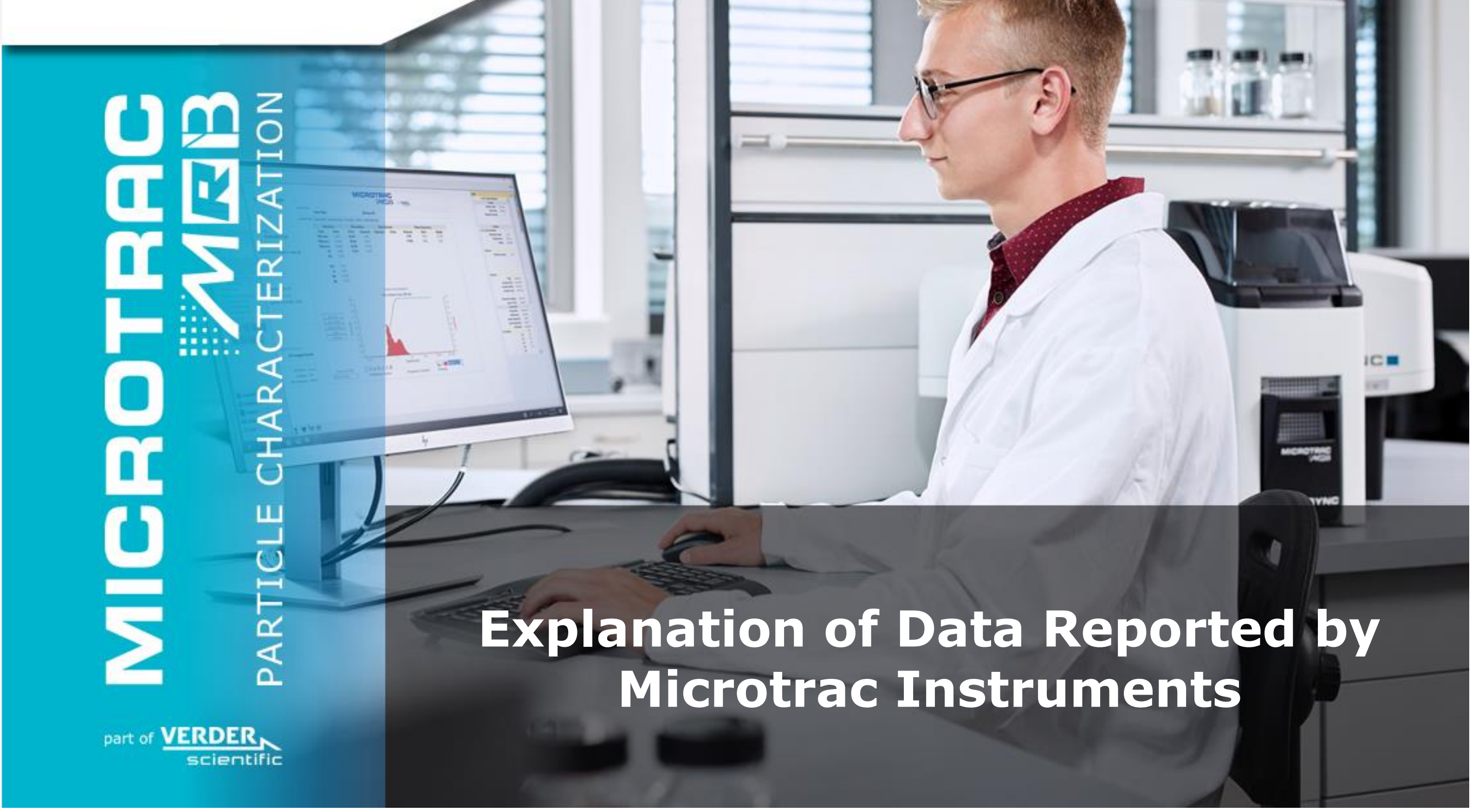
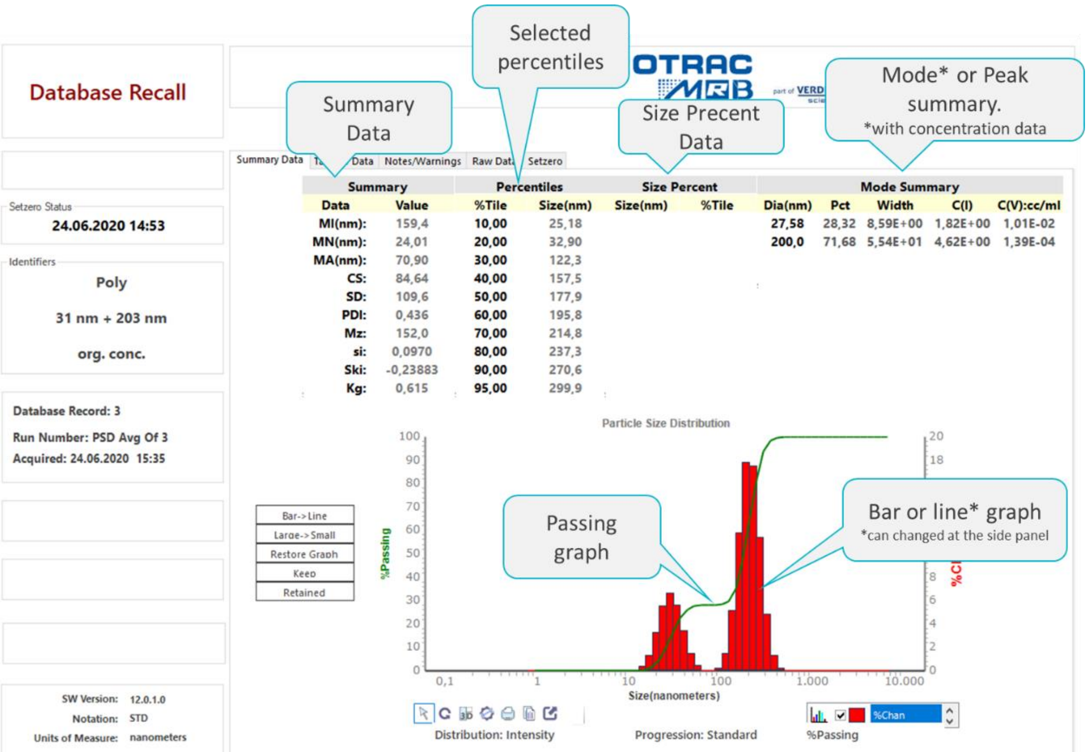



# Explanation of Data Reported by Microtrac Instruments

## Terminology, abbreviations and calculations shown on reports

Microtrac data include many values that are essential to developing particle size distribution specifications and evaluating data. Each of these items is explained as well as changes to be expected. The display provides a quick look at values while actual printed reports and exported data are developed in the "Reports" section. For more detailed information, please refer to the "User's Manual" in the HELP section of Microtrac FLEX software or contact Support@Microtrac.com.



***Summary Data –***

**MV** – Mean diameter in microns of the "volume distribution" represents the center of gravity of the distribution. Mie or modified Mie calculations are used to calculate the distribution. Implementation of the equation used to calculate MV will show it to be weighted (strongly influenced) by a change in the volume amount of large particles in the distribution. It is one type of average particle size or central tendency.

$$MV = \Sigma V_i d_i / \Sigma V_i$$

**MI** – (Nanotrac only) Mean diameter of the intensity distribution. Intensity distribution is not calculated using Mie theory or Modified Mie theory.

$$MI = \Sigma I_i d_i / \Sigma I_i$$

**MN** – Mean diameter, in microns, of the "number distribution" is calculated using the volume distribution data and is weighted to the smaller particles in the distribution. This type of average is related to population or counting of particles.

$$MN = \Sigma(V_i / d_i^2) / \Sigma(V_i / d_i^3)$$

**MA** – Mean diameter, in microns, of the "area distribution" is calculated from the volume distribution. This area mean is a type average that is less weighted (also less sensitive) than the MV to changes in the amount of coarse particles in the distribution. It represents information on the distribution of surface area of the particles of the distribution.

$$MA = \Sigma V_i / \Sigma(V_i / d_i)$$

**CS** – Calculated surface – Provided in units of $M^2$/cc, the value provides an indication of the specific surface area. The CS computation assumes smooth, solid, spherical particles. It may be converted to classical units for SSA of $M^2$/g by dividing thru value by the density of the particles. It should not be interchanged with BET or other adsorption methods of surface area measurement since CS does not take into effect porosity of particles, adsorption specificity or topographical characteristics of particles.

$$CS = K / MA$$

**SD** – Standard Deviation in microns, also known as the Graphic Standard Deviation ($\sigma g$), is one measure of the width of the distribution. It is not an indication of variability for multiple measurements.

$$SD = (84\% - 16\%)/2$$

**Mz** – Graphic Mean provides a less coarse-particle weighted mean particle size than MV. While it includes the median value, it can provide a different and possibly better control value since both small particles and large particles are included in the calculation. Units are microns.

**Mz –** Graphic Mean = $(16^{th} + 50^{th} + 84^{th}) / 3$

**PDI** – Polydispersity Index (Wave DLS Only) – dimensionless measure of the broadness of the size distribution calculated based on ISO 22412:2008(E) specification.

$$P_i = 2\bar{x}_{DLS}^2 \frac{\sum_{i=1}^{N} \Delta Q_{int,I} \left(1/x_i^2 - 1/\bar{x}_{DLS}^2\right)}{\sum_{i=1}^{N} \Delta Q_{int,i}}$$

**$P_i$ = Polydispersity index** **$x_{DLS}$ = average particle size (MI)** **$x_i$ = Channel size**

**$\Delta Q_{int,I}$ = intensity weighted amount of particles**

**SDg or Ai –** Often known as σi - Inclusive Graphic Standard Deviation. Includes more than 90% of the distribution and includes tails of distributions. The SD includes only 67% of the distribution.

| **SDg Value** | **Terminology** |
|---|---|
| 0.35 | Very well sorted (Very narrow) |
| 0.35 - 0.5 | Well sorted |
| 0.50 – 0.710 | Moderately well sorted |
| 0.71 – 1.0 | Moderately sorted |
| 1.0 – 2.0 | Poorly sorted |
| 2.0 – 4.0 | Poorly sorted |
| > 4.0 | Extremely poorly sorted (very broad) |

**SDg –** Graphic Standard Deviation = $((84^{th} - 16^{th}) / 4) + ((95^{th} - 5^{th}) / 6.6)$

**KG -** Often known as SKg - Kurtosis (peakedness) of a distribution is taken from sedimentology and uses phi values for calculation. It measures the departure from normality of a curve. Peakedness refers to "how sharp" a peak is. Terms exist to describe the magnitude of kurtosis or how sharp the peak is. Platykurtic (from the Greek meaning "fat") describes a distribution having low kurtosis while leptokurtic (Greek meaning "slim") describes a distribution having high kurtosis. The following describes values for KG

| **KG Value** | **Terminology** |
|---|---|
| < 0.67 | Very Platykurtic |
| 0.67 – 0.90 | Platykurtic |
| 0.90 – 1.11 | Mesokurtic |
| 1.11 – 1.50 | Leptokurtic |
| 1.50 – 3.00 | Very leptokurtic |
| > 3.00 | Extremely leptokurtic |

**Kg –** Graphic Kurtosis = $(95^{th} - 5^{th}) / (2.44 * (75^{th} - 25^{th}))$

**Ski –** Inclusive Graphic Skewness – Skewness is a measure of how asymmetrical a curve is and how it varies from a normal, bell-shaped curve. Ski includes 90% of the distribution and includes the "tails" of the distribution. A symmetrical curve has a Ski value of 0.00. Values of 1.00 to 0.30 show fines influencing the skew. Values of -0.30 to -1.00 show coarse particles as influencing the skew

**Ski -** Graphic Skewness = $(((16^{th}+84^{th} - (2*50^{th})) / (2 * (84^{th} - 16^{th}))) +$

$((5^{th} + 95^{th} - (2 * 50^{th})) / (2 * (95^{th} - 5^{th})))$

**Sizes –** The default unit for size is micrometres. The sizes in this table are not customizable and are determined by the optical of the instrument. Customized sizes are selectable in the SETUP portion of the software and are displayed in Size Percent Data.

**Percentiles –** Software selectable Percentile Points in microns, show the percentage of the volume (or weight if the density for all the particles is the same) that is smaller than the size indicated. Percentiles can be shown as percent larger and indicates the volume percent larger than the size shown. The "50 percent point" is the "median diameter" or D50 and represents one type of average particle size.

**Peaks Summary**– Microtrac software automatically provides information on multi-modal distributions. The "Dia", "vol%" and "width" identify individual modes.

**Dia** – The 50% (D50) of each mode is calculated after determining the minimum and maximum sizes contributing to the specific peak under consideration. For two modes, each will have a separate 50%. When only one mode is present, the Dia will equal the 50% of the particle distribution.

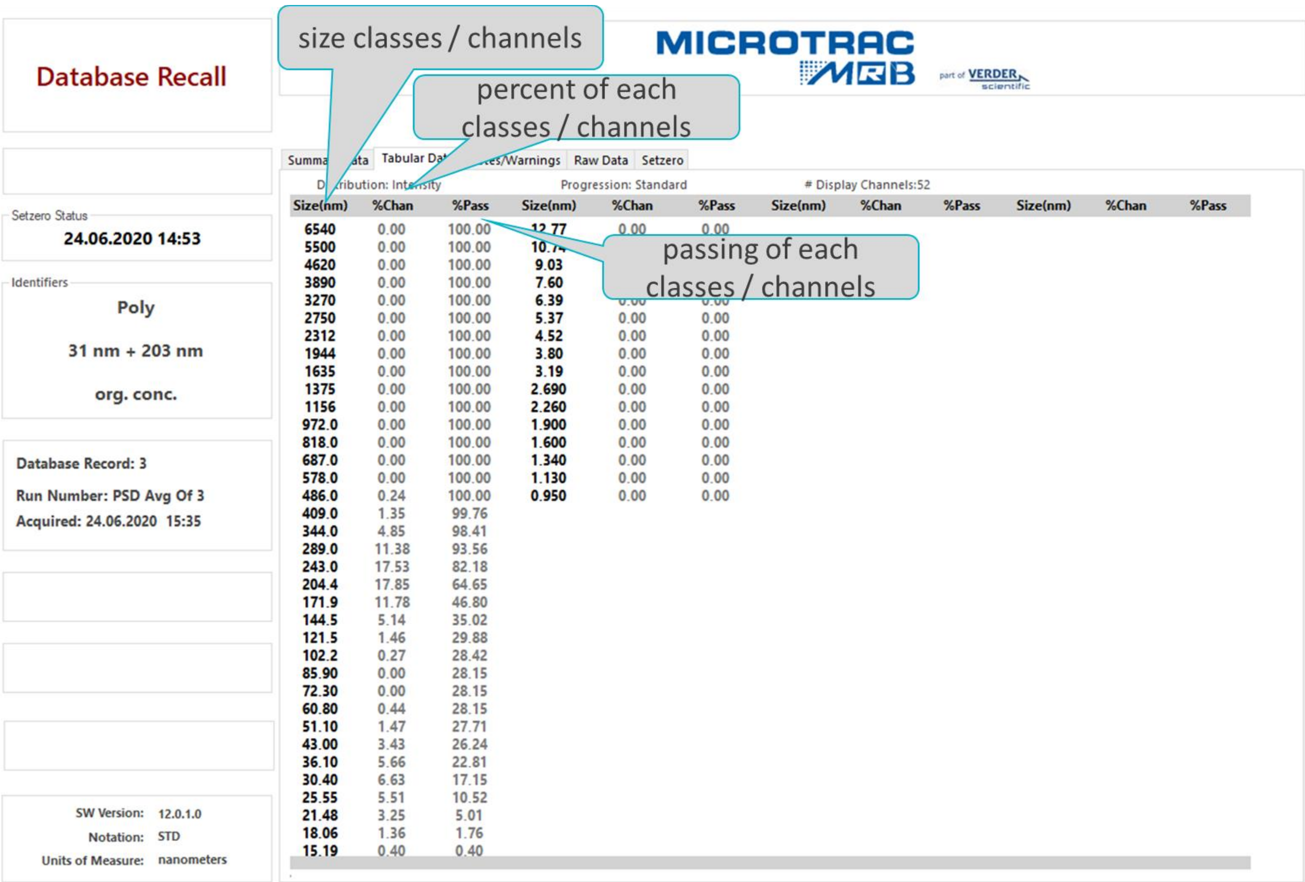
**Width** – Indicates the width of the peak under consideration. For two modes, each will have a calculated width given in microns. When only one mode is present in the distribution, the width = 2 (SD) = 84% - 16%.

**Vol** – The calculated contribution in percent of each peak to the total volume of the distribution.

**RMS Residual** – (Root mean square) Microtrac performs calculations to provide particle size distributions. The calculation is completed when software-decided least error is attained. The RMS is presented as percent.

**Tabular Data** - The measuring range of the instrument is divided into fixed "channel" or particle sizes. Particles sizes are identified on the left column in units of microns or sieve sizes as selected by the operator. Cumulative data values are on the same line as the particle size and are read as "percent smaller (passing) than". The data may also be displayed as "percent larger (retained) than". For data presented as "percent smaller than", volume percent-in-channel (%-CHAN) values are read as volume percent between the particle size on the same line and the line below. For data presented as "percent larger than" or "%RETN", the volume percent between sizes is read as the amount between the size on the same line and the size above.

Example: In the tabular data display shown below, (%Pass/smaller than), 82.18 % of the volume is smaller than 243 nm. The volume percent between adjacent sizes for percent passing format is shown beside the larger size. For instance, 17.53 % lies between 243 nm and the next smaller size (204.4 nm). When data are presented in the PERCENT RETAINED/LARGER format (not shown), as would be indicated as %RTN label at the top of the data column, the percent between sizes would be located beside the respective size. It will indicate the percent between 243 nm and the next larger size (in this case the next larger size for 243 nm would be 289 nm and the percent between the two sizes will be identical to that above). Thus, the percent passing data and percent larger than data provide the same information with slightly different formats.




| Size(nm) | %Chan | %Pass | Size(nm) | %Chan | %Pass | Size(nm) | %Chan | %Pass | Size(nm) | %Chan | %Pass |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6540 | 0.00 | 100.00 | 12.77 | 0.00 | 0.00 | | | | | | |
| 5500 | 0.00 | 100.00 | [illegible] | [illegible] | [illegible] | | | | | | |
| 4620 | 0.00 | 100.00 | 9.03 | [illegible] | [illegible] | | | | | | |
| 3890 | 0.00 | 100.00 | 7.60 | [illegible] | [illegible] | | | | | | |
| 3270 | 0.00 | 100.00 | 6.39 | [illegible] | [illegible] | | | | | | |
| 2750 | 0.00 | 100.00 | 5.37 | 0.00 | 0.00 | | | | | | |
| 2312 | 0.00 | 100.00 | 4.52 | 0.00 | 0.00 | | | | | | |
| 1944 | 0.00 | 100.00 | 3.80 | 0.00 | 0.00 | | | | | | |
| 1635 | 0.00 | 100.00 | 3.19 | 0.00 | 0.00 | | | | | | |
| 1375 | 0.00 | 100.00 | 2.690 | 0.00 | 0.00 | | | | | | |
| 1156 | 0.00 | 100.00 | 2.260 | 0.00 | 0.00 | | | | | | |
| 972.0 | 0.00 | 100.00 | 1.900 | 0.00 | 0.00 | | | | | | |
| 818.0 | 0.00 | 100.00 | 1.600 | 0.00 | 0.00 | | | | | | |
| 687.0 | 0.00 | 100.00 | 1.340 | 0.00 | 0.00 | | | | | | |
| 578.0 | 0.00 | 100.00 | 1.130 | 0.00 | 0.00 | | | | | | |
| 486.0 | 0.24 | 100.00 | 0.950 | 0.00 | 0.00 | | | | | | |
| 409.0 | 1.35 | 99.76 | | | | | | | | | |
| 344.0 | 4.85 | 98.41 | | | | | | | | | |
| 289.0 | 11.38 | 93.56 | | | | | | | | | |
| 243.0 | 17.53 | 82.18 | | | | | | | | | |
| 204.4 | 17.85 | 64.65 | | | | | | | | | |
| 171.9 | 11.78 | 46.80 | | | | | | | | | |
| 144.5 | 5.14 | 35.02 | | | | | | | | | |
| 121.5 | 1.46 | 29.88 | | | | | | | | | |
| 102.2 | 0.27 | 28.42 | | | | | | | | | |
| 85.90 | 0.00 | 28.15 | | | | | | | | | |
| 72.30 | 0.00 | 28.15 | | | | | | | | | |
| 60.80 | 0.44 | 28.15 | | | | | | | | | |
| 51.10 | 1.47 | 27.71 | | | | | | | | | |
| 43.00 | 3.43 | 26.24 | | | | | | | | | |
| 36.10 | 5.66 | 22.81 | | | | | | | | | |
| 30.40 | 6.63 | 17.15 | | | | | | | | | |
| 25.55 | 5.51 | 10.52 | | | | | | | | | |
| 21.48 | 3.25 | 5.01 | | | | | | | | | |
| 18.06 | 1.36 | 1.76 | | | | | | | | | |
| 15.19 | 0.40 | 0.40 | | | | | | | | | |

# Optional Information

**Zeta Potential**

Data | Sample Information

| Measured Data | |
|---|---|
| Zeta Potential | 43,4 mV |
| Polarity | Negative (Auton |
| Mobility | 3,39 um/s/V/cm |
| Conductivity | 23 uS/cm |
| Field Strength (Req/Act) | 10 / 10,0 kV/m |
| **SOP** | |
| Zeta Run Time | 30 sec |

Zeta potential measurements are subject to many influences. The list provided shows several of the most important aspects of parameters that require control to achieve repeatable measurements. The values requested are voluntary and are not required for zeta potential measurements to be conducted successfully. The values become a permanent record with any saved data and allow easy record keeping of conditions imposed for the measurement.

Zeta Potential Measurement Section - The values presented use Nanotrac Wave II with Zeta option measurements and calculations.

**Zeta potential** – magnitude of zeta potential

**Polarity** – Provides the identification of the positivity or negativity of zeta potential value.

**Mobility** – Provides the magnitude and direction of travel of the particles when exposed to the imposed electric field. Negative sign indicates that the particle is moving towards the cathode (+).

**Conductivity** – Provided in units of microSiemens per cm (µS $cm^{-1}$)

**Zeta Potential** – From Henry's Formula for mobility: The value represents the potential difference between the dispersion medium and the stationary layer of charge attached to the particle. Zeta potential is related to colloidal dispersion stability. Zeta potential values greater than the absolute value 25 mV are an indication of stability. The chart below may be used as an approximate guide. Good stability will be experienced when the value is 40 to 60mV (either negative or positive).

Henry's formula:

$$\mu D = \zeta \, 2\varepsilon \, f(\kappa a)/3\,\eta$$

$$\zeta = 3\eta\mu D / 2\varepsilon f(\kappa a) = q/2\pi\varepsilon d$$

ζ = zeta potential; ε= dielectric constant; μ=mobility; η=viscosity; q=charge; d=diameter

$f(\kappa a)$ = Debye Huckel parameter (depends upon concentration and size). Where κ represents inverse distance of surface from the shear plane). For Microtrac zeta potential, assume Smoluchowski approximation where $f(\kappa a) = 3/2$ and zeta potential is calculated as:

$$\zeta = \eta\mu D / \varepsilon$$

**Charge** – A calculated value equal to a sphere having a charge distribution which is proportional to the electrophoretic mobility of the particles being measured:
$q = 3\pi\mu D\,\eta\, d$

Sample Concentration Values – Depending upon the instrument model (Nanotrac or diffraction), separate values are used. This section describes them.

**Diffraction** –

**%Transmission** indicates how much of the original laser is not used for scattering. Thus, a value of 0.90 indicates that 90% of the laser is not undergoing scattering by the particles or that 10% of the laser is being scattered by the particles. As sample amount increases, more scattering of the laser occurs and the %T decreases.

**Loading Value/Factor** – Sum of the signals received from the detector system. Signals are due to light being scattered and converted by the detector silicon segments to electrical values.

**Nanotrac –**

**LI** – Termed the Loading Index. A summation of the electrical signals received by the detector system. This value is used for determining the correct concentration for measurement.

**Ci** – Termed the Concentration Index. The LI above is modified by considering light scatter efficiency. Large particles tend to scatter light better than smaller particles. This effect is taken into account for Ci. This value does not provide total signal as the Li. Ci is rarely used for determination of correct concentration for measurement.

# List of abbreviations

V = Volume percent between sizes.

d = Size represented by the centre (geometric progression) between any 2 sizes.

I = Intensity percent between sizes

P = Density of the particles

K = Ratio of Area to Volume of sphere

ρ = Specific gravity

$N_A$ = Avogadro's number

Lower case "$_i$" refers to individual channel or bin sizes.

Σ = Symbol meaning that each operation is added to the next in the series

to achieve a sum of all