P_1 = Static Pressure at Inlet
P_2 = Static Pressure at Outlet
r = Hydraulic Radius of Restriction
η = (eta) Absolute Viscosity of Fluid
L = Length of Restriction

geometry of the LFE.

It shows the linear relationship between volumetric flow rate (Q), differential pressure (ΔP), and absolute viscosity (η).

To use the Poiseuille Equation, an internal restriction is created. This restriction is known as a Laminar Flow Element (LFE), represented by r and L in Equation 1.

The LFE forces the gas molecules to move in parallel paths along the length of the passage, eliminating flow turbulence and creating a state of laminar gas flow beneath the Reynolds threshold of 2000. (The Reynolds number of 2000 is commonly accepted as the theoretical threshold. This number will vary depending on surface characteristics.)

Next the differential pressure drop is measured within the laminar region.

Finally, the viscosity of the gas (η) must be determined as affected by gas temperature.

This procedure is performed internally by the microprocessor.

Theory of Operation: Mass Flow Conversion

Alicat mass flow devices start with the volumetric flow rate calculation as previously described. Additional measurements and calculations are incorporated to determine the actual mass flow rate of the gas.

Ideal gas laws show us that the density of a gas is affected by its temperature, absolute pressure and compressibility.

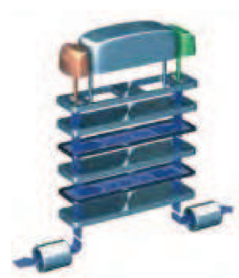
Using non-ideal gas laws requires a reference to a standard temperature and pressure (STP) condition for “normalizing” the mass flow calculation.

Essentially this is a determination of the density of the gas at sea level and a predetermined temperature as related to the actual flow conditions.

In order to determine the mass flow rate, two correction factors must be applied to volumetric flow rate: temperature effect on density and absolute pressure effect on density (Equation 3).

Equation 3: $M = Q(T_s / T_a)(P_a / P_s)(Z_s / Z_a)$

Where:
M= Mass Flow
Q = Volumetric Flow (From Equation 2)
T_s = Absolute Temperature @ Standard Condition in Kelvin
T_a = Absolute Temperature @ Flow Condition in Kelvin
P_a = Flow Absolute Pressure
P_s = Absolute Pressure @ Standard Condition
Z_a = Compressibility at Measured Conditions
Z_s = Compressibility at Standard Conditions



In an Alicat mass flow instrument, a discrete absolute pressure sensor and a temperature sensor are placed in the laminar region of the flow stream.

The sensors send information to the microprocessor which determines mass flow.

A series of calculations is performed and flow rate data is updated an average of 1,200 times/second.

This allows for extremely fast, real time measurements of flow that are sensitive enough to report pulsations in flow, as well as step changes.