Tip of the Month/No. 4

Tip of the month – The most common errors when using vacuum pumps and how to avoid them, Part 1 – Rotary Vane Pumps

The ideal vacuum solution at the best price is almost always the preference from the viewpoint of the customer. This fact poses the danger that a less optimal pump solution is selected for cost reasons, a decision which could eventually cause the customer to experience less uptime and higher maintenance cost. Selecting reliable vacuum pumps and the corresponding accessories as well as sensible monitoring and operating modes will pay for themselves in the long run.

In the following, you will find a summary of the important information and insights for the operation, equipment selection, and maintenance of commonly used vacuum pumps. In this issue and in upcoming "tips of the month" we will show you the most common errors when using rotary vane pumps, Roots pumps and turbopumps as well as measures to avoid them.

It must be explicitly stated that the accompanying images are only examples and no conclusions should be drawn about the reliability of the brands shown.

1. The Rotary Vane Pump
Its excellent price/performance ratio and its technical reliability and longevity are the main components contributing to the rotary vane pump's decades of success. Compression over more than six decades and the gas type-independent intake capacity characteristics are some of this pump type's impressive features. As the rotary vane pump operates on the principle of internal compression, is oil-lubricated and -sealed, the main criteria for this pump's reliability and longevity are pumping off steam, chemical attacks and aging lubricant.

1.1. Pumping Vapors
Most rotary vane pump manufacturers specify the so-called vapor tolerance in hPa and/or vapor capacity in grams/hour. This information signifies water vapor. When the gas ballast valve is open and the pump is at operating temperature, condensation of the pumped water vapor is prevented when the inlet pressure is below the given value. During a drying process, it is not the pump's pumping speed that determines the pump size according to its vapor capacity, but the amount of water accumulated per unit of time. It is imperative that the pump warms up with a closed vacuum-side valve and opened gas ballast for about 15 to 30 minutes in order to reach its optimal operating temperature (oil) of about 70 to 80 °C. Vapors can only be pumped at the correct operating temperature with an opened gas ballast valve. The delayed opening of the high vacuum valve is easy to integrate into the control system. The following table shows the dependency of the pump temperature and the consequences of non-compliance.

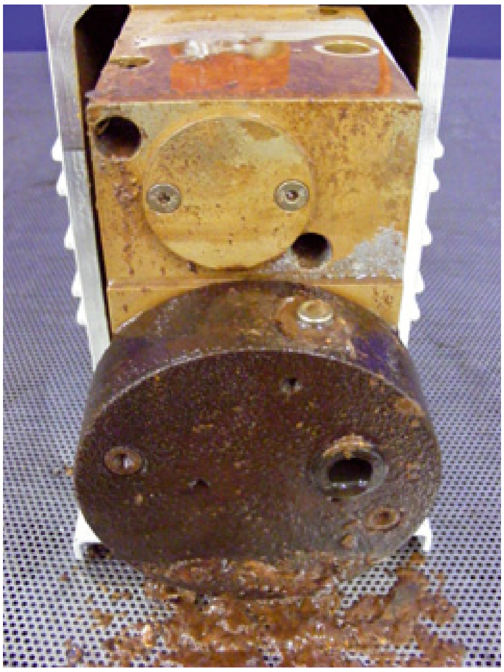

Figure 1: Heavily corroded rotary vane pump caused by operating without gas ballast.

Medium to be pumped	Temperature	Condensation	Result
Soluble in lubricant	Tp > Ts Tp < Ts	no yes	Minimal oil dilution Oil dilution
Not soluble in lubricant	Tp > Ts Tp < Ts	no yes	Forming an emulsion

Tp – Pump operating temperature/Ts – Boiling temperature of vapors at the exhaust port of pump

After ending the pumping process, it is strongly recommended to allow the pump to continue running with an open gas ballast for about 15 minutes, so that any steam still inside the pump can escape through the exhaust. This procedure regenerates the operating fluid and prevents standstill corrosion as well as a possible pump failure.

The necessary pre- and post pump operation can easily be integrated into the controller with a timing element. If the system requires an ultimate pressure with a gas ballast of less than 1 to 2 hPa, a two-stage rotary vane pump must be used. It is important to note that the vapor tolerance and vapor capacity of a two-stage rotary vane pump will be lower in comparison to a single-stage pump.

1.2. Operating Fluid

Operating fluid (pump oil) fulfills three important functions in a rotary vane pump: it seals, lubricates valves and bearings, and guides the compression and friction heat over the aluminum casing to the outside to cool the pump.

Maintaining the oil level is an important preventative and routine maintenance for all oil-sealed rotary vane pumps and vacuum pumps with a transmission and lubricant. If the oil level drops too low, the pump system can no longer be lubricated. The pump system becomes blocked due to lack of lubrication, which leads to the pump's failure. A too low oil level has the continued result that the low oil volumes do not create optimal dissipation of the compression heat. The pump overheats, leading to rapid aging of the fluid until the pump fails due to lack of lubrication and the formation of oil carbon. Therefore, it is imperative to make sure that the pump's oil level does not fall below the middle of the inspection glass.

The operating fluid must be regularly checked for color, viscosity, or contaminants. A water content of more than 5 % turns the oil a milky color. This occurs when the gas ballast valve remains closed, the pump down process is turned on while still cold or the maximum vapor capacity is exceeded. Fig. 2 clearly shows how the color changes towards black with increasing wear of the fluid. The fluid must immediately be changed if it reaches color 6 (from left). The color scale applies to the oil P3 (Pfeiffer Vacuum).

Changing the oil every 12 months as a preventative measure is recommended.

If the user is not sure whether the used fluid is resistant to the process gases, the manufacturer should be consulted to determine the correct operating fluid and the pump design.

Figure 2: Color scale of the fluid aging for mineral oil.

When pumping down oxygen in concentrations higher than atmospheric oxygen levels, mineral oil cannot be used due to oxidation and rapid aging of the operating fluid. Special oils with BAM approval for oxygen must be used in this case. When doing so, note that the fluid used has a sufficiently low vapor pressure at the pump's operating temperature so that the desired ultimate pressure, limited by the total pressure (vapor pressure of the oil), can be achieved.

1.3. Oil Misting on the Exhaust Side

For functional reasons, all rotary vane pumps mist fine oil droplets from the exhaust along with the pumped gas or vapor. The quantity of the misted oil droplets is determined by the inlet pressure of the pump. The higher the pressure, the greater the oil emission. Existing empirical values for the oil emission place it at about 3 mg oil per standard cubic meter pumped at more than 100 hPa.

For example:
For an inlet pressure of 200 hPa and a pumping speed of 60 m^3/h, a singlestage rotary vane pump with these pumping speeds will emit about 850 mg of oil within 24 hours. If the oil content of such a pump is about 5 liters, the oil level will have sunk to critical levels in two days of continuous operation. If the pump continues to operate, the operator can expect damage to the pump due to insufficient lubrication.

Exhaust-side oil mist separators are used to prevent oil emission and to protect the pump from insufficient lubrication. These filters contain cartridges in which the oil droplets are retained and are deposited in the filter casing. If the process permits, the separated oil can be fed back to the pump via an automatic oil return unit using a float switch or gas ballast recirculation. If larger quantities of water vapor are being pumped during a drying process or if the pump is processing corrosive vapor, reusing oil is not recommended. The vapor condensing in the filter will be fed back into the pump and heavily reduce the oil's lubrication capabilities and durability, which in turn can lead to the pump's early failure. In addition, there is also a danger of standstill corrosion will increase due to higher concentration of condensed steam in the pump container and in the oil. In this case, the missing oil must be replenished from time to time.

It is important to ensure that the oil mist filter can process the same quantity of gas as the rotary vane pump. If the filter's a) nominal size or b) maximum gas throughput is too low, the oil droplets will not have time to settle into the filter cartridge due to the too high gas velocity. They simply escape through the exhaust and the oil mist filter is rendered largely ineffective.

Oil mist filters must always be used if no central extraction is available for the exhaust line and emissions must be minimized or avoided due to work safety and the provisions of the Technical Instructions on Air Quality Control (TA Luft). The oil mist also exudes an unpleasant smell that spreads everywhere and creates an undesirable oil film.

1.4. Oil Migration to the Inlet Side

When operating a rotary vane pump at ultimate pressure of less than 0.5 hPa, a migration of oil molecules takes place to the inlet side for functional reasons.

In processes, mainly in the high- and ultra-high vacuum ranges, hydrocarbons are undesirable and unacceptable, as they damage the process and the equipment. This contamination can only be removed with considerable time and expense.

To avoid the oil's migration, one must install molecular sieves, catalytic traps, or cold traps on the inlet side of the rotary vane pump. With catalytic traps, the copper catalyst breaks the hydrocarbons up into water and hydrogen and subsequently pumps them off. It is recommended to regenerate the used Zeolite traps (molecular sieves) at regular intervals by bakeout to about 250 °C. To this end, the manufacturers offer suitable heating elements as accessories. The catalytic traps can be regenerated by ventilation.

The pumping speed of the rotary vane pump in the molecular flow regime is reduced by the conductance losses (resistance). This must be taken into account when selecting the pump size, depending on its use. This also applies to the following dust filters. Please refer to the manufacturer's specifications for the conductance values (in liters per second) in various pressure ranges.

Figure 3 and Figure 4: Inlet port of a rotary vane pump without a dust filter. Rotor was tarnished in the cylinder. Pump system must be replaced.

1.5. Dust in the Process

Processes exist that generate particles or are laden with dust. In order to protect the pumps from mechanical damage and lengthen the operating fluid's longevity, it would be useful to install dust filters on the inlet side. Depending on the application, there are dust filters with filter cartridges made of paper, polyester, carbon fibers, or oil-wetted packing (Raschig rings). A two-stage combination with a cyclone separator and filter cartridge is one option for abrasive dusts. The cyclone possesses the additional advantage that hot particles can cool down thanks to the rotation movement in the cyclone. (Fig. 3 and 4)

1.6. Dimensioning the Inlet and Exhaust Lines

The nominal diameters of the inlet and exhaust port are designed by the manufacturers according to the maximum pumping speed of the pump. Therefore, it is important that the inlet line corresponds to the pump's nominal diameter, as the pumping speed could otherwise be significantly reduced due to conductance losses, specifically in the molecular flow range. The exhaust line should also at least correspond to the pump's nominal diameter, otherwise small nominal sizes and high gas throughput would cause unacceptable counter-pressure that would place continued mechanical stress on the pump and cause increased wear and failure. In addition, the noise level will rise significantly.

If the exhaust line leads upward, the line should be formed like a siphon at its deepest point so that condensing steam on its way up and out cannot flow back into the pump. The siphon can be emptied through a low outlet. In addition, a condensation separator can be installed about 20 to 50 cm above the pump nozzle in the exhaust line, which would also collect the condensate. Mounting it directly on the pump's exhaust line is not recommended, as the condenser takes on the temperature of the pump by nature of being directly connected to it, resulting in reduced effectiveness.

1.7. Sufficient Ventilation
As rotary vane pumps must emit heat due to their compression work, they must be provided with sufficient ventilation and, if necessary, additional fans. This is especially valid for pumps built into plants or noise absorption hoods. If the ventilation requirements are not observed, the equipment can overheat and damage the pump.

Many of these instructions are also applicable to other vacuum pumps, such as roots pumps, diaphragm pumps, and dry pumps.

We would be happy to assist you in optimizing your vacuum solutions for specific applications – go ahead and ask us:

http://www.pfeiffer-vacuum.com/contact

www.norm.gr sales@norm.gr