Tip of the Month/No. 15

Pump down curves and what you can learn from it, Part 2

Question:
In your last tip, you wrote about pump down curves with rotary vane pumps. Does all that also apply for turbopumps, when I run my system at lower pressure ranges under high vacuum?

Answer:
Even if vacuum is defined as empty space, it does not mean that there are no gases at all left in high vacuum systems. The base pressure of a system is determined by the pumping speed of the high vacuum pump(s) used and the gas load which flows from the vacuum chamber. This gas flow is made up of various components, which determine the shape of a pump down curve.

Background:
In our last tip, we explained the effects of water on the pump down process. Even at low pressures, water vapor can greatly affect the achievable base pressure of a system. Water may outgas from the surfaces of the vacuum chamber. The outgassing rate depends to a great extent on the surface materials, such as metal, glass or plastics. In addition to the material, the quality of the surface can also have a major influence on the outgassing rate.

Take, for example, a standard KBH type cubical chamber from our product range.

The medium-sized chamber has an edge length of 500 mm. This corresponds in cubic geometry to a surface of 15,000 cm^2. On this surface, a supply of gas is adsorbed which is slowly released from the surface. This outgassing takes place much more slowly than the pumping down of gas that is freely present in the room. Data for the outgassing rate from surfaces can be found in tables attached to vacuum textbooks. For the chamber material (stainless steel 1.4301 or SS 304), an outgassing rate per unit area of approximately $1.3 \cdot 10^{-9}$ mbar$\cdot$l$\cdot$s$^{-1}\cdot$cm^{-2} is specified. This rather unwieldy unit gives a gas flow in mbar$\cdot$l$\cdot$s^{-1} in relation to a surface area in cm^{-2}.

If the value of the outgassing rate per unit area is multiplied by the surface area of our chamber, this results in an outgassing rate of $1.95 \cdot 10^{-5}$ mbar$\cdot$l$\cdot$s^{-1}. If we evacuate the chamber with a HiPace 300 type turbopump with a pumping speed of 300 l/s, we theoretically obtain a base pressure of $6.5 \cdot 10^{-8}$ mbar. Data given in tables are usually measured after a pumping time of one hour. We therefore need an hour to reach the specified pressure. The outgassing rate can be reduced by pumping or baking out the vessel for a prolonged period.

If we choose a stainless steel door, we will be unable to observe processes in the chamber. However, replacing a stainless steel door with a transparent acrylic glass door changes the material and the surface of the door and also affects the desorption gas flow. In tables, the desorption rate per unit area of acrylic glass is given as around $300 \cdot 10^{-9}$ $mbar \cdot l \cdot s^{-1} \cdot cm^{-2}$.

This means that if we replace 1/6 of the stainless steel surface with the acrylic door, we get a desorption gas flow totaling $7.66 \cdot 10^{-4}$ $mbar \cdot l \cdot s^{-1}$ and thus a base pressure of $2.55 \cdot 10^{-6}$ mbar. Essentially, the observation facility through the transparent door is achieved at the cost of attaining a higher base pressure, reduced thermal stability of the materials and reduced bakeability.

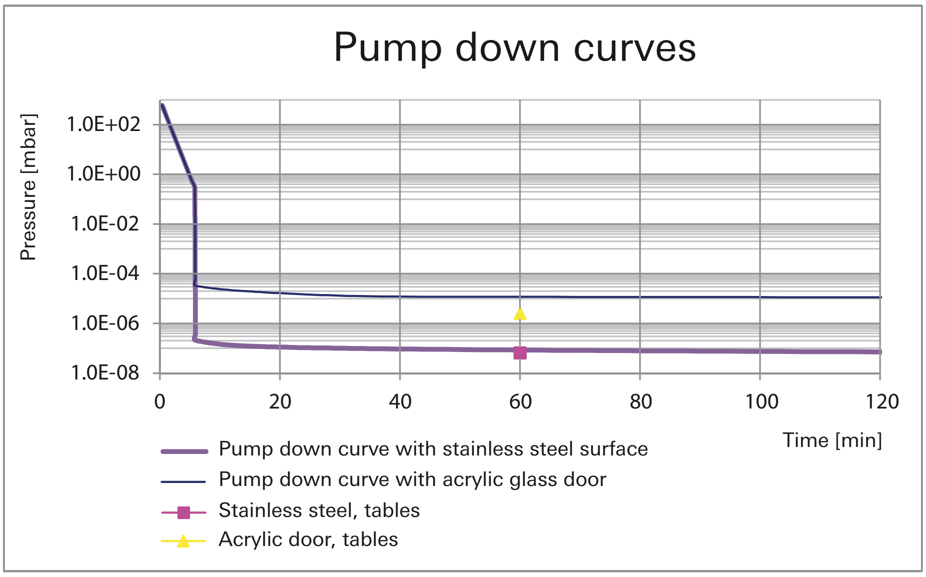

Figure 1: Pump down curve of a vessel with 500 mm edge length; pumping system: backing pump and HiPace 300 turbopump

Figure 1 shows a comparison of the pump down curves of an identical chamber with a stainless steel door and an acrylic glass door. In addition to the data points which every user can calculate manually from publicly available tables after an hour, complete pump down curves with a commercially available simulation program are also shown. Depending on the origin of the data in the tables, it is sometimes possible to achieve a good correlation, as can be seen from our model. However, in the literature, a span of more than three decades is given for stainless steel. The large variation is due to different alloys, pre-treatments, surface finishing and baking out. From our model with the acrylic glass door, we can immediately see significant deviations from figures given in the literature. We would therefore recommend scaling, or even selecting new pumps, on the basis of the measured data. This means that we recommend plotting a reference curve in both the low vacuum and high vacuum range.

As a rule of thumb, it can be said that the outgassing rate of metals is relatively low while plastics provide much higher contributions to the total gas flow. Exceptions to this rule are found in metals such as zinc or brass alloys, which also exhibit very high outgassing rates. The outgassing rates of elastomers can be affected by the chemical composition and additives. Mechanical or thermal pre-treatment can drastically reduce the outgassing rate. So it pays to invest in vacuum-compatible materials.

In Figure 1, we assume that the pump is directly connected to the chamber. In Figure 2, we see the influence of an elastomer seal that insulates the chamber flange from the turbopump connection flange. In addition to desorption from the surface of the seal, we also assume permeation through the elastomer material. It becomes obvious that the turbopump seal only has a minor effect compared to the acrylic glass chamber door.

If we equip our chamber with additional flanges and the corresponding seals, the impact of surface desorption and permeation through elastomers will be stronger and the achievable base pressure will continue to rise.

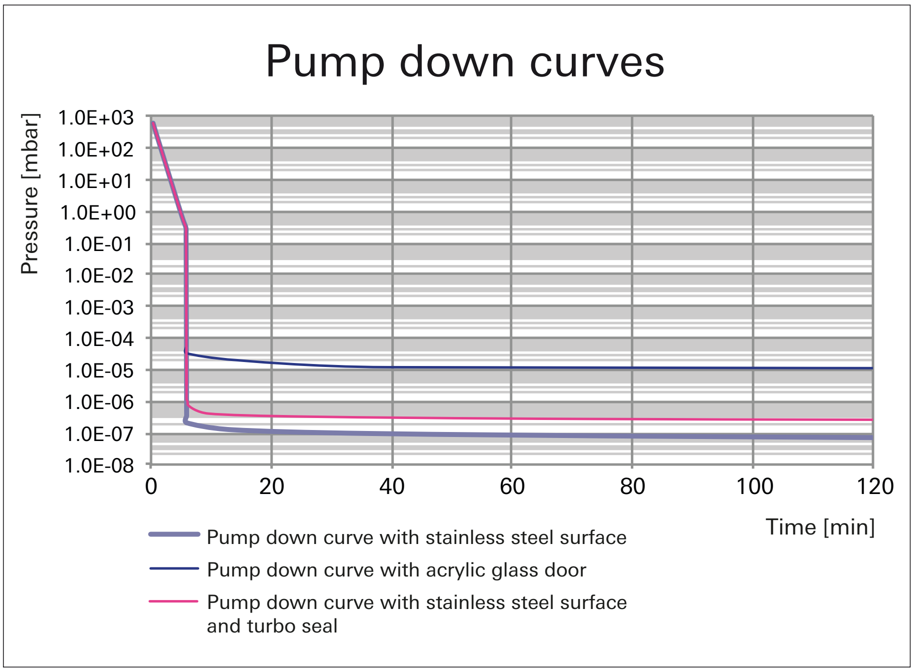

Figure 2: Pump down curve of a vessel with an edge length of 500 mm; pumping system: backing pump and HiPace 300 turbopump as well as a DN 160 PTFE seal with a thickness of 5 mm and 2 mm compression

The above paragraphs only describe the gas flows that form in the system as a result of the design. If a system needs to be ventilated, the surfaces will become coated again with water vapor from the atmosphere while they are being ventilated with air. If the system is ventilated with dried air, or even better with dry nitrogen or argon, coating of the surface can be significantly reduced. When pumping down after ventilation with a dry inert gas, low pressures are reached much faster than when ventilated with ambient air. The chamber should only be opened to carry out any work that is needed.

In addition, operational gas flows can occur. If a vacuum system is operated with base pressure for an extended period, it is possible for oil from the operating media to diffuse back from an oil-lubricated backing pump into the fore-vacuum line. We referred in our last tip to the enlargement of surfaces in coating systems and the associated higher amount of adsorbates. Finally, leakage currents also contribute to an increase in the base pressure of a vacuum system.

So in high vacuum, too, we should remember: Deviations between a reference pump down curve and a measured curve often allow faults to be detected at a glance. Detailed analysis of a pump down curve allows a better understanding of the processes involved and offers approaches to problem solving.

Do you have a question yourself which you would like us to answer on this page as a new tip of the month? If so, please let us know. (info@pfeiffer-vacuum.de)

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