



TIPS AND TRICKS FROM THE EXPERTS

Compression ratio of turbopumps Definition, calculation, and use of data

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.

Defining the compression ratio

The compression ratio is usually determined without any gas throughput inside 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 turbopump, the compression ratio is therefore usually referred to as K_0 . The compression ratio of a turbopump 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.

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

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

Formula F1: Calculating the compression ratio

The compression ratio depends on several factors. The most important ones are the gas type and the design of the turbo-

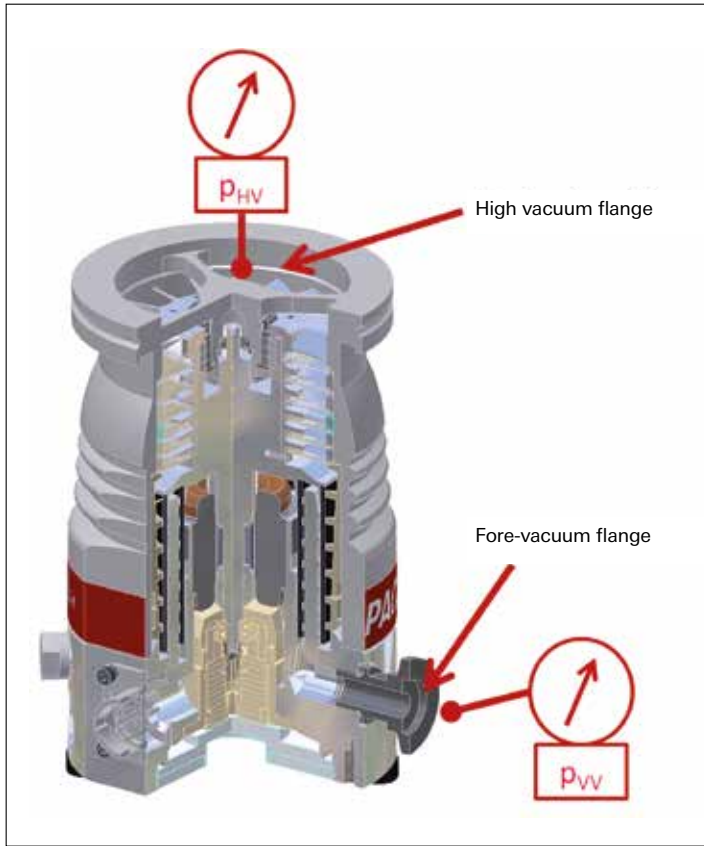


Figure 1: Cross-section of a turbopump

pump. The pumping action of a turbopump is based on the fact 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 its molecular motion (see table 1).

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

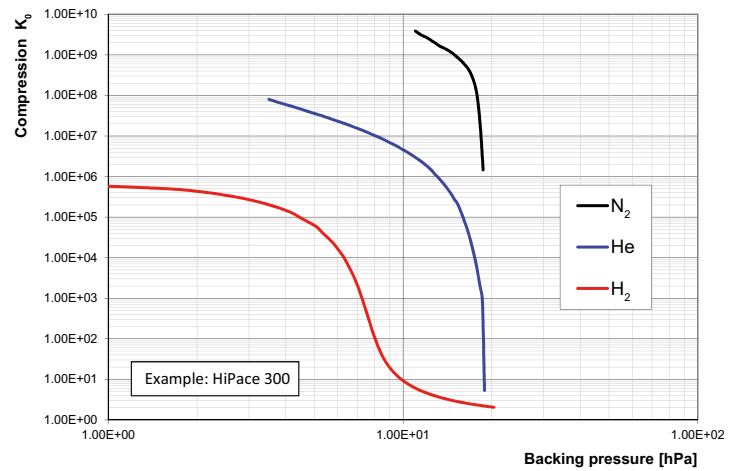


Figure 2: Gas-type dependency of the compression ratio

In modern turbopumps, there are generally several pumping principles combined. The so-called turbo pumping stages are common to all turbopumps. They can be seen by looking 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, also side channel stages are used. They all pump light gases more effectively in higher pressure ranges than just turbo stages, as shown in figure 4 by using the example of helium gas. The compression ratio of Holweck stages, found in HiPace turbopumps from Pfeiffer Vacuum, is outstanding for this gas.

Gas	Molare masse [g/mol]	Mean velocity [m/s]	Mach number
H ₂	2	1,762	5.3
He	4	1,246	3.7
H ₂ O	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: Molecular masses and mean velocities of various gases

Interpretation and use of the data

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 turbopump 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 by operating a rotary vane pump, a theoretical final pressure of less than $1 \cdot 10^{-9}$ hPa is obtained through transposing formula F1.

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

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

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

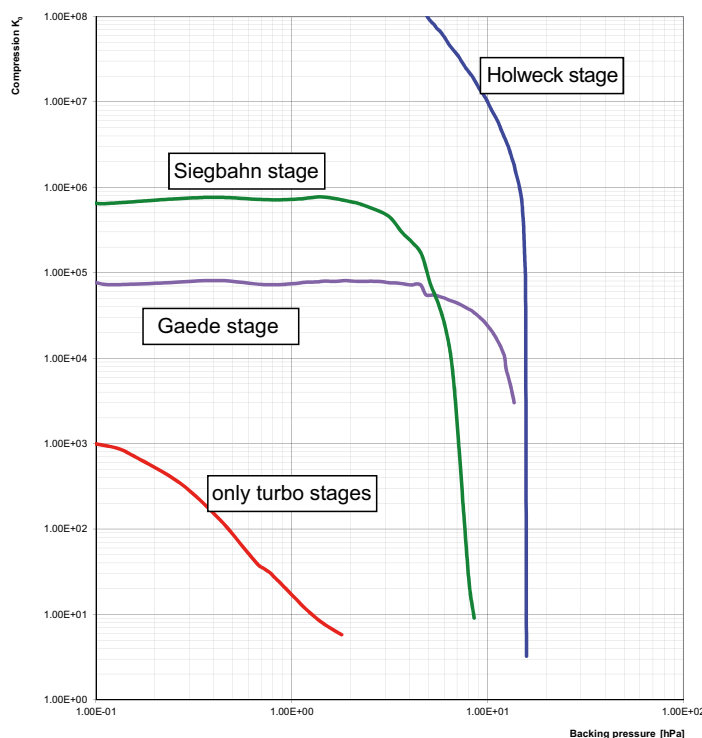


Figure 4: Comparison of helium compression with different pump principles

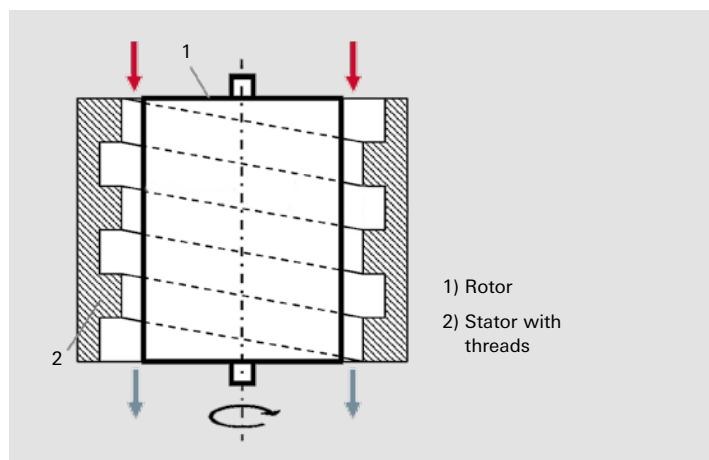


Figure 3: Operating principle of a Holweck stage, whose compression ratio is outstanding

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