

# Connecting Volume



Uncertainties can be introduced to flow measurements from interactions between flow sources and flow measurement instruments, interconnecting plumbing, thermal instabilities and pressure variations. One of the easiest ways to lower errors during flow measurements is to lower the connecting volume between the calibrator and the device under test.

If the connecting volume were equal to zero, the flow rate in the device under test would be the same as in the calibrator. Thus, reducing the connecting volume proportionately reduces measurement errors. However, Mesa Laboratories piston provers were designed to minimize connecting volume effects. This is achieved by measuring the piston displacement only after the piston has been displaced a fixed distance prior to flow measurement initiation.

If the connecting volume, measurement volume, and gas density change during a measurement are known, a correction algorithm can be used to account for gas density changes:

$$\dot{M}_{cv} = V_{cv} \left[ \frac{\rho_i - \rho_f}{\Delta t} \right] \quad (\text{Equation 1})$$

$\dot{M}_{cv}$  = mass change in the connecting volume during the measurement interval  
 $V_{cv}$  = connecting volume  
 $\rho_i$  = initial gas density in connecting volume  
 $\rho_f$  = final gas density in connecting volume  
 $\Delta t$  = measurement interval

However, the Mesa Labs piston prover uses an algorithm that removes some of the connecting volume effects by measuring gas pressure before and after the measuring interval, and by using the known measurement volume of the DryCal assuming a small connecting volume. Keep in mind that this assumes an ideal gas under isothermal conditions. The correction can be calculated using the equation below:

$$F_{cor} = F \left[ \frac{P_2}{P_a} + \left( \frac{P_2 + P_1}{P_a} \right) \frac{V_{conn}}{V_{mea}} \right] \quad (\text{Equation 2})$$

$F_{cor}$  = flow corrected for connecting volume  
 $F$  = measured flow  
 $P_2$  = gas pressure at end of gas flow measurement interval  
 $P_a$  = standardizing or ambient gas pressure  
 $P_1$  = gas pressure at beginning of flow measurement interval  
 $V_{conn}$  = estimated minimum connecting volume  
 $V_{mea}$  = known measured volume of gas

The pressure changes in this formula only account for pressure in the connecting volume. The temperature variations are generally negligible due to the high-speed nature of Mesa's piston provers. To minimize uncertainties introduced by connecting volume, Mesa Labs suggests maximum connecting volumes of 0.03 to 0.3 liters, as a function of the piston model (Table 1). If a piston prover has a larger connecting volume out of the recommended range, studies have shown that in some installations introducing backpressure regulators between the flow source and the calibrator can greatly lower uncertainties from large connecting volumes (Morrell 2013).

When looking to lower uncertainties in calibration equipment, Mesa recommends lowering the connecting volume. If this is not possible, adding a backpressure regulator can lower effects from large connecting volumes. If connecting volume remains a concern, equation 2 illustrates how flow can be corrected for connecting volume using pressure, volume and measured flow rates. Ultimately, Mesa Labs piston provers were designed to minimize connecting volume effects by its unique measurement protocol and internal correction algorithm.

**Table 1**

Tubing Diameter	Maximum Connecting Volume (cc)	Maximum Recommended Tubing Length (meters)				
		1/8 inch	1/4 inch	3/8 inch	1/2 inch	1-1/2 inch
Ultra Low Flow Cells	2	1	0.15	-	-	-
Low Flow Cells	30	4.2	1.1	0.5	-	-
Medium Flow Cells	100	14	3.5	1.6	-	-
High Flow Cells	300	42	10	4.7	-	-
Ultra High Flow Cells	1000	-	-	-	22	-
DryCal 1020	1700	-	-	-	-	1.5

*Citation:*

Morrell, Edward, Mesa Laboratories, Nj 07405 Usa Butler, and Emorrell@mesalabs.com. "INTERACTIONS BETWEEN GAS FLOW MEASUREMENT INSTRUMENTS AND GAS FLOW SOURCES." Flomeko Proceedings. The 16th International Flow Measurement Conference: Flomeko 2013, France, Paris. IMEKO, 2013. Web. 6 June 2016. <[http://library.ceesi.com/techlib\\_readlist.aspx?yr=2013&orgid=29&eid=410](http://library.ceesi.com/techlib_readlist.aspx?yr=2013&orgid=29&eid=410)>.