Estimating the Uncertainty of Density Measurements

The density measured with an instrument (such as our FKT series meter) is a direct relation to temperature and ambient pressure sensor readings. Density is given by the ideal gas law:

$$\rho = \frac{P}{R \cdot T}$$

Where ρ is density, P is the ambient (static) pressure, T is the temperature of the flow and R is the gas constant. The temperature should be in absolute units (Kelvin or Rankine). Each sensor reading (P, and T) has an uncertainty (U) associated with it, so the full density uncertainty is expressed below: (see http://www.flowkinetics.com/uncertainty-analysis.htm)

$$U_\rho = \sqrt{\left(\frac{\partial \rho}{\partial P}\right)^2 {U_P}^2 + \left(\frac{\partial \rho}{\partial T}\right)^2 {U_T}^2}$$

The differentials, based on the ideal gas law above, are:

$$\frac{\partial \rho}{\partial P} = \frac{1}{R \cdot T}$$

$$\frac{\partial \rho}{\partial T} = \frac{-P}{R \cdot T^2}$$

The uncertainty for each reading depends on the characteristics of each sensor and should be determined from the manufacture's specifications.

As an example, assume an instrument with the following uncertainties:

$$U_T = \pm 1℃\ or\ \pm 1K$$

$$U_P = \pm 0.5\%\ of\ full\ scale$$

Also the following flow conditions are used:

$$P = 15\ to\ 115\ kPa$$

$$T = 73\ to\ 1050\ K\ (-200\ to\ 777℃)$$

$$R = 287.026 \frac{Joule}{kg \cdot K}$$

For this example assume the full scale for the ambient (or absolute) pressure sensor is 115 kPa. So the uncertainty values are:

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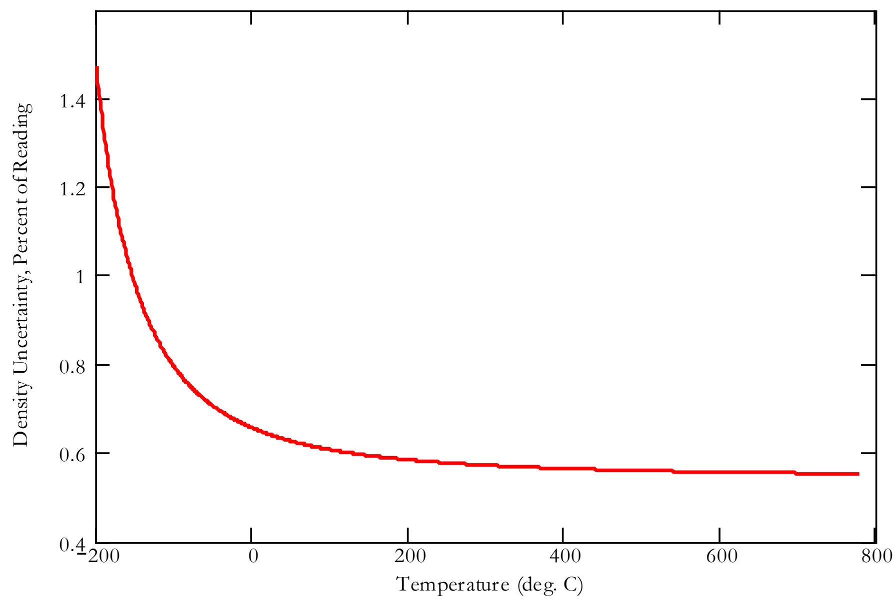
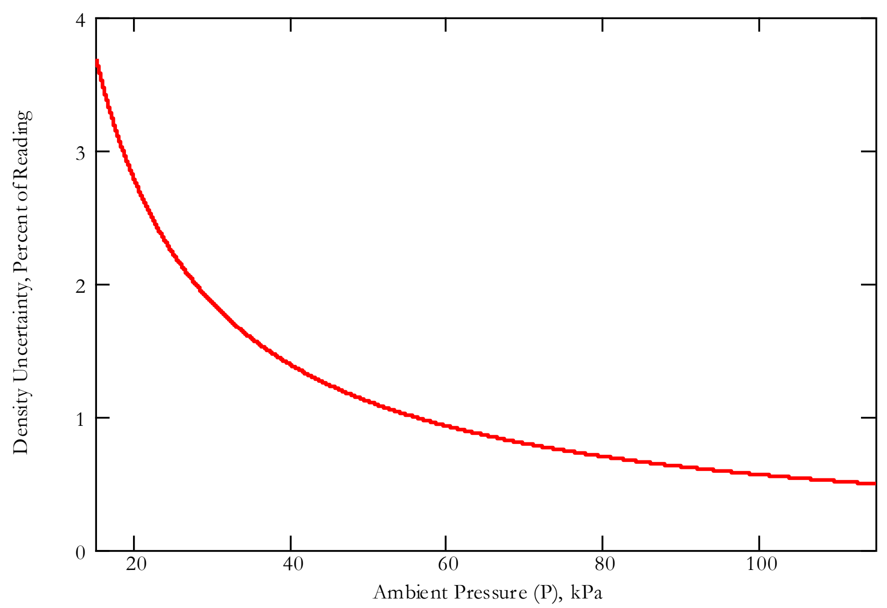
$$U_T = \pm 1°\text{C} \; or \; \pm 1K$$

$$U_P = \pm 552 \; Pa$$

Using the above values the plot of density uncertainty as a fraction of reading for different temperatures is shown below. The ambient pressure is 101325 Pa.



If the temperature is kept at 20°C the density uncertainty variation with ambient pressure is shown below:



The plots show the uncertainty in the density increases significantly for low temperature and ambient pressure. For this example, at standard ambient conditions, the density uncertainty is about 0.6% of reading.