Precise flow measurement of arbitrary gas species over a wide range

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Numerous applications of vacuum technology require the precise measurement of gas flow. Challenges are very small flows in UHV experiments and sensitive leak detection, very large flows in tests of powerful coarse-vacuum pumps, and the use of exotic gases in plasma-coating and semiconductor processing. One basic approach for gas measurement is the usage of constrictions with known properties (conductance) which reduces the problem of flow measurement to the problem of pressure measurement. Various types of constrictions may be employed, i.e. the thin orifice, the Venturi-nozzle, and capillary-like devices.

The flow through the various constrictions depends on type and dimensions of the constriction as well as on the experimental conditions. This may be illustrated by examples: In case of an orifice, the throughput in the molecular regime is proportional to the thermal molecular velocity of the gas, and in the viscous regime it additionally depends on the isentropic exponent. In case of a capillary, the throughput is determined by the viscosity of the gas species. In the talk, the behaviour of gas flowing through the various constrictions and the theoretical calculation of throughput is sketched. This fundamental approach provides insight in the important flow properties and to derive general scaling laws.

There is a strong need for precise experimental investigations of the characteristics of constrictions. The need stems essentially from two motivations:

- Testing the fundamental theoretical models which are used in the ab-initio calculations. Preferably, the corresponding measurements are performed on devices with perfect shape and well-known mechanical dimensions in order to obtain a decisive quantitative comparison of theory and experiment.
- Precise determination of the conductance of individual devices which are employed for precise measurements of gas throughput in practical applications. Frequently, these devices do not have perfect shape, their surfaces are not perfectly smooth, and their actual dimensions are not known with sufficient accuracy. Furthermore, the actual flow may differ from the simplified ideal flow behaviour assumed in the calculations.

In experimental investigations of gas flow through a constriction, the flow can be precisely measured by two fundamental methods: First, measuring the gas volume (at known pressure and temperature) passing per time interval through a duct. Second, measuring the pressure change in a vessel (with known volume) caused by gas flowing into or out of the vessel. In the talk, different technical realizations of these methods are shown and their performances are discussed. An analysis of direct and indirect error sources and the accuracy is performed.

Keywords: gas flow measurement, orifice, Venturi-tube, metrology

Reference: K. Jousten (ed.): Wutz Handbuch Vakuumtechnik, 9th ed, Wiesbaden: Vieweg, 2006

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