Kenelec Scientific

PARTICLE COUNTER CALIBRATION

IS ISO-21501 THE COMPLETE SOLUTION?

Jason Kelly Calibration Services Engineer
Kenelec Scientific Australia

INTRODUCTION

With recent trends in many Industries for cleaner environments for processing of products, optical particle counters have become increasingly more strategic in environmental monitoring of cleanrooms. From pharmaceutical, medical device, biotechnology, semiconductor, military/space exploration, automobile to the emerging presence in the food industry particle counters play a critical role in keeping a militant watch over the environmental conditions of a cleanroom and process area's. With new cGMP guidelines and traceability, particle counter accuracy is essential in maintaining a quality environmental monitoring system.

With such a big role to play in product quality and ensuring overall product safety especially in the pharmaceutical, medical device and biotechnology industries. How accurate are particle counters once they are calibrated outside of the factory? The only real way to find out is to make some kind of comparison against references following a well documented and validated calibration procedure. Hence the arrival of ISO 21501.So what happened before ISO 21501 ? First of all let's define what calibration actually means.

WHAT IS CALIBRATION ?

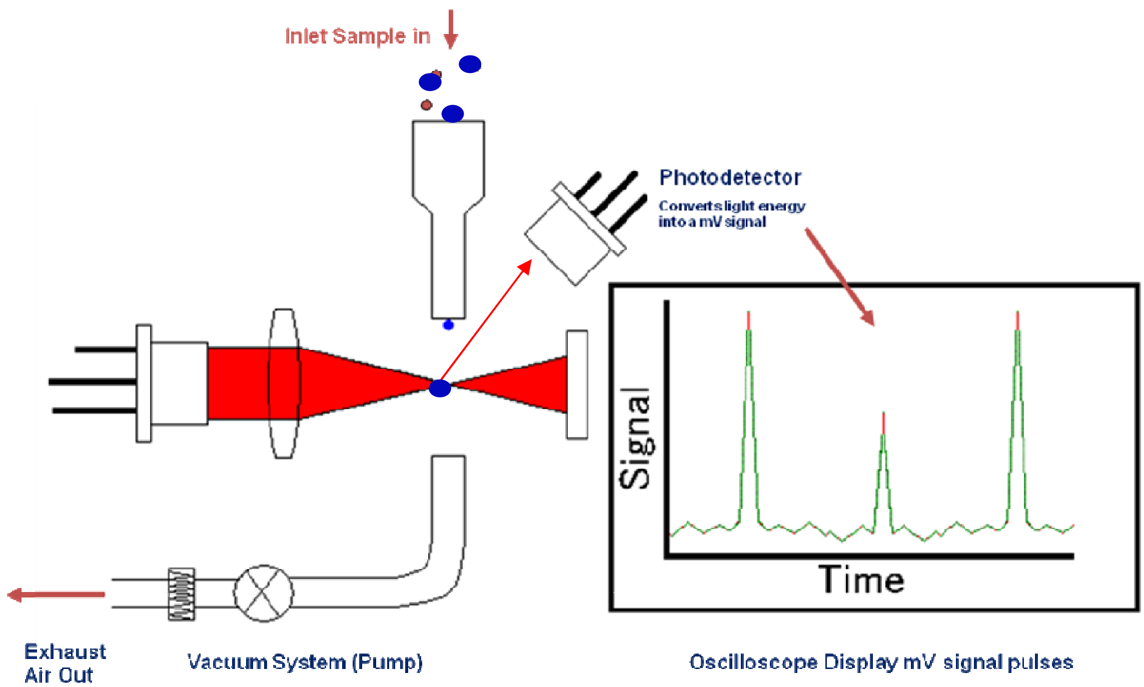
"Calibration is the process of establishing the relationship between a measuring device and the units of measure. This is done by comparing a device or the output of an instrument to a standard having known measurement characteristics. To improve the quality of the calibration and have the results accepted by outside organizations it is desirable for the calibration and subsequent measurements to be "traceable" to internationally defined measurement units. Establishing traceability is accomplished by a formal comparison to a standard which is directly or indirectly related to national standards, international standards, or certified reference materials.

> "***Quality management systems call for an effective metrology system which includes formal, periodic, and documented calibration of all measuring instruments. ISO 9000 and ISO 17025 require effective calibration systems***".

SO HOW DO PARTICLE COUNTERS WORK ?

Particle Counting technology has its roots in the early 1900's John Tyndall an Irish physicist scientifically characterized the scattering of light by dust and large molecules in the air, now known as the Tyndall Effect[1], (similar to Rayleigh scattering[2]). In studying the interactions between light and the constituents of air, he developed the nephelometer (an instrument for measuring suspended particulates in a liquid or gas colloid) .

The technology has since evolved and become more accurate due to laser technology and microelectronics. Basically a particle counter takes a sample and the particles in that sample pass through a laser beam thus scattering the light energy, the electronics inside the sensor convert this light energy into a voltage. This voltage is proportionate to the size of the particle or the amount of light the particle scatters or reflects.

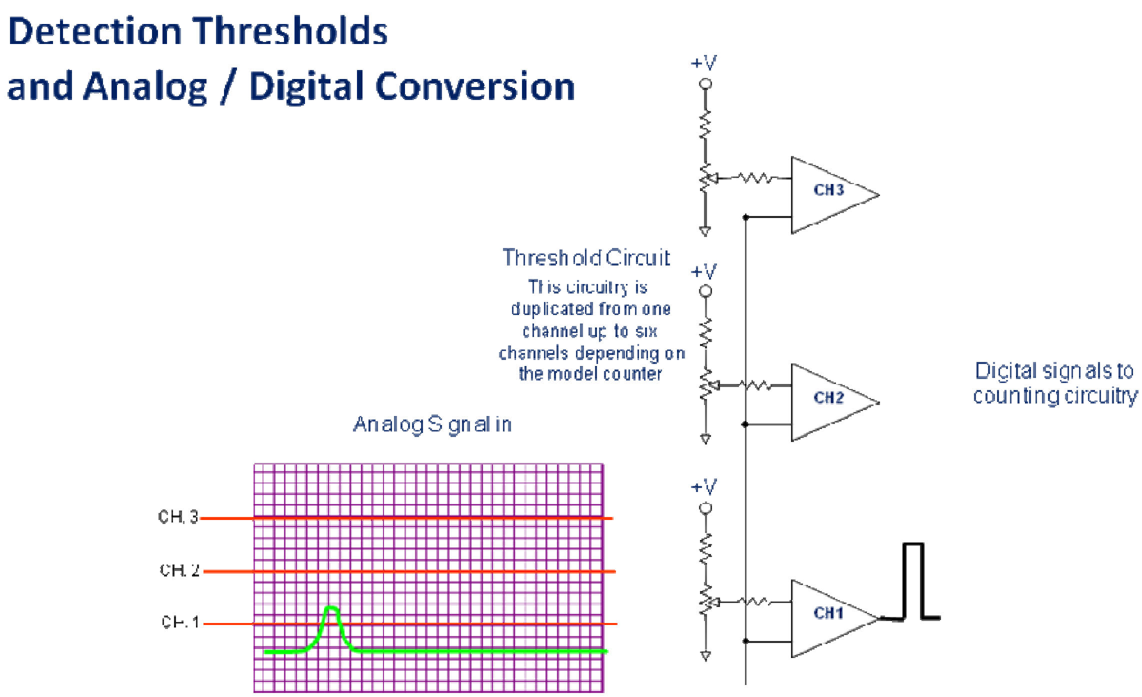


1 The **Tyndall effect** is an effect of light scattering by colloidal particles or particles in suspension

2 **Rayleigh scattering** (named after Lord Rayleigh) is the elastic scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of the light. It can occur when light travels in transparent solids and liquids, but is most prominently seen in gases

ANALOGUE TO DIGITAL CONVERSION

The electronic circuitry picks up the voltage signal from the photodetector (which converted the light energy into the voltage signal). Digital threshold circuitry accurately size and count the particles



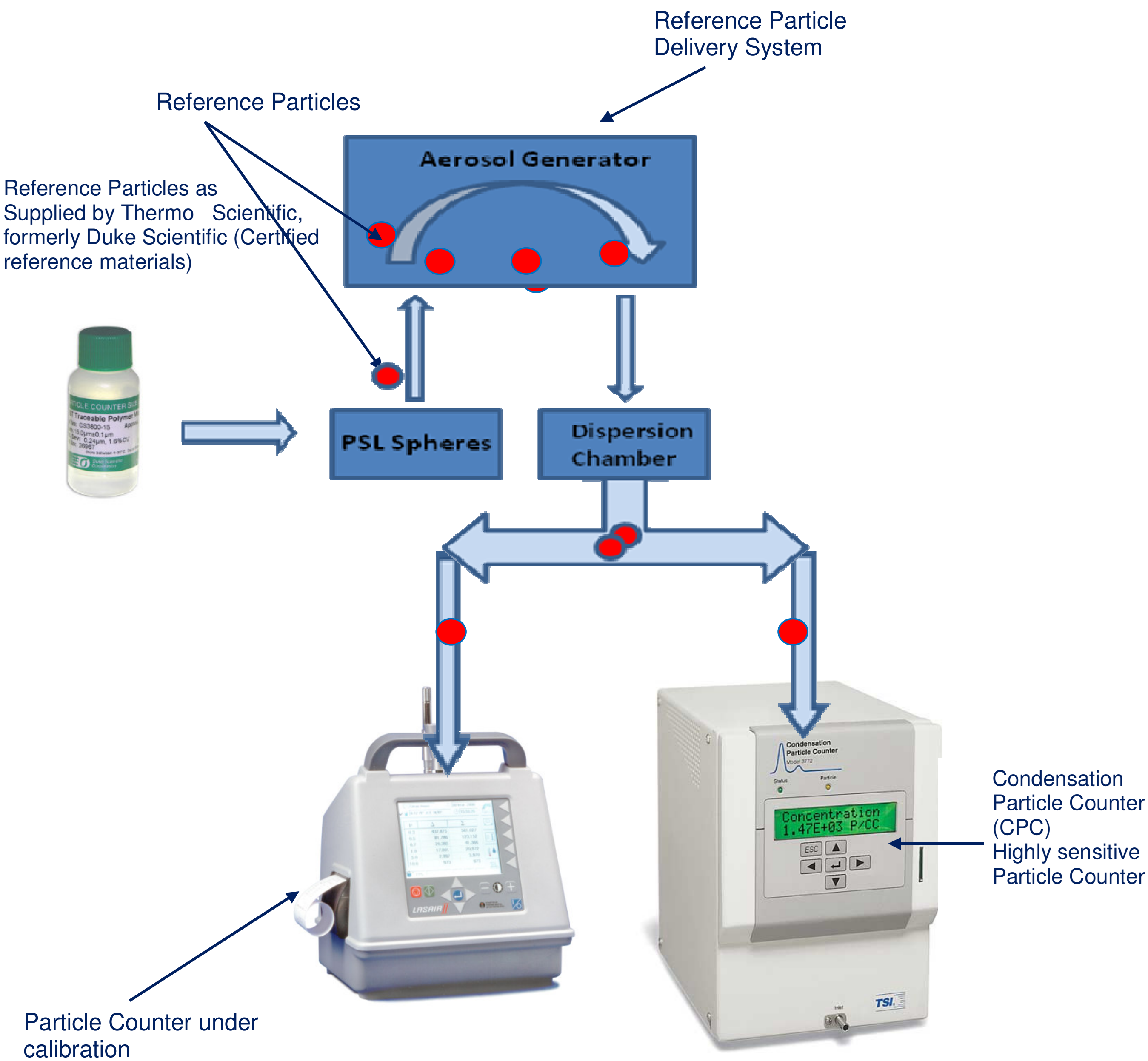
SO HOW ARE PARTICLE COUNTERS CALIBRATED ?

Primary particle counter calibration is carried out by the manufacturer and was usually conducted following manufacturer procedures and guidelines from ASTM and JIS B 9921 where a Condensation Particle Counter (CPC) is used as a reference unit so with this standard the accuracy of the Particle Counter was set. Size calibration was checked using a PHA. (See Fig 1. Primary Particle Counter Calibration)

What happens after the calibration interval is up? For field calibrations the previous methods followed were not adequate. Particle Counter Service centers across the world used different methods and followed different guidelines.

Particle counter manufacturers went in two different directions with field calibrations. Some chose a calibration method using a calibrated reference unit and followed guidelines in ASTM F649-1while other particle counter manufacturers used a pulse height analyser (PHA) [3] and followed guidelines in ASTM(4) F328-98 and some parts of JIS(5) B 9921.

FACTORY CALIBRATION OF NEW PARTICLE COUNTER



Count efficiency was verified during the factory calibration as well as size calibration using certified reference materials such as polystyrene latex spheres (PSL).

Fig 1. Primary Particle Counter Calibration (Factory Calibration)

CALIBRATION WITH REFERENCE PARTICLE COUNTER

Following ASTM F649-01(Field Calibration)

Following the reference particle counter method (also known as count match calibration) the particle counter is calibrated using reference particles and is compared to a calibrated reference unit. This method of calibration calibrates the accuracy of the particle counter. Sizing is also calibrated but is based on channel splitting method and the Particle Counter is effectively used to calibrate itself.

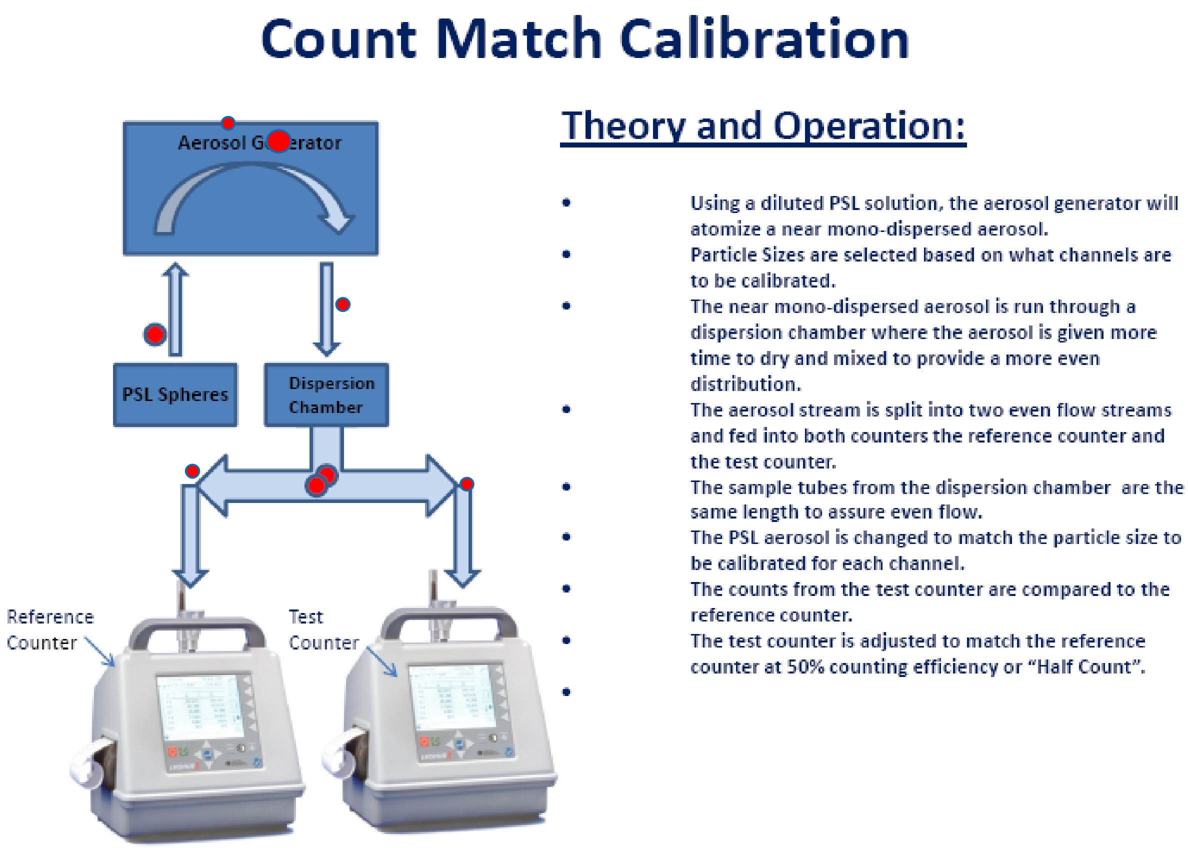


Fig 2. Using Reference Unit Method

Fig 3. Certified reference particles polystyrene latex spheres
(References used to calibrate particle counters)

CALIBRATION WITH PHA FOLLOWING ASTM 328
(Field Calibration)

With the PHA method each particle size is calibrated using reference particles. Older Particle Counters had set electronic thresholds for each particle size. So when a specific channel was calibrated the reference particle size for that channel was sampled through the particle counter, the PHA distribution was displayed and the median voltage was checked against the threshold. (See fig 5. example of ideal particle response Gaussian curve).The new threshold was then set. Other manufacturers had set thresholds for specific sizes which never changed. The PHA method only calibrated based on size. Therefore a perfectly calibrated particle counter with all channel thresholds aligned to the reference particle sizes could be out of specification in relation to accuracy. Since there was no procedure to check the accuracy it was taken for granted it should be fine once size was verified and that the reference particles sizes were always the same size from batch to batch (which is not the case as there are slight changes in size.)

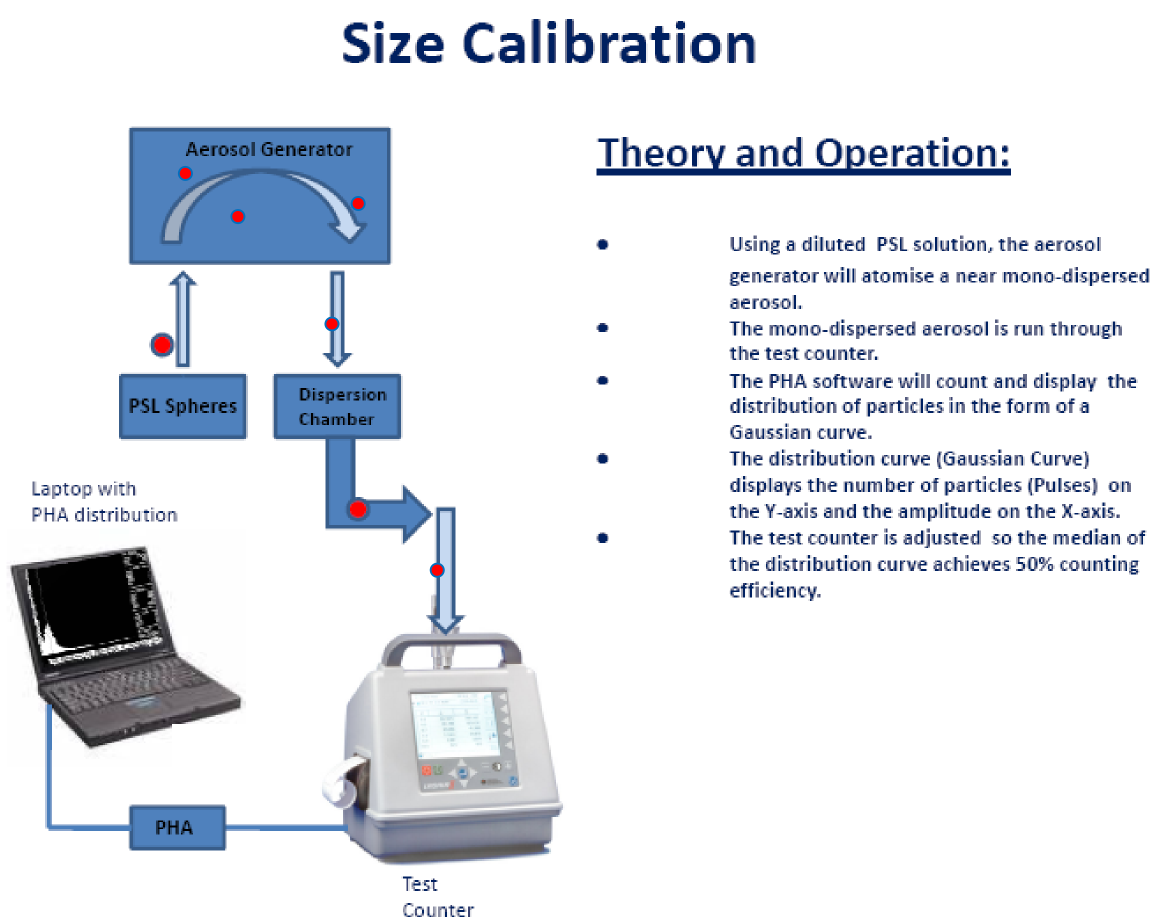


Fig 4. Using PHA Method

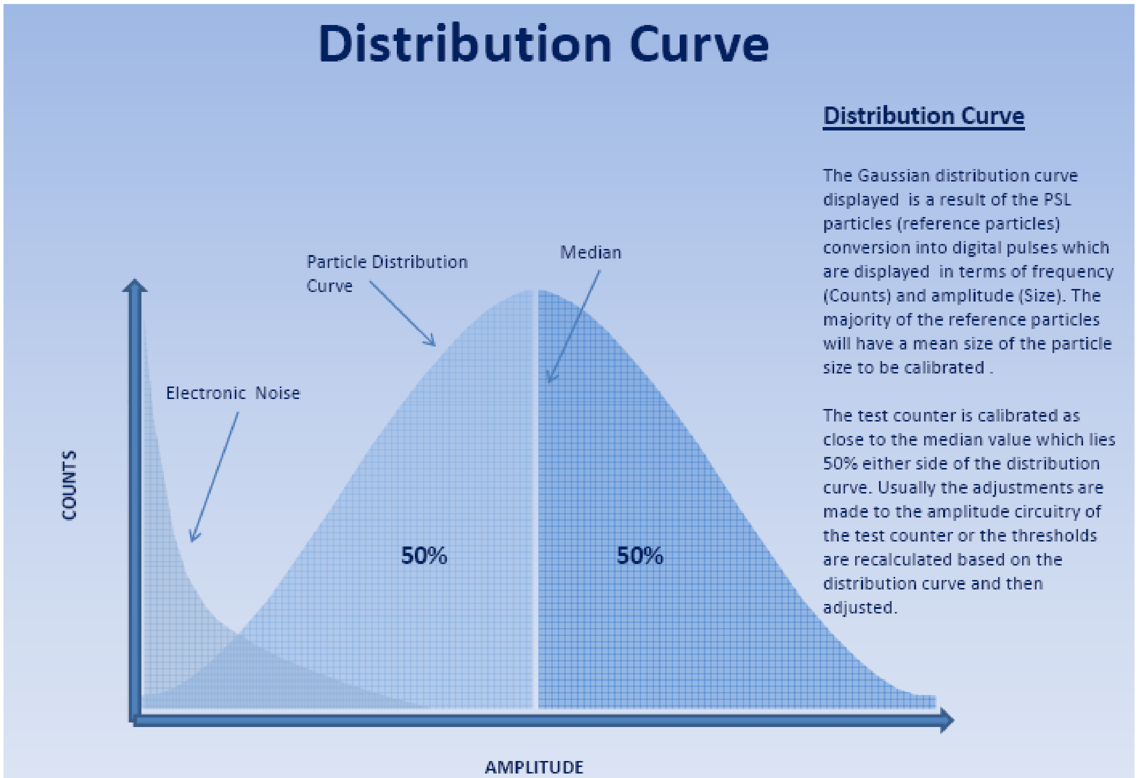


Fig 5. Gaussian Distribution Curve

ISO 21501: THE COMPLETE SOLUTION

With so much emphasis on particle counter importance and the various different guidelines ISO 21501 has been developed to harmonise the current situation. ISO 21501 is at last a complete solution to the calibration of particle counters. ISO 21501 addresses inherent issues within previous particle counter calibration guidelines where either sizing or accuracy calibrations were performed in the field.

Firstly it requires that **BOTH** methods are followed (i.e. the PHA for sizing calibration and the Ref Unit for accuracy calibration).
Secondly **Size Resolution** must be reported. This is the measure of the ability of the particle counter to distinguish between particles of different size and is the verification of size calibration.
Thirdly and most importantly **Count Efficiency** must be reported this is the ratio of counts between the reference unit and the particle counter. The reference unit must be more sensitive than the particle counter with its counting efficiency a known value and itself be calibrated by a higher sensitive instrument like a CPC. Counting efficiency is the verification of the accuracy of the calibration. See example report below using 0.5um reference particles.

COUNT EFFICIENCY TEST

Test uncertainty	5.0 %		
Inst resolution	0.03 %	Assign 1000 degrees of freedom	
Spec	5.0 %	Assign 50 degrees of freedom	

Reference particles

Size (0.5 µm)	2.5 %	Cal Cert

Test conditions

Nominal flow	2.83 L/min			
Flow balance	2 %	of count	Assign a relative uncertainty of 25%. $v = 0.5(100/25)^2 =$	8
Flow uncertainty	%	NA		

UUT	PMA Aimet model 501	s/n	42954
Spec	10 %		

Observed count		Test	Ref	η %
	1	3359	3384	99.3
	2	3547	3383	104.8
	3	3515	3520	99.9
	4	3669	3546	103.5
	5	3614	3605	100.2
	6	3673	3581	102.6
	7	3674	3717	98.8
	8	3754	3712	101.1
	9	3755	3735	100.5
	10	3829	3856	99.3
Average		3638.9	3603.9	101.0
Max - Min		9.0	470.0	6.0
Error %				1.0 PASS

Red entries to be added by lab officer.
Blue entries result from calculation

Count Efficiency	101.0 %		
Standard deviation	1.98 %		
ESDM	1.14 %	Test repeatability	Degrees of freedom = 2
Inst resolution	0.03 %	Assign 1000 degrees of freedom	

ISO 21501 states that counting efficiency should be between 90-110% for particles 1.5 to 2 times greater than the smallest channel and for the smallest channel to have a counting efficiency between 30-70%

Uncertainty of Measurement Model for Count Efficiency

MODEL

Count Efficiency Error = 100-(Indicated Count - Reference instrument count)/Ref instrument count

Uncertainty calculation

Component	U, u or a	Units	Divisor, d	u_i	c_i	v	c_iu_i	$(c_iu_i)^2$	$(c_iu_i)^4/v$
Reference Spec	5.000	%	2	2.5000	1	50	2.50000	6.25000	0.78125
Reference Resoln	0.028	%	1.732	0.0160	1	1000	0.01602	0.00026	6.59E-11
Flow Balance	2.000	%	1.732	1.1547	1	8	1.15470	1.33333	0.222222
UUT resoln	0.027	%	1.732	0.0159	1	1000	0.01587	0.00025	6.34E-11
Test repeatability	1.144	%	1.000	1.1436	1	9	1.14364	1.30791	0.190069
							Sum	8.8917	1.1935
							uc	2.9819	
							v_{eff}	66	
							k	2.00	
							U (95%) ±	6.0	%

Count efficiency is 101.0 % with an expanded uncertainty of ± 6.0 % with a coverage factor of 2

Fig 6. Sample report for Count Efficiency and Uncertainty of Measurement
Courtesy of Kenelec Scientific Australia

UNCERTAINTY OF MEASUREMENT

Finally the introduction of Uncertainty of Measurement (UoM) into the standard gives the end user some sort of confidence regarding the performance of the instrument. UoM is a complex science when it comes to the world of particle counting for those of you out there not familiar with the concept have a read of the Guide to the Expression of Uncertainty in Measurement also known as the ISO GUM and you will never be the same again. UoM is the Metrologists nirvana and is widely used in the world of Metrology. However with the right methodology and attitude UoM can be applied to particle counters with reasonable results expected with a minimum uncertainty of less than 10%.Liquid particle counters should have a lower minimum uncertainty than airborne particle counters.
With the spotlight firmly on particle counters more and more customers are calling for recognized accredited quality systems from their vendors such as ISO 17025 : ***General requirements for the competence of testing and calibration laboratories.*** Originally known as ISO/IEC Guide 25, ISO 17025 adds in the concept of competence and traceability into the equation. It applies directly to those organisations that produce testing and calibration results. Part of the requirement of ISO 17025 is reporting UoM.

Ideally a particle counter calibration laboratory which calibrates to ISO 21501 and is accredited to ISO 17025, NIST, NATA, UKAS etc, etc, is the best option. At the moment not many labs with this type of accreditation exist but I expect this will change based on the emergence of tighter controls and higher expectations from customers using critical monitoring equipment such as particle counters.

UoM as mentioned gives the user something to work with and considering the importance of Particle Counters in today's Industries the extra confidence given with an UoM report helps significantly the decisions some Quality Managers and Qualified Person's face on a daily basis in the pharmaceutical sectors.

SUMMARY OF ISO 21501 REQUIREMENTS

- **Size calibration**
- **Verification of size setting**
- **Counting efficiency**
- **Size resolution**
- **False count rate; maximum particle number concentration**
- **Sampling flow rate**
- **Sampling time**
- **Sampling volume for liquid particle counters**
- **Calibration interval to be defined**

HOW ARE PARTICLE COUNTER MANUFACTURERS RESPONDING?

Some particle counter manufacturers have already begun to pay attention with the latest release of new models on the market stating compliance to ISO 21501 illustrating their agreement and wiliness to work with the new standard.

One particular manufacturer has risen to the challenge leading the way in validating its worldwide service centers by using the same calibration bench setup with reference equipment traceable to the gold standard CPC reference unit called the “Universal Reference Unit” this approach has increased the repeatability and accuracy of calibrations performed outside of the factory. All calibration technicians must be factory trained and each service center is revalidated periodically to ensure the high standards are kept in place. The calibration procedure itself reduces errors in reference particle aerosol generation and is automated to eliminate the human error factor taking advantage of electronic adjustments during the calibration process.

Fig 7. New Portable Particle Counter designed to comply to ISO 21501
Courtesy of Particle Measuring Systems USA

SO WHERE DOES THIS LEAVE YOU ?

If your company relies on particle counter data in a cGMP regulated industry you should insist your particle counter vendor complies to the new standard.
If you are looking for a new particle counter or particle counter calibration services make sure of compliance to ISO 21501. If your company operates to an International Quality Management System such as ISO 9001 then vendors with ISO 17025 accreditation are an added bonus this assures their calibration laboratory follows a Quality Management System with qualified calibration technicians, a suitable laboratory with traceable references, organizations such as NIST/NVLAB in the USA, NPL, UKAS in the UK and NATA, NMI in Australia routinely accredit laboratories to ISO 17025.

"The accuracy of your Particle Counter is an important tool in the fight against cleanroom contamination".

Remember Particle Counter Calibration following :

ISO 21501 =

A MORE ACCURATE PARTICLE COUNTER CALIBRATION

3. **PHA Pulse Height Analyser displays particle counts and amplitudes of pulses graphically on a PC or laptop. The distribution is a representation of the number of particles counted and the size concentration. Used for particle size calibration.**
4. **ASTM : American Society of Testing Materials**
5. **JIS : Japanese Industrial Standard**

References : ISO 21501, ISO 17025, ISO GUM
JISB 9921
ASTM F328-98(2003), ASTM F649-01
Fundamentals of Particle Counters (Calibration) J.Kelly 2007

Images : Courtesy of Particle Measuring Systems, Thermo Scientific, formerly Duke Scientific,Kenelec Scientific Australia & TSI.