PARTICLE MEASURING SYSTEMS
www.pmeasuring.com
5475 Airport Boulevard, Boulder, Colorado 80301-2339
303.443.7100 1.800.238.1801 Fax: 303.546.7380
Customer Service Center 1.877.475.3317
Instrument Service 1.800.557.6363

Sampling High-Pressure Gases

This paper describes fundamental relationships between air or gas volume, pressure, and flow, and how these relationships affect particle counting. Also, a simple plumbing technique is offered as an alternative method for occasionally sampling high-pressure inert gases.

Sample Volume, Pressure, and Flow Rate

When a sample volume of media (air or gas) moves from a high-pressure zone to a low-pressure zone, the movement causes changes in pressure and flow. An accurate particle counter must account for these changes because they can rapidly occur. Mass flow controllers or pressure sensors inside the particle counter can compensate for changes in volume and pressure, and provide constant flow.

Volume, pressure, and flow have different units of measure, so they are distinct and offer unique challenges for particle counters. Volume is the amount of space occupied by a three-dimensional object and is measured in cubic units (e.g., cubic feet). Pressure is the amount of force per unit area and is typically measured in pounds-per-square-inch (e.g., PSI). Flow is the movement of media during a specific time period and is commonly measured in cubic-feet-per-minute (CFM) or liters-per-minute (LPM).

Arguably, pressure has the most significant effect on the particle counter's flow rate and the sample volume available for analysis. Particle counter design requires an understanding of Boyle's Gas Law (shown below) that states: as pressure increases, volume decreases.

$$P_1V_1 = P_2V_2$$

where P = pressure and V = volume

Applying the equation above, we can understand that a cubic foot of air at sea level is not equal to a cubic foot of air at 5000 feet. The higher altitude and correspondingly lower atmospheric pressure allow the volume of air to expand.

When compared to sea level pressure, atmospheric pressure at 5000 feet is about 18% less. As an example, if a volume of air at sea level contains 10 particles, the same volume at 5000 feet will contain about 6 particles. This result occurs because the particles disperse through the expanded volume that has increased about 189% at the higher altitude. If a flow rate control system is not in place, a particle counter adjusted to provide one CFM of air at sea level, will provide significantly inaccurate particle counting data at much higher altitudes.

Flow Rate Control

Volumetric corrections for ambient air pressure are necessary, so particle counters usually have flow-rate controls that change pump speed or allow excess airflow to bypass the sampling chamber.

These controls are adjustable through software settings or mechanical adjustments, or are automatically regulated based upon ambient pressure conditions. Each method monitors the ambient pressure, which is equal pressure on both sides of the pump, and approximates the pump's correct flow rate.

So, if a particle counter is adjusted for sea-level pressure (14.69 psi) and then is taken to an altitude of 5000 feet (12.23 psi), the particle counter will require altitude control adjustments.

NOTE: Particle Measuring Systems' Lasair® III Particle Counters (**Figure 1**) will automatically recognize an over-pressure condition and reject the sample as invalid data. Other particle counters ignore an over-pressure environment and allow the sample to proceed, which provides inaccurate particle data.

Sampling gases at pressures greater than sea level, such as 40–100 psi, are more challenging. Connecting pressurized air or gas to a particle counter can defeat its flow-metering system. High Pressure Diffusers (HPDs) were developed to correct this problem. HPDs (**Figure 2**) reduce the gas pressure to approximate sea level pressures. They operate by allowing some of the excess air/gas to vent—or diffuse—to the atmosphere. Then, the particle counter's flow-metering system can function as designed.

Figure 1. Lasair III Particle Counter

Figure 2. High Pressure Diffuser

Although the HPD is a good solution for periodically sampling high-pressure gases, some customers may use an economical pressure-release valve. The pressure-release “T” valve easily connects to most high-pressure air/gas lines and provides a solution for customers who infrequently sample their air/gas lines. However, this option is more costly in terms of air/gas consumption because the valve discharges higher gas volumes than normally required for monitoring. If high-pressure air/gas sampling is more frequent, an HPD may offset the costs of air/gas loss.

Conclusion

Altitude, or more specifically, atmospheric pressure, has a significant effect on particle counters and must be considered when monitoring particle contamination. The particle counter should provide some method to compensate for different altitudes. If sampling high-pressure gases is required, the user has several options: a dedicated gas particle counter; an HPD; or a pressure-release “T” valve.

Dedicated gas counters were not discussed because they are beyond the scope of this article. Deciding which option to choose is simply a matter of determining the particle size requirements, frequency of sampling, and financial costs of gas consumption.

Author: Steven Kochevar
Senior Applications Engineer
Particle Measuring Systems

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