Tip of the month / No. 19

What is a compression ratio?

A compression ratio is generally the ratio of discharge pressure to intake pressure of a pump. For the turbomolecular pumps, in particular, it is the ratio of the pressure measured at the fore-vacuum flange, to the pressure measured on the high vacuum flange.

The compression ratio is usually determined without any gas throughput through the pump. This is known as the zero throughput, which is identified by the index "0". In the literature and the technical data for a turbomolecular pump, the compression ratio is therefore usually referred to as K_0.

The compression ratio of a turbomolecular pump is measured in practice by increasing the backing pressure through gradually introducing a gas into the fore-vacuum line, while measuring the ensuing high vacuum pressure.

The compression ratio is dependent on several factors. The most important are the type of gas and the design of the turbomolecular pump.

The pumping action of a turbomolecular pump is based on the principle that more gas particles flow from the high vacuum side to the fore-vacuum side than the opposite way around. This is achieved by the targeted acceleration of particles by the rapidly rotating rotor blades. The lighter the gas, the faster is its molecular motion (see table 1).

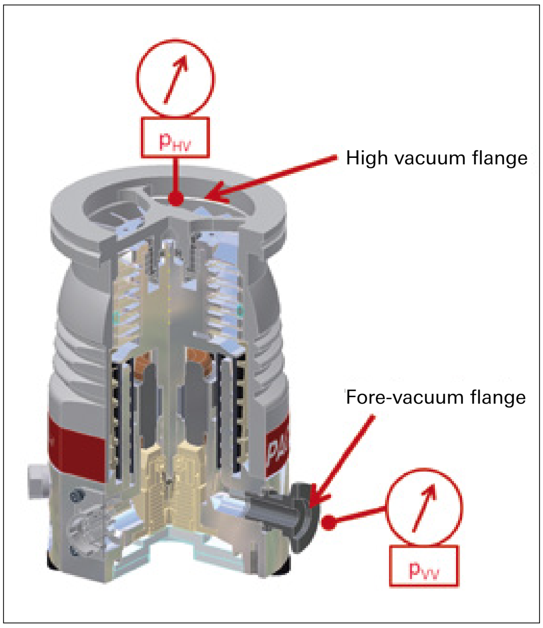

Figure 1: Cross-section of a turbopump

$$K = \frac{p_{VV}}{p_{HV}}$$

p_{VV} = Pressure at the fore-vacuum flange
p_{HV} = Pressure at the high vacuum flange

Formula F1

Gas	Molar masse [g/mol]	Mean velocity [m/s]	Mach number
H_2	2	1,762	5.3
He	4	1,246	3.7
H_2O	18	587	1.8
N_2	28	471	1.4
Air	29	463	1.4
Ar	40	394	1.2
CO_2	44	376	1.1

Table 1: Molar masses and mean velocities of various gases (Vacuum Technology Book)

In light gas molecules, the backflow velocity towards the high vacuum side is therefore higher than for heavier molecules. Since with light gas molecules there are more gas particles present on the high vacuum side as a result, the pressure there is correspondingly higher and the compression ratio is therefore lower (see figure 2).

In modern turbomolecular pumps there are generally several pumping principles combined. The so-called turbo pumping stages are common to all turbomolecular pumps. These can be seen if you look into the high vacuum flange of the pump. The similarity in appearance to a turbine gave this pump its name.

To increase the compression ratio, pumping stages are often used downstream of the turbo stages. The pumping principles differ depending on the manufacturer. There are stages known as Holweck, Gaede or Siegbahn stages; on rare occasions even side channel stages. What they all have in common is that they more effectively pump light gases, in particular, in higher pressure ranges than just turbo stages, as shown in figure 3 using the example of helium gas. The compression ratio of Holweck stages, found in HiPace turbomolecular pumps, is outstanding for this gas.

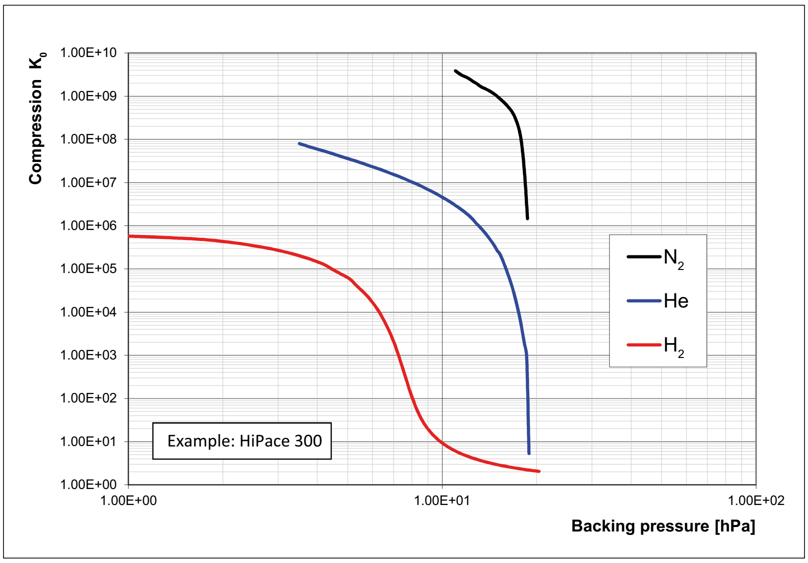

Figure 2: Gas-type dependency of the compression ratio

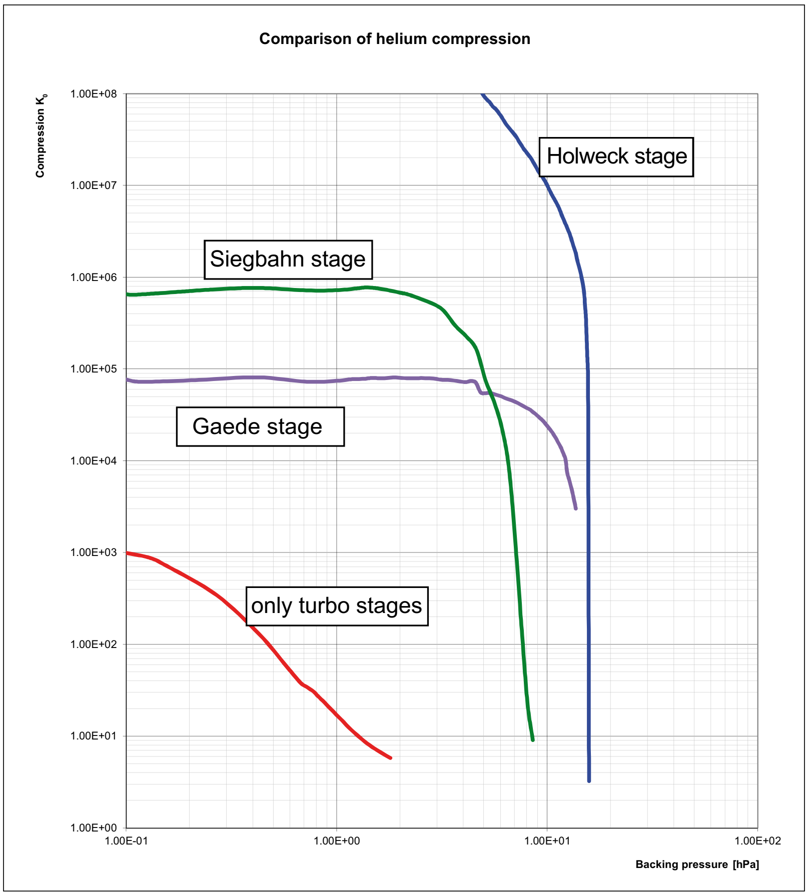

Figure 3: Comparison of helium compression with different pump principles

How can I read this data, and what practical consequences do they have for me?
The compression ratio K_0 for the most important types of gas (usually nitrogen, argon, helium and hydrogen) is part of the catalog data of a pump and can certainly be found in the technical data.

The higher the compression ratio, the lower the final pressure is to be expected on the high vacuum side. The easiest way to explain this is with an example:

A HiPace 300 type turbomolecular pump has a compression ratio K_0 for helium of more than $1 \cdot 10^8$.
If a backing pump with an ultimate pressure of 0.1 hPa is used, for example using a rotary vane pump, a theoretical final pressure of less than $1 \cdot 10^{-9}$ hPa is obtained through transposing formula F1

$$p_{HV} = \frac{p_{VV}}{K_0} = \frac{1 \cdot 10^{-1}}{1 \cdot 10^8}\ [hPa] = 1 \cdot 10^{-9}\ [hPa]$$

In practice, however, these pressures can hardly be reached, since due to permeation of gas molecules through seals and desorption by chamber walls, there is always a gas flow present through the pump. Nevertheless, a turbomolecular pump with a high compression ratio can reach a substantially lower final pressure than a turbomolecular pump with a lower compression ratio.

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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