Separation, Filtration & Condensation

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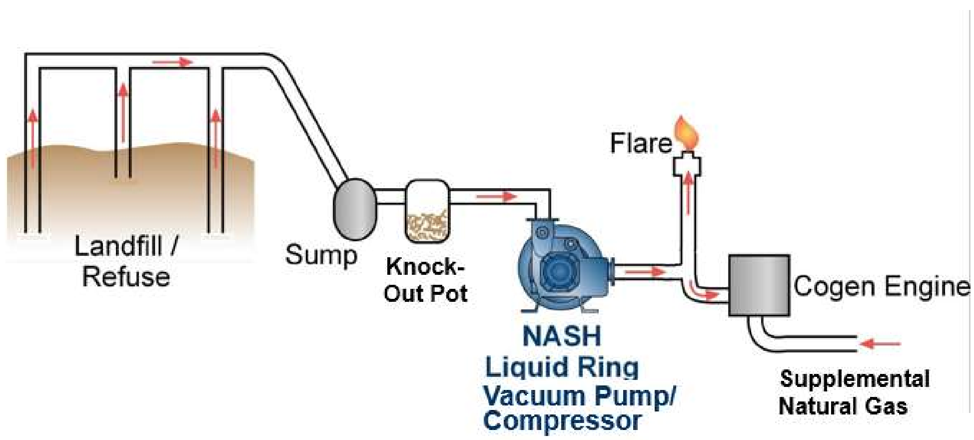
Over the last few months, I've run into quite a few vacuum applications recently where the incoming process vapor, liquid, soft solids, or powders have presented interesting challenges to liquid ring pumps and dry pumps. These applications extend into various industries: mining, plastic extrusion, poultry, chemical, etc. The central theme remains the same: how do we stop process carry-over from getting into the pumps?

Even though liquid ring vacuum pumps are a lot more tolerant of process carry-overs than any dry vacuum technologies, vacuum pumps are still not trash cans. Too many chicken bones can lock up even a Nash pump; too much ammonia condensing in a liquid ring pump can change the seal liquid's vapor pressure, causing cavitation; water or solid gets in a claw pump can crash it; fine dust can break apart the vanes of a dry rotary vane pump; moisture condensing in an oil rotary vane can create damaging emulsion… All these challenges, why would we ever use a vacuum pump? Luckily, there are a lot of strategies out there to overcome them.

Separation

One of the most common solutions to prevent capture process carry-overs is an inlet separator (also called a knock-out pot), especially for vacuum applications that involve water. This simple equipment slows down velocity of incoming gas mixture, liquid and soft solids would fall out and collect inside the separator. In the below example of landfill gas extraction application, the knock-out pot prevents waste fluid or solids from getting into the Nash liquid ring compressor.

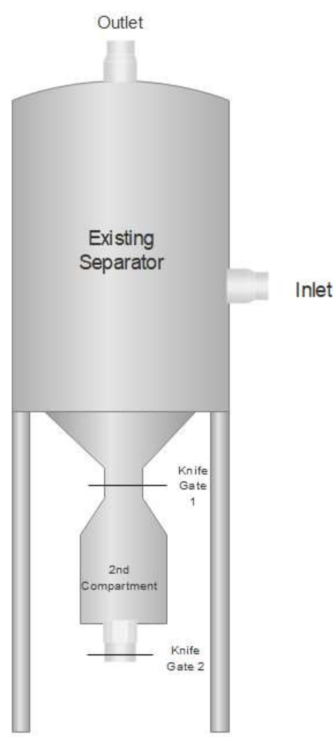


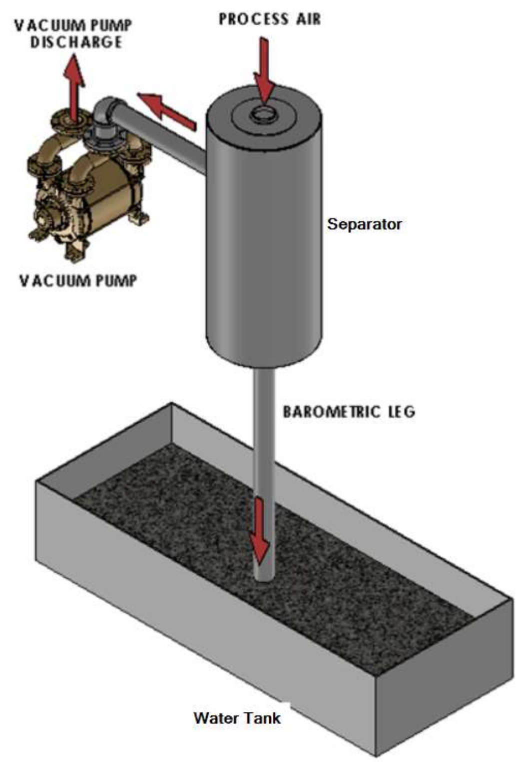
To remove the collected liquid solid mixture from the separator, these solutions are commonly used:

1. Positive pressure fluid pump to evacuate separator under vacuum. This pump would be triggered either by a level switch or a timer. This pump needs to be sized to overcome the operating vacuum and the rate at which fluid is collected inside the separator. However, this pump is susceptible to corrosion and erosion from the carry-over fluid mixture.
2. Double-compartment separator. More commonly used in applications with heavy liquid carry-over or carry-over containing abrasive substance that can erode an evacuation pump. A basic

setup looks like the below image on the left. Essentially, a second vacuum compartment is installed below the main separator unit, enclosed by two pneumatically actuated knife gates. During normal vacuum operation, Knife Gate 1 is open while Knife Gate 2 is closed. Process fluid carry-over would collect in the second compartment at the bottom. Triggered by either a timer or a level switch inside the top separator, Knife Gate 1 would close, and Knife Gate 2 would open to evacuate the fluid captured in this second compartment via gravity.

3. Barometric leg. A method that does not involve any moving part or controls component is a barometric leg. The basic setup is in the diagram below on the right. Process carry-over fluid drains by gravity through the barometric leg into the water tank it's submerged in. The height of the leg is determined by the operating vacuum depth. 1 In-Hg is about 13.6 in-H2O. So, for a typical dewatering vacuum application, where 15 in-Hg might be the deepest vacuum level during operation, a barometric leg of at least 17 feet would be needed. Any deeper in vacuum level, the pump will start sucking up water from the drain tank at the bottom of the barometric leg. This can be prevented by having a vacuum relief valve at the inlet of the pump, however.





Filtration

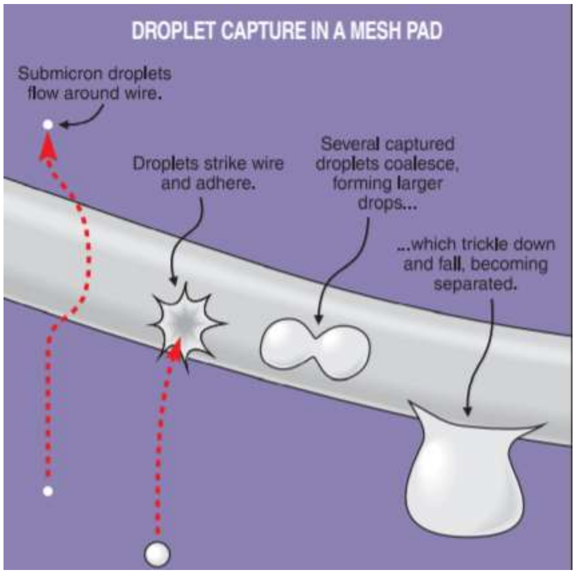
Because an inlet separator's performance depends on the density of the carry-over fluids or solids, heavier substance such as water or sludge can be easily captured, but lighter dust and finer powder might not. Some applications will require filters as another line of defense, this is especially important for dry vacuum pumps. Dry rotary vane pumps, for example, are particularly vulnerable to carry-over fine dusts and powders. Because the vanes in a dry vane pump rub against the pump housing without any lubrication, debris and dusts can quickly wear down vanes like sandpaper, significantly reducing vane's life. Other dry pumps such as oil lubricated vanes, claw, and regen blowers are all vulnerable to carry-overs, but at lesser degree than a dry vane pump. Liquid ring vacuum pumps, on the other hand, are significantly better at handling dust and powder ingestions.

There is a huge variety of vacuum filters out there. Below are some typical ones offered by Solberg.

When selecting an appropriate filter option, take note of these specs:

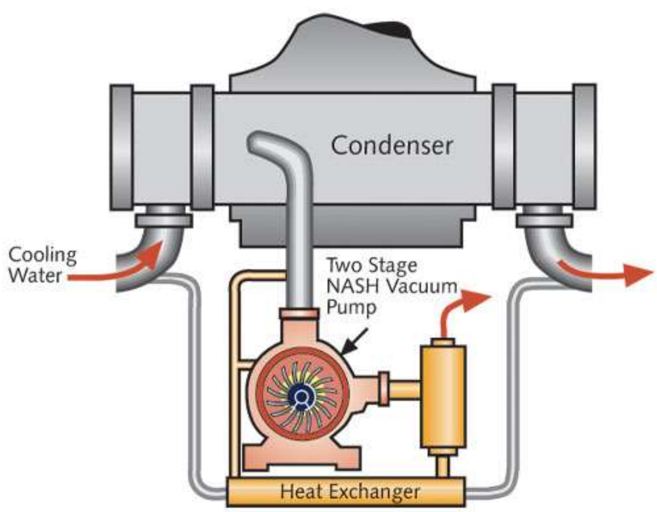
- Connection size. This can quickly help you home in on the model of filter that would most likely work for your pump.
- Flow rate. Make sure you are converting the pump's ACFM capacity at operating vacuum depth to SCFM used in most filter specs.
- Paper element vs. polyester element. Polyester element costs more, but it can be repeatedly washed and cleaned for reuse.
- Filtration micron rating. If you aren't sure of your carry-over particle size, we often recommend starting with finer micron rating, especially for critical dry vacuum applications.
- Mist removal? For liquid droplets that are too small for vacuum separator, demister pads can capture droplets down to 3 microns in size. The denser the droplet relative to the gas, the larger the droplet relative to the demister filament, and high the velocity, the more likely the droplet will strike the filament. These droplets will coalesce and form larger droplets, which will eventually fall and become separated. If the velocity is too low, the droplet too small, or too

light compared to the gas, the droplet will simply flow around the filament. See diagram below.

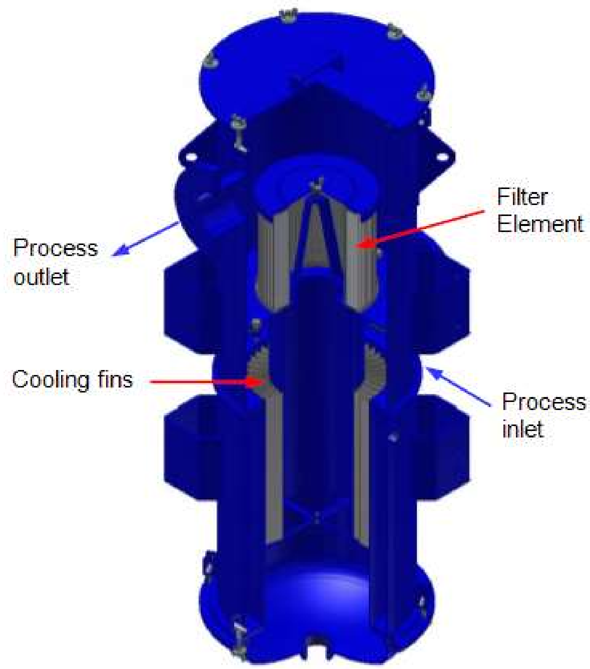


Condensing

Separators can capture process fluids and larger solids, further filtration are effective against fines and mists, but gas and some vapor would pass right through both. This was a challenge that puzzled me and my colleagues at my previous job for months years ago. Our oil-sealed Nash pump systems were making oil-water mixture very quickly and required oil change almost every other day. It took us embarrassingly long to figure out we were condensing water in our oil system. Once we put in an inlet condenser unit, taking inspiration from this setup in power plant condenser systems below, we were able to solve this.



A shell-and-tube, plate-and-frame, or welded heat exchanger can all be an effective condenser solution. However, most processes that need this solution don't produce condensing fluids that are just clean water. Condensable tend to be sludgy and sticky, require regular cleaning of the condensers. Solberg came out with a vapor condensing separator recently, which aims at solving this pain point. See below image.



This dual-shelled design allows cooling water to flow through the cooling fins in between the two shells, condenses incoming vapors, which collects at the bottom for periodic discharge and cleaning. A filter element or demister pad can be installed at the top section of this unit to capture fluid droplets and solids. I wish we had one of these units years ago, it would have saved me a lot of pain from brushing out the shell-and-tube heat exchangers we used as condensers.

I hope you find this email useful. Take care and have a great week!