for good measure

Mass Flow Testing in Large Volumes

Mass flow test techniques may be a viable option when small leaks need to be measured in large test volumes. However, to establish stable test conditions it is necessary to ensure the pressure source is stable; it is unlikely that a live regulator system, where the delivery pressure is sourced from the factory air supply through a pressure reducing regulator will ever be stable enough to allow repeatable readings.

Repeatable low flow measurements are best obtained when the flow measuring device is connected between the test and a reference volume and is measuring the make up flow as the air in the reference volume flows into the test volume to make up for the loss in pressure due to the leak as shown in the figure below:

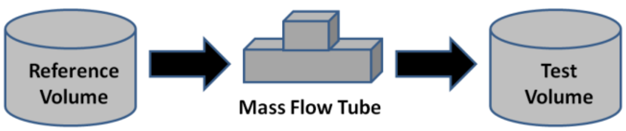

Figure 1: basic test configuration.

Measurement limits

A test unit fitted with a mass flow device will, by default, be configured to measure leak and flows values in volumetric units and above 100 cc/min will read the flow rate directly. However, in low flow applications where the air is supplied from a reference volume the quantity of air flowing through the flow device is modified by the ratio and relationship between the reference and test volumes as follows: $F_a = F_m\left(1 + V_t/V_r\right)$

Where F_a = Actual flow rate

F_m = Measured flow rate

V_t = Test volume

V_r = Reference Volume

Example

A transmission unit of say 120 liters internal volume is to be tested with a pass fail decisions based on 10 cc/min of air flow rate.

Direct flow (live regulator)

If this was a direct flow application, a 100 cc/min flow tube would be the largest flow rated tube capable of the application; it has the required resolution, but would not be desirable as the customer would be working 10% below the meter's range.

Ideally, the reject level should be between 30 and 70% of the meter’s range. Therefore, a 20 cc/min flow tube would give the best signal levels while providing a resolution of 0.01 cc/min, which would be ideal for gauge capability studies. However, a flow test of 10 cc/min is a low flow application and deserves to be configured as a differential flow tester as shown in figure 1. and discussed below.

How big should the reference volume be?

As big as possible: The bigger the reference volume the slower the pressure will drop due to the leak and therefore the test pressure will be closer to the set point. The actual size of the reference volume may depend on the mechanical or aesthetic constraints of the total installation. As a guide the reference should not be smaller than 50% of the test volume. For this example assume that these constraints limit the reference to 50 liters (fractionally below the small limit, but the nearest proprietary size).

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Test parameters;

Test pressure	340 mbar (5 psig)
Leak rate	10 cc/min
Test Volume	120 liters
Ref. Volume	50 liters

Calculate the measured flow rate for a 10 cc/min leak.

Transposing the formula on page 1 to make the measured flow rate the subject we get:

$$F_m = \frac{F_a}{\left(1+{V_t}/{V_r}\right)} = \frac{10}{\left(1+{120}/{50}\right)} = 2.94$$

cc/min

This application requires a flow tube where the measured value is greater than 30% of its range, and depending on how much above the flow rate is to be measured, let's say less than 70% of full scale. Therefore a flow tube should be selected that has a maximum flow capability of between 4 and 10 cc/min. Either a 5 cc/min or a 10 cc/min flow meter would be suitable.

Estimate the Stabilization Step Time.

The minimum delay between filling the test part to test pressure and making the measurement will depend on how long it takes for the test system to develop the appropriate pressure drop across the flow element and reach a steady state for the given leak rate.

If a 10 cc/min flow tube is chosen and it is a low Delta P unit requiring just 0.2 mbar to measure 10 cc/min ,and assuming a linear relationship, it will require a delta P of 0.2 x 10/2.94 = 0.06 to read 2.94 cc/min (0.049 cc/sec) we can calculate when 0.06 mbar change has developed as follows:

$$Stab\ time_{\sec} = \frac{\Delta P_{mbar}}{leak\ rate_{cc/\sec}}\ x\ \frac{test\ volume_{cc's}}{atmos.\ press._{mbar}}$$

=

$$\frac{0.06}{0.049}\ x\ \frac{120{,}000}{1{,}013} = 145 \text{ secs.}$$

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