



Maintenance and Troubleshooting of Oil Diffusion Pumps



Agilent VHS-4 Diffusion Pump

Solution Note

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Oil diffusion pumps are still a widely used type of high vacuum pump. This is because they are relatively inexpensive, highly reliable, and very durable. Yet oil diffusion pumps require careful maintenance in order to maintain a high level of performance and maintain the integrity of the vacuum chamber. This application note will explain practical steps that can be taken to ensure optimal performance of oil diffusion pumps in a production environment.

How oil diffusion pumps work

Diffusion pumps differ from conventional mechanical pumps in that they use a high-speed jet of fluid to direct gas molecules in the pump throat down to the bottom of the pump and out the exhaust, which is usually called the foreline. The high-speed jet is produced by boiling the fluid, such as silicone oil, and then directing the vapor through a series of vertically-stacked cone-shaped jet assemblies. Typically there are three jet stages of diminishing size with the largest at the bottom and the smallest at the top.

The boiling oil moves upward through the jet assemblies and then is expelled in a downward direction at the top of each assembly. Exiting from the jets, the high-energy oil droplets travel downward in the periphery of the chamber at speeds up to 335 meters per second. The vapor jets entrain gas molecules and direct them towards the exhaust port, where they are pumped away by a roughing pump. The effect of removing molecules is to create high vacuum in the upper portion of the pump, which is connected to the vacuum chamber.

A roughing pump lowers the pressure inside the diffusion chamber to approximate 10^{-2} mbar or lower. This makes it possible for the diffusion pump to create a vacuum ranging from 10^{-3} to 10^{-9} mbar (10^{-1} to 10^{-7} Pa). Pumps and jet designs have evolved over the years and improved synthetic fluids have been developed, enabling the high levels of vacuum to be achieved with this pump technology. The pump external housing (or shell) is generally water-cooled to prevent thermal runaway.

In all diffusion pumps, a small amount of backstreaming, movement of oil molecules into the vacuum chamber, occurs. In many applications, this is acceptable. In more critical applications, an optically-dense baffle is typically provided to deflect particles before they can reach the process stream. A trap is placed above the baffle and cooled to a low temperature to condense hydrocarbons and water vapor from the pump chamber. Due to the possibility backstreaming, diffusion pumps may not be suitable for use with the most sensitive analytical equipment.

Operating diffusion pumps

A large amount of energy is stored in an oil diffusion pump so careful attention must be paid to ensure safe operation.

- Oil diffusion pumps should never be used for roughing because exposure to atmospheric pressure levels can cause hot hydrocarbon fluids to ignite or explode.
- Air leaks into the system also present safety concerns for the same reason.
- Avoid contaminating the pumping fluid with foreign matter because it can change its viscosity and obstruct flow passages.
- Operation of the diffusion pump without circulating cooling water to the main body cooling coils is also dangerous, and will lead to unstable operation.

Some more basic operating rules:

- Do not turn on the heater without fluid in the pump. This may damage the heaters and pump assembly.

- Do not air-release the pump while the boiler is hot. Most diffusion pump fluids break down under these conditions.
- Do not power the pump heaters unless cooling water is circulating. This can cause the pump and fluid to overheat, and will lead to unstable operation.
- Do not operate the pump without a foreline baffle. This may cause a greater than normal fluid loss.

Diffusion pump maintenance

It is recommended to keep logbooks for diffusion pumps to track maintenance history, and operational manuals to ensure maintenance is done per the manufacturer's recommendations.

During maintenance activity, the surfaces inside the vacuum diffusion pump need to be kept very clean in order to avoid contaminating the vacuum chamber. Even a single fingerprint can outgas water vapor and other molecules. When a pump is disassembled for routine maintenance and cleaning, it should be purged with dry nitrogen just prior to use. When a diffusion pump is pumping at a slower than normal rate, look for outgassing of moisture on the surfaces of plastics or other volatile substances or a leak.

Check the condition and level of the fluid when the pump is cold. Withdraw a sample through the drain and visually check the level of fluid through the sight glass. Use new o-ring gaskets when replacing fill and drain plugs. During maintenance intervals, if there is diffusion pump oil loss, log the amount. This loss of fluid can be caused by:

- Air leaking into the pump
- Inadequate water cooling
- Continuous operation in the overload inlet pressure range, also referred to as the "knee" of the curve.
- Failure to insert the foreline baffle in the pump assembly.

The recommended frequency at which the diffusion pump fluid should be changed depends on the specific process. Slight discoloration of the fluid does not affect pump performance but material build-up can lead to inefficient heat transfer. For a dedicated manufacturing process, it is possible to establish

color based standards to help provide guidance for fluid replacement.

It's important to note that new fluid is subject to outgassing. This can cause periods of foreline pressure fluctuations. These will quickly resolve themselves as the fluid becomes fully degassed.

If multiple processes are run on the same pump or vacuum chamber, there is the risk of cross-contamination of byproducts through the fluid. It may become necessary to change the fluid more often in this situation.

After maintenance, the pumpdown characteristics of the system should be monitored. The best approach is to keep a log that compares the pumpdown curves after maintenance over time. This approach will help to provide an early warning of system leakage. When a leak is identified, the first step should be to check the following items:

- The integrity of the inlet and foreline connections
- The tightness of the drain and fill plugs
- The other compression fittings, such as those that connect the high-vacuum gauges

- Threaded connections, such as the foreline gauge.

Also check the performance and accuracy of the vacuum gauges used in the system.

In some cases, cooling coils may become obstructed due to solid deposit buildup. Check the flow meters used to measure the cooling water flow to ensure that water can flow freely through the coils and that the flow rate does not fall below the manufacturer's specifications.

Heater elements may burn out from time to time and need to be replaced. As a preventive precaution, when the pump is cold, check that the heaters are bolted snugly to the boilerplate and that all heater terminal connections are fastened tightly inside the junction box. Also, check the total heater power input and load balance.

The following other items should be checked on a regular basis:

- The position of the system valves should be checked before repositioning
- The level of the diffusion pump fluid
- Confirm that water is flowing through the cooling water lines.

Diffusion Pump Troubleshooting Guide

Fault	Probable Cause	Corrective Action
Poor system pressure	Leaks in system, virtual or real	Locate and repair
	High process gas load	Measure gas load, eliminate cause
	System is dirty	Clean system to reduce outgassing
Poor ultimate pressure	Contaminated pump fluid	Examine and clean pump; replace fluid
	Low heat input	Check voltage. Check for continuity, burned-out element, poor thermal contact
	Inadequate cooling water flow	Check water pressure. Check tubing for obstructions and backpressure
	Cooling water is too cold	Check temperature
	Cooling water flow is too high	Adjust water flow
	High forepressure	Check for leak in foreline, poor mechanical pump performance, breakdown of mechanical pump fluid
	Water in Quick Cool coil	Check and remove cause
Slow pumpdown	Low heat input	Check heaters
	Low fluid level	Add fluid
	Malfunctioning pump assembly	Check and repair or replace
	Improperly located jets	Check and repair or replace
	Damaged jet system	Check and repair or replace
Inlet pressure surges	Incorrect heater input	Check and correct
	Fluid outgassing	Condition fluid by operating the pump for a few hours
	Leak in system ahead of pump inlet	Check and correct
High chamber contamination of the pump fluid	Forepressure too high	Check for leak in foreline, poor mechanical pump performance, breakdown of pump fluid, and incorrect valve operation
	Prolonged operation in overload range	Adhere to operating procedures
	Cutting over from the backing pump too early in the pump down cycle	Cut over at a lower chamber pressure
	Improper system operation and air release procedures	Adhere to operating procedures
Pump will not start	Safety circuits or protective devices prevent contactor from staying closed	Check utilities, flow devices switches, interlock. Check thermostat operation

Conclusion

Diffusion pumped vacuum systems often provide the most efficient and cost-effective environments for production processes. To secure these benefits, it is extremely important to follow the simple maintenance practices described here or as recommended by the pump manufacturer. A small investment in planned maintenance can yield a high return in the ongoing high-level performance of your production system.

References

"Diffusion Pumps Performance and Operation", Hablanian, American Vacuum Society 1994.

Hablanian, M. H., High Vacuum Technology, 2nd ed. New York: Marcel Dekker, 1997:207.

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