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# Testing Valves for Particle Generation

Industry standards continue to push toward cleaner processes, and valves have always been notorious for generating particles. Over many years, Particle Measuring Systems (PMS) has been asked to recommend a particle-free valve for specific processes. PMS has not defined a specific valve or manufacturer that meets particle-free operation, but we have developed guidelines for testing particle contamination generated by valves. This paper will discuss those guidelines.

## Standards and Suggested Practices

The Semiconductor Manufacturing Technology (SEMATECH) task force wrote guidelines for testing valves, which was later adopted by the American Society for Testing and Materials (ASTM). These guidelines are very comprehensive, so PMS was asked to develop a document that is more streamlined and easy to understand. Still, if you would like to reference the documents mentioned above, here are the specific titles:

SEMASPEC *Test Method for Determination of Particle Contribution by Valves in Gas Distribution Systems*

ASTM F1394 - 92(2005) *Standard Test Method for Determination of Particle Contribution from Gas Distribution System Valves*

## Particle Traps

Commonly, valves are referred to as *particle traps* and for good reason. When the valve is closed, the media (liquid or air) carrying particles can deposit those particles on the valve's closed gate. Then, when the valve opens, these trapped particles will release into the media stream and create a large spike in the particle contamination.

The simple movement of a valve includes frictional components that add particles to the media. Rotating ball valves, pivoting butterfly valves, rising gate valves, and common globe valves all contribute particles to the process. Globe valves (*Figure 1*) are the most common, and as shown in the cutaway view below, particles can stick to any surface that comes into contact with the media. Additionally, the rotating stem creates friction within the threads and this friction creates particles.

Different valve materials, like Teflon®, reduce the frictional component but do not *eliminate* particle generation. Still, Teflon valves are a better choice than most other materials. The tubing connected to the valves often contributes more particles than the valve, so selecting the proper tubing can provide significant particle reduction.

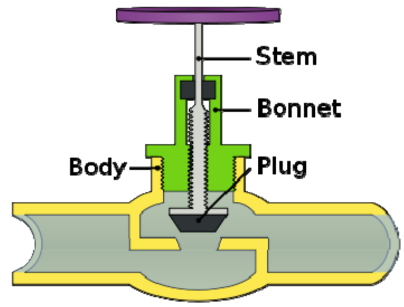


***Figure 1: Globe Valve***

## Particle Tubing

The testing plan should consider the tubing material because it will connect directly to the valves. Then, a well-defined layout for the tubing installation should maximize particle transport. These two factors strongly affect the reliability of valve testing data.

The tubing material is critical, along with the length, diameter, and bends. PMS has performed numerous tests and written several documents that describe tubing for particle transportation. Some tubing materials are not always available or affordable. Table 1 lists the preferred materials for successful particle transport while minimizing particle generation (with the most preferred tubing material listed first).

| |
|---|
| **Stainless steel** |
| **Conductive polymer** |
| **Polyester** |
| **Vinyl (if plasticizer does not interfere)** |
| **Polyethylene** |
| **Copper** |
| **Glass** |
| **Teflon** |
| **Aluminum** |

***Table 1: Tubing Materials***

Bev-A-Line® conductive polymer 3/8" ID tubing is commonly installed with aerosol manifold systems, while Teflon Galtek PFA tubing is commonly installed with liquid particle counter systems. Teflon is used instead of conductive tubing because when sampling polar liquids the electrostatic losses are minimal. Both materials offer superior particle transport, for their respective application, and can be purchase at a reasonable cost.

When planning the tubing installation, the test facility should consider the length, diameter, and bends. Air flow velocity inside the tubing is sharply influenced by the sample tubing and particle transportation will greatly improve with proper tubing selection and installation.

To minimize particle loss in tubing, the tubing should always lie flat (if possible) with minimal bends. If tubing bends are required, the bend radius (measured to the inside curvature) should not be less than 6 inches. Also, the tubing diameter and materials should be conducive to particle transport.

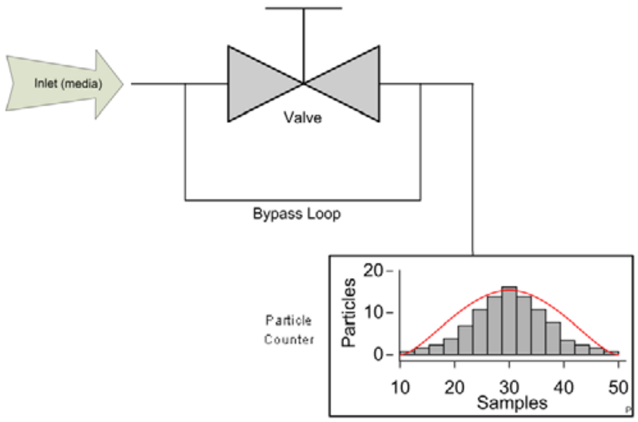


***Figure 2: Valve Testing Diagram***

*Figure 2* illustrates a basic valve-testing platform. The inlet is open to the *media*, either unfiltered or filtered. The media is simply defined as air or liquid that passes through the valve. If using unfiltered media, the background particle counts must be subtracted from the particle counts contributed by the valve. If using filtered media, the background counts should be negligible, so any particle counts should have been contributed by the valve.

Next, the valve is installed in parallel to the bypass loop. The bypass loop provides constant flow to the particle counter; otherwise, low flow conditions will cause the particle counter to stop sampling. Both the bypass loop and the exhaust line from the valve connect to a T-fitting.

The particle counter connects to the other side of the T-fitting. The particle counter's pump or vacuum supply pulls media through the system. As particles are drawn into the particle counter, they will be sized and counted.

## Test Procedure

### *Preparation*

1. Verify the particle counter's calibration.
2. Prepare the particle counter's software by entering the test recipe as described below in the ***Testing*** section below.

### *Testing*

Once the system has been prepared for testing, follow the procedure described below. Unless otherwise specified, the same procedure is followed for each test.

***1. Background Particulate Testing***

a. Configure the system as shown in *Figure 2*, with the exception of the valve. In place of the valve is a length of tubing (known as a *spool piece*). The particle counter's sample interval is set to 10 minutes, with continuous sampling.
   - Specifically, after finishing one sample interval, the particle counter will reset the data then start the next sample interval.

b. The particle count data is analyzed at the *smallest particle channel.*
   - The smallest particle channel is defined by the user or process, and meets the valve's purity specifications.

c. Continuous sampling is taken until a sample interval provides very few particle counts.
   - In air, extremely clean valves produce < 30 particles/m$^3$ (cumulative counts).
   - In liquids, extremely clean valves produce < 10 particles/mL (cumulative counts).

d. After successfully performing this test, the data provides the background level of particulate contamination.

***2. Static Particulate Testing***

a. Once the background count has been determined, the valve is plumbed into the system in an OPEN position.

b. The particle counter begins sampling the media for 10 minutes at the flow rate specified by the particle counter.
   - This sample removes any loosely-attached particles in the valve.

c. The particle counter or software should collect and store all data.

***3. Dynamic Particulate Testing***

a. Next, set the particle counter to 20-second sample intervals, continuously, until stopped by the operator.

b. Close the valve, leave it closed for a 5-second period, then reopen the valve.
   - The particle counter should be continuously recording the data, in 20-second sample intervals.

c. The particle counter continues to sample particle data until the system returns to the baseline level achieved in Step **3.b**.

d. Steps **3.b** and **3.c** are repeated twice, for a total of three open/close cycles.

Once the data has been collected and recorded, testing is complete. Remove the valve from the testing platform and begin testing the next valve (if applicable).

## Data Analysis

When testing valves, the data will often show a peak as the valve opens. This peak occurs when the particles trapped on the valve are freed into the system. Afterward, the particles reach an equilibrium state and the particle counts may start to gradually decrease.

*Figure 3* illustrates data from a 3-port valve, and there are three defined peaks. The first peak occurred when the valve port A was opened. The initial particle surge was followed by a gradual decrease in particle activity.

Near sample 46 in *Figure 3*, the valve was closed, then, quickly re-opened. This created a second peak as the particle surge appeared, then started to diminish until the valve was closed again. When both valves were closed the particle counts were nearly zero.

The third peak occurred when both valve ports open. Since the pressure drop was more gradual, the particle counts slowly increased until they reached equilibrium. Eventually, after enough time passes, we would expect particle counts to fall, but this could take some time.

The third peak clearly illustrates that even when open, valves can add particles to a system. Also, it is important to remember that these particles were not coming from an outside source, as the entire valve was sitting in a HEPA-filtered enclosure. These particle counts were being emitted by the valve assembly.

## Summary

The procedures listed in this paper provide a quick method for measuring particle counts contributed by valves. The data from the tests can be used to compare different types of valves or compare similar valves from different manufacturers. Either way, knowing the purity of valves before installation could lead to process improvements and reduce particle contamination in the final product.

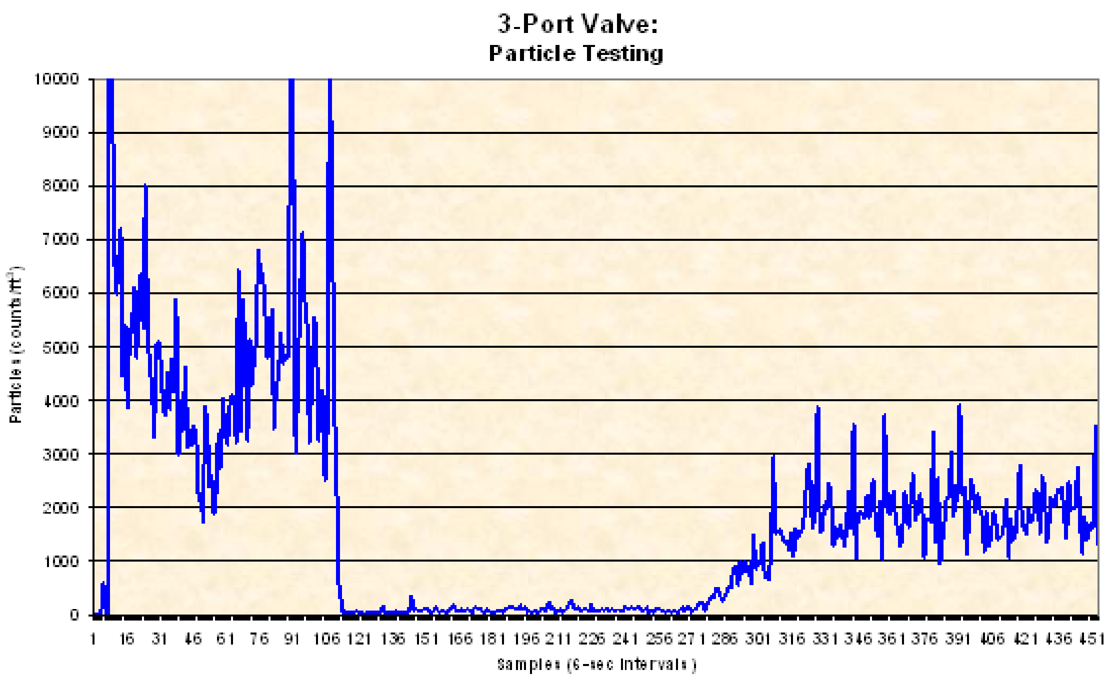


***Figure 3: Valve Testing Data***

**Authors:**

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***Rebecca Thompson*** earned a B.S. in Chemical Engineering from the University of Colorado. In 2007, she joined Particle Measuring Systems and currently works as an Applications Engineer. During her career, she has authored many application notes and supported customers around the world in their particle counting applications.