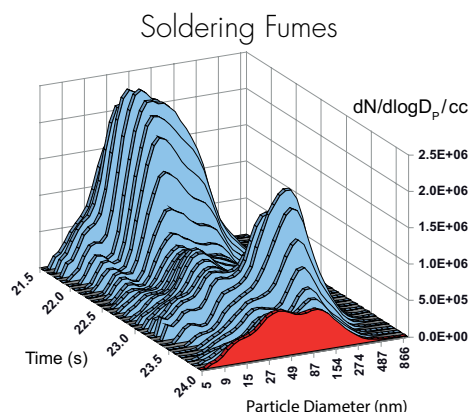


## Fast Aerosol Size Distributions

For size, number and mass measurement  
of rapidly-changing PM 1 & PM2.5 aerosols



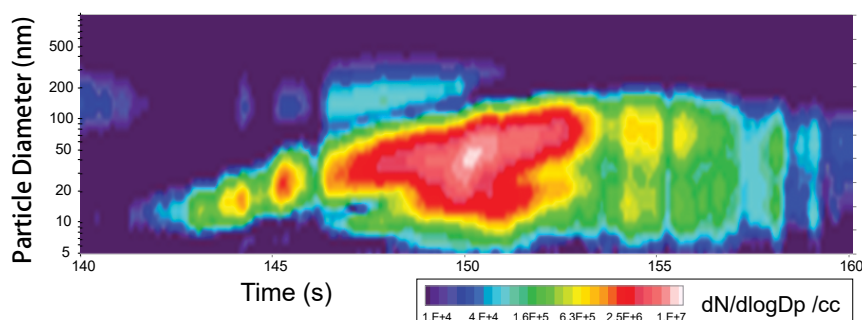
- Fastest time response (200 ms  $T_{10-90\%}$  @ 10 Hz)
- Widest size range (5 nm – 1  $\mu\text{m}$  or 2.5  $\mu\text{m}$ )
- Class-leading accuracy & reproducibility
- Widest concentration range (9 orders)
- Best sensitivity

— amongst fast response particle sizers

*...make the DMS500 the instrument of choice for:*

Ambient, Roadside & Occupational Monitoring  
Raw Engine Exhaust and Stack Sampling  
Combustible and E-cigarettes  
Engineered Nanoparticles  
Flame Sampling  
Gas Turbines  
Pyrotechnics...

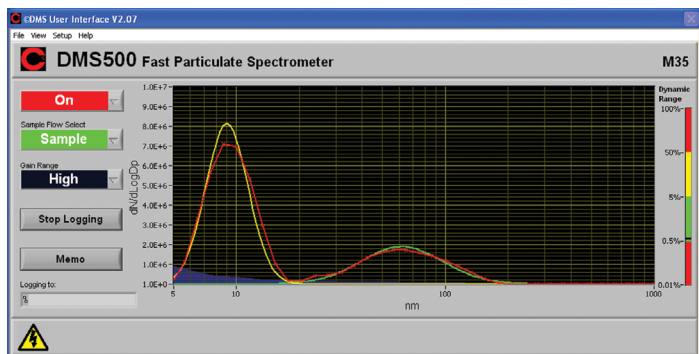
Light duty vehicle brake particle measurement



## Introduction to the DMS500 MKII

The Cambustion DMS500 was the world's first production real-time nanoparticle sizer.

Producing a full size spectrum 10 times per second with a step change response ( $T_{10-90\%}$ ) as low as 200ms, the DMS500 also outputs a unique real-time bimodal fit to the data, giving particle size, number and mass in each aerosol mode. No post-processing of the plain text data file is required.



Since its launch in 2002 the DMS500 has become the aerosol sizing instrument of choice at research institutes, universities, vehicle OEMs and government & standards laboratories worldwide. It is an ideal alternative to slow scan instruments where accurate measurement of rapidly-changing aerosols is required. It combines the latest in patented aerosol measurement technology with Cambustion's many years of experience at the forefront of transient emissions instrumentation and research.

In this time, Cambustion have continued to lead the field, introducing many new innovations and improvements. In 2008 the DMS500 *MkII* further improved the concept by offering over three times the sensitivity of the *MkI*, thus becoming the most sensitive fast-response electrical mobility instrument on the market. With its wide dynamic range the DMS500 is well suited to general aerosol science applications as diverse as cigarette smoke, ambient/roadside monitoring, pyrotechnic studies, engineered nanoparticle sizing, wood smoke, stack sampling and gas turbine studies.

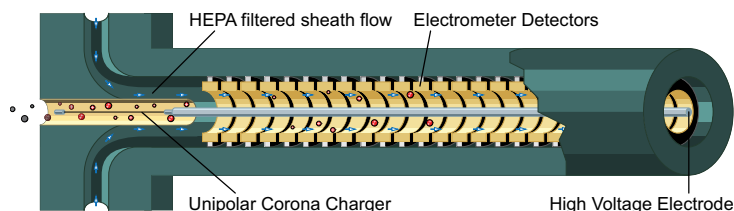
It is available with several options to suit various applications:

- Internal, fully integrated rotating disc diluter (1:1 – 500:1)
- Heated sampling line (with primary dilution of 1:1 – 6:1)
- Standard measurement range: 5 nm – 1  $\mu$ m
- Switchable 5 nm – 2.5  $\mu$ m range option
- Smoking Cycle Simulator for smoking studies
- Dual-gain range option for high concentration applications\*

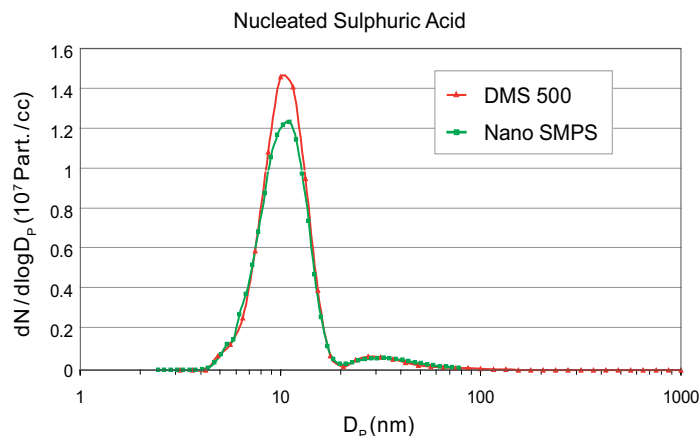
\* e.g. cigarette smoke research where sensitivity is not a limiting factor and reduced dilution is desired.

## Operating Principle

The DMS500 uses a unipolar corona discharge to place a prescribed charge on each particle proportional to its surface area — unlike an SMPS, no radioactive charger is required. The charged aerosol is then introduced into a strong radial electrical field inside a classifier column. This field causes particles to drift through a sheath flow to the electrometer detectors. Particles are detected at different distances down the column, depending upon their electrical mobility. The outputs from the 22 electrometers are then processed in real time to provide spectral data in 38 or 45 size classes and other desired parameters. The unique patented Space Charge Guard electrode prevents image charge artefacts (caused by large charged particles passing electrometers at the top of the column) without the additional complex software correction which would otherwise be required. To view an animation please visit: [www.cambustion.com/products/dms](http://www.cambustion.com/products/dms)



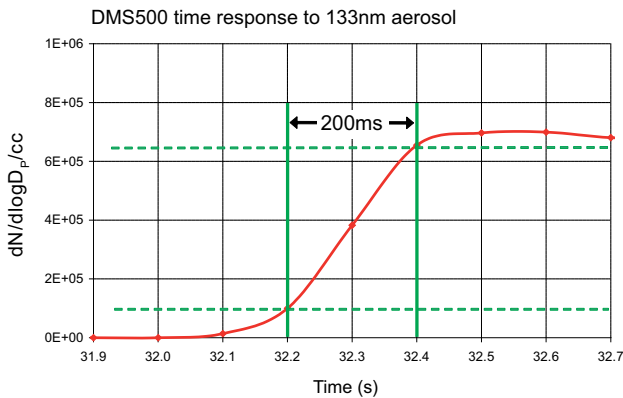
The DMS500 classifier operates at fixed pressure, which ensures that the calibration stays accurate even when sampling from high or low ambient pressures (e.g. at altitude). This is important as sample pressure changes the mean free path of the aerosol, greatly affecting the conversion of mobility to size, which as a non-linear effect cannot be easily corrected for. Fixed pressure facilitates the wide size range of the instrument, improves time response and isolates the instrument from fluctuating sample pressure. The short residence time in the classification system and surface tension effects ensure that volatile particles do not evaporate, and research proves good agreement with SMPS measurements for volatile nucleation aerosols under steady state conditions.



A high sample inlet flow rate (up to 8 slpm) and the unique use of multiple sheath flows in the charging system minimize particle loss by diffusion, even down to 5nm.

## Fastest Available Time Response

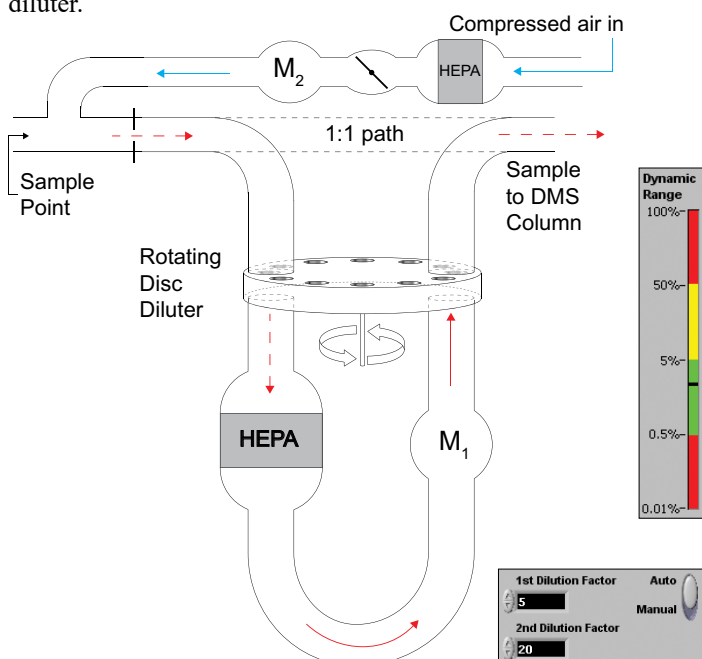
The DMS500 remains the fastest available nanoparticle size spectrometer with an output data rate of up to 10Hz. However, a fast data rate is not sufficient in itself. An instrument can only be deemed suitable for measuring rapidly-changing aerosols after considering its response to a transient, rather than simply the data logging frequency — the speed of the electronics of an instrument should not be equated to its true time response.



Using Cambustion's long experience in the fluid mechanical design of fast response analysers, the DMS500's response to a step change in concentration ( $T_{10-90\%}$ ) is just ~200 ms, or ~300 ms with a 5 m sample line (1  $\mu$ m range). By Nyquist's criterion, 200 ms is the minimum response time which can be correctly resolved by an instrument with a 10 Hz sampling rate.

## Fully Integrated Sampling and Dilution system

The DMS500 is fitted with a primary dilution stage (metered compressed air) and an optional secondary high ratio rotating disc diluter.



Primary dilution at the point of sampling avoids condensation and agglomeration, and the high ratio secondary diluter allows

sampling from a very wide range of aerosol concentrations with over 9 orders of magnitude dynamic range. This single instrument is thus suitable for applications ranging from ambient monitoring to sampling the highly concentrated smoke from pyrotechnic devices or mainstream cigarettes.

Control of the dilution system is integral to the PC-based user interface and the measured particulate concentration is automatically corrected for the total applied dilution. The signal strength indicator on the display guides the user to set dilution to an appropriate level. When prompted by the software, cleaning takes only 10 minutes with the supplied tool.

The instrument measures its own baseline sensitivity during the auto-zeroing function and plots this on the interface. The optional heated sampling line can operate at up to 191°C and allows sampling directly from the exhaust stream of an engine or stack without the need for any further dilution.

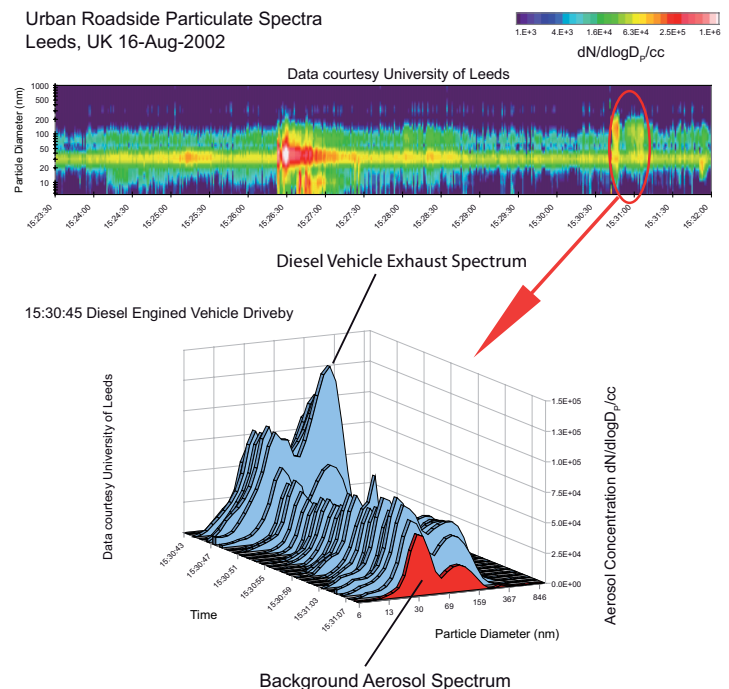
For low temperature applications, conductive silicone rubber tubing can be attached to the supplied front mounted cyclone.

## Aerosol Science Applications

*Note: please see the alternative brochure for automotive applications — [www.cambustion.com/products/dms500/engine](http://www.cambustion.com/products/dms500/engine)*

## Ambient, Roadside and Indoor Monitoring

Urban Roadside Particulate Spectra  
Leeds, UK 16-Aug-2002



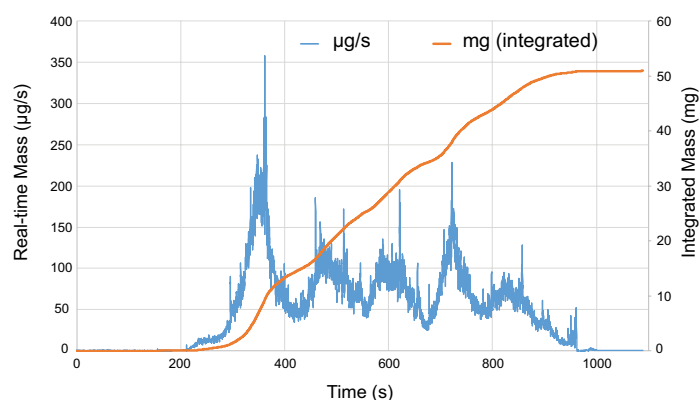
With the best sensitivity amongst real-time particle sizers, the DMS500 *MkII* brings transient capabilities to ambient pollution measurement. The instrument is capable of unattended operation with scheduled sampling and auto-zeroing via its unique built in HEPA filter system, and there is no limit to the length of data files. External devices such as cameras can be triggered when the particle concentration exceeds a preset level. The rapid response

ensures that in roadside monitoring for instance, individual vehicle events can be isolated for study.

The sample data above shows a roadside ambient spectrum comprising mostly gasoline traffic. The event at 15:26 corresponds to a gasoline vehicle drive-by, producing fresh nucleation mode material. This is clearly distinguished from the event at 15:31 which corresponds to a Diesel vehicle drive-by under high load. The highlighted extract shows the drive-by of the large Diesel vehicle producing an accumulation mode at  $\sim 75$  nm. The background is composed of two modes — an agglomerated nucleation mode at  $\sim 30$  nm, mostly due to gasoline traffic, and an accumulation mode produced by Diesel traffic.

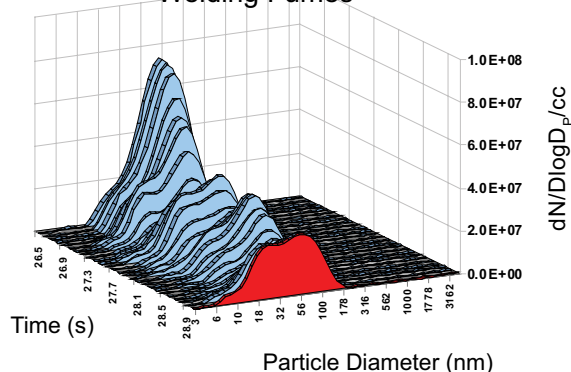
The DMS series has also been used in studies monitoring indoor ambient environments with aerosols as diverse as cooking fumes,

## Real-time and integrated mass data from burger cooking



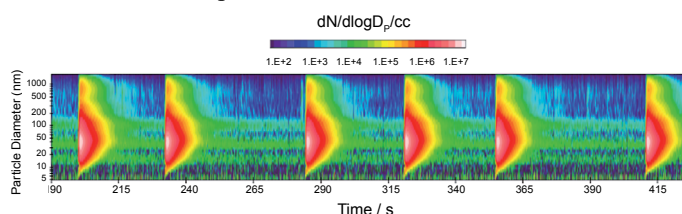
engineered nanoparticles (including nanotubes), grinding fumes and welding fumes (below).

## Welding Fumes

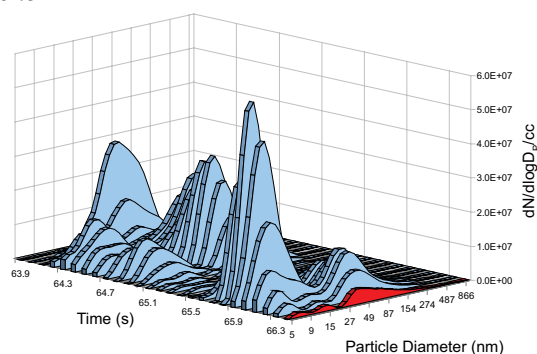


## Pharmaceutical

This plot shows the release and evolution of the aerosol from an inhaler over several puffs — data collected in real-time.

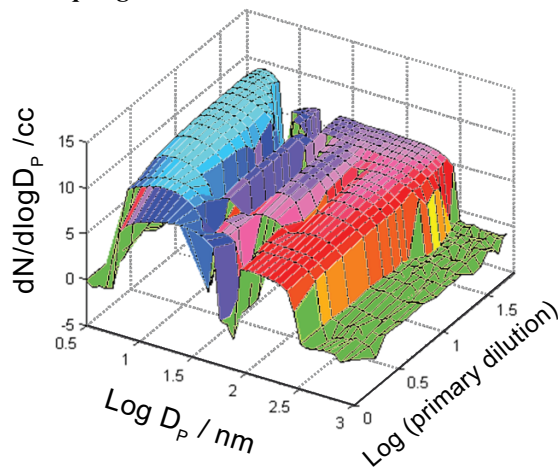


## Woodsmoke



The plot above shows pine smoke sampled with the DMS500 at the full 10Hz data rate. Note that some features of this spectrum last just 200–300ms; even with a high sampling rate, these subtleties would be blurred out with any instrument with a true response time slower than this.

## Flame Sampling & Combustion Science



The graph above shows particle size distributions from a flame, into which a solution of  $MgCl_2$  was atomized. The DMS500's primary dilution system was used to provide a flow of nitrogen for dilution and quenching at the sample probe, and the plot shows the size spectrum as a function of this dilution.

(Fennell, P.S., Dennis, J.S. and Hayhurst, A.N. *5th International Seminar on Flame Structure*, The Siberian Academy of Sciences, Novosibirsk, July, 2005.)

## Cigarettes, e-cigarettes and heat-not-burn

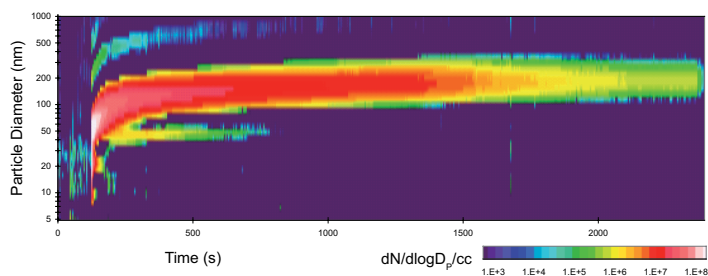
The unique combination of a wide size range and rapid response makes the DMS500 ideal for cigarette smoke studies. The upper end of cigarette smoke aerosols fall within the 500–1000 nm region so it is important to resolve this, especially for accurate mass calculation. The Smoking Cycle Simulator (SCS) accessory allows a controlled smoking profile to be reproduced whilst providing representative dilution. For more information visit [www.cambustion.com/products/scs](http://www.cambustion.com/products/scs)

## Airbags / Pyrotechnics

Deployment of vehicle airbags releases a large number of ultrafine particles in a short period, which then undergo agglomeration to larger sizes. The DMS500 is well suited to resolving both the initial release of particles, and subsequent evolution of the aerosol:



Particle emission and agglomeration from an airbag inflator



Data courtesy Ryan Wood, School of Technology, Oxford Brookes University

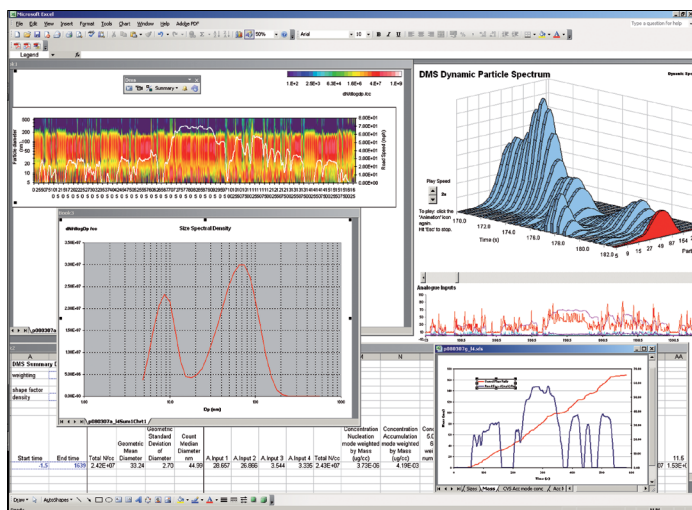
## Other Applications

The DMS500 is also suitable for stack sampling and gas turbine studies. A variety of supporting application notes regarding sampling techniques and correlation data are available at [www.cambustion.com/applications](http://www.cambustion.com/applications)

## Powerful, Easy to Use Software

Controlled via desktop or laptop PC, features include programmable operation, digital remote control and four channels each of analogue input and output for seamless integration with existing laboratory equipment.

The unique multi-lognormal fit uses a Bayesian statistical algorithm to produce a fit to the data in real time. This can be used to separate the aerosol into constituent modes, and greatly simplifies data analysis where a full spectrum is not desired. It also allows higher spectral resolution; aerosols as narrow as  $\sigma_g = 1.05$



may be correctly resolved. Mass calculated from a lognormal function is far less prone to error caused by fluctuations in the spectrum at large sizes. The algorithm uses statistical significance and the instrument's measured noise base to determine the number of modes present. The PC software includes full error detection and warnings. The instrument is ready to use in 30 minutes from switch-on, an internal HEPA filter allows automatic setting of the zero concentration every time with no need for access to the sample point.

The DMS500 is completely remotely controlled from the PC. Ethernet communications enable easy switching between different

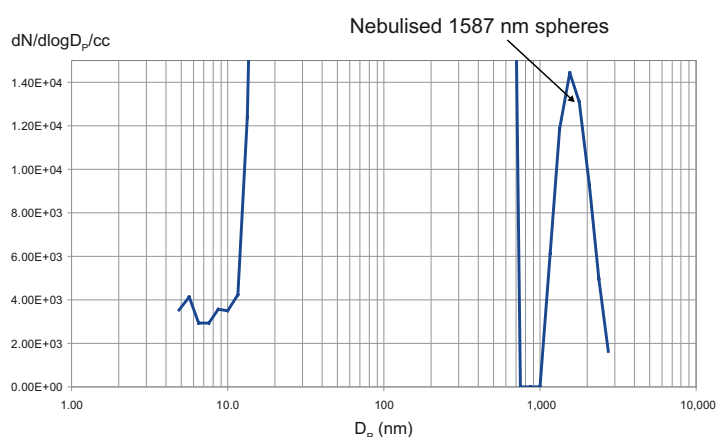
computers. Communication via text commands to an ethernet port is also available, using the AK protocol.

## MS Office Data Presentation Tools

DMS500 data files require no post-processing and are tab-delimited text. The only limit to their length is the available hard disk space, making the DMS500 ideal for ambient studies where long files can be produced. A single file contains summary information as well as the full size spectrum. The plain text data files can be opened in MS Excel, MATLAB/Scilab or equivalents. A freely distributable Excel add-in assists with data analysis and produces contour plots/waterfall animations to share with collaborators, with no need for them to install any additional proprietary software. All graphs produced by the add-in are fully MS Office-compliant and can be imported directly, e.g. into PowerPoint. Other tools in the package allow summary of data over time intervals, and the application of alternative calibrations to existing data sets.

## Calibration

The DMS500 is traceably size calibrated against standard polystyrene latex spheres (see plot below), and with a variety of representative aerosols through comparison with a Differential Mobility Analyser (DMA). A traceable standard electrometer is used for number calibration via a methodology similar to that recommended for Condensation Particle Counter (CPC) calibration. Aerosols used include real soot and volatile sulphuric acid. This final empirical calibration therefore uniquely takes account of any particle transport losses inside the instrument, including the diluter, or inaccuracies in the theoretical charging model. Cambustion are happy to discuss any aspect of data inversion or calibration with our customers and have published papers on this subject.



Due to the slight differences in charging spherical particles and agglomerates inherent to *all* instruments which use a corona charger, Cambustion again led the field in 2006 by introducing a separate empirical calibration with soot; available for Diesel and GDI engine applications or others with highly fractal aerosols, to give good correlation with (for example) solid particle number CPC based systems. Recent studies show class-leading accuracy & reproducibility between DMS500 instruments, over the last 10 years.

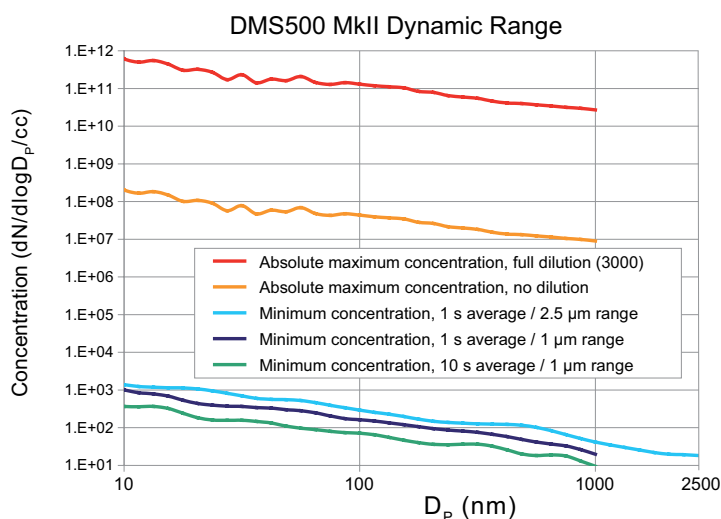
## Specifications:

Particle size range	5 nm – 1 µm or 5 nm – 2.5 µm versions
Spectral Elements	38 (1 µm) or 45 (2.5 µm) (at 16/decade; 32/decade also available)
Size Classification	Electrical Mobility
Charger Type	Unipolar Diffusion
Dilution Factor Range	1 – 5 (one stage) 1 – 3000 (optional two stage)
Sample Flow Rate	8 slpm (1 µm range) / 2.5 slpm (2.5 µm range) at 0°C + 100 kPa
Analogue Outputs	4; software configurable, 0–10 V, 47Ω
Analogue Inputs	4; software configurable, ±10 V
Instrument Zeroing	Automatic; internal HEPA filter
Stabilisation Time	30 minutes from switch on
Number of Electrometers	22
Minimum resolvable GSD	1.05 (lognormal output)
Output Data Rate	10/sec – 1/min
Time Response	$T_{90-10\%} \sim 200$ ms (1 µm range) $T_{90-10\%} \sim 500$ ms (2.5 µm range)
Calibrations: Non-Agglomerate	By NIST traceable PSL spheres & DMA size selected NaCl/H <sub>2</sub> SO <sub>4</sub> with standard electrometer.
Agglomerate (soot)	DMA size selected soot, comparison with standard electrometer
Max Concentration	$\approx 10^{11}$ dN/dlogD <sub>p</sub> /cc (diluter on)
Max Data File Length	Unlimited
PC Interface	Ethernet
Remote Control	AK Protocol
PC Option	Laptop or desktop
Electrical Supply	100–115 or 220–240 V 1500 W
Inlet Pipe (No heated line)	6 mm O.D. pipe stub on cyclone
Exhaust pipe connection to heated line	6 mm or ¼ inch Swagelok or ¼ inch BSP thread
Vac pump exhaust extract	12 mm internal diameter pipe
Compressed air (for direct engine exhaust sampling only)	Oil-free @ 3–8 bar gauge Dewpoint 3°C or lower
Max Primary Dilution & Line Temperature	191°C (with heated sample line)
Max Sample Temperature	800°C (with heated sample line)
Minimum Sample Pressure	600 mb (4,200 m / 13,000 ft equivalent)
Instrument Dimensions / Weight	930h × 380w × 520d mm with wheels / 80 Kg
External Pump Dimensions / Weight	4431 × 328w × 372d mm with wheels / 44 Kg
Calibration interval	12 months
Warranty period	12 months (extendable)

## Sensitivity:

Note that the following sensitivity information is expressed in terms of size spectral density, dN/dlogD<sub>p</sub>/cc. When comparing with other instruments' specifications, bear in mind that sometimes these are expressed in terms of total concentration (particles/cm<sup>3</sup>) versus size, which is not a useful metric for size distributions (and should only really be used when expressed as the integral over a finite range of sizes). To compare with these, the dN/dlogD<sub>p</sub>/cc values below should be divided by 16. For ease of comparison, these N/cc/size class figures are given in the last column.

RMS at 1 Hz, 1 µm range	dN/dlogD <sub>p</sub> /cc	~ N/cc/class
10 nm	$1.0 \times 10^3$	63
30 nm	$4.0 \times 10^2$	25
100 nm	$1.7 \times 10^2$	11
300 nm	$8.0 \times 10^1$	5
Sensitivity to typical Diesel accumulation mode (80 nm, $\sigma_g = 1.8$ )	Number: ~170 N/cc Mass: ~0.5 µg/m <sup>3</sup> Indicates typical level at which lognormal mode falls below detection threshold	



Key features of the DMS500 classifier are protected by Cambustion patents: GB2,374,671 (2003), GB2,378,510 (2003) and US6,828,794 (2004).

For more information, references to academic literature and application notes, please contact:

sales@cambustion.com Tel: +44 1223 210250

www.cambustion.com Fax: +44 1223 210190

Cambustion  
J6 The Paddocks,  
347 Cherry Hinton Road,  
Cambridge CB1 8DH  
United Kingdom

All specifications subject to change without notice.



ISO 9001:2015 cert.# FS73100  
ISO 14001:2015 cert.# EMS74721