CALIBRATION CERTIFICATE FAILURE EXPLANATION FOR AEROTRAK® PARTICLE COUNTERS

APPLICATION NOTE CC-119 (US)

This application note works through the "As Found Calibration Certificate" of the AeroTrak® Particle Counters and explains common failures. An explanation of the failure mode, possible reasons, and impact are discussed for each failure a customer may see. Also included, is an explanation of Counting Efficiency and why a 0.3 µm instrument is not needed to measure 100% of the 0.5 µm particles, as commonly believed. This application note assumes that the reader already has a basic understanding of how particle counting technology works. For a more in-depth look at each elements of a particle counter calibration, please refer to Application Note CC-117.

Size Calibration and Verification of Size Setting

Size Calibration and Verification of Size Setting								
Nominal Particle Size	**Gain Stage**	**Previous Digital Cutpoint**	**As Found Digital Cutpoint**	**Measured Particle Size**	**Size Error**	**Allowable Range**	**Pass/Fail**	**Expanded Uncertainty**
0.3 µm	A	30	24	0.29 µm	-4.8%	±10%	Pass	3.9%
0.5 µm	A	325	325	0.50 µm	0.0%	±10%	Pass	3.9%
0.7 µm	B	3	3	0.70 µm	0.0%	±10%	Pass	3.9%
1 µm	B	8	8	1.00 µm	0.0%	±10%	Pass	3.9%
2 µm	B	20	20	2.00 µm	0.0%	±10%	Pass	3.8%
5 µm	B	179	179	5.00 µm	0.0%	±10%	Pass	3.8%

This section of the Certificate shows the current sizing capabilities of the particle counter as compared to the last time it was calibrated. The Digital Cutpoint is a value associated with a given size of a particle. When polystyrene latex (PSL) particles of a known size are measured during calibration, the intensity of the signal interpreted by the optics is then associated with that size of particle (see Figure 1). During the As Found Calibration, PSL particles of a known size are again measured to see if the value previously found still matches. The difference between the Digital Cutpoints is the Size Error. There are two possible failure modes for this section.

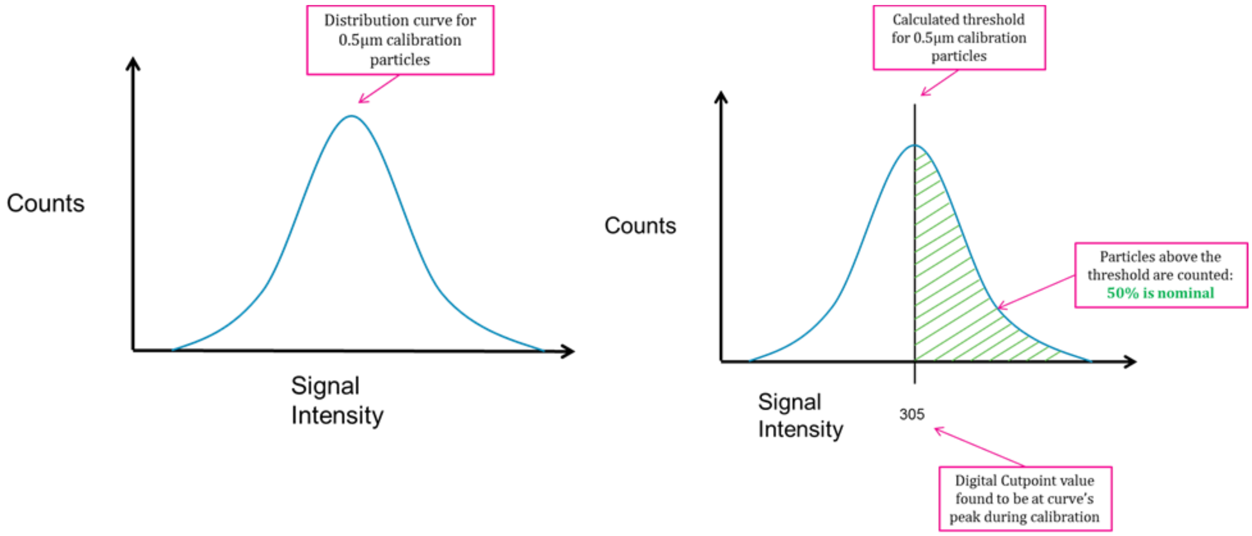

Figure 1

If the Size Error fails on the positive side, it means that the Digital Cutpoint has risen since the last calibration (see Figure 2). One possible reason for this failure may be that the airflow through the system is too slow. Particles passing through spend more time in the laser beam, causing more light to scatter and a higher intensity signal to be interpreted. This failure's impact is that some particles measured will be interpreted as larger than they actually are.

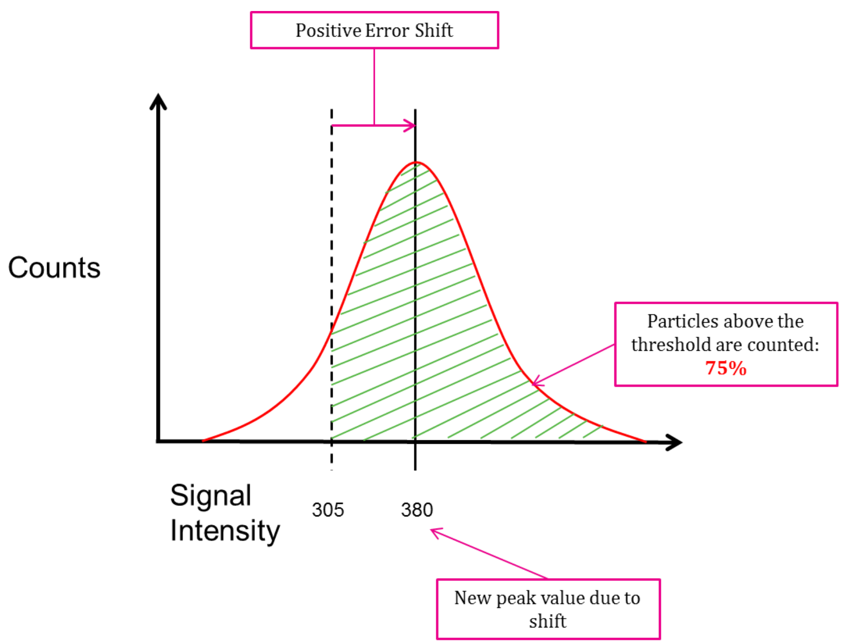

Figure 2

If the Size Error fails on the negative side, it is because the Digital Cutpoint has fallen since the last calibration (See Figure 3). Common reasons for this failure are contaminated optics (some scattered light is lost), laser misalignment or laser power drop (not enough light hitting the particles), or airflow is too fast (particles do not spend enough time in the laser beam). This type of failure may mean that the lower end of the channel was undercounted, and the higher end of the channel was over counted.

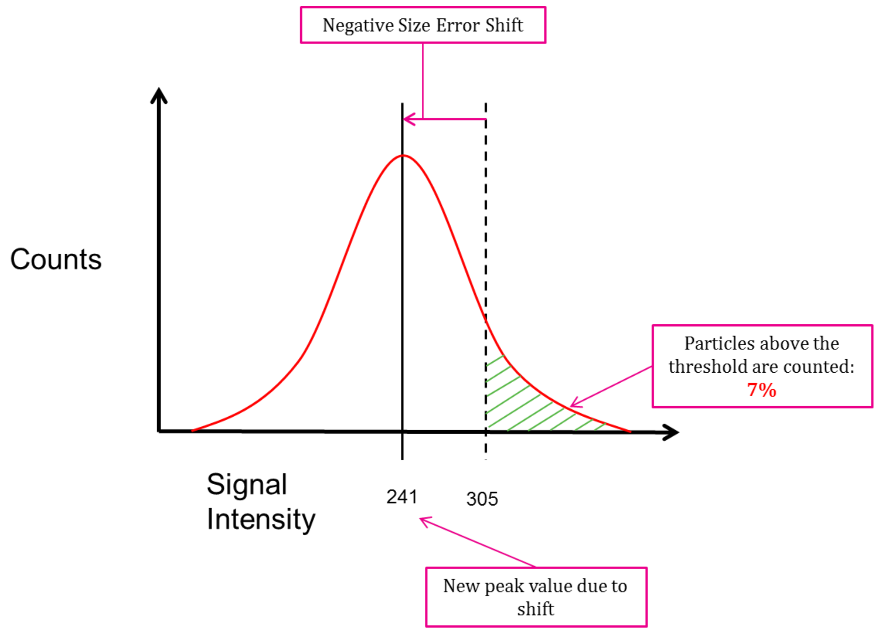

Figure 3

Counting Efficiency

Counting Efficiency			
Particle Size	**Actual**	**Allowable Range**	**Pass/Fail**
0.3 µm	32%	50% ± 20	Pass
0.5 µm	92%	100% ± 10	Pass

Counting Efficiency is tested to ensure that the particle counter is accurately counting the number of particles that pass through it. The particle counter under test is compared to a reference instrument (see Figure 4).

Counting Efficiency is tested at two particle sizes. The first size must be close to the minimum detectable particle size, and the second size is to be 1.5 to 2 times larger than the minimum detectable particle size. ISO 21501-4 requires that the counting efficiency near the minimum detectable size be 50 ± 20%, and the larger particle size be 100 ± 10% (the 50% requirement will be explained later in this application note).

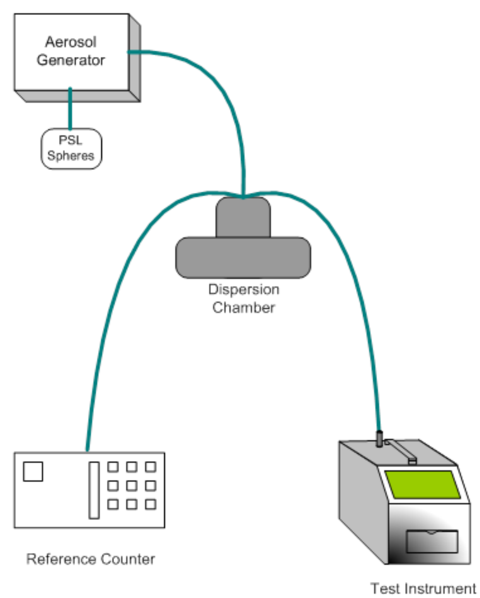

Figure 4

While very uncommon, a particle counter may have a high failure for the Counting Efficiency (the instrument under test (IUT) counted too many particles compared to the reference instrument). If this failure occurs, the most likely explanation is because the flow to the IUT was higher than the reference instrument, or there was a leak in the system allowing extra particles to get into the IUT.

This would be a conservative error, meaning the instrument was possibly counting more particles than it should have been.

More commonly, if the IUT fails this aspect of the calibration, it is a low failure, meaning the IUT counted too few particles compared to the reference instrument. Possible reasons for this failure are low flow to the IUT, contaminated or misaligned optics, or low laser power. The impact of the IUT counting too few particles is that the environment may have been dirtier than the instrument interpreted.

Size Resolution

Size Resolution			
Particle Size	**Measured**	**Allowable Range**	**Pass/Fail**
0.5 μm	5.3%	≤15%	Pass

Size Resolution is the ability of the instrument to differentiate between similarly sized particles. It is calculated in relation to the standard deviation of the distribution measured with the pulse height analyzer. As the standard deviation of the distribution increases, the instrument's ability to differentiate sizes is reduced.

The only failure possible is a high failure, and is most likely caused by contaminated and/or misaligned optics. When this happens, the instrument is not as able to differentiate similarly sized particles.

False Count Rate

False Count Rate						
Sample Time (min)	**Sampled (L)**	**Measured Counts (#)**	**Concentration (#/m³)**	**95% UCL (#/m³)**	**Allowable Range (#/m³)**	**Pass/Fail**
20	57	0	0.00	53.0	≤70.7	±10%

The purpose for the False Count Rate test is to ensure that the particle counter is not counting particles when it shouldn't be. A HEPA filter is placed over the inlet, and the instrument is set to the minimum detectable size.

Ideally, no particles would be counted in this configuration. However, if too many particles are counted, and the test is failed, it may be because of a dirty instrument, leaks in the system (particles getting introduced into the flow somewhere other than the inlet), or particles stuck to the side of the flow system became dislodged and counted during the False Count Rate test. This is a conservative failure, and indicates that the particle counter potentially counted too many particles.

Sampling Flow Rate

Sampling Flow Rate (L/min)				
Nominal	**Actual**	**Error**	**Allowable Range**	**Pass/Fail**
2.83	2.83	0.0%	±5%	Pass

The Sampling Flow Rate test is done to ensure that there is the correct flow of air through the instrument. If the particle counter fails the test because the flow is too high, it may be because the critical orifice is damaged (remotes only), or because the pump and/or pressure transducer is operating incorrectly. If a high failure has occurred, the particles may have been sized too small (in the laser beam for too little time). Additionally, since the flow was higher, there may have been more particles flowing through the system, which means the counting efficiency may have been too high.

More commonly, if there is a Sampling Flow Rate failure, it is a low failure. This could be caused by a leak in the system, contamination, pump or pump electronics issues. This failure may cause particles to be measured as larger than they really are (in the laser beam for too long). Also, since there are fewer particles flowing through the system, the counting efficiency may be too low.

Measuring "All" of the 0.5 µm Particles—A Simple Explanation

Previous to ISO 21501-4 calibration standards, many particles counters had lower quality and questionable performance when measuring smaller sized particles. Now, ISO 21501-4 ensures that particle counters perform adequately, even at the smallest cutpoint. In the past, there was a general misunderstanding that if a 0.5 µm instrument "counted only 50% of the 0.5 µm particles," then a 0.3 µm instrument would be needed to count 100% of the 0.5 µm particles. Misunderstanding of this concept, and of ISO 21501-4 calibration standards, led many competitors to upsell customers to more expensive particle counters.

When a particle counter is calibrated, it uses Polystyrene Latex (PSL) particles of a known size with a known standard deviation from that size. Even though these particles are created in a lab to NIST traceable standards, nothing is perfect. If 0.5 µm PSL particles are used during calibration, some of them will invariably be smaller than 0.5 µm and some will be larger than 0.5 µm. When these PSL particles are introduced to the particle counter, they are sized and counted. The larger the particle, the higher the voltage of the signal interpreted by the instrument. Since the standard deviation of the PSL particle size is known, the median of the histogram is taken to be the threshold for the size of particle being measured (Figure 5), in accordance with ISO 21501-4. The 50% of counts above that threshold are larger than 0.5 µm and the 50% of counts below the threshold are smaller than 0.5 µm.

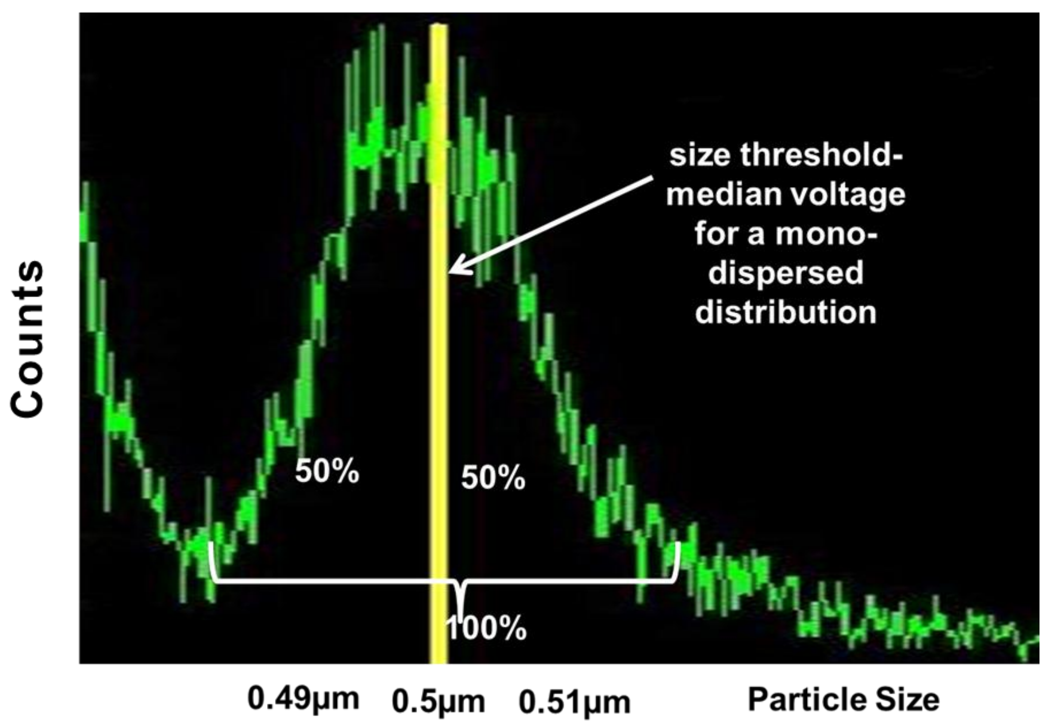

Figure 5

This is why a 0.5 μm channel counting 50% of the 0.5 μm calibration PSL particles is nominal. The other 50% of the PSL calibration particles are smaller than 0.5 μm and should not be counted as 0.5 μm particles. When using an instrument with a 0.3 μm channel and a 0.5 μm channel, 50% of the calibration PSL particles will still be counted in the 0.5 μm channel, the remainder will be counted in the 0.3 μm channel because they are actually smaller than 0.5 μm and therefore not large enough to be counted in the 0.5 μm channel.

In summary, the 50% is referring to *calibration PSL particles* of a known size and standard deviation. In real world applications, a 0.5 μm instrument will still count all of the 0.5 μm particles in the sampled air.

UNDERSTANDING, ACCELERATED

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