

SVC Topics

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PVD Processes: Mechanical Vacuum Pumps

Mechanical pumps are positive displacement pumps that take a large volume of gas at low pressure and compress it into a smaller volume at higher pressure. Some mechanical pumps can be used as air compressors. The earliest vacuum pumps were mechanical pumps—Gaede developed a mechanical pump in 1905 that is very similar to the oil-sealed rotary vane pumps used today.

Many mechanical pumps have multiple stages that operate from a common motor and shaft. These pumps can be either belt-driven or direct-drive. Some direct-drive pumps can be disassembled by separating the pump from the motor, leaving the manifolding on the system. This is particularly useful when pumping hazardous gases, so that the pumping manifold can stay sealed while changing the pump motor.

Mechanical pumps are used to "rough" a vacuum system from atmospheric pressure through the viscous flow range to a low pressure (~100 mTorr), where the system is switched to the high-vacuum pumping system. By using only the mechanical pump in the viscous flow range, backstreaming of oils from the mechanical pump into the vacuum system is minimized. Appropriately sized, zeolite-containing oil traps can be used in the roughing line to further minimize oil backstreaming.

Mechanical pumps are used to "back" high-vacuum pumps, and the pumping capability should not be restricted by the conductance between it and the high-vacuum pump. The mechanical pump is connected to the high-vacuum pump using a foreline manifold. The foreline pressure on the diffusion-type high-vacuum pump is an important factor in contamination control. If it is too high, backstreaming from the diffusion pump into the processing chamber occurs. If it is too low, backstreaming of oil from the mechanical pump into the diffusion pump occurs.

Oil-sealed Pumps

The most common mechanical pumps are oil-sealed, such as the rotary vane pump shown in the figure. The vanes are held in contact with the wall by the action of the spring. These pumps are available to about 100 ft³/min pumping capacity. When oil-sealed mechanical pumps are used with chemicals, or when particulates are formed in the processing, oil filtration systems should be used to filter out particulates and neutralize acids in the oil. The pumps can be air-cooled or water-cooled, and the system can include an oil cooler.

Many mechanical pumps are equipped with a ballast valve to allow the introduction of dry, diluent gases (*e.g.*, dry nitrogen or dry air) directly into the pump intake, as shown in the figure. These diluent gases reduce the partial pressure of condensable vapors so that liquids do not condense in the pump.

When pumping corrosive materials, the internal parts of the pumps can become corroded, so the internal surfaces should be continuously coated with oil by a splashing action, which is achieved by having a highgas throughput, using the ballast valve. In addition, the pump should be run "hot" in order to help volatize



Mechanical pumps.

liquids in the oil. Contaminant fluid in the pump oil degrades the performance of the pump to the point that the lowest pressure attainable is the vapor pressure of the contaminant fluid. Fluids in the oil also cause frothing, which results in sealing problems in the oil-sealed pumps. Frothing can be observed through the oil level viewing window.

Mechanical pumps generally use hydrocarbon oils for sealing. When pumping reactive chemical species, hydrocarbon oils may be easily degraded. The perfluorinated polyethers (or PFPE, which contain only fluorine, oxygen and carbon) may be used to provide greater chemical stability, although these pump oils have inferior lubricating properties compared to the hydrocarbon oil. When using this type of oil, the mechanical pump may have a sump heater to decrease the viscosity of the oil, particularly for start-up.

If the mechanical pump stops turning because of power failure, a belt break or a bearing seizure, the pump may "suck back," bringing air from the high-pressure side back through the pump. This will suck some of the oil out of the pump into the foreline. This can be avoided by having a "suck-back" valve in the pump, or by having a ballast valve or orifice in the foreline that brings the foreline up to pressure without having to suck back through the pump (failsafe design).

The temperature of the pump should be monitored and overheating should be detected and alarmed. Oil levels in mechanical pumps should be routinely checked and periodically changed, and vibration from the pumps should be isolated from the vacuum system by means of flexible connections.

The mechanical pump is typically exhausted outside the building. The exhaust manifold of the mechanical pump should not introduce a backpressure during start-up, and should be sized accordingly. The exhaust line should have an oil "demister" that condenses oil vapor in the exhaust line and lets it flow back into the pump.

Some vacuum processing, such as etching, can generate hazardous gases that can condense in the pump oil. A chlorine-containing gas, along with water or oxygen, for example, can produce phosgene (COCl₂)—a poisonous gas. If the pumps are used to pump hazardous materials, the pump oil should be treated as hazardous waste and disposed of accordingly.

Oxygen is used in some PVD processing. Compression of pure oxygen, in contact with hydrocarbon oils, may cause an explosion if there is a hot spot in the chamber. A lessexplosive gas mixture, such as air, should be used whenever possible. Alternatively, a ballast valve or ballast orifice can be used to dilute the gas mixture to a less-explosive composition, and/or oxidationresistant pump oils can be used.

Dry Pumps

Higher pumping speeds are provided by single- and multi-stage "blowers," which use close mechanical tolerance for sealing. The most common types are the "Roots" (lobe) blowers and "claw" blowers shown in the figure. Other types of pumps, such as screw, scroll and piston, are also available. These pumps are sometimes called "dry pumps," because they do not use oil for sealing. Dry pumps often use oil-lubricated bearings, however, so they are not really oil-free, but they minimize the potential of oil contamination in the deposition system.

Dry pumps are more tolerant of particulates and vapors than are the oil-sealed mechanical vane pumps. They may have gas-injection ports to allow purge gases to be introduced to aid in sweeping particulates through the pump. The temperature of a blower pump should be monitored and overheating should be detected and alarmed. When oil is used to lubricate the bearings, the oil level should be routinely checked and periodically changed.

Blowers generally do not exhaust to atmospheric pressure because

compression of large amounts of gas to high pressures leads to extensive heating. Mechanical pumping packages are available that have a blower backed by an oil-sealed mechanical pump capable of pumping rates of greater than 10,000 ft³/min. Often the pumping chamber of the dry pump becomes contaminated with oil from the oil-sealed mechanical pump, thereby becoming "less dry" with use.

The diaphragm pump is a mechanical dry pump that compresses the gases by a flexing diaphragm and can be used when the gas load is not high. Some diaphragm pumps have an efficient pumping range of 10 Torr to atmospheric pressure with a gas throughput of ~1.5 liters/sec, and an ultimate vacuum of 10⁻⁶ Torr. The diaphragm pump can be used to back a molecular drag pump or a turbomolecular pump with molecular drag stages, making a very oil-free pumping system for low throughput pumping requirements, such as leak detectors. P&SF