

2011 Naneum Newsletter One



Report on the latest tests of NPS500.

The NPS500 is a versatile and user friendly instrument with a wide range of applications in various fields. It provides aerosol particle number size distributions and directly measured total particle number concentrations on-line and *in situ* wherever you need it.

It is small, light, simple to use and accurate.

No radioactive material is needed.

First portable nanoparticle spectrometer NPS-500 (www.naneum.com) with onboard PC shows excellent results in comparisons with reference instruments.

A novel DMA enables high resolution to be achieved in a portable design.



The instrument is controlled with a touch screen. It enables data to be collected onto a USB flash data storage container. Data can be exported to versatile user friendly software or to any spreadsheet program.

It has a unique option to switch between SMPS mode and CPC mode. In CPC mode the total number concentration is recorded.

Size selection of aerosol particles with NPS500 in SMPS mode (Comparison with reference methods)

Accuracy of the size selection by NPS500 was compared with a reference method (electrostatic classifier, TSI series 3080L). A mono-disperse aerosol particles of NaCl

and PSL were generated using a nebuliser (PMS, Inc) and classified with the DMA. In addition Cr₂O₃ aerosol particles were generated with Naneum generator (NG100). These particles were classified with a TSI DMA 3081 (3080 series) and measured with an NPS500.

The aim of the tests was to compare the size of particles obtained with the NPS500 with the size of particles obtained with reference methods. Comparison of NPS500 aerosol particle size data with reference methods reveals a very good agreement, see Figure 1. The average difference in the sizing aerosol particles is 3%.

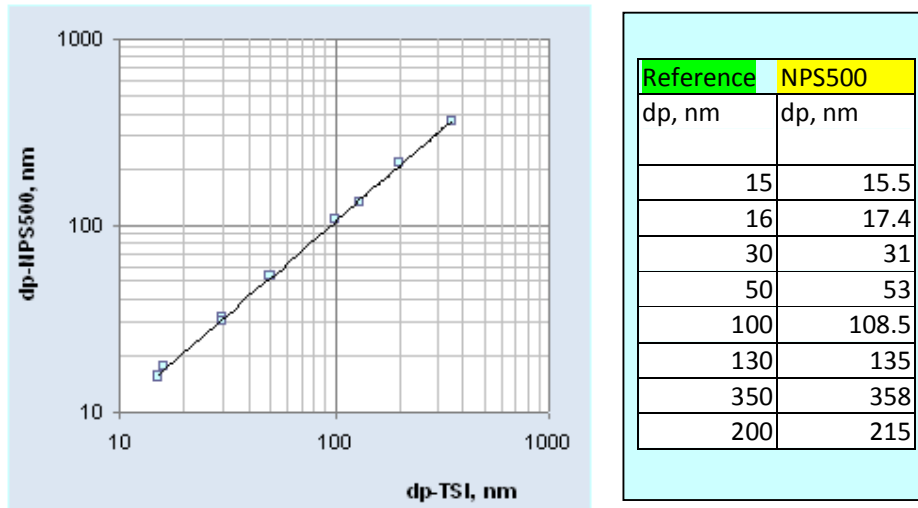


Figure 1. Comparison of data on aerosol particle size obtained with the NPS500 and with reference method (TSI 3081) in Canterbury UK.

Tests and calibration of the size fractioning with NPS500 are regularly carried out. Figure 1 shows a typical data set.

Typical aerosol particle size distributions obtained with NPS500 and with reference methods

Aerosol particle number size distributions obtained with NPS500 were compared with reference instruments (SMPS, TSI and SMPS, Grimm). Typical aerosol number particle size distributions are shown in Figure 2 and Figure 3. The size distributions are very similar and positioned at the same size. The NPS500 size distribution revealed complex structure that was not resolved with the reference method. The NPS500 distribution is a bit higher in the middle and narrower, Figure 3. This normally indicates a better resolution.

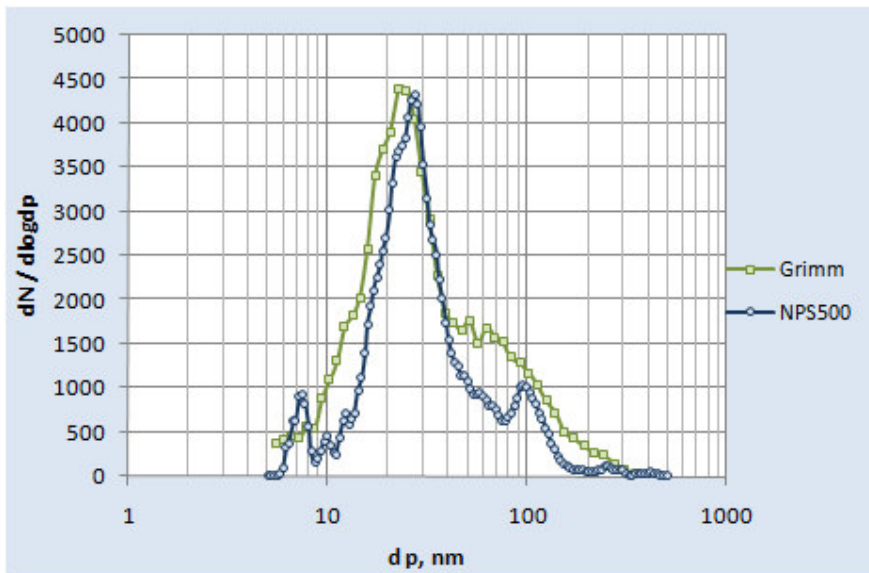


Figure 2. A typical comparison of size distributions of atmospheric aerosols (cm^{-3}) in an aerosol laboratory (Canterbury) obtained with NPS500 and with a reference instrument.

In Figure 2 NPS500 shows three distinct modes are positioned at 7.5nm, 28nm and 100nm. These modes were not resolved in the data obtained with Grimm SMPS. Atmospheric aerosols often reveal complex bi-modal or multi-modal structure. The nature of these peaks may be related to complexity atmospheric chemistry or caused by manmade aerosol particles. Analysis of this size distribution revealed that they could not be explained by multiple charging.

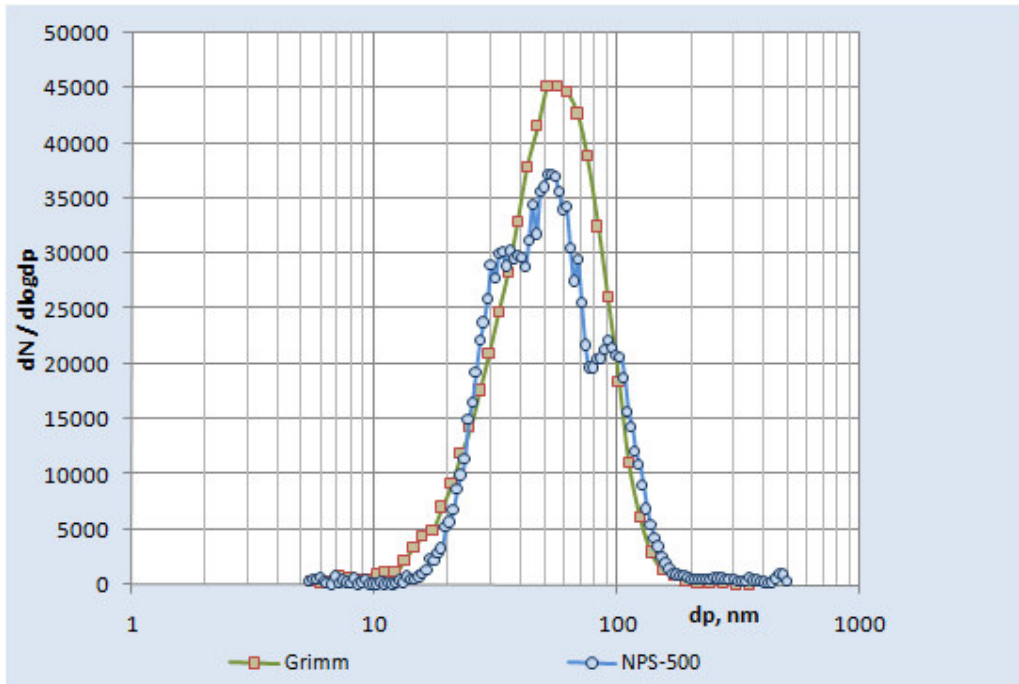


Figure 3. A typical comparison of size distributions of ZnO aerosols (cm^{-3}) obtained with NPS500 and with a reference instrument.

In the series tests related to data shown in Figure 3 Naneum Zn/ZnO generator was used to generate nanoparticles. Two or three distinct modes were normally observed in the tests. They represent various mechanisms of nanoparticle formation and variation in chemical composition, e.g. Zn or ZnO. In Figure 3 three peaks at 35nm, 54nm and 90nm were observed with NPS500. The reference method did not resolve these peaks. It confirms that NPS500 resolution is superior to the resolution of reference methods.

Resolution of NPS500 is superior to reference methods

In general the resolution of a DMA (DEMC) or SMPS is determined by ratio of the aerosol flow rate to the sheath flow rate. The resolution of the reference instruments based upon the cylindrical geometry of the separating column was evaluated to be 10% (the sheath flow rate 3 l/min and the aerosol flow rate of 0.3 l/min).

Naneum NPS500 DEMC is based upon the flat geometry and it incorporates an especially designed aerosol inlet/outlet for a better resolution. The engineering design was based upon numerical modelling with finite element multi-physics (Navie-Stokes and Laplas) software Comsol. This software enables the optimal geometry of the selector with the highest possible resolution for a portable instrument to be found. An example of these calculations is shown in Figure 4.

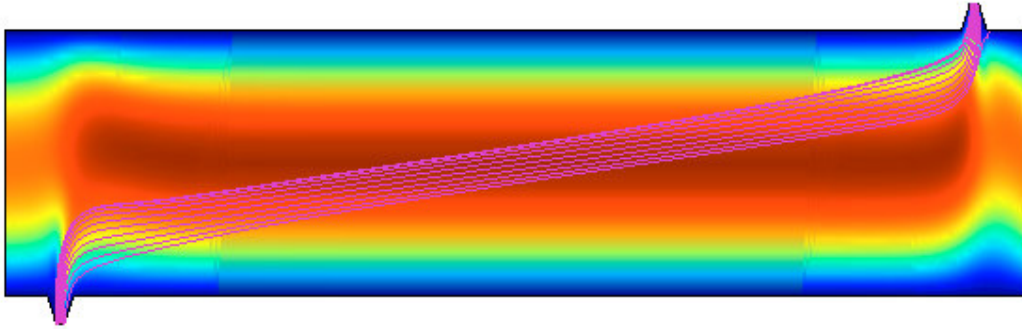


Figure 4. In the picture above the trajectories are shown for the potential difference $V=360V$. The sheath flow rate is $Q_{sh}=3$ l/min; the sheath flow mass moves from the left to right. The aerosol flow rate is $Q_{aer}=0.3$ l/min is in the left low inlet. The aerosol outlet (right top) is equal to 0.3 l/min. Particle mobility is $Z_p=0.001$ cm²/s/V. The colour represents the flow velocity field. The gap between the plates is 5 mm. Trajectories of charged aerosol particles are shown in pink.

It can be seen that aerosol particle trajectories are not linear due to complex interaction of the air mass velocity and the electric field. There are two important features – defocusing and focusing of aerosol particles trajectories in the inlet and outlet. It is better seen in Figure 5.

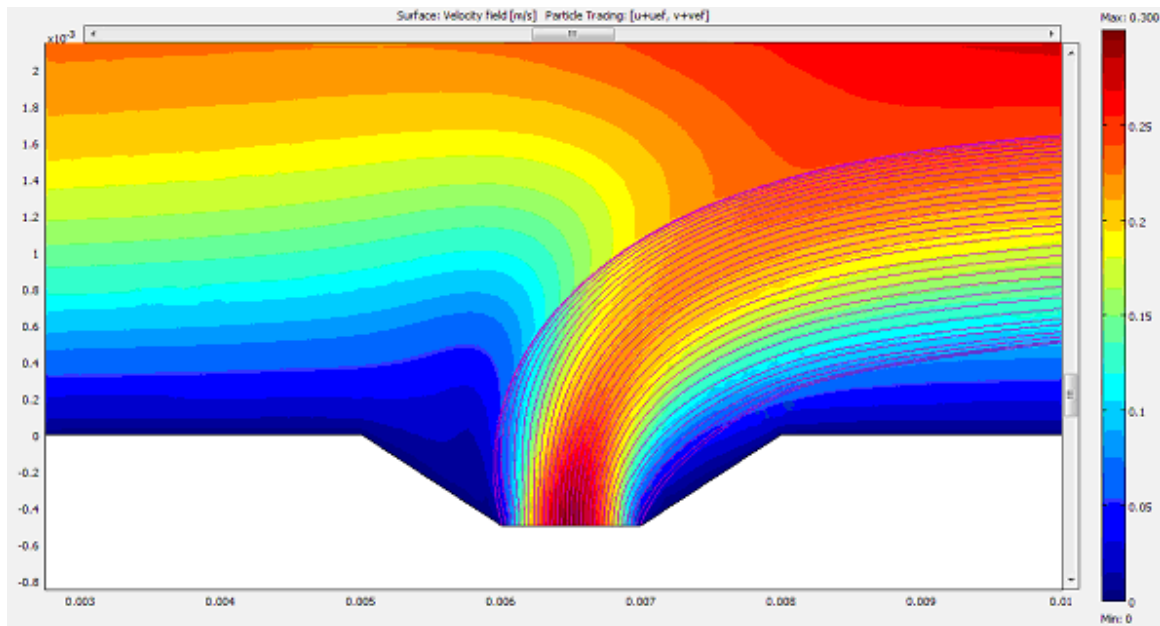


Figure 5. Trajectories of particles in the Naneum DEMC at the aerosol particle inlet $Q_{sh}= 1.875$ l/min and $Q_a=0.3$ l/min. $dp= 30$ nm; $V=4,650$ volts.

The trajectories in the unit formed by electric force and the velocity field. It is important to recognise that the velocity field is not symmetrical in the respect of inlet – outlet due to influence of the momentum of the air. The modelling confirms that at the flow rates ($Q_a=0.2$ l/min and $Q_{sh}= 1.8$ l/min) the resolution of NPS500 is 3.8%.

This is considerably (almost 3 times) better than the resolution for a cylindrical geometry DMA.

The resolution of NPS500 was also evaluated in the direct measurements of mono-disperse traceable PSL aerosols and NaCl aerosols generated with a nebuliser and fractionated with a DEMC. Two graphs obtained with NPS500 are shown in Figure 6 and Figure 7.

There are two distinct peaks in Figure 6. The σ_g for the main peak at 100nm is 1.047. The second peak that is attributed to double charged 100 nm particles also has the same $\sigma_g = 1.047$. Therefore, the resolution Δdp is 4.7%. This is very close to the resolution found in calculations.

A more complex structure of size distribution in Figure 7 is attributed to multiple charges that occur at various stages of NaCl aerosol generation and size fractionating. It also reveals the same $\sigma_g = 1.047$.

The high resolution is important for many applications especially in ENP characterisation, aerosol sources identification and occupational hygiene. Each distinctive mode in an aerosol particle size distribution and their combination is a unique signature of the aerosol nature and its evolution. It is a novel valuable feature of NPS500 design that enables a high resolution to be achieved in a portable instrument.

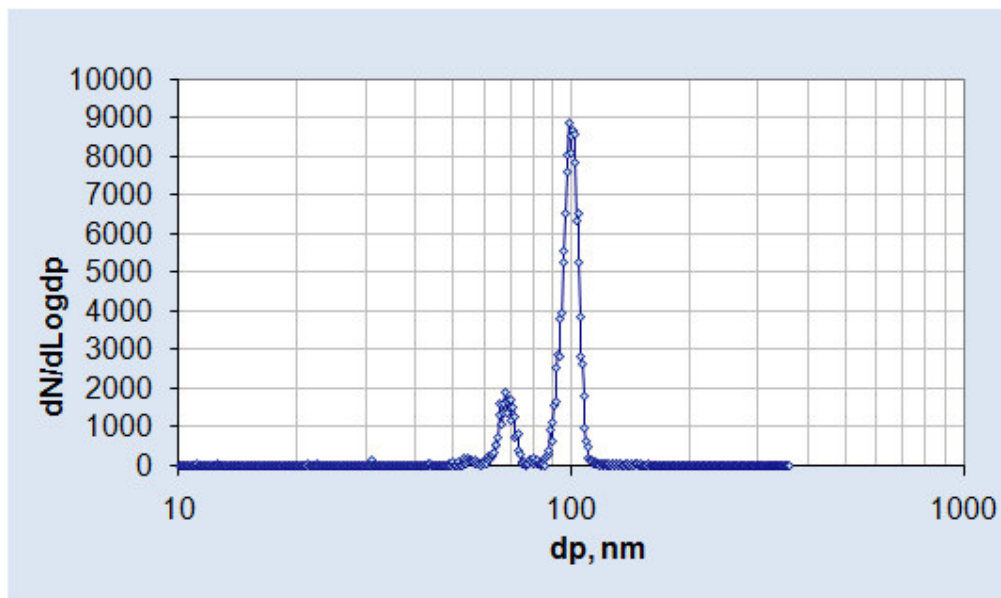


Figure 6. An example of aerosol size distributions (cm^{-3}) obtained with NPS500 for 100nm PSL particles (Denver CO). Double charged particle peak is at 68 nm.

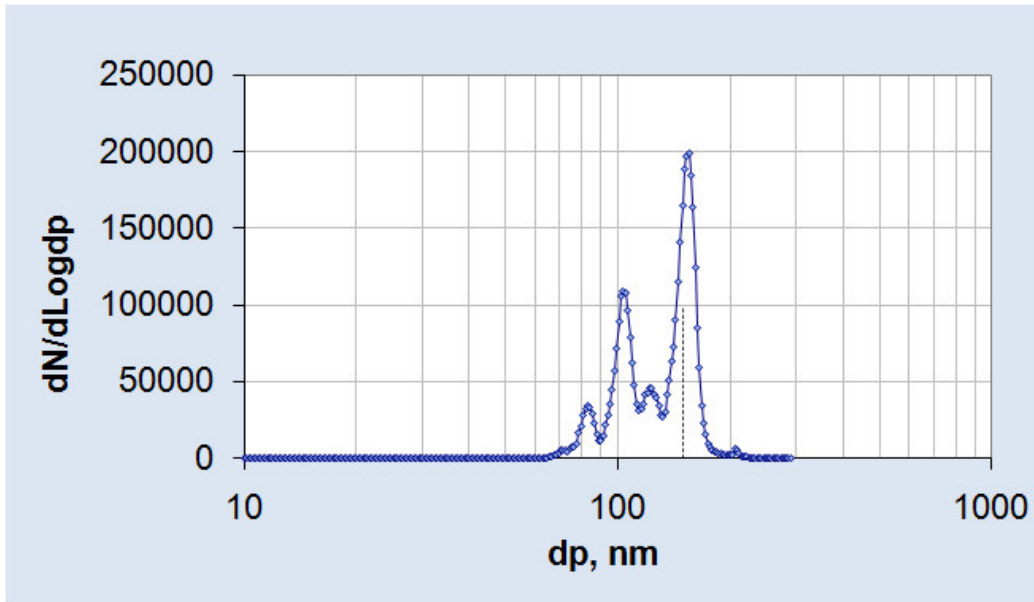


Figure 7. 1 An example of aerosol size distributions (cm^{-3}) obtained with NPS500 for 100nm NaCl particles (Denver CO).

Another important feature of NPS500 is a unique uni-polar charger based on a stable **Naneum corona** designed for the instrument. It is a proprietary technology that minimises the presence of multiple charged particles and produces mainly particles with a single elemental charge. Examples of mono-disperse aerosol particle size distributions without multiple charges are shown in Figure 8.

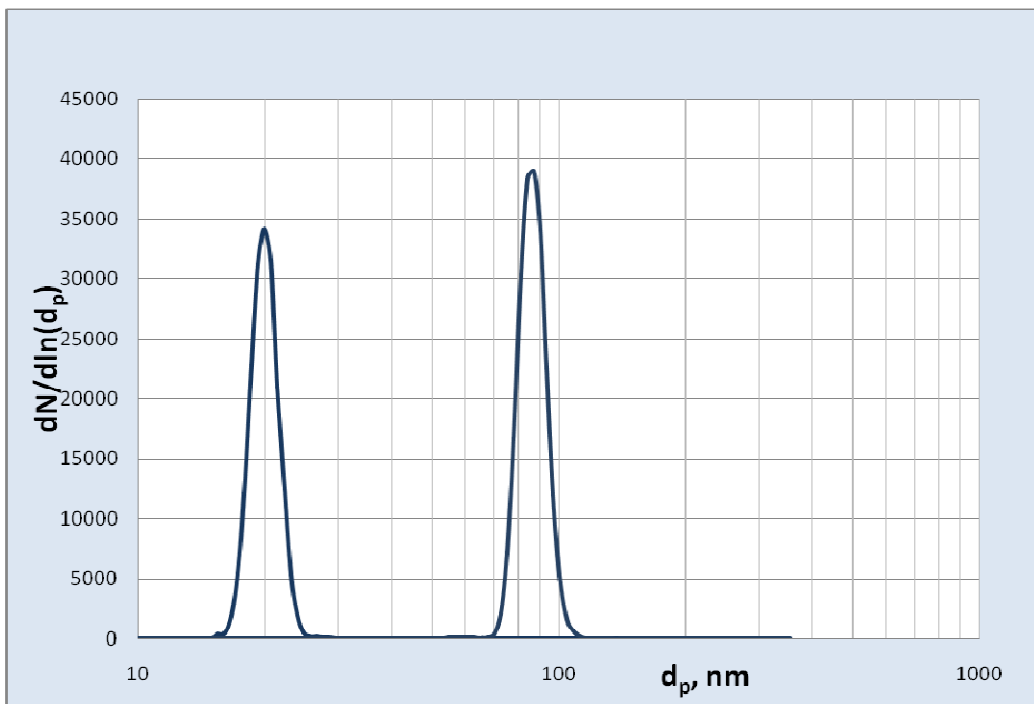


Figure 8. An example of aerosol size distributions (cm^{-3}) obtained with NPS500 for Cr_2O_3 nanoparticles fractionated with DMA PMC500.

Naneum corona enables to minimise effect of multiple charging even for larger particles. An example of this is shown in Figure 9. Particles of DMS were generated with Naneum generator and charged with a Naneum corona charger. On the contrary, conventional bi-polar neutralisers based upon radioactive sources produce much more particles with multiple charges. This makes relationships between the measured counts and size distributions more complex and might cause errors.

The Naneum corona was designed with Comsol numerical finite element software. It was optimised to avoid multiple charges and simplify the transfer function.

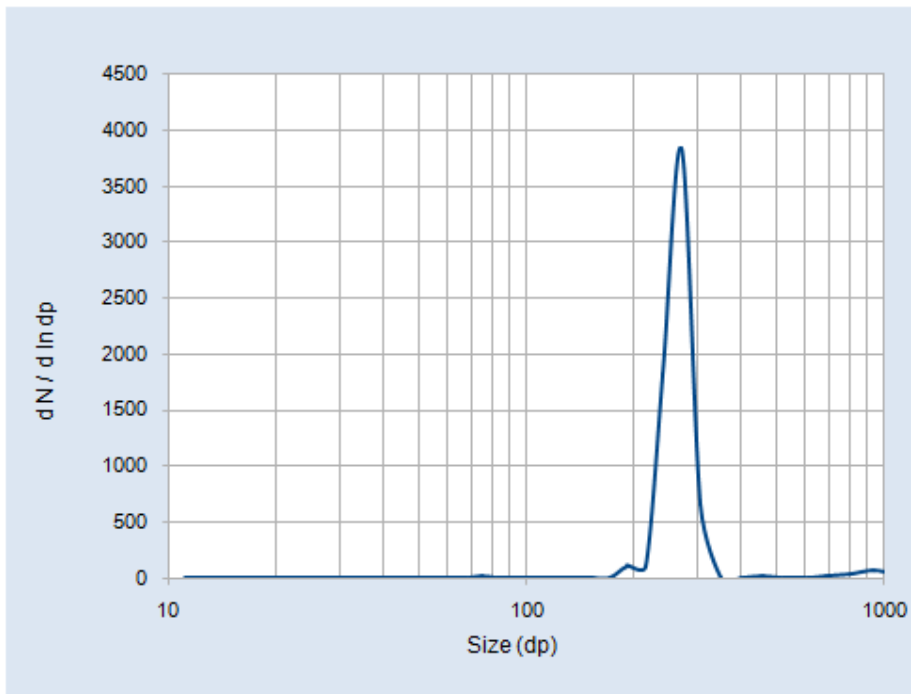


Figure 9. Aerosol size distribution of DMS particles of 270 nm charged with C2000 and recorded with a Grimm SMPS.

Number concentration measurements of aerosol particles with NPS500 in the CPC mode (Comparison with reference methods)

Cr_2O_3 aerosol particles were generated with Naneum generator (NG100). These particles were counted with an NPS500 working in CPC mode and compared with reference methods: either CPC (TSI 3007) or CPC (Grimm).

Comparison of NPS500 aerosol particle number concentration data with reference methods reveals an excellent agreement, see Figure 10. The average difference in the sizing aerosol particles is less than 10%.

Figure 10 represents a typical set of test data. Normally each NPS500 instrument is tested and calibrated at the factory in comparison with a reference instrument.

In addition, comparison of CPC (TSI 3007) with CPC (Grimm) has been carried out. It shows that both instruments provide similar data. The difference was less than 20%. Therefore, NPS500 enables the total concentration of aerosol particles to be measured correctly in a good agreement with leading instruments on the market.

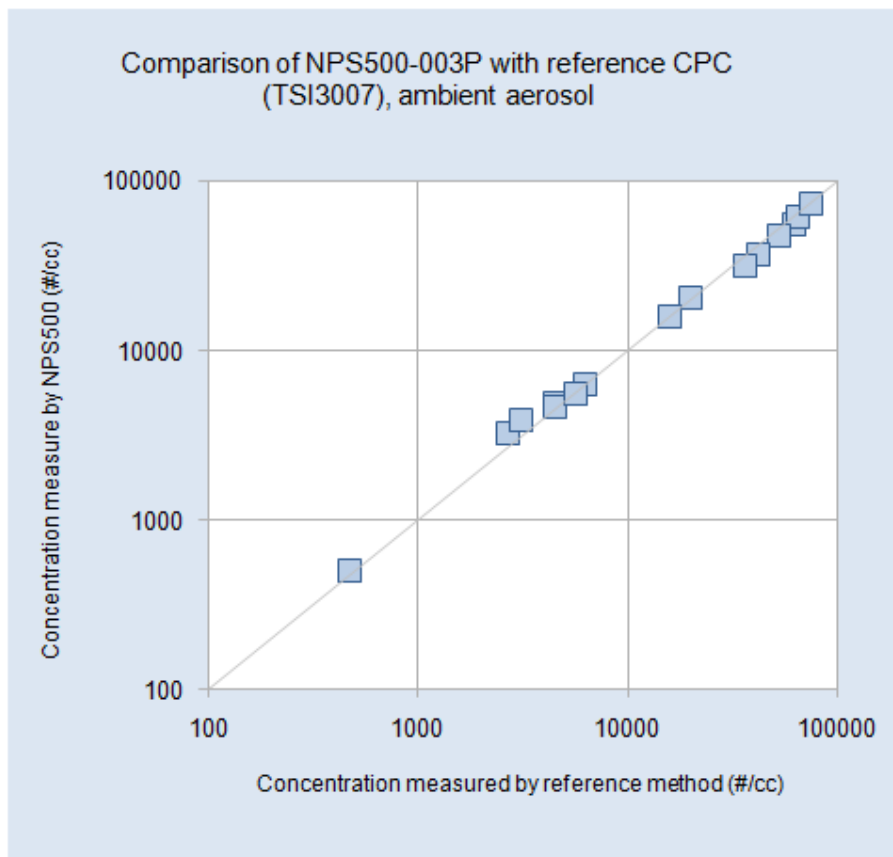


Figure 2. Comparison of data on aerosol number particle concentration obtained with NPS-500 and with reference methods (Canterbury UK).

Conclusions

NPS500 being a portable light SMPS demonstrate performance of a desktop instrument and with a better resolution for the same sheath flow to aerosol flow ratio.

The instrument has many important advantages:

It does not require a PC to operate.

All operations are controlled by a touch screen.

There is no any radioactive source onboard.

NPS500 does not require any alcohol to operate.

It works in two modes as SMPS.

The instrument is very easy to operate and maintain.

It can be operated outdoors and in industrial environments.