Basic DryCal Application and Calibration Guide

1.0 The DryCal Measurement Cycle

Operation of a DryCal is extraordinarily simple, and little training is required. However, any measurement interacts with the device being calibrated to some degree. Often, these interactions are negligible. However, sometimes device interactions can seriously affect measurement accuracy. Here we will explain what happens during a DryCal measurement to aid in using the instrument appropriately.

In its inactive state, the DryCal will, like any device, exhibit a constant insertion pressure drop. At all but the highest flows, the pressure drop is very small. In the inactive state, gas flows from the inlet to the outlet through the bypass valve (Figure 1). When a measurement cycle begins, the bypass valve closes, and the gas is directed into the cylinder, effectively inserting the piston in series with the gas flow, allowing measurement. Timing commences after the piston has accelerated to the flow stream's speed. At the end of the timed cycle, the valve opens and the piston falls to its inactive position at the bottom of the cylinder.

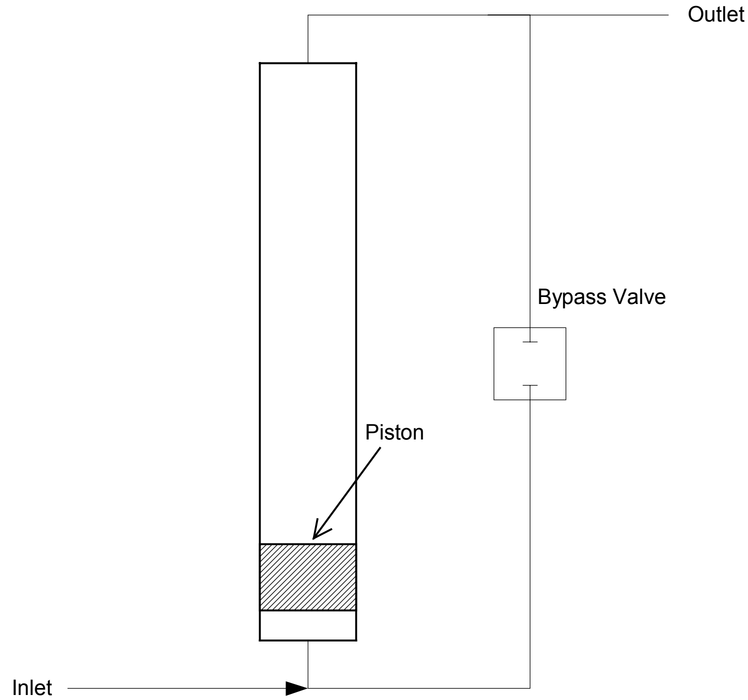

Figure 1 Basic Piston Prover

In real-world applications, there are significant dynamics to consider. At the beginning of a cycle, pressure rises rapidly until the piston accelerates to the speed of the flow stream. Figure 2 is an illustration of a typical DryCal's internal pressure during a measurement cycle. A near-maximum flow rate is illustrated to accentuate the pressure variations. The initial pressure pulse, lasting some tens of milliseconds, reaches a peak of about 0.5 kPa, or 0.5% of its working, near-atmospheric pressure. The pressure settles out to about 0.1 kPa (0.1% of working pressure) during the timed period. This pressure represents the added pressure due to the weight of the piston. Very small oscillations continue due to the piston's underdamped nature.

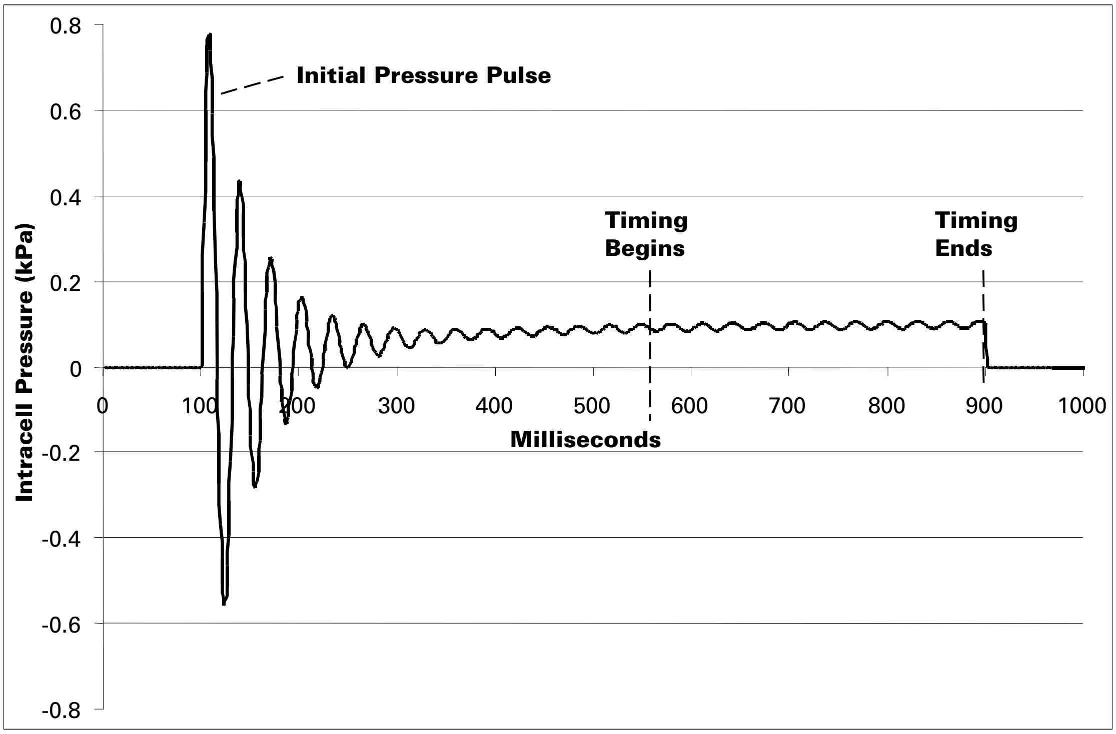

Figure 2 DryCal Internal Pressure

2.0 Application Precautions

Although the DryCal's dynamic pressure effects are very small, in some circumstances they may affect the measurement or interact with the device under test. For the above reasons, certain precautions should be observed when using a DryCal.

Initial Pressure Pulse

The initial pressure pulse is small, about 1% of an atmosphere or less. However, even so small an increase may affect some very sensitive transducers for several seconds. For example, the resonant transducers used in LFE systems such as the DH Instruments Molbloc or capillary-based systems. For this reason, the LFE instrument may not be accurate for a number of seconds after the start and the end of a DryCal measurement cycle. When calibrating such systems, a stable flow source should be used and the LFE read before and after the DryCal cycle.

Intra-Cycle Pressure Change

After the initial brief pressure pulse, the change in insertion pressure is typically 0.1% of an atmosphere (~0.1 kPa or 1 cm water column). This is usually insignificant. For example, flow from a 100 kPa gauge pressure (15 psi) source will change by 0.1%. However, very low pressure sources will show larger flow change during a DryCal cycle and may require compensating calculations to achieve DryCal's best applied accuracy.

Inventory (Dead) Volume

Inventory volume consists of all the space contained between the flow source's point of restriction and the timed portion of the cylinder. This includes tubing, empty space within the DryCal base, the lower portion of the measuring cylinder and any other space contained within the test setup.

It is important to keep inventory volume to a minimum. Excess inventory volume amplifies the effects of minute pressure variations within the DryCal cell. In extreme cases, the excess volume also prevents gas pressure from accelerating the piston properly, causing significant errors in readings. Ideally, the volume contained between the cell and the flow source should be on the order shown in Table 1, which also shows the volume as an equivalent length of tubing.

Table 1 Recommended Maximum External Volume and Tubing Lengths

Cell Size	Recommended Max. Volume (cc)	Recommended Maximum Length (meters)		
		3mm ID (1/8")	6mm ID (1/4")	9mm ID (3/8")
Small	9	1.2	0.3	X
Medium	46	6.5	1.6	0.7
Large	118	16.7	4.2	1.9

3.0 Comparison vs. Calibration

Calibration consists of comparing an instrument with one of significantly greater accuracy (ideally, at least four times the accuracy of the device under test). We use the term "comparison" in most of the following applications because, depending upon their respective accuracies, either device can be calibrating (or simply compared with) the other.

For example, a 0.2% LFE can calibrate a 1% DryCal, while a 0.15% DryCal can calibrate a 0.6% LFE. On the other hand, a 0.15% lab prover cannot calibrate a 0.15% DryCal to its rated accuracy (or vice-versa). One can calibrate the other to only 0.3% with great certainty, so we simply call it a comparison.

4.0 Comparison of DryCal with Piston or Bell Provers

Piston or bell provers have a much longer measurement time than DryCals. For this reason, it is possible to compare them simultaneously, but certain precautions must be observed. When the DryCal begins its cycle, the piston's weight causes the internal pressure to rise by about 0.001 atmospheres (~0.1 kPa). If a simple pressure regulator feeds the test chain, we are simply using the resistance of the entire flow chain to set our flow rate. The rate will then change significantly when the DryCal is in its measurement cycle. This will cause the actual flow measured during the DryCal cycles to be less than the average flow seen by the piston or bell prover.

To render this effect insignificant, the flow must not be affected significantly by the DryCals's cyclic pressure increase. This can be achieved by use of a sonic nozzle as the stable flow source, or by feeding a fixed restrictor with a precisely regulated pressure of more than 200 kPa, as in the Bios MFS Flow Bench. Note that at 200 kPa (30 PSI), the dynamic flow decrease of a simple restrictor caused by the piston's weight will be about 0.05%.

For this type of calibration, we can use the setup shown in Figure 3. The adjustable regulator is used to set the flow rate within the range of a properly sized flow restrictor. A piston or bell prover cycle is instituted. The DryCal and the prover can then be alternately measured using the fixed flow source.

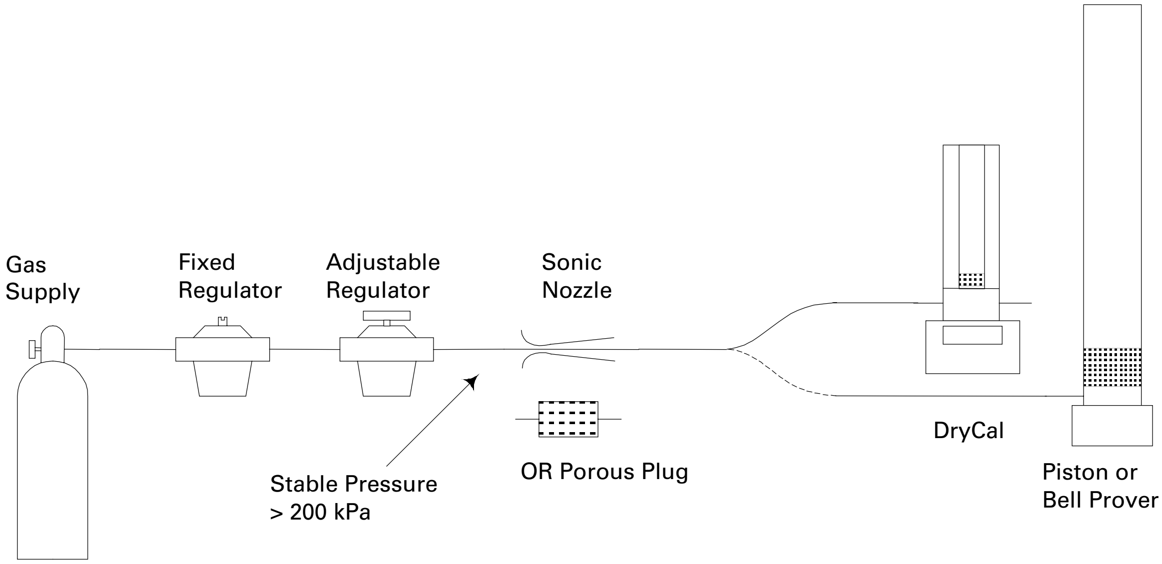

Figure 3 Setup for Piston or Bell Provers

An alternative approach can be used with piston provers, as shown in Figure 4. A cycle is initiated on the prover, which is much slower than a DryCal. The DryCal is then started in a cyclical mode, averaging its flow. Before the prover ends its cycle, the DryCal is stopped and the average flow read.

The DryCal can be set for sufficient cycles in its average to allow interruption by the “stop” button, or smaller averages, such as 5 or 10 readings, can be taken during the prover cycle. It should be noted that the periodic pressure pulses might cause oscillations in bell provers, reducing the bell prover’s accuracy somewhat.

In certain circumstances, the sonic nozzle or porous plug flow generator may be replaced with a mass flow controller (MFC). However, due to MFC instability, very misleading results may be obtained, especially if the MFC is turned down to less than 10% of full flow. Because MFC stability is typically less than DryCal accuracy, Bios does not recommend the use of an MFC as a calibration flow generator.

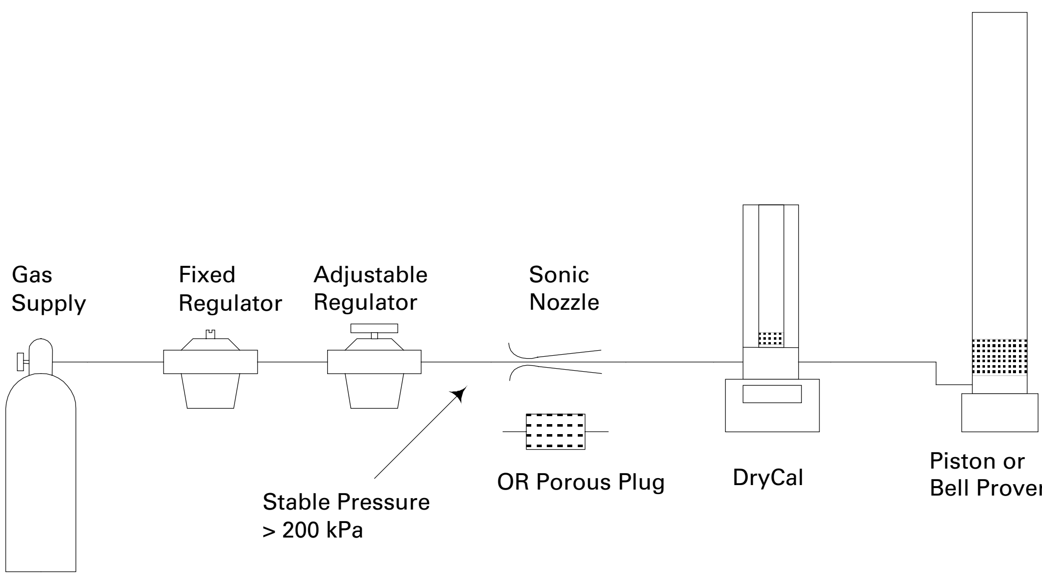

Figure 4 Alternative Setup for Piston Provers

5.0 Vacuum Comparison of DryCal with Piston or Bell Provers

The DryCal operates similarly in both pressure and suction applications. Sometimes, however, users wish to compare the DryCal under suction (vacuum) conditions. With a piston or bell prover, the setup of Figure 5 can be used.

The restrictor should be sized to provide a drop of at least 70 kPa (21 inches or 500 mm Hg). The purpose of the restrictor is to render the piston insertion pressure change (0.1 kPa) relatively insignificant, as in the similar pressure calibration methodology.

In volumetric, comparisons, it is important to compensate for the difference in outlet temperature from input temperature. Although the pressure is the same on each end, the restrictor and the pump affect the outlet temperature and flow must be normalized to the inlet (ambient) temperature.

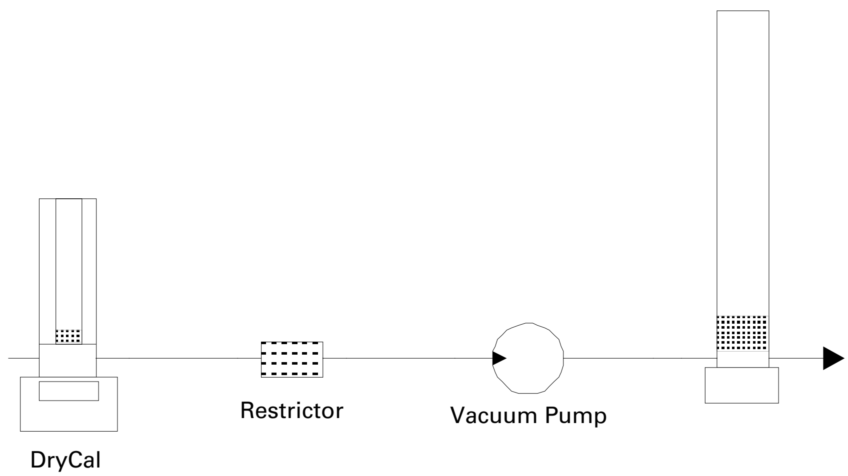

Figure 5 Vacuum Setup for Piston or Bell Provers

6.0 Comparison of DryCal with Laminar Flow Element Transfer Standards

When the DryCal begins its cycle, the piston's acceleration causes the internal pressure to spike briefly by about 0.01 atmosphere (~1 kPa). The pressure then remains elevated by about 0.001 atmosphere (~0.1 kPa) due to the piston's weight. If a simple pressure regulator feeds the test chain, we are simply using the resistance of the entire flow chain to set our flow rate. The rate may then change significantly when the DryCal is in its measurement cycle. This will cause the actual flow measured during the DryCal cycles to be less than the average flow seen by the laminar flow element (LFE). Moreover, the initial pressure pulse may cause the LFE instrument's sensitive pressure transducers to be destabilized for several seconds.

For the latter reason, the LFE instrument should be read only immediately before the DryCal reading, and afterward only when the LFE instrument's readings stabilize. At low flows, the DryCal measurement may take sufficient time to allow LFE stabilization. In that case, the instruments can be read simultaneously.

In addition, the flow must not be affected significantly by the DryCals's cyclic pressure increase. This can be achieved by use of a sonic nozzle as the stable flow source, or by feeding a fixed restrictor with a precisely regulated pressure of more than 200 kPa. (At 200 kPa [30 PSI], the dynamic flow decrease caused by the piston's weight will be about 0.05%.)

For this type of calibration, we can use the setup shown in Figure 6. The adjustable regulator is used to set the flow rate within the range of a properly sized flow restrictor.

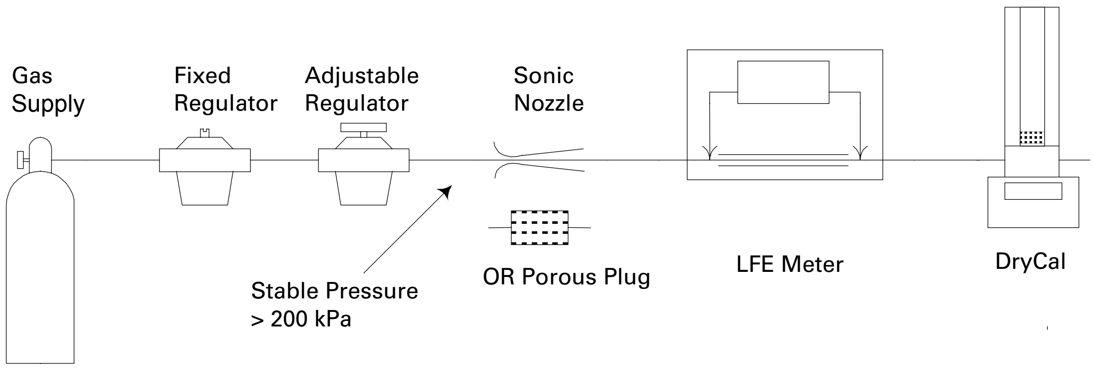

Figure 6 Setup for LFEs

7.0 Comparison of DryCal with Sonic Nozzle Transfer Standards

A high quality sonic nozzle used above its critical pressure ratio will supply a constant flow despite changes in its outlet pressure. For this reason, a calibrated sonic nozzle can be compared to a DryCal by simply connecting its outlet to the DryCal's inlet as shown in Figure 7.

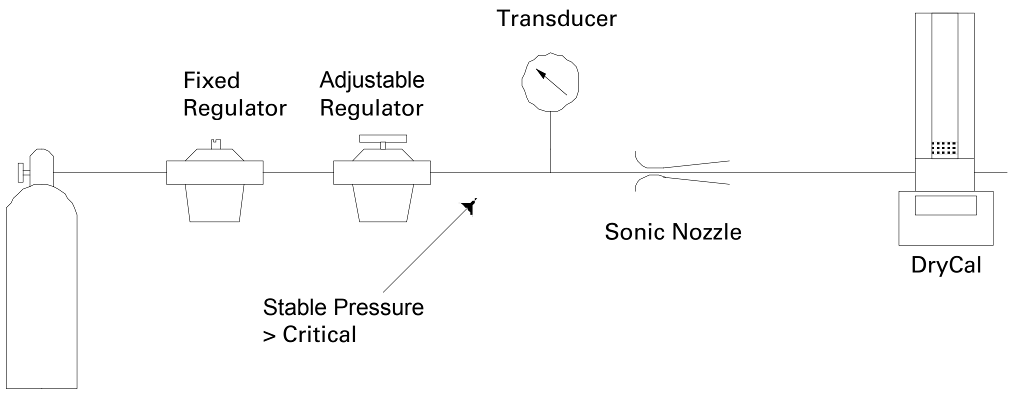

Figure 7 Setup for Sonic Nozzle Transfer Standard

8.0 Vacuum Comparison of DryCal with Sonic Nozzle Transfer Standards

The DryCal operates similarly in both pressure and suction applications. Sometimes, however, users wish to compare the DryCal under suction (vacuum) conditions. With a calibrated sonic nozzle, a simple setup such as that shown in Figure 8 can be used. There is one precaution, however. The sonic nozzle's pressure must be measured during the DryCal cycle to obtain the actual flow that the DryCal is measuring. In turn, the pressure transducer must not be upset by the DryCal's initial pressure pulse and must have rapid response relative to the DryCal cycle time. This method is therefore most suitable for flows in the lower part of a DryCal's range.

It should be noted that cycling of the DryCal would cause a slight change in the nozzle's inlet pressure. Even though the pressure transducer is read during the DryCal cycle, the nozzle may not achieve internal thermal equilibrium during the cycle, slightly reducing accuracy.

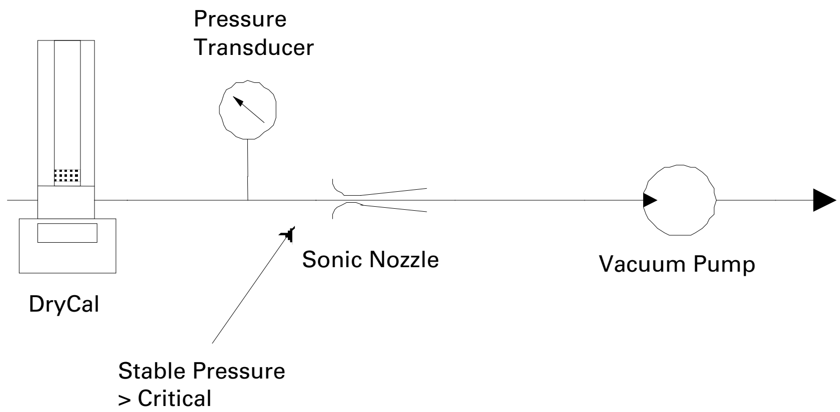

Figure 8 Vacuum Setup for Sonic Nozzle Transfer Standard

9.0 Calibration of Mass Flow Controllers (MFCs)

Modern mass flow controllers have fast response times on the order of milliseconds. They can simply be connected to an appropriate inert gas source and their output stream applied to the DryCal, as in Figure 9. Proper calibration consists of comparing the DryCal reading to the MFCs actual indicated flow and not to its control signal.

If a slow flow controller is to be calibrated, it is best to calibrate it in its metering mode. Apply the appropriate signal to fully open the controller's internal valve (full scale or digital "open), and calibrate the device as shown for mass flow meters (MFMs), below.

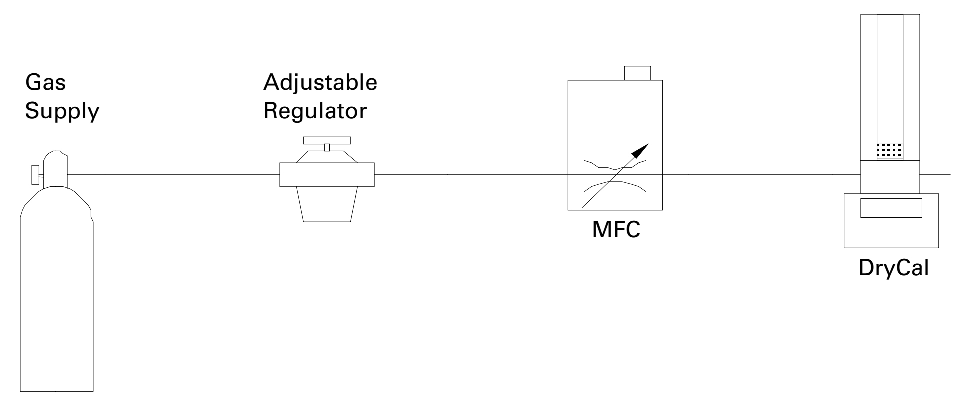

Figure 9 Setup for Calibrating MFCs

10.0 Calibration of Mass Flow Meters (MFMs)

Mass flow meters can be calibrated with the setup of Figure 10, which is similar to that shown for LFE transfer standards. Again, the flow must not be affected significantly by the DryCals's cyclic pressure increase. This can be achieved by use of a sonic nozzle as the stable flow source, or by feeding a fixed restrictor with a precisely regulated pressure of more than 200 kPa. (At 200 kPa [30 PSI], the dynamic flow decrease caused by the piston's weight will be about 0.05%.)

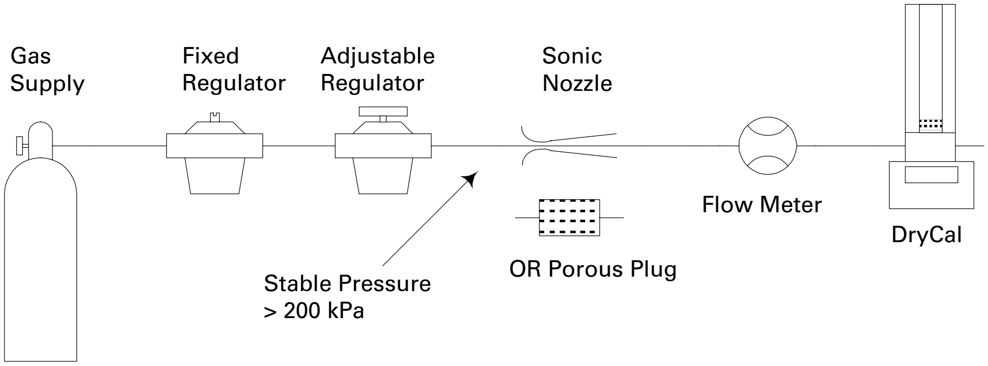

Figure 10 Setup for Calibrating Mass Flow Meters

11.0 Calibration of Rotameters (Variable Area Flow Meters)

Variable-area meters can become unstable when connected in series with a volume. Cavity resonance may even occur. They are best calibrated using the setup of Figure 11. The flow stream is alternately applied to the DryCal and to the device under test. A sonic nozzle or a large "swamping" pressure restriction is used to render the differences in the two devices' insertion pressures insignificant with respect to the required accuracy.

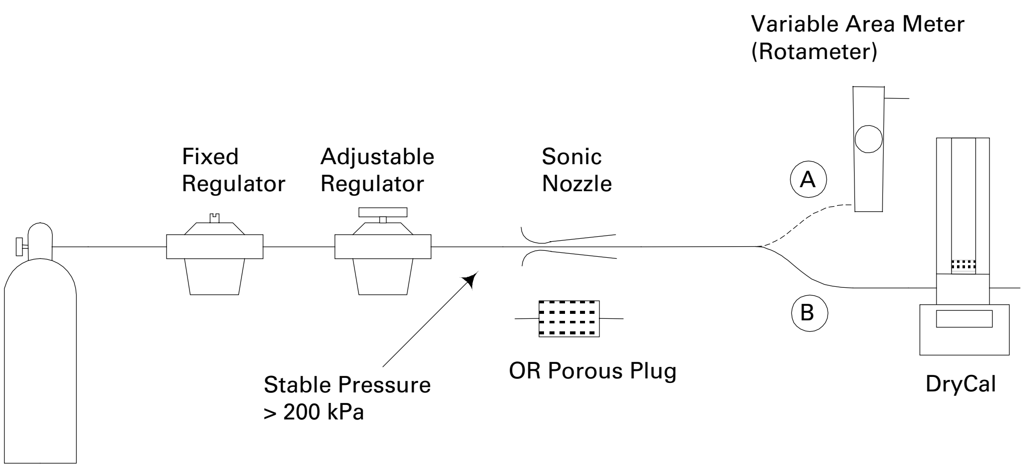

Figure 11 Setup for Calibrating Rotameters (Variable Area Flow Meters)

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