

The (incompressible) velocity measured by a [Pitot static tube](#) and a pressure based instrument ([such as our FKT series meter](#)) is calculated from the recorded differential (or dynamic) pressure,  $q$ , and density,  $\rho$ , of the fluid. The velocity is given by

$$V = \sqrt{\frac{2 \cdot q}{\rho}}$$

If the density is calculated using the ideal gas law then the velocity, based on dynamic pressure ( $q$ ), temperature ( $T$ ) and ambient pressure ( $P$ ) sensor readings, becomes

$$V = \sqrt{\frac{2 \cdot q \cdot R \cdot T}{P}}$$

where  $R$  is the gas constant. Temperature is in absolute units (such as Kelvin or Rankine).

Each sensor reading ( $q$ ,  $P$ , and  $T$ ) has an uncertainty ( $U$ ) associated with it, so the full velocity uncertainty may be expressed below: (see <http://www.flowkinetics.com/uncertainty-analysis.htm>)

$$U_V = \sqrt{\left(\frac{\partial V}{\partial q}\right)^2 U_q^2 + \left(\frac{\partial V}{\partial T}\right)^2 U_T^2 + \left(\frac{\partial V}{\partial P}\right)^2 U_P^2}$$

Substituting the differentials, based on the velocity equation, the above expression becomes:

$$U_V = \frac{R}{2P} \cdot \sqrt{\frac{2 \cdot P}{q \cdot R \cdot T}} \sqrt{(T \cdot U_q)^2 + (q \cdot U_T)^2 + \left(\frac{q \cdot T \cdot U_P}{P}\right)^2}$$

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 a test with the following test conditions and parameters:

$$P = 101325 \text{ Pa (Ambient pressure)}$$

$$T = 293.15 \text{ K (20°C) (Ambient temperature)}$$

$$R = 287.026 \frac{\text{Joule}}{\text{kg} \cdot \text{K}} \text{ (Gas constant for air)}$$

$$q \text{ full scale} = 1240 \text{ Pa (Full scale dynamic pressure for a 5 inchH2O sensor)}$$

$V$  full scale = 45.5 m/sec (Full scale velocity for a 5 inchH2O sensor)

$P$  full scale = 115000 Pa (Full scale pressure for absolute/ambient sensor)

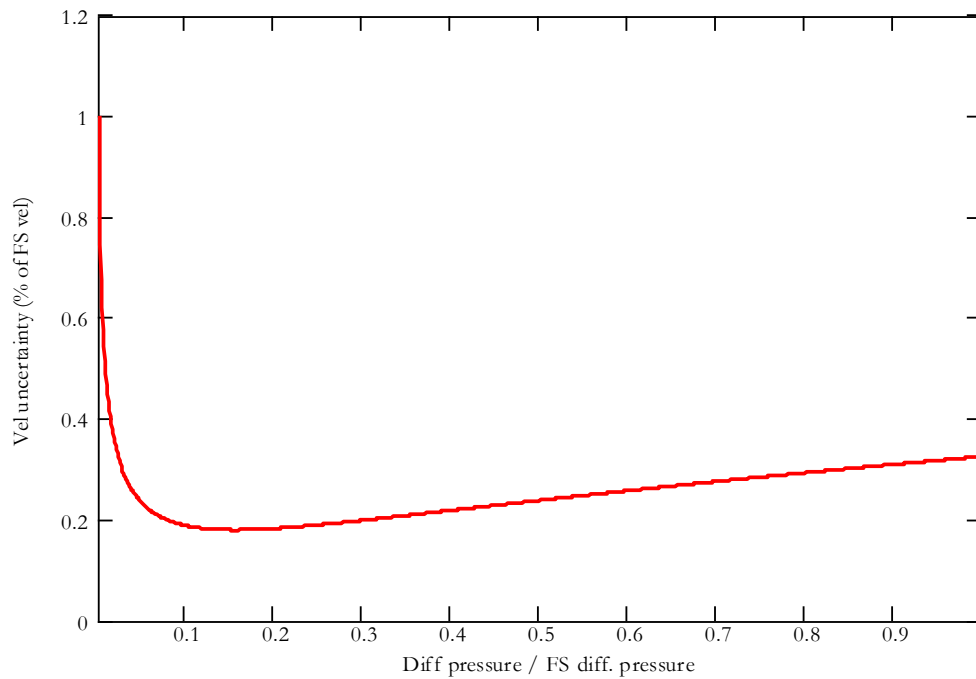
Using the values above the uncertainties are:

$$U_q = \pm 0.1\% \text{ of } q \text{ full scale} = \pm 1.2 \text{ Pa}$$

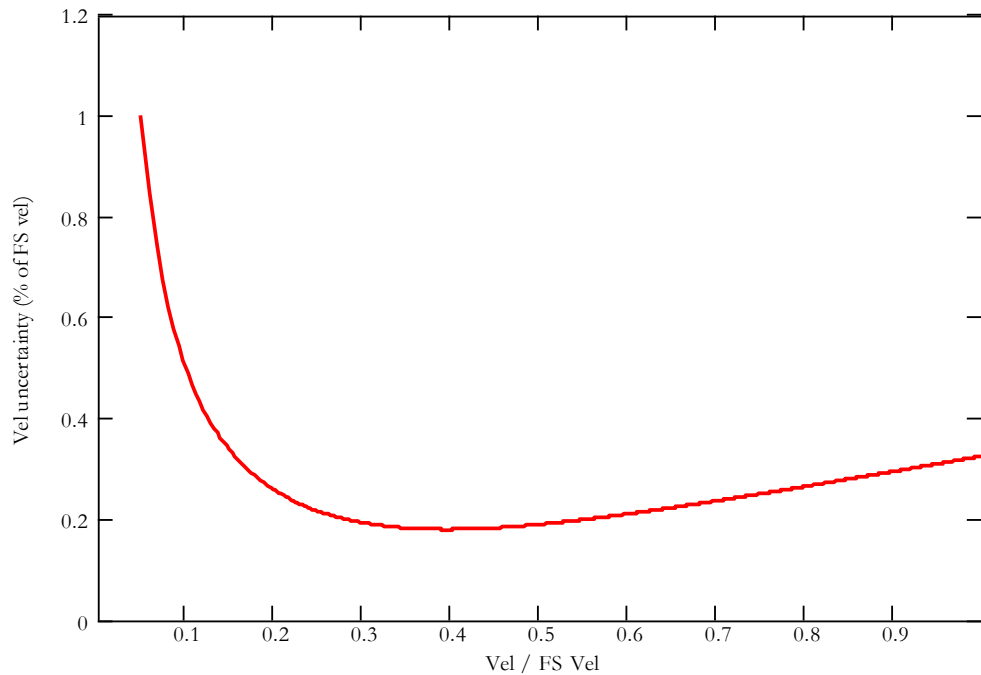
$$U_T = \pm 1^\circ\text{C or } \pm 1\text{K (Fixed value)}$$

$$U_p = \pm 0.5\% \text{ of } P \text{ full scale} = \pm 552 \text{ Pa}$$

Using the above values in the full uncertainty expression and plotting for different values of dynamic pressure, as a ratio to full scale differential pressure, gives



The uncertainty, as a function of velocity, is shown below:



The plots show, that as with any Pitot based system, the uncertainty in the velocity is larger than that in the differential pressure. However, as long as measurements are not taken at the low end of the transducer's range, accuracy is still maintained.

To prevent large velocity uncertainties the dynamic pressure should not be measured below a certain point. For this example we can assume that the desired maximum allowable uncertainty in velocity is 1% of full scale velocity. Substituting this value into the equations above and solving for the minimum dynamic pressure results in the following:

$$\frac{q \text{ minimum}}{q \text{ full scale}} = 0.25\%$$

Or in terms of velocity:

$$\frac{V \text{ minimum}}{V \text{ full scale}} = 5\%$$

So for our example the minimum dynamic pressure for a maximum of 1% velocity uncertainty is

$$q \text{ minimum} = 3.1 \text{ Pa}$$

$$V \text{ minimum} = 2.27 \text{ m/sec}$$

So the recommended velocity range is 2.27 to 45.46 m/sec. Readings taken below the minimum will have uncertainties above 1% of full scale velocity and may not be useful for practical purposes.