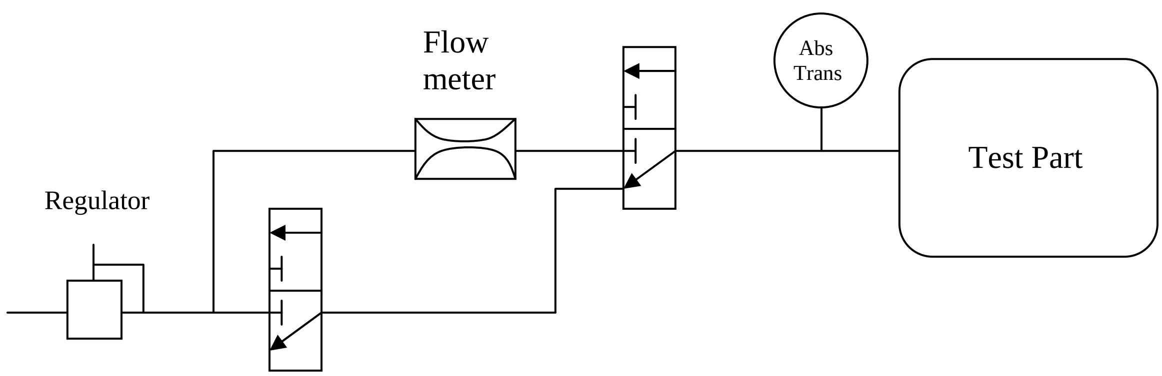
Direct Mass Flow vs. Differential Mass Flow Tests

Testing parts for a leak using mass flow technology requires a sensitive flow meter capable of sensing very small changes in flow rate. The flow meter should have minimal resistance to flow so that it does not require a large pressure drop in the part to overcome the resistance of the meter. The flow meter needs a high enough range so that it will not reach overflow conditions during the transition from bypass flow (fill cycle) to direct flow (test cycle). The air supply for the mass flow test must be clean and dry. The test air flows through the flow meter for each test. The flow meter typically has a very small flow path so therefore it is suspectible to contamination. Most flow meters use a thermal transfer method of measuring air flow and are therefore depend on the specific heat factor of the air. Moisture in air affects the specific heat factor of the air. Therefore it is important for consistency to have dry air.

The most important aspect of a reliable and accurate flow test is to have a reliable and constant supply pressure for the test. The simplest mass flow circuit would be direct mass flow. For direct mass flow a regulator or constant pressure source supplies air directly to a flow meter that is connected to a test part. There may be some additional valves to bypass the flow meter to quickly fill the part. Below is an example of a Direct Mass Flow circuit.



For a direct mass flow test, it assumes that the reference pressure provided by the regulator is constant to a factor 30 to 100 times better than the possible pressure loss generated in the test part due to the expected reject leak rate. For instance if a test part with a volume of 1000 cc has a leak rate of 1 sccm during a test time of 20 seconds, the part will lose 0.005 psi or 0.00025 psi/sec. This pressure loss differential of 0.005 psi as compared to the reference pressure causes a flow through the flow meter of 1 sccm. It is the loss of 0.00025 psi/sec that will generate a 1

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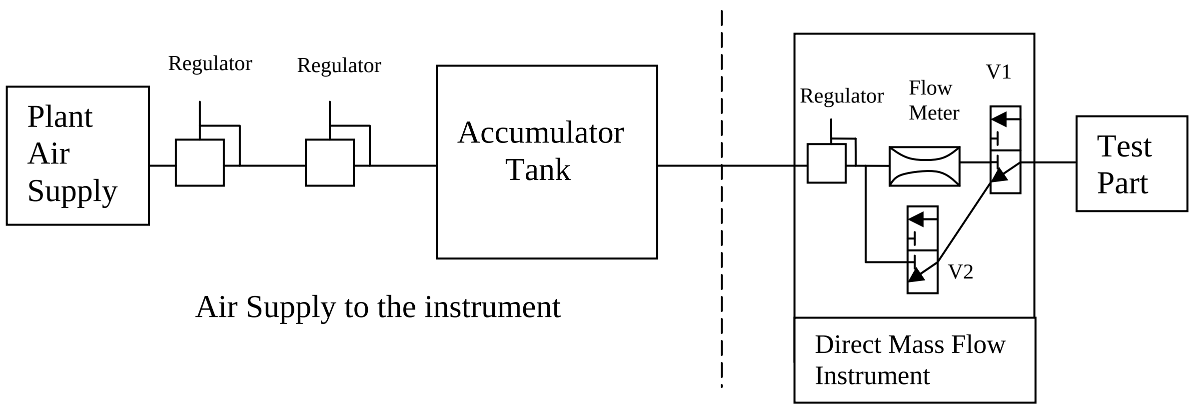
sccm flow output signal. This assumes that the reference pressure has a variation less than 0.000005 psi/sec during the test cycle. Since a mass flow test result is simply the final flow reading at the end of a sequence of timers, the actual flow result and the repeatability of multiple flow tests are depend on how well the regulator can maintain a very constant pressure through the test sequence. Within a plant environment it is difficult. Therefore, the smaller the leak rate or the smaller the pressure change generated by the leak in the test part, the more critical the control of the reference pressure becomes. There are two approaches to control the reference pressure.

Direct Mass Flow Measurement

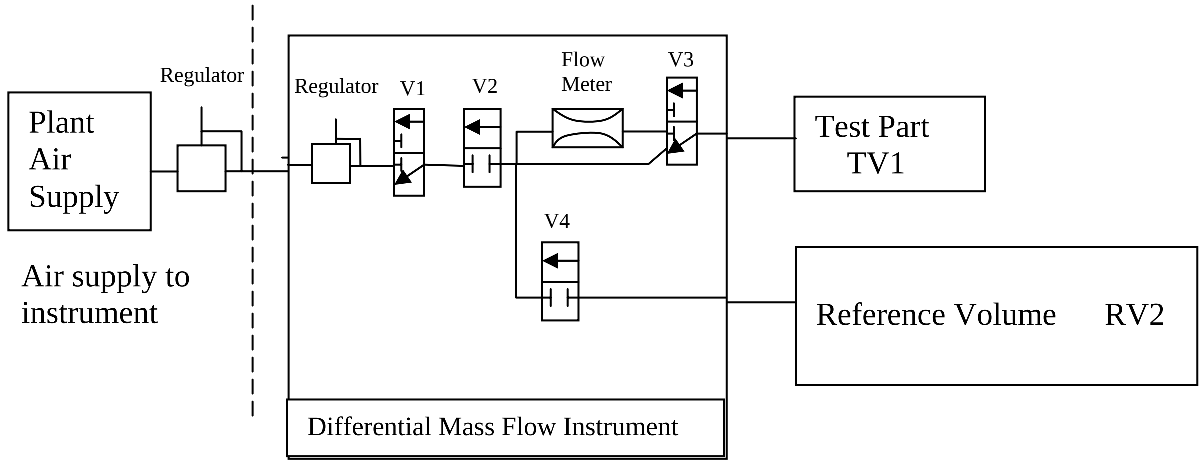
To use the direct mass flow approach, the biggest problem is using plant air that fluctuates cyclically and instantaneously due to usage throughout the plant. To achieve successful results, additional equipment must be added between the plant air supply and the mass flow instrument. The added equipment usually includes a series of precision regulators and an accumulator tank that has a volume ten times that of the part. Each of the regulators reduce the plant air pressure by 5 to 10 psi to the next regulator or the accumulator tank. The direct mass flow instrument then takes its supply air from the accumulator tank through a final precision regulator to the mass flow meter. This series of regulators and accumulation tank filter, reduce, or eliminate the pressure turbulence of the plant air supply and create a stable reference pressure for a direct mass flow test.



The direct mass flow approach measures the rate of air flow going to the part that makes up for the air that is leaving the part (leak rate) plus any pressure effects for changing temperature or volume in the part or part's test circuit. To get a true leak rate measurement there must be enough stabilization time for all or most of the temperature and/or volume changes in the part to normalize.before taking this final instantaneous flow reading. Because this method of measurement assumes that the supply pressure is infinite and constant, the flow reading of the flow meter directly equals the leak rate of the part.

Differential Mass Flow Measurement

Another approach to achieve a stable reference pressure for mass flow testing is the Differential Mass Flow Method. For this method the stable reference pressure for the mass flow test is provided by using a reference part within the test circuit and measuring the relative flow between the reference part and the test part through a flow meter as a result of a leak in the test part.



For the differential mass flow instrument, plant air fills both the Test Part and a Reference Volume for each test. After pressurizing these two volumes, they are isolated from the plant source air by switching the fill/exhaust valve (V1) and closing the isolation valve (V2) to allow the volumes to stabilize in pressure to each other. After a suitable stabilization time, the flow select valve (V3) is activated to connect the two volumes via the flow meter. After additional stabilization time where the overall volume of V1 plus V2 are connected together through the flow meter, a final flow reading is taken of the air transferring for the Reference Volume (RV2) to the Test Part (TV1). During this final phase of the leak test, the Test Part (TV1) and the Reference Volume (RV2) act as one volume (TV1+RV2) from which a leak is measured. Therefore when there is a leak in the Test Part, the pressure in the overall volume (TV1+RV2) decays. The flow measured by the flow meter is the air transferred from the Reference Volume to the Test Part and does not directly represent the air flow from the leak in the Test Part. The air flow measured by the flow meter is proportional to Leak Rate based on the ratio of the Reference Volume (RV2) and the Total Volume (TV1+RV2)

Leak Rate = Flow meter reading x (TV1+RV2)/RV2, if sufficient stabilization time is given to reduce any temperature or volume change effects.

The differential mass flow systems must be calibrated in some way to determine the ratio of these volumes so that an accurate representation of the leak rate can be measured. For small leak rate applications, it is desireable to have a Reference Volume that is significantly larger than the Test Part volume so that measured flow rate of the flow meter will be close to the actual leak rate.

Ie. Reference Volume = 100, Test Part Volume = 10
(TV1+RV2) /RV2=1.1,
It is optimal to have this ratio as close to one as possible.

Reference Volume =10, Test Part Volume = 10
(TV1+RV2)/RV2 = 2.0
A higher ratio means that the actual flow through the flow meter is low verses the actual leak rate.

If the Reference Volume is equal to the Test Part Volume, only half of the Leak Rate flow will be measured by the flow meter. Therefore the flow reading will be significantly lower than the actual leak rate or a very small reading verses the full scale of the flow meter. The instrument must be calibrated to determine the ratio of the Flow meter reading to the actual leak rate.

Conclusion

Maintaining a steady reference pressure (repeatable, consistent) for each test is absolutely essential for a good flow test. The stability of this pressure directly affects the accuracy and repeatability of the flow test. A stable reference pressure must be provided by installing multiple regulators and an accumulator for the source air to the instrument in order to use a Direct Mass Flow instrument. Or a reference part (whose volume is several times larger than the test part) can be used with a Differential Mass Flow instrument. The Differential Mass Flow method requires a calibration to determine the ratio of the Flow Meter reading to the Leak Rate value. The simplest and easiest method is the Direct Mass Flow method as long as the supply air to the instrument can be held stable and the leak rate is easily measured.