Adsorption traps, usually copper wool, depend upon the oleophilic nature of the metal surface to sorb the backstreaming oil. When nearing saturation, the trap must be removed from the pumping line for solvent cleaning.

Although these traps can be used effectively, there is no room for error in their operation. One mistake can result in an oil-contaminated system. Another potential problem is that all three types often have a room temperature surface, usually the trap housing, that can serve as an oil-creep surface to allow oil to pass through the trap. These problems are often exacerbated by allowing the OS pump to operate continually. The longer the pump's inlet is maintained at molecular flow conditions, the more oil transfer will occur. Cycling the pump on and off, as required by the process, will help reduce oil transfer. The use of high quality vacuum-distilled oils that have a low vapor pressure is also a worthwhile precaution.

If, after a review of the available protection options, there is still concern about either the process harming the pump or the pump harming the process, it becomes necessary to make the OS vs OF decision in favor of OF pumps. This first-stage decision leads directly into another complex decision stage. Which OF pump is best for the process? There is a large number of OF pumps available on the market that use different pumping mechanisms, and all of them might work well for one application while they might not work either well or at all for another. Choosing the wrong type can be a disaster, but it is well worth the trouble to work your way slowly through the various pumping options before making the final decision. It's a long decision path, but it must be followed if the right solution to the OS vs OF decision is found.