UMassAmherst | Environmental Health & Safety

Vacuum Pump SOP

Summary:

This fact sheet talks about four main types of vacuum pumps (rotary vane vacuum pumps, diaphragm vacuum pumps, combination/hybrid vacuum pumps, and scroll vacuum pumps) that are used in low to medium vacuum applications, tips for minimizing the hazards when operating in the lab, when and how to use cold traps, and recommendations for using vacuum pumps with highly hazardous chemicals.

- *Use vacuum pumps with vacuum capacity appropriate to the application. Rotary vane and diaphragm pumps are used for most wet applications. Do not use aspirators.*
- *Ensure apparatus is rated for vacuum level.*
- *Always use a trap when using solvents or other volatile materials.*
- *Follow all manufacturer's guidance for maintenance, including oil changes, and operation.*

Main Types of Vacuum Pumps:

Vacuum pumps are used in a wide variety of lab settings to remove air and other vapors from a vessel or system. Applications that use vacuum pumps include rotary evaporators, vacuum ovens, schlenk lines, drying manifolds, freeze-dryers, aspirations, desiccators, and filtration equipment. You may be exposed to hazardous chemicals and vapors if not using them properly. This fact sheet covers common types of vacuum pumps used in low to medium vacuum applications in the lab.

Rotary Vane Vacuum Pumps:

Rotary vane pumps are most commonly used. Rotary vane vacuum pumps reach deep ultimate vacuum levels (typically 10^{-2}-10^{-4} Torr or 1-10^{-2} Pa) and have high displacement capacity, which make them an excellent choice for freeze drying applications. They work particularly well for aqueous solvent and samples with high boiling points. Rotary vane pumps can be categorized into belt-drive pumps and direct-drive pumps. The operating temperature of belt driven pumps is usually lower than direct-drive pumps and belt-drive pumps operate at a lower RPM (revolutions per minute). Note that belt drive pumps should always have a guard over the belt and moving components to prevent injury. Rotary vane pumps are typically also used as rough pumps for more specialized high vacuum applications. Rotary vane pumps contain oil, and the oil must be changed on a regular basis to ensure the proper functioning of the pump. The oil change schedule is highly dependent on the application. Use of volatile materials, particularly without adequate trapping devices, can lead to contamination of oil that necessitates frequent oil changes.

Belt-Drive Pump
(https://www.welchvacuum.com/en-us/belt-driven-pump)

Direct-Drive Pump
(https://www.welchvacuum.com/en-us/rotary-vane-pumps)

Diaphragm Vacuum Pumps:

Almost all types of samples, including a combination of acids and solvents, can be used in diaphragm pumps. They are an excellent choice for both concentration and evaporation. Diaphragm pumps do not use oil (i.e., they are a dry pump), and can typically be cleaned of most volatile materials simply by operating in a clean environment. Gross contamination can necessitate change of the diaphragm. Ultimate vacuum levels of these pumps are not extremely deep (typically 100-0.1 Torr or 10^4-10 Pa) and displacement capacities are much lower than other types of vacuum pumps. They cannot be used for freeze-drying.

Diaphragm Gas Pump
(https://knf.com/en/us/solutions/pumps/series/diaphragm-gas-pump-n-6303-ex)

Diaphragm Liquid Pump
(https://knf.com/en/us/solutions/pumps/series/diaphragm-liquid-pump-fp-150)

Combination or Hybrid Vacuum Pumps:

The ultimate vacuum level and displacement capacity with combination pumps is similar to those of rotary vane pumps. These pumps combine the power of rotary vane pumps (typical vacuum down to 10^{-3} Torr or 0.1 Pa) with the robustness of diaphragm pumps. As such, they are best suited for freeze-drying volatile or corrosive samples since they can be used with a variety of acidic samples and others that contain harsh chemicals like nitric acid, beryllium monohydride (HBe), acetonitrile, and trifluoroacetic acid (TFA).

https://www.labconco.com/product/combination-pumps/84

Scroll Vacuum Pumps:

Like diaphragm pumps, scroll pumps are dry pumps so they do not use oil. Compared to diaphragm pumps, scroll pumps can reach deeper ultimate vacuum levels (typically down to 10^{-2} Torr or 1 Pa) and have higher displacement capacities. They are ideal for use in applications that require a dry pump, however they can also be used for freeze-drying since they can be used with solvent and aqueous solvent samples like acetonitrile, acids below 20% concentration. Scroll pumps can also work with concentration applications. While scroll pumps typically do not require much maintenance, entrained solid particles can impede performance and require cleaning and parts replacement. Scroll pumps are also typically quite expensive compared to other types of pumps.

https://www.labconco.com/product/scroll-pumps/6017

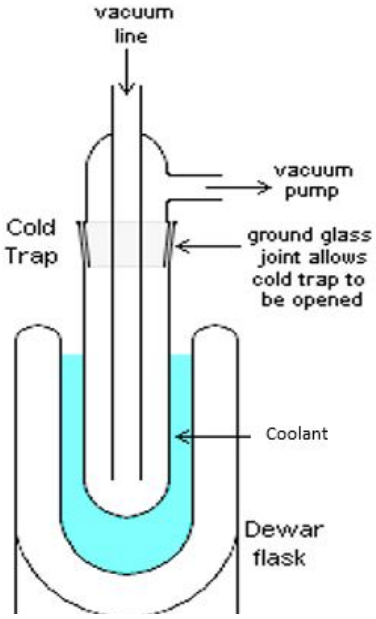
Vacuum Pump and Apparatus Considerations

- Wear safety glasses, lab coat, long pants, close-toed shoes and gloves (when handling hazardous materials) when performing all vacuum operations.
- Make sure electrical cords and plugs are free from defects. Avoid using extension cord or power strips if possible.
- Ensure that belt guards are in place during operation.
- Check oil levels and change oil when necessary. Change oil when it begins to darken or turns opaque.
- Keep records of all pump maintenance and do not use defective pumps.
- Pump oil must be appropriate for the pump and compatible with vapors that will pass through.
- Place pumps in a well-ventilated space (such as a fume hood, an exhausted pump cabinet, or under an exhaust snorkel) to avoid exposure to hazardous exhaust and heat accumulation. If pumps are not exhausting hazardous materials, they do not need to be ventilated, provided that an oil mist separator is used for oil containing pumps.
- Do not operate vacuum pumps in confined areas near flammable or combustible materials.
- Place the pump on a tray to contain any spilled oil. Use absorbent padding to contain and remove extraneous oil. Oil and oil soaked padding should be handled as hazardous waste.
- Ensure that gas ballasts are used correctly when present. These are typically opened for a short time to remove contaminants from oil and then closed to ensure that the pump does not overheat.
- Use correct vacuum tubing (thick walls) and replace old tubing. Use the shortest length needed.
- Consider shielding any glassware under vacuum. Carefully inspect vacuum glassware before and after each use for cracks or defects that could lead to implosion.
- Do not use solvents which might damage the pump without an appropriate trap.

- Connect the pump inlet and outlet properly. Reversing the flow direction can pressurize apparatus leading to rupture, failure of vessel, or oil contamination.
- Close valve between vessel and pump before turning off pump to avoid introducing oil into system.
- Be sure to slowly bleed vacuum lines (breaching of the reduced pressure system) before disconnecting traps or other equipment.
- Use a liquid trap with an appropriate disinfectant when a vacuum is used with hazardous biological materials.
- Know the risks and properties of the chemicals you are working with. SDS sheets can be found through CEMS: https://cems.unh.edu/umass/CEMS/.

Use a Cold Trap:

A cold trap is a condensing device to prevent contamination in a vacuum line or pump. If a vacuum pump is required for lower pressures, a cold trap should be used to condense **solvents** and other volatile liquids to avoid exposure to these materials and damage to the vacuum pump. Always use a cold trap in between rotary evaporators and the pump. When using a cold trap:



Typical configuration of a cold trap

- Locate the cold trap between the system to be evacuated and the vacuum pump.
- Ensure that the cold trap is of sufficient size and cold enough to condense vapors present in the system and avoid line blockages. Attempting to use a cold trap with evacuation of highly concentrated solvent vapors can lead to blockage in the trap and loss of vacuum. Use other vapor trapping means (such as condensers) or appropriately sized cold traps to avoid this. A second cold trap may be helpful to minimize the amount of volatile chemicals reaching the pump. However, even with a second cold trap, highly volatile compound (e.g. ether) may still form blockages in the cold trap very quickly.
- Empty the trap after each use. If a trap becomes clogged, immediately shut off the vacuum, disconnect the trap and ensure it is open to atmosphere to prevent explosion. Allow the trap to thaw in a fume hood to empty.
- Use of dry ice/solvent mixtures is appropriate to create a cold trap. Liquid nitrogen can also be slowly added with stirring to solvents to form a “slush”. Solvents should be chosen such that the freezing point of the solvent assures sufficient cooling capacity for the application. Use solvents with low vapor pressure for traps whenever possible to minimize potential for exposure and flammability hazards.
- Use cryogenic gloves when handling cryogens or dry ice.

- Dry ice and liquid nitrogen should only be contained in an open system with pressure releasing capabilities to avoid the potential for pressure increase and explosion as the materials sublimate or boil, respectively.
- Never use liquid nitrogen to cool the trap (except for ultrahigh vacuum systems) as this can cause condensation of liquid oxygen.

Use with Highly Hazardous Chemicals:

Vacuum pumps which are used to evacuate systems containing toxic, corrosive, or volatile substances must be vented appropriately. Failure to properly vent the pump can result in contamination of the lab with hazardous chemical vapors.

- Pumps for rotary evaporators using highly toxic chemicals (e.g. chloroform) must be located in a fume hood, vent to dedicated lab exhaust, or be equipped with adequate condensers and traps to prevent emission of toxic vapors into the lab. Please see the rotary evaporator fact sheet for more information.
- For pumps used to evacuate highly reactive, corrosive, or toxic gases, use a sorbent canister or scrubbing device capable of trapping the gas when possible. This may be required in some cases depending on the quantity and nature of gas released. All hazardous pump exhaust, regardless of whether not scrubbing systems are used, must be directed to hazardous exhaust. In some cases, hard connections to exhaust are required for building and fire code compliance. Please contact EH&S if you have questions or concerns about exhaust connections.
- Use of an oil mist separator is recommended to prevent oil loss and prevent exposure of lab occupants to aerosolized oil and contaminants.

Please contact EH&S at (413)545-2682 or email askehs@umass.edu if you have questions about the safety of your vacuum pump set-up.

References:

1. University of Pennsylvania, Fact Sheet: Vacuum Pump Use and Installation. https://ehrs.upenn.edu/health-safety/lab-safety/chemical-hygiene-plan/fact-sheets/fact-sheet-vacuum-pump-use-and
2. University of Pennsylvania, Vacuum Pump Explosion in Chemistry Building. https://ehrs.upenn.edu/health-safety/lab-safety/safety-alerts-and-faqs/vacuum-pump-explosion-chemistry-building
3. The University of Texas at Austin, Vacuum Pump Safety. https://ehs.utexas.edu/programs/labsafety/vacuum-pump-safety.php
4. LABCONCO, How to select the right vacuum pump. https://www.labconco.com/articles/how-to-select-the-right-vacuum-pump
5. University of California, Berkley, Vacuum System Hazards and Precautions. https://www.ehs.berkeley.edu/sites/default/files/lines-of-services/workplace-safety/71vacuumsystems.pdf
6. Princeton University, Pressure and Vacuum Systems. https://ehs.princeton.edu/laboratory-research/laboratory-safety/laboratory-equipment-and-engineering/pressure-and-vacuum-systems