It's a Dirty Job

Vacuum Filtration

Filtration in hydraulics and compressed air is an industry all by itself that has evolved over the years to offer the user endless choices and methods. A comparison often made to vacuum filtration is based upon compressed air filtering methods. This is an obvious comparison to make, although not an accurate or wise one. The principle reason for utilizing filtration in a compressed air system is to protect the application from particulate matter drawn in through the intake of the compressor or picked up in the airlines feeding the machinery, water which has been created during the compression stage of compressed air generation or oil capture, which is a carry over from a lubricated compressor. However, filtration in a vacuum system is to protect the components of the vacuum system, particularly the pump or venturi from the debris or liquids on the application-- a complete polar opposite of compressed air filtration. Consequently, the difference in vacuum filter construction, element porosity, filtration method and physical size compared to the flow through the filter is considerably different.

This article discusses industrial material handling such as vacuum cup lifting as its basis of reference and operational princples. In medical, hospital and laboratory applications where biological hazards are present in vacuum lines and equipment, necessary precautions should be considered and independent professional advice should be sought before selection, installation and maintenanceof any vacuum equipment, including the filtration package(s), is undertaken.

"Micron" is the universal term for filtration porosity. Although not officially recognized as an SI unit, being replaced by the term "micrometer" (even though this is the name of an engineering measuring instrument) in 1968 with the symbol mµ. However, the word "micron" is still, to this day, the unofficial term used for filter porosity. One micron is one millionth of a meter or 1×10^{-6} m (an easier visualization would be 0.001mm) and is symbolized by µ (from the Greek letter mu). In compressed air installations, it is not uncommon to see 0.1µ or even 0.001µ filtration elements being used. However in a vacuum system, the porosity of a filter element normally ranges between 5µ and 100µ. The reason for this is very simple. Vacuum is basically a negative pressure of -14.7psi(g). If a 0.001µ element was used, it would create a tremendous restriction in the vacuum flow of the system. Furthermore, this type of fine filtration is simply not necessary in vacuum applications.

Remember that a vacuum filter is protecting the vacuum pump or venturi and other components such as valves and switches and so on from the application debris. Some applications require very little filtration if any at all, because the product being handled and the product picking area environment is very clean, such as semiconductor manufacturing or other clean room environments. However, wood panel manufacturing, steel sheet handling, brick and masonry production require a high degree of vacuum filtration due to the amount of media present on the surface of the product. There are many types of vacuum filter, but they all have the same intended task, which is to protect the vacuum components. Quite often for very dirty applications, different types of filters are used together.

The first filter (the one nearest the application) is often referred to as a prefilter. Fig 1 shows a typical prefilter, which has a porosity of 100µ. This would be typically used to prevent larger debris such as wood dust or brick particulate damaging the vacuum generation equipment. As you can see from the element detail, the element is steel mesh. This filter has the advantage of collecting larger debris with minimum flow restriction and also allows the user to clean the element periodically instead of replacing it. The filter head has ports on opposite sides of the head and is normally inserted in the vacuum line. This filter is commonly referred to as an "inline filter" due to this porting arrangement.

Fig 1

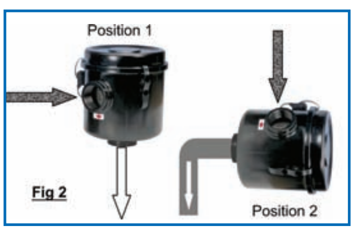

Fig 2

Fig 3

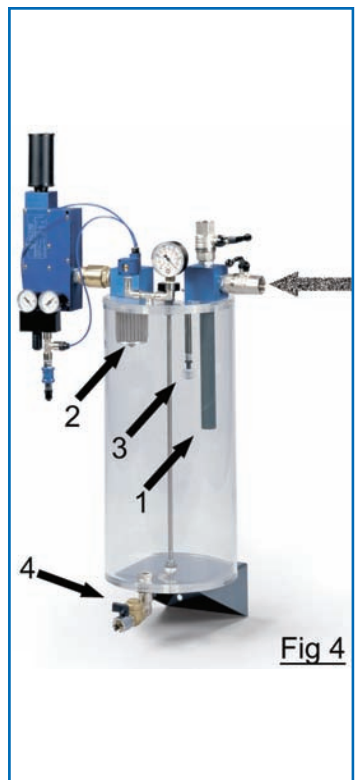

Fig 4

The filter unit shown in Fig 2 is a typical vacuum inlet filter, which is normally connected directly to the venturi or vacuum pump. The L port arrangement is designed to facilitate the vertical connection of the pump port with the application port being in a horizontal direction. However, it is recommended to install these filters at 90º to prevent the collected debris from "falling" into the vacuum pump port when the element is removed. Fig 2 demonstrates this. The typical element porosity for this type of filter is <10µ and is a good general purpose vacuum filter. The elements are available in paper or polyester from most manufacturers.

In applications that have a lot of dust or fine particulate matter such as ceramic tile, stone, marble and wooden panel manufacturing, the L port type filter as shown in Fig 2 starts to collect this dust very quickly and in turn the flow rate through the element decreases rapidly (vacuum differential).

The filter shown in Fig 3 is an oil bath type filter. The element of this filter is very coarse and very similar to wire wool and so coarse that a micron rating is not even applicable. This element acts like a crude prefilter trapping large particles in the vacuum line and also baffling, and in turn slowing down and separating the air steam. At the base of the filter is a bath of oil. The oil used for this has a viscosity of around ISOVG25 (approximately SAE5). As the fine particulates pass through the wire mesh, the air stream is directed onto the surface of the oil. As the air changes direction to exit the filter through the horizontal port, the particles in the air stream fall out and stick to the surface of the oil. The clean air exits towards the vacuum pump.

The benefit of the oil bath type filter is the ability to trap small particulates without the loss of vacuum flow or an increase of differential pressure, which would be a characteristic of the standard filter shown in Fig 2 as explained above. These filters are normally used as prefilters for the L port filters shown in Fig 2.

One of the biggest problems in vacuum filtration is trapping liquids such as water that has been pulled through the vacuum lines from the application. Water will pass through all of the filters previously described. If it can be trapped, the volume within the filter bowl is very small, and therefore carryover happens very quickly. Fig 4 shows a liquid trap filter that has a holding capacity of 10 gallons. Liquid in the air stream enters the unit and is directed downwards through the vertical tube (1). This prevents fast moving air from simply crossing over to the outlet opposite. The outlet port is covered by a coarse filter element (2) preventing particulate matter from passing through in the air stream. As the vessel starts to fill, the float switch (3) sends a signal to the operator to indicate that the vessel needs emptying via the drain valve at the base of the unit (4).

Very important considerations when attempting to trap water in a vacuum system are the vacuum level in which the system is being operated at and the ambient temperature of the installation area. Water boils at 212ºF (100ºC) at an atmospheric pressure of 1013mbar(a), which is the universally agreed atmospheric pres-

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sure at sea level. As the atmospheric pressure decreases (vacuum is being created), the boiling point of water decreases. For example, at a vacuum level of 28"Hg, the water in the system will start to vaporize (boil) at a temperature of 77ºF. This ambient temperature is certainly not uncommon during the summer months. In fact, if the temperature is 86ºF, the water will vaporize at a vacuum level of only 27.5"Hg.

The problem this creates is very simple and potentially very expensive. As the water enters the vacuum system, it collects in the filter bowl/vessel and boils into a gas (vaporizes). It is then carried through the vacuum filter in the air stream, into the vacuum pump where the air is compressed back to atmospheric pressure (the compression stage of all vacuum pumps). The vapor turns back into a liquid (because the atmospheric pressure has returned to normal), and the pump eventually breaks down as it is unable to compress this liquid. This has been quite the head scratcher for users of vacuum pumps in a liquid present application where the filter is dry but the pump exhaust is spitting out water!

A typical application where this occurs is in vacuum clamping (CNC stone cutting machinery, for example) where the user wants as high a vacuum as possible to prevent workpiece movement and uses a liquid trap vacuum filter to prevent the machine cutting fluid entering the vacuum pump. The easiest way to solve this situation of boiling the water is to simply reduce the vacuum level in the system by means of a vacuum relief valve or preferably a vacuum regulator (far more accurate), which will prevent the system from going over a specified vacuum level. Alternatively, using a vacuum pump that is able to handle an amount of liquid also solves this problem. These types of vacuum pumps will be discussed in another issue of This is Vacuum.

Multiple Filter Points

One of the most troublesome methods of vacuum filtration is where the user has many vacuum filters at different points in the vacuum system. This means that the user has to check periodically more than one filter to ensure that the system is working at its maximum efficiency with minimum pressure drop (vacuum differential), and all filter elements are maintained and cleaned. This is particularly apparent when the user installs vacuum cups with an integral filter or an inline filter for each vacuum cup. The textbook theory behind this is good, being that the media or dirt from the application is trapped at the vacuum cup, preventing dirt from traveling through other components such as valves and vacuum control equipment.

This method works well on one or two vacuum cups, but more often than not there are many vacuum cups in use and therefore the user does not know the condition of the "filtration system" unless they check each individual cup. The condition of a small wafer-like element inside a vacuum cup is sometimes not visually apparent, and although it looks clean, it could be saturated with embedded media. Of course in the real world, these daily or even hourly checks are not carried out, and the only time these small filters are checked is when the vacuum cup stops working as vacuum flow cannot get through the blocked element. This type of system can be very unreliable, and of course machine downtime is a very expensive event for all production installations.

The best way to filter a vacuum system is to have one central filtration system, normally close to the vacuum pump or at least upstream of all the components where it can be easily reached and serviced. Critics of this method may suggest that the components in the vacuum system, such as valves and so on, could be blocked by media, but in the majority of applications, using the correct equipment, these components are unaffected. A proper vacuum valve for instance has good oversize orifices, and if there is an air flow through the vacuum system, the dirt will pass straight through these valves in the majority of cases. However, if it is known that an application is very dusty, the vacuum should not be applied until the cup is pressed or sealed against the load being handled. This prevents the "vacuum cleaning" effect where the vacuum system simply sucks up all the debris before the cup makes contact with the load. Whereas, if the cup is sealed against the load before the vacuum is applied, there is minimum air flow in the system and therefore the dust remains on the product being handled instead of being carried through the vacuum system.

Another good method is to "blow" air through the vacuum system to clean the cup lines before and after the cups have made contact with the load. This is a very popular method with so called multi-function vacuum generators where the unit consists of two solenoid valves, one for vacuum on/off and the other for the compressed air blow off. In respect to multi-function vacuum generators, these normally incorporate a small vacuum filter inside the actual unit. This feature is one of the multi functions. These very small filter elements are notorious for getting blocked by dust, particulates and especially liquids such as oil on metal stamping lines, making these applications very unreliable because as in the case of the filtered vacuum cups, these elements are not inspected or changed until problems start to occur.

Of course if the application is very clean, this point of use method is arguably ideal. However, a single point filter system certainly offers simple servicing and inspection with speedy element changes, and scheduled maintenance is easy for the user.

As with all industrial applications, there are a thousand different ways of completing a task. The information provided in this text is meant as a good general guide for ensuring a vacuum system runs and operates as a user would like it to: reliably, efficiently and with the least amount of irregular maintenance as possible.

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