**Rotameter Analysis** (by Dr. Lewis, Dec 2009)

A rotameter is calibrated at a given temperature (Tcal) and pressure (Pcal). The corresponding volumetric flow rate at the calibrated conditions of Tcal and Pcal is usually reported as a standard volumetric flow rate at standard conditions (Pstd, Tstd). Standard conditions and calibrated conditions are not necessarily the same. If the experimental conditions (Pexp, Texp) are different than the calibrated conditions, the standard volumetric flow rate reading must be corrected. If the experimental and calibrated conditions are the same, no correction is necessary. To summarize,

Tcal, Pcal: T and P of rotameter during calibration

Texp, Pexp: T and P of rotameter during the experiment

Tstd, Pstd: T and P for which the standard volumetric flow rate is defined

From theory, the actual volumetric flow rate of a rotameter used for gas at any operating T and P is proportional to the square root of the inverse density. Therefore, for an ideal gas

 $Q\_{cal}^{act}≈\sqrt{\frac{1}{ρ}}≈\sqrt{\frac{T\_{cal}}{P\_{cal}∙MW\_{cal}}}$ and $Q\_{exp}^{act}≈\sqrt{\frac{1}{ρ}}≈\sqrt{\frac{T\_{exp}}{P\_{exp}∙MW\_{exp}}}$ (1)

where the first equation represents the actual flow rate at calibration conditions and the second equation represents the actual flow rate at experimental conditions. The ratio of the two equations gives:

 $Q\_{exp}^{act}=Q\_{cal}^{act}\sqrt{\frac{P\_{cal}}{P\_{exp}}\frac{T\_{exp}}{T\_{cal}}\frac{MW\_{cal}}{MW\_{exp}}}$ (2)

This is the correction equation if you know the actual volumetric flow rate at calibration conditions and you want to know the actual volumetric flow rate at experimental conditions. This is the equation reported in Airflow Hint #2 on the UO lab website. However, the rotameter usually gives a standard volumetric flow rate at calibration conditions. The standard volumetric flow rate is related to the actual volumetric flow rate according to (assuming ideal gas):

 $Q\_{cal}^{std}=Q\_{cal}^{act}\frac{T\_{std}}{P\_{std}}\frac{P\_{cal}}{T\_{cal}}$ (3)

$Q\_{cal}^{std}$ is the reading of the rotameter as you are doing the experiment. Thus, the actual volumetric flow rate at experimental conditions is:

 $Q\_{exp}^{act}=Q\_{cal}^{std}\frac{P\_{std}}{T\_{std}}\sqrt{\frac{T\_{cal}}{P\_{exp}}\frac{T\_{exp}}{P\_{cal}}\frac{MW\_{cal}}{MW\_{exp}}}$ (4)

Similar to equation (3), the standard volumetric flow rate at experimental conditions can be related to the actual volumetric flow rate at experimental conditions:

 $Q\_{exp}^{std}=Q\_{exp}^{act}\frac{T\_{std}}{P\_{std}}\frac{P\_{exp}}{T\_{exp}}$ (5)

Substituting (5) into (4) gives:

 $Q\_{exp}^{std}=Q\_{cal}^{std}\sqrt{\frac{P\_{exp}}{P\_{cal}}\frac{T\_{cal}}{T\_{exp}}\frac{MW\_{cal}}{MW\_{exp}}}$ (6)

This is the correction equation if you know the standard volumetric flow rate at calibration conditions and you want to know the standard volumetric flow rate at experimental conditions. Again, $Q\_{cal}^{std}$ is the reading of the rotameter as you are doing the experiment if the rotameter gives the standard volumetric flow rate rather than the actual volumetric flow rate. As shown by Equation (6), if the experimental and calibrated P, T, and MW are the same, no correction is necessary. Note the difference between the correction using Equation (6) and Equation (2). Equation (2) is applicable for actual volumetric flow rates and Equation (6) is applicable for standard volumetric flow rates. Since most rotameters give $Q\_{cal}^{std}$ during the experiment, Equation (6) is what you would use to obtain the “true” standard volumetric flow rate at experimental conditions.

Example 1: When a rotameter is calibrated using H2 (MWcal=2) but experimentally is used for He (MWexp=4) with Tcal=Texp and Pcal=Pexp, then the standard volumetric flow rate is less than what is read by the rotameter according to:

 $Q\_{exp}^{std}=Q\_{cal}^{std}\sqrt{\frac{MW\_{cal}}{MW\_{exp}}}=Q\_{cal}^{std}\sqrt{\frac{2}{4}}=0.7Q\_{cal}^{std}$

Example 2: When a rotameter is calibrated at Pcal=14.7 psia (1 atm) but experimentally is used at Pexp=58.8 psia (4 atm) with Tcal=Texp and MWcal=MWexp (same gas), then the standard volumetric flow rate is greater than what is read by the rotameter according to:

 $Q\_{exp}^{std}=Q\_{cal}^{std}\sqrt{\frac{P\_{exp}}{P\_{cal}}}=Q\_{cal}^{std}\sqrt{\frac{58.8}{14.7}}=2.0Q\_{cal}^{std}$

Example 3: When a rotameter is calibrated at Tcal=293 K but experimentally is used at Texp=298 K with Pcal=Pexp and MWcal=MWexp (same gas), then the standard volumetric flow rate is slightly less than what is read by the rotameter according to:

 $Q\_{exp}^{std}=Q\_{cal}^{std}\sqrt{\frac{T\_{cal}}{T\_{exp}}}=Q\_{cal}^{std}\sqrt{\frac{293}{298}}=0.99Q\_{cal}^{std}$