Physikalisch-Technische Bundesanstalt
Nationales Metrologieinstitut

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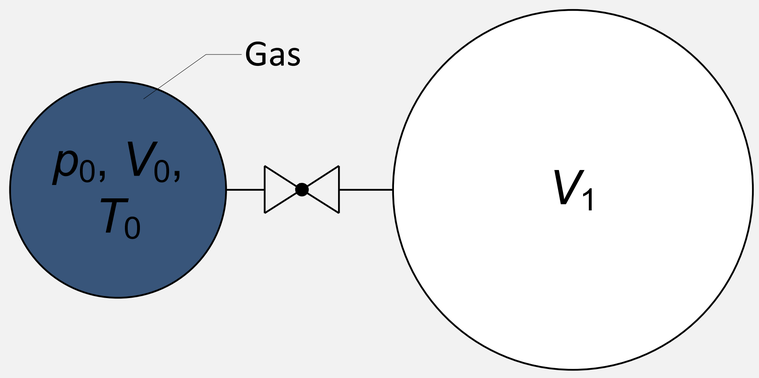
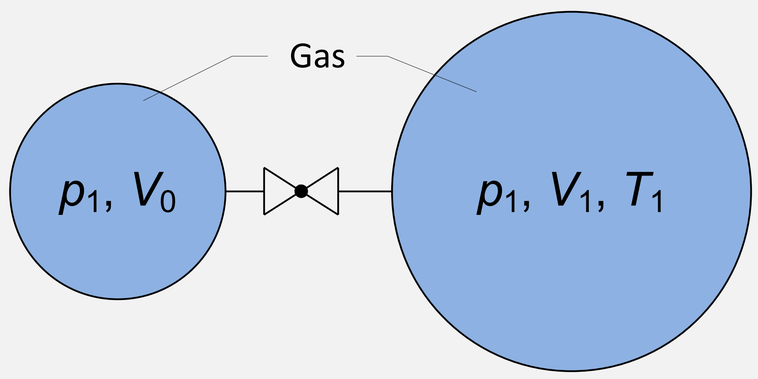
Static Expansion

Method

The static expansion method relies on the expansion of a fixed amount of gas from a small volume into a much larger volume. Using the ideal gas law the generated pressure is determined from the volume ratio, the initial pressure, as well as the temperature of the gas before and after expansion.



Before expansion, valve closed: Gas contained in a small volume V_0 with high pressure p_0. Volume V_1 is evacuated.



After expansion, valve opened: Gas is distributed in both volumes V_0 and V_1 with lower pressure p_1.

Model Equation

Ideal gas law:

$$pV = Nk_B T$$

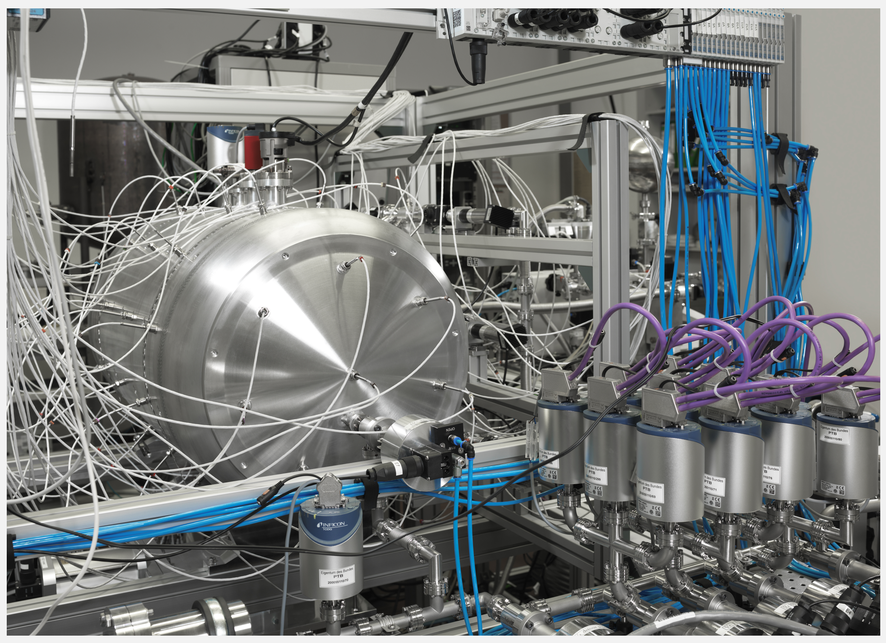
By expanding gas from the volume V_0 under pressure p_0 at temperature T_0 to the volume V_1, a pressure p_1 is generated:

$$\frac{p_0 V_0}{T_0} = Nk_B = \frac{p_1(V_0 + V_1)}{T_1}$$

$$\Rightarrow p_1 = p_0 \frac{V_0}{V_0 + V_1}\frac{T_1}{T_0} = p_0 f \frac{T_1}{T_0}$$

with N the number of gas molecules and k_B the Boltzmann constant. The smaller the expansion ratio $f = \frac{V_0}{V_0+V_1}$, the smaller the pressure after the expansion. V_0 and V_1 are called starting and calibration volume, respectively.

The Primary Standard SE3



Static expansion primary standard SE3

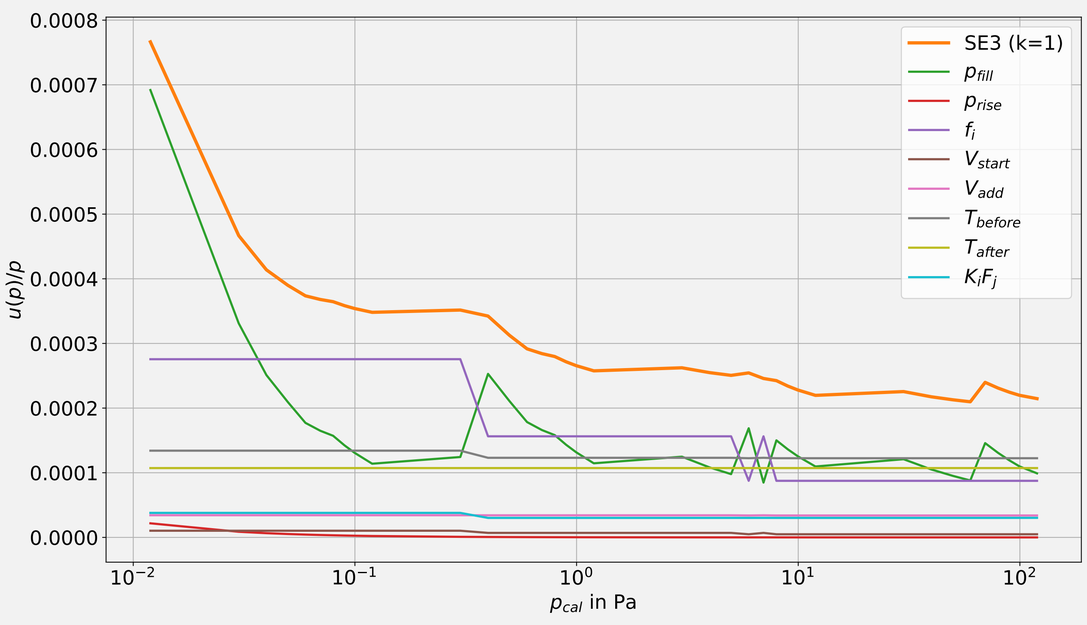
This primary standard generates calibration pressures by expanding gas from one of three different starting volumes with V_s = 0.02 L, V_m = 0.2 L and V_l = 2 L to the calibration volume of V_1 = 200 L in a single step. With a starting pressure of 100 Pa expanded from V_s a calibration pressure of 1×10^{-2} Pa can be generated whereas 100 kPa and V_l generate 100 Pa.

SE3 Uncertainty

The total uncertainty $u(p)$ is calculated from the uncertainty contributions of the input quantities x_i via Gaussian uncertainty propagation

$$u(p) = \sqrt{\sum_{i=1}^{N}\left(\frac{\partial p(x_i)}{\partial x_i}\right)^2 u(x_i)^2}.$$

The most important contributions are the uncertainty of the filling pressure p_{fill}, the uncertainty of the volume ratios f_i and the uncertainty of the temperature of the starting volume T_{before}.



Uncertainty contributions of the generated pressure in the range 1×10^{-2} Pa to 100 Pa.

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