Tip of the month/No. 14

Pump down curves and what one can learn from them, Part 1 - Low and medium vacuum

Question:
The pumps in my vacuum system are starting to get old and it takes much longer for them to pump down. I recently requested an alternative solution for the existing pumping system from you. One of your colleagues asked me many details about my system and then finally asked for a pump down curve. What is that anyway and what can one derive from it?

Answer:
A pump down curve describes a time-dependent pressure drop in a vacuum system. In a graphical representation, the time is applied to the X-axis and the pressure to the Y-axis. For the known geometry of the vacuum chamber and pumps, a pump down curve can be calculated. Any deviations between the calculated and the measured pump down curve will often provide information about problems in the vacuum system. This also applies to the comparison of curves measured over long-term use with a reference curve.

Background:
A reference curve can be measured, when the system runs properly and without any problems after startup. Under these conditions, the pressure drop is measured over the time during pump down. The time is generally applied linearly to the X-axis and the pressure is applied logarithmically to the Y-axis. The measurement can either be taken manually, using a system control, or using our software packages for pressure gauges.

To software for our DigiLine measurement instruments:

To software for our ActiveLine measurement instruments:

In our example, in Figure 1, you can see the calculated pump down curve of a 100-liter chamber. A Duo 65 rotary vane pump was used as a vacuum pump. We use this curve as the standard for comparison.

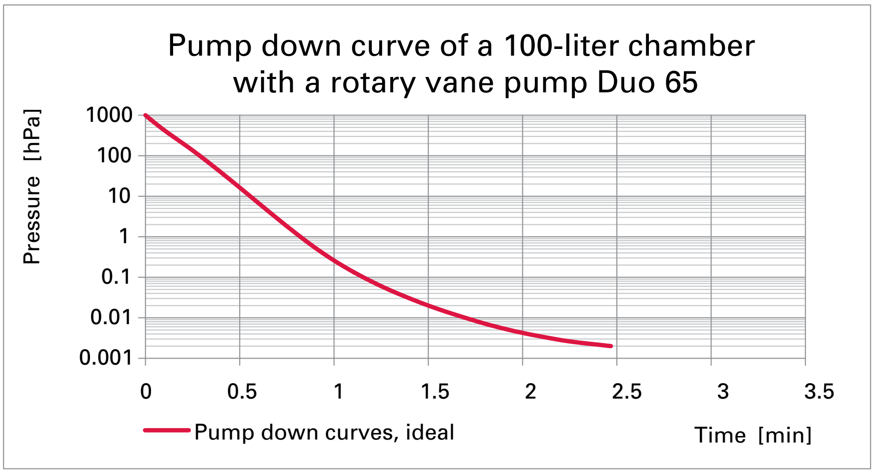

Figure 1: Pump down curve of a 100-liter chamber with a rotary vane pump Duo 65

In Figure 1, we assumed that the pump is directly connected to the chamber. In Figure 2, you can see the effect of a flexible corrugated hose on the pump down behavior, which is used as a connection between the chamber and the pump. The tube has a length of 1000 mm and a diameter of 40 mm.

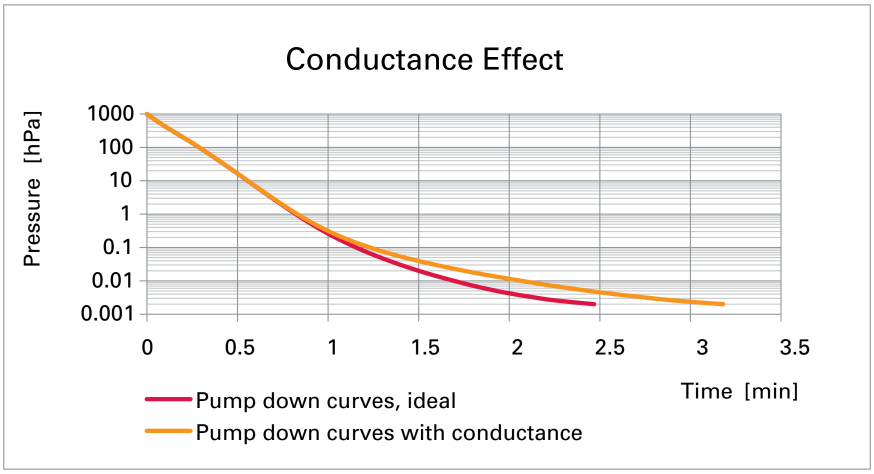

Figure 2: Conductance Effect

The connecting bellows has almost no effect on pump down time above a pressure of approximately 1 hPa. But if we want to further evacuate the chamber down to 0.01 hPa, the pump down process will take about 20 % longer, solely due to the effect of the bellows. A solution for this is to shorten the connection piece or to increase the piping diameter.

Flow resistance depends linearly on the length, but in the third or fourth power on the diameter. If in doubt, as a corrective measure rather the diameter should be increased than the connection shortened. In this case, the comparison between the two curves shows the influence of the pipe and can help in the design of the connection between the chamber and the pump.

Now we can deal with the influence of operating the vacuum system. Figure 3 shows the influence of a small amount of water on the pump down process.

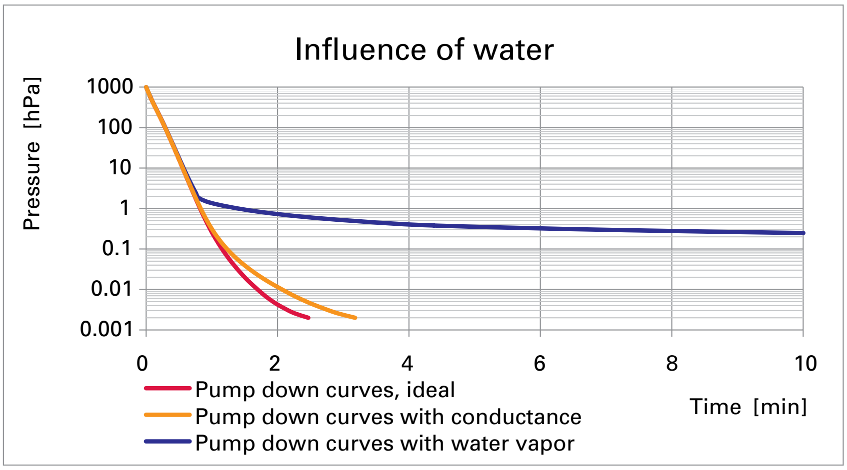

Figure 3: Influence of water

The previously achieved base pressure is missed by more than a factor of 100 and the time scale seems to be almost extended to infinity. This example appears to be constructed and dramatic. But in fact, this is a measured curve from an existing coating system. Over time, both the parts and the carriers have been coated. Coating of the parts is a well-controlled process in order to achieve a dense layer with high adhesion and tailored tribological properties. However, coating of the carriers is a random process which leads to a coating with a loose, brittle multi-layer structure with low adhesion. The loose, layered structure tends to release particles and form a large surface area. On this surface area, which has built up over time, large amounts of water vapor can now accumulate, and these thin absorbent layers cannot be detected with the naked eye. The time required for the pump down has not suddenly become longer, but has been slipping over an extended period of time during operation.

The first step of pumping down water vapor from vacuum chambers consists of a slow desorption of the water film adhering to the inner surfaces of the vacuum chamber. This particular surface process is significantly slower than the pump down of a gas or a vapor, which is already in the gaseous phase.

Figure 3 shows the bend of the pump down curve in the range between 10 and 1 hPa, which is typical for a water vapor adsorbed layer on a surface of the vacuum chamber or from installations. This value may change depending on the vapor pressure of the medium or the accessibility of the surface.

For example, if you cleaned your vacuum system with a highly volatile alcohol, such as isopropanol, the alcohol will evaporate quickly. Evaporation takes place more quickly than the pump down and no bend in the pump down curve is observed as in the water entry in Figure 3. Oils and operating fluids from backing pumps may indeed have a significant impact on and create a hump in the pump down curve with a lower pressure than in our example. This also applies to water vapor desorption, which does not come from a free surface but, for example, from a winding. Figure 4 shows the effect of using a film for thermal insulation in the interior of the vacuum chamber.

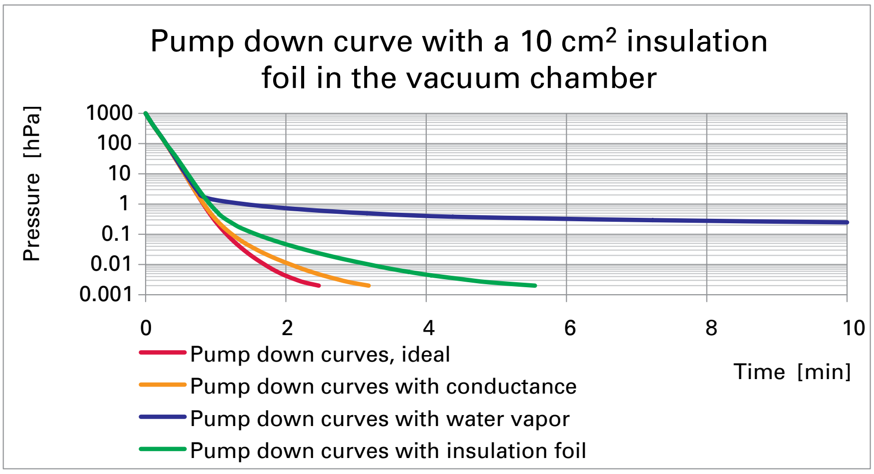

Figure 4: Pump down curve with a 10 cm^2 insulation foil in the vacuum chamber

The desorbing medium is actually water vapor, but due to the stronger bond to the surface and the slow escape from the foil winding, the water signal only appears at a lower pressure. In our example, the addition of just 10 cm^2 of foil insulation, leads to an extension of the pump down time up to a base pressure of 75 %. In addition to insulation foils, cable sheathing or other plastics in the vacuum can display similar effects.

So before you invest in new pumps, be sure to analyze the pump down curve. By looking at the deviations between a reference curve and a measured curve, faults can often be detected at a glance. The detailed analysis of a pump down curve improves the understanding of the processes involved and provides basic approaches for problem solving.

When moisture enters into the system, an external drying of the used components or the cleaning of the vacuum chamber is often better in achieving the target values for the down pump time than investing in larger pumps. In particular, the surface treatment of the chamber in the high vacuum is one of the most important parameters for the achievable ultimate pressure. Next month in the second part of this tip, we will analyze the pump down curves in the high vacuum.

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)

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