MEASURING ACTUAL, STANDARD, AND NOMINAL VELOCITY WITH A TSI® DP-CALC™ MICROMANOMETER

APPLICATION NOTE TI-115

The line of DP-CALC™ micromanometers can make velocity or flow rate measurements when used with a Pitot-static tube. Because the DP-CALC™ micromanometer makes a pressure-based measurement, it can display velocity and flow rate in three different ways. These three types are called actual, standard, and nominal.

Nominal velocity is a velocity reading that is between actual and standard velocity. It is a good estimation of the actual or standard velocity. Nominal measurements are made using a pitot tube.

Actual velocity is the velocity at which a molecule would be traveling in the air stream.

Standard velocity is the velocity as if the measurement was taken with a thermal anemometer at standard temperature and barometric pressure.

Introducing the Equations

The equations for calculating actual, standard, and nominal velocity are shown below. Actual, standard, or nominal flow rate are calculated from velocity by multiplying the corresponding velocity by an area.

$$\text{Nominal Velocity} = v_{nom} = K\sqrt{\frac{(2)(p)}{(\rho_{std})}} \qquad \text{(Equation 1)}$$

$$\text{Actual Velocity} = v_{act} = K\sqrt{\frac{(2)(p)}{(\rho_{act})}} \qquad \text{(Equation 2)}$$

$$\text{Standard Velocity} = v_{std} = K\sqrt{\frac{(2)(p)(\rho_{act})}{(\rho_{std})(\rho_{std})}} \qquad \text{(Equation 3)}$$

where

K = constant dependent on differential pressure and velocity measurement units
p = differential pressure
p_{act} = actual air density
p_{std} = standard air density

Standard values are set by the manufacturer. TSI's standard conditions for air density is 0.075 lb/ft^3 (1.20 kg/m^3). This is the density of air at a temperature of 70°F (21.1°C) and a barometric pressure of 406.8 inches H_20 (101.4 kPa). At standard conditions, nominal equals standard equals actual. As temperature or pressure changes, nominal falls somewhere between standard and actual.

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TSI's Instruments

The Model 8702 DP-CALC™ micromanometer does not have the ability to correct for changes in air density. As a result, it displays all velocity and flow rate readings as nominal values. Manual calculations are needed to get to actual and standard velocity.

When you first receive the Model 8705, it will read in nominal velocity. Once you set the temperature and barometric pressure to the testing conditions, the Model 8705 will automatically read in actual or standard based on selection by the **STANDARD/ACTUAL** key. To read nominal velocity again, you must set the temperature and barometric pressure back to the standard values.

Why Measure in Standard or Actual?

Thermal anemometers measure velocity of air mass and display it as standard velocity. This can be converted to actual air velocity to those who are interested in the actual air velocity.

Air mass is what gives air its heat holding capacity. Since thermal anemometers measure air mass and display it as standard velocity, most people doing measurements on indoor air are more concerned with standard air velocity.

The DP-CALC™ Model 8705 can automatically calculate either standard or actual for you. If you are using the Model 8702, you can still calculate standard or actual with density correction formulas. We will step you through the derivation of the equations in the following sections.

Deriving the Density Correction Formulas

The standard and actual velocity equations can be rewritten using the nominal velocity equation, as shown below.

$$\text{Actual Velocity} = v_{act} = v_{nom}\sqrt{\frac{\rho_{std}}{\rho_{act}}} \qquad \text{(Equation 4)}$$

$$\text{Standard Velocity} = v_{std} = v_{nom}\sqrt{\frac{\rho_{act}}{\rho_{std}}} \qquad \text{(Equation 5)}$$

The air density ratio in Equations 4 and 5 is similar to the density correction factor. The density correction factor is defined as:

$$\text{Density Correction Factor} = K_d = \frac{\rho_{act}}{\rho_{std}} = \frac{(T_1 + T_{std})(P_{act})}{(T_1 + T_{act})(P_{std})} \qquad \text{(Equation 6)}$$

where

K_d = density correction factor
p_{act}= actual air density
p_{std} = standard air density
T_1 = temperature conversion to degrees Rankine or degrees Kelvin
T_{std} = standard temperature
T_{act} = ambient temperature
P_{std} = standard pressure
P_{act} = barometric pressure

The tables below contain the values of the T1, Tstd, and Pstd for Equation 6. Make sure that the measurement units of all the temperature variables used in the equation are the same. Also make sure that the measurement units of the pressure variables used in the equation are the same. If the measurement units are not the same, the density correction factor will be wrong.

Table 1: Temperature Variables

Temperature Measurement Units	T_1	T_{std}
°C	273.15	21.1
°F	460	70
°R (Rankine)	0	530
°K (Kelvin)	0	294.25

Table 2: Pressure Variables

Pressure Units	P_{std}	Pressure Units	P_{std}
atm	1.0	millibar	1013.25
bar	1.01325	mm H_2O	10332.7
ft H_2O	33.90	mm Hg	760
in. H_2O	406.8	Pa	101325
in. Hg	29.921	psi	14.696
kPa	101.325	torr	760

Putting the density correction factor into Equations 4 and 5 results in the following equations which can be used with the charts to figure Actual or Standard Velocities:

$$\text{Actual Velocity} = v_{act} = v_{nom}\sqrt{\frac{1}{K_d}} \quad \text{(Equation 7)}$$

$$\text{Standard Velocity} = v_{std} = v_{nom}\sqrt{K_d} \quad \text{(Equation 8)}$$

The table below shows the difference between nominal, actual, and standard velocity at some different conditions. Notice that when actual conditions equal standard conditions, the density correction factor is 1.00 and all forms of velocity are equal.

Measurement Conditions	K_d	Nominal Velocity (ft/min)	Actual Velocity ft/min)	Standard Velocity (ft/min)
70 °F, 406.8 in. H_2O	1.00	2000	2000	2000
50 °F, 406.8 in. H_2O	1.04	2000	1961	2040
70 °F, 390 in. H_2O	0.96	2000	2041	1960
90 °F, 390 in. H_2O	0.92	2000	2085	1918

The density correction factor will generally be a value in the range of 0.30 to 1.70 depending on the ambient conditions.

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