PFEIFFER VACUUM

TIPS AND TRICKS FROM THE EXPERTS

Impact of backing pumps on the vacuum system

In many applications, the maximum end pressure of a vacuum system is mainly traced back to the parameters of the high vacuum pump in use. But the characteristics of vacuum systems are not only determined by the high vacuum pump but to a remarkable degree also by the backing pump and the alignment inside the whole pumping station.

A vacuum pump or a pumping station supports the gas flow which is emitted by the vacuum system. In case of a vacuum process to which process gases are added, the gas throughput is determined by this process gas flow. If, in contrast, the vacuum system is supposed to reach a low end pressure without added gases, the gas throughput is mainly determined by the gas emitted from the inner surfaces of the vacuum system.

Selecting a suitable backing pump

If a backing pump is selected for a pumping station, the pump must generate a pressure which is smaller than the maximum fore vacuum pressure of the high vacuum pump in use. This maximum fore vacuum pressure can be found in the specifications of each and every turbopump and is named “forevacuum max.”, “max. fore vacuum” or “fore pressure”. Depending on their construction type and manufacturer, modern turbopumps with Holweck stage can be operated with a high fore vacuum pressure of more than 20 mbar. So the possibilities of selecting the pumps from the standard backing pumps offered are almost not limited at all. This does not restrict the selection of standard backing pumps. Many backing pumps such as oil-lubricated rotary vane pumps, compact diaphragm pumps or high-performance dry pumps can generate this fore vacuum pressure against atmosphere.

Figure 1: The multi-stage Roots pumps of the ACP series work clean and reliably

In many applications, for example in the thin-film technology, turbopumps are not optimized for minimal end pressure but for other parameters such as maximum gas throughput. In a first step before the actual vacuum process, low pressure is generated quite often as a cleaning measure. Therewith, gases on the surfaces of vacuum chambers or substrates are removed. The turbopump thus has to generate the low starting pressure at first and then must be able to support the process gas flow from the vacuum chamber. In short, the backing pump needs to generate a sufficiently low pressure under different operating statuses.

Oil-free backing pumps of the ACP series convince with their advantages

Rotary vane pumps are the classic backing pumps for turbopumps. They are relatively low-priced, reliable, and durable. Nevertheless, the operating fluid in use – the pump oil – is a possible source of hydrocarbon pollution. In consequence, oil-lubricated backing pumps hold a risk and cannot be used for demanding vacuum applications.

An oil-free alternative is the ACP series by Pfeiffer Vacuum. The ACP pumps are multi-stage Roots pumps, which provide long-time stability and reliability thanks to their contact-free construction principle. As there are no seals between the rotor and the stator in these kind of pumps, there is no wear compared to other oil-free pumps. Thus, no particles are generated.

Different gas composition with lower pressures

During a pump down process, the composition of the gas-displacing medium changes. At the beginning, dominating gases in the air such as nitrogen, oxygen, and argon are pumped. In lower pressure areas, the gases emitted by the surfaces dominate the complete gas composition – they are mostly hydrogen and water vapor. The backing and the high vacuum pump must be able to support these gases as well with a high degree of efficiency.

Pumping of water vapor

In a vacuum system, the main gases in the air (nitrogen, oxygen, and argon) have to be pumped very quickly. The inner surfaces of the vacuum system are covered with water vapor, which is emitted from the surfaces slower than it can be pumped.
If a water molecule is emitted from the surface into the gas phase, it can move to the turbopump in the molecular flow and be pumped out of the vacuum system. At the fore vacuum flange of the turbopump, these water molecules are collected together with other gas atoms and molecules and exhausted through the fore vacuum line and the backing pump. At the inlet of the backing pump, the pressure is comparatively lower. It increases up to atmospheric pressure or lightly above when flooding into the direction of the pump outlet. In the area of the highest pressure present in the pump, there is the danger of re-forming a condensable medium from the gas to the liquid phase. This must be prevented. If condensation appears inside the backing pump, the vapor pressure of the condensate determines the reachable end pressure of the backing pump. With a clean rotary vane or ACP pump, this means that the end pressure of around 10^{-2} mbar would increase to several mbar. In addition, the condensate may lead to massive corrosion inside the pump.

To avoid this, so-called gas ballast is used in many cases. Thereby, gas is additionally let in into the vacuum pump. Gas ballast heats up the pump and opens the outlet valves earlier than without gas ballast. Gas ballast can be used in ACP pumps as well as in rotary vane pumps. However, the added gas leads to a slight increase in the reachable end pressure of the fore vacuum pump.

Pumping of light gases

With pressures in the high vacuum range, molecular flows and thus movements of single gas atoms and molecules are present. Therefore, the efficiency of the turbopump for single gas atoms and molecules must be examined. This can be done by determining the so-called compression ratio. With the compression ratio, there are relatively big differences between the behavior of light gases such as hydrogen (mass 2 u „atmonic mass units“) and helium (mass 4 u) as well as the dominating air gases such as nitrogen (28 u), oxygen (32 u) and argon (40 u). The compression ratio of turbopumps for nitrogen is normally very high (approximately $1 \cdot 10^8$ to $1 \cdot 10^{11}$), but much lower for light gases (circa $1 \cdot 10^2$ to $1 \cdot 10^5$).

The light gases hydrogen and helium are important for vacuum systems: hydrogen is emitted from metallic materials in the vacuum chamber. Helium serves as working gas in low temperature technology and in leak detection. Thus, the performance of the backing pump for light gases has to be checked. Light gases in turn enter the backing pump at comparatively low pressure and are emitted at atmospheric pressure or slightly above. Every counter pressure at the exhaust of the backing pump – no matter if it is a valve, an exhaust silencer, an oil mist filter or only the static pressure of an air column – can prevent the very small gas flow of the vacuum system from leaving the backing pump. Thereby, the fore vacuum pressure and therewith the end pressure may increase. To reach a low end pressure in the high vacuum range anyway, light gases have to be diminished effectively from the fore vacuum system.

This can be realized, for example, by slightly decreasing the pressure at the backing pump´s outlet. There is thus a kind of pumping effect at the outlet of the backing pump. The needed pressure decay is around 20 mbar. Very often, this value can already be reached when connecting the pump to an exhaust system.

Also with the use of gas ballast or purging gas, the backing pump can process more gas then simply with the gas flow from the high vacuum system alone. This is valid for an ACP pump at the size of several standard liters per minute (slm). The end pressure of the backing pump is slightly downgraded by the additional gas load. The purging gas is a heavy gas such as dried air or nitrogen. As a reminder: the compression ratio of a turbopump is higher for heavy than for light gases. Even if the end pressure in a backing pump is increased by a heavy gas, the end pressure in the high vacuum range is optimized anyway by the outcasting of light gases.

This could be proven in several experiments. Thanks to the use of a needle valve at the connection of the gas ballast, the gas throughput was made controllable and users could thus make fine adjustments. A currentless closed, electromagnetic valve in series allows for blocking the purge gas flow in case of an energy shut down.

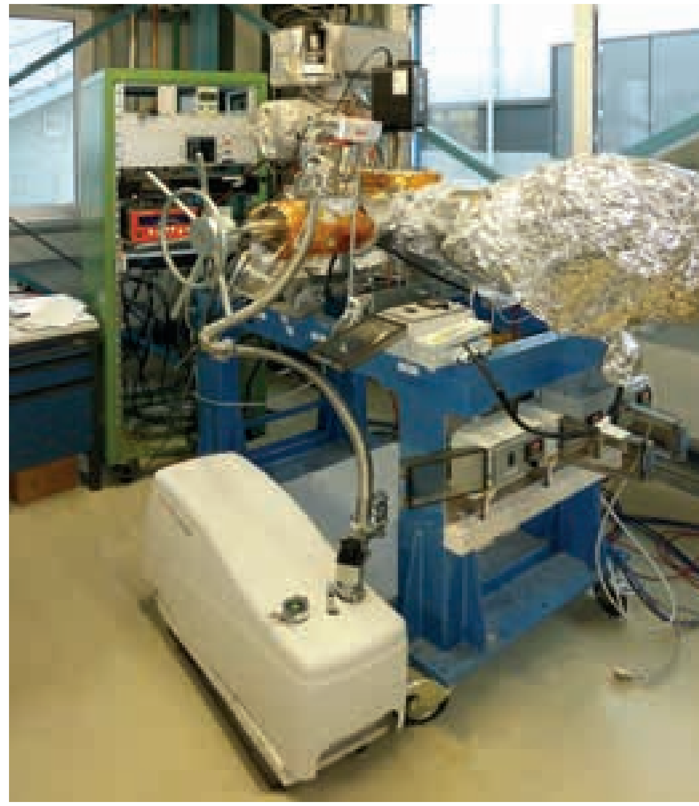

Figure 2: Test setup for qualifying a pump combination of ACP backing pump and HiPace turbopump

Combination of ACP and HiPace: optimal solution

In the past, several test setups have been built up by various users. With them, the most suitable combination of backing and turbopump should be qualified. Out of the the many combination possibilities, the one of the ACP Roots pumps with the turbopumps of the HiPace series was by far most convincing. The results of different tests as well as the experience of the last years show that this pump combination has decisive advantages compared to other concepts.
The pump combination of an ACP backing pump with a HiPace turbopump by Pfeiffer Vacuum

- is completely fluor-free and thus does not hold any danger of process pollution
- is exteremly maintenance friendly
- works energy efficient and cost saving
- has a low noise level

has an extremely low end pressure.

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