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Performance Calculator Instructions

(Download the Performance Calculator at http://www.pmeasuring.com/support/papers/particlemonitoring/liquid/PerfCalc)

Introduction

Frequently, particle counter users are faced with trying to determine which particle counting system will provide the best statistical data for monitoring their ultrapure liquid system. When comparing the specifications of different particle counters, many of the specifications appear similar making it difficult to ascertain which system is superior and most appropriate for monitoring the liquid system in question.

Particle Measuring Systems has addressed the need for a gauging device by developing a simple tool named the Performance Calculator. The Performance Calculator allows users to enter the relevant specifications of different particle counting systems. Once the information is entered, the Performance Calculator produces measures that indicate a particle counter's ability to produce good statistical data allowing users to improve control over the liquid system saving the time and costs associated with responding to false alarm conditions.

Description

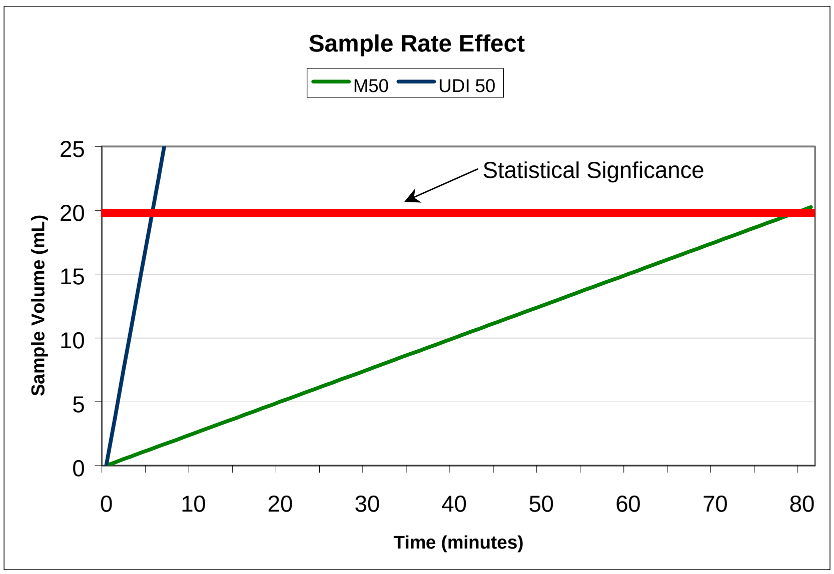
The Performance Calculator allows the user the ability to input different parameters of up to three particle counters. Once each particle counter's parameters are entered, the Performance Calculator will produce information on how the particle counter's sensitivity and sample volume affect the data. This benefit is illustrated through looking at the number of alarms that may be generated on a given system.

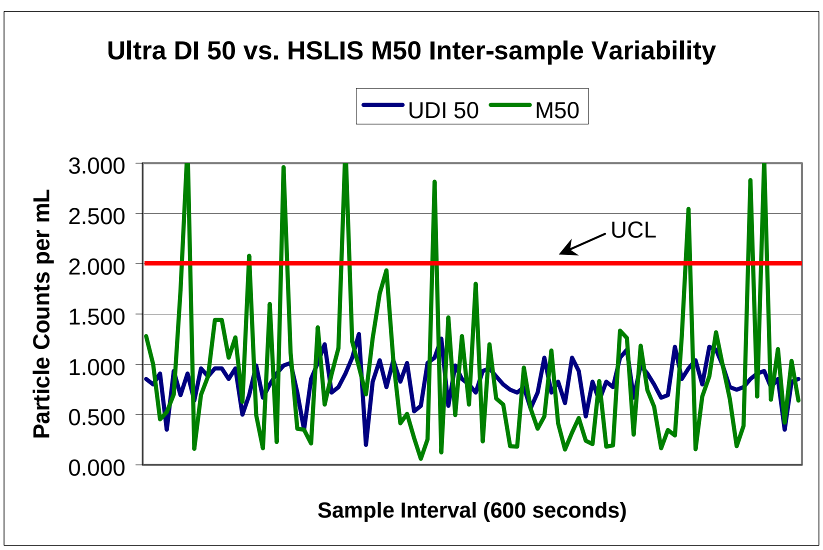
There are three main variables that influence the quality of data for liquid particle counters. These are sample rate, sensitivity, and the Particle Size Distribution (PSD) within the liquid being sampled. The first, sample rate, influences the particle counter's ability to obtain a meaningful description of the sample. This is explained through simple population statistics where the larger the sample the better the description of the population. The benefit of increasing the sample volume for particle counters is realized when trying to establish different control limits for the liquid system. Because a large sample volume provides a better description, the user is able to set more stringent controls on the system. In particular this is realized through inter-sample variability. As the sample volume increases, inter-sample variability decreases which in turn reduces the probability that false alarms will be generated on the system making the liquid system easier to control.

To help illustrate the importance of sample volume, the Particle Measuring System (PMS) HSLIS M50 and Ultra DI® 50 particle counters are compared. The specifications of each instrument are found below:

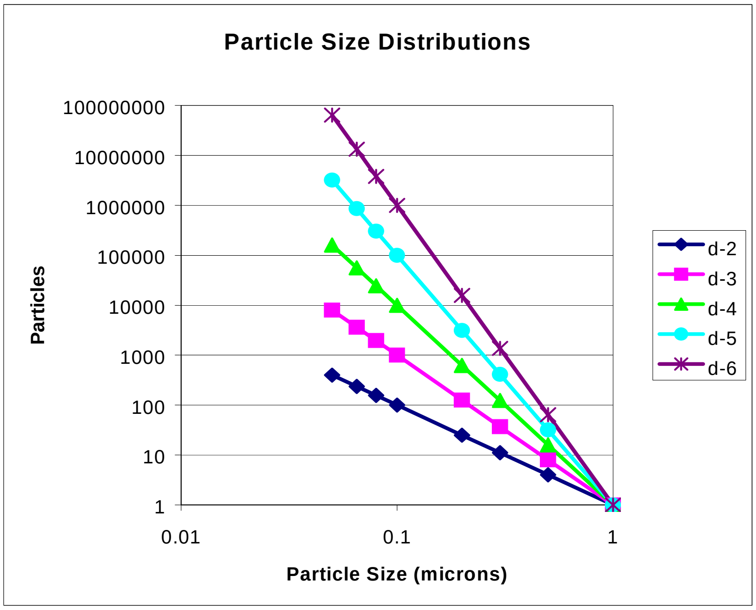
	HSLIS M50	Ultra DI 50
Sensitivity	0.05 m	0.05 m
Flow Rate	100 ml/min	1,000 ml/min
View Volume	0.25 %	0.375 %
Sample rate	0.25 ml/min	3.75 ml/min

Each instrument has equivalent sensitivity, but the sample rate is significantly different (sample rate is a product of flow rate and view volume). The importance of the sampling rate is illustrated in the following two figures. As seen in the first figure, instruments that have a low sample rate will take a longer period of time to reach a statistically significant sample. For instance, if it takes 20 mL to obtain a statistically significant sample, it will take the HSLIS M50 80 minutes versus 5.33 minutes for the Ultra DI 50 to obtain a statistically valid sample. The increased sample rate results in a 15x time saving!





The second figure shows how a larger sample population reduces inter-sample variability. As the figure illustrates, the instrument with the larger sample volume, in this case the Ultra DI50, does not create as many alarm conditions and provides an overall better description of the population due to decreased statistical variation. This allows the user to define tighter control limits without the worry of having to baby sit a system that creates false alarms.



The remaining variables that affect data quality are sensitivity and sample PSD. Sensitivity is the smallest size particle that can be detected by a particle counter. Particle Size Distribution, as the name implies, is the manner particles are dispersed within the sample. These two variables are interrelated for determining which particle counter is appropriate for monitoring the system. This relationship is explained by first understanding the different types of PSDs. Examples of different PSDs are found below in Figure 3.

Knollenberg and Veal (1) discovered that particles had a certain distribution within DI water systems that could be approximated by the power law expression of:

$$N = AD^B$$

N = Number of particles per ml
D = Particle diameter in microns
A = Constant
B = Constant

Using this expression, Knollenberg and Veal found that a typical distribution for DI water systems could be estimated by $N = 0.0006D^{-3}$.

Applying Knollenberg and Veal's work, Mitchell (2) found this expression could also be used for other ultrapure liquids to approximate the PSD. Applying this to particle counters, more sensitive instruments will count more particles in a given period with sample volume remaining equal. For instance, if comparing between 0.1 and 0.2 m sensitive particle counters with equivalent sample volumes that are sampling from a D^{-3} particle distribution, the user could expect to find 8 times the number of particles with the more sensitive instrument!

$N_{0.2\ m} = D^{-3} = 1/(0.2^3) = 125$ particles 0.2 m

$N_{0.1\ \ m} = D^{-3} = 1/(0.1^3) = 1,000$ particles 0.1 m

The importance of the number of particles the instrument detects helps determine which particle counter is most appropriate for the liquid being sampled. For instance, if sampling a liquid with a D^{-3} distribution with a concentration of 1,000 particles/ml 0.2 m and greater, an instrument with a maximum concentration of 5,000 particles/ml may be overwhelmed if the sensitivity is 0.1 m or 0.05 m. On the other hand if the concentration is very low, such as 1 particle/ml 0.2 m, the user would be able to specify a more sensitive instrument to obtain a better description of the PSD without overwhelming the instrument.

Explanation

First presented at Watertech-Portand (3), the Performance Calculator was created from basic particle counting statistics (2) to illustrate the potential number of false alarms that could be generated per day. As seen in figure 4, the Performance Calculator also produces Upper Control Limits (UCL) for each defined particle counting system to show how sensitivity and sample volume combine to reduce variability and improve control over a system.

Criteria

Smallest detected particle Size	0.10	microns
Particle concentration	0.50	*total particles present in sample greater than 0.10 microns per ml of fluid*
Sample Interval (seconds)	600	*seconds*
Alarm Level	20.00%	*percent above expected particle concentration*
Particle Distribution Power Function	-3	diameter^X (normally expect diameter^{-3} distribution)

Particle Counter	Instrument A	Instrument B	Instrument C	
Sample Volume	0.05	0.25	3.75	*ml/ min*
1^{st} Channel Particle Size	0.05	0.05	0.05	*microns*

Results

	Instrument A	Instrument B	Instrument C	
Expected concentration >=1st Channel	4.000	4.000	4.000	*particles/ ml*
Samples per day	144	144	144	*n*
Volume per sample	0.50	2.50	37.50	*ml*
Detected Particles >= 1st Channel	2.00	10.00	150.00	*per specified distribution*
Detected Particles >= 0.10 microns	0.25	1.25	18.75	*per specified distribution*
Standard Deviation >= 1st Channel	2.828	1.265	0.327	*particles/ ml*
Standard Deviation >= 0.10 microns	1.000	0.447	0.115	*particles/ ml*
P(sample exceeds Alarm Level)	0.3886	0.2635	0.0072	
Upper Alarm Level	4.80	4.80	4.80	*1^{st} channel and greater per specified distribution*
Alarms per day	55.97	37.95	1.03	*from statistical variation*

Possible Control Limits	Instrument A	Instrument B	Instrument C	
90.0% UCL >= 1st Channel	7.62	5.62	4.42	*particles/ ml*
95.0% UCL >= 1st Channel	8.67	6.09	4.54	*particles/ ml*
99.87% UCL >= 1st Channel	12.49	7.79	4.98	*particles/ ml*
90.0% UCL >= 0.10 microns	1.78	1.07	0.65	*particles/ ml*
95.0% UCL >= 0.10 microns	2.15	1.24	0.69	*particles/ ml*
99.87% UCL >= 0.10 microns	3.50	1.84	0.85	*particles/ ml*

Within this spreadsheet, the user defines the particle counting systems to be compared by inputting different criteria found within the active cells (orange). Once the information has been entered, the Performance Calculator will issue results (blue) showing how the instruments compare.

Summary

Developed to assist in the selection of particle counters for ultrapure liquid applications, the Performance Calculator provides a means to benchmark different systems in regards to sensitivity, sample volume and a liquid system's Particle Size Distribution. In addition, the Performance Calculator indicates which particle counting system will provide the best control over a process in terms of reducing control limits and inter-sample variability. By controlling the statistical variation, the user will be able to reduce the time and associated costs of responding to false alarm conditions

References

1. Knollenberg, R.G., Veal, D.L., "Optical Particle Monitors, Counters, and Spectrometers: Performance Characterization, Comparison and Use". Proceedings of the 37th Annual Technical meeting of the Institutes of Environmental Sciences, May 1991.
2. Mitchell, J., "Statistical Analysis of Particle Instruments for Liquid-borne Particles: Understanding the Impact of Size Sensitivity and Sample Volume", Proceedings of the 44th Annual Technical Meeting of the Institute of Environmental Sciences, April 1998.
3. Mitchell, J., Bast, B., "Comparing Particle Counter Performance Characteristics for Analyzing High-Purity Water", Ultrapure Water Journal, February 2000.

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