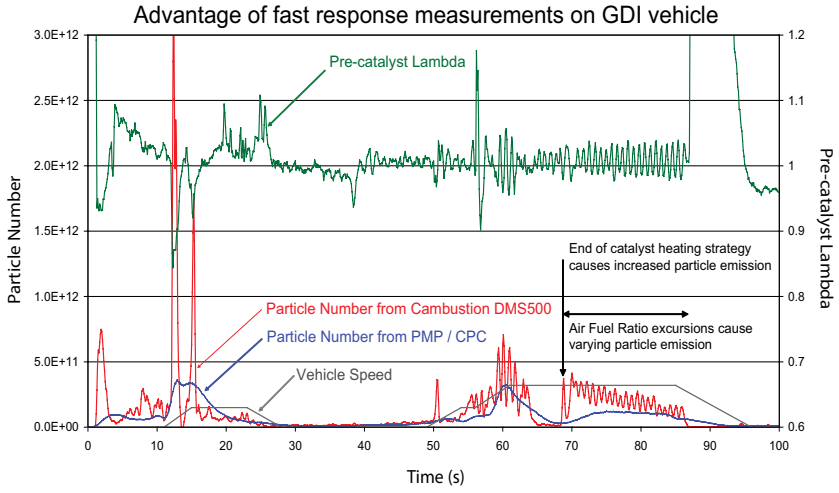
CAMBUSTION DMS500 MkII

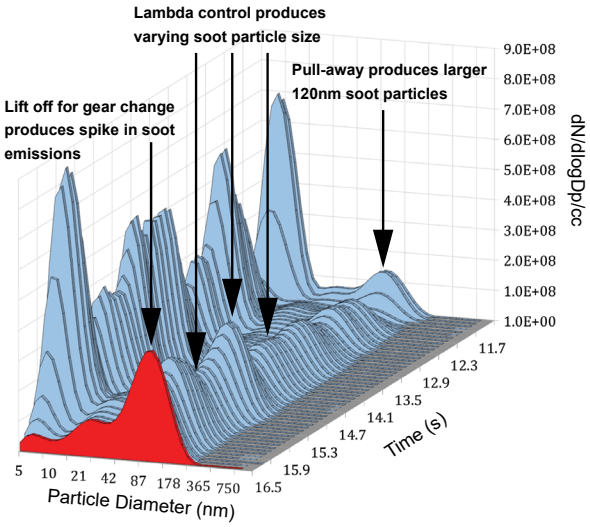
The Rapid Response Engine Particulate Analyzer

- Particle size distributions from 5nm – 1µm (5nm – 2.5µm option)
- Particle Number (PN) with selectable 10nm & 23nm roll-offs
- Particle Mass (PM)

...all from a single instrument!

Available with Catalytic Stripper option to remove volatile particles





- Altitude testing
- Sub 0°C sampling capability
- Pre- and post-GPF/DPF, tailpipe or CVS sampling
- Fastest available time response (10 Hz data, 200 ms $T_{10\text{-}90\%}$)

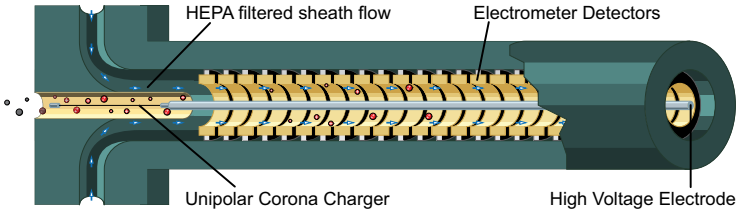
Introduction to the DMS500 *MkII*

The Cambustion DMS500 was the world's first production real-time nanoparticle size spectrometer. Since its launch in 2002 it has become the particulate instrument of choice at research labs, universities and the majority of vehicle OEMs worldwide.

In 2008 the DMS500 *MkII* updated this concept with specific attention to evolving engine testing requirements, incorporating enhancements such as higher sensitivity (ideal for post-DPF/GPF or GDI measurements) and a more flexible dilution system. Designed with engine test cell use in mind, it combines the latest in particle measurement technology with Cambustion's many years of experience at the forefront of transient engine emissions instrumentation and research.

Such refinement means that the DMS user does not need to be a particle expert. Unique and powerful data summary features allow the user to remain detached from the underlying complex aerosol data, acquiring the metric they need whilst advanced users still have access to the full particle size spectrum.

Operating Principle



The DMS500 uses a high voltage discharge to charge each particle proportional to its surface area. Charged particles are introduced into a classification section with a strong radial electrical field. This field causes particles to drift through a sheath flow toward the electrometer detectors. Particles are detected at different distances down the column, depending upon their aerodynamic drag/charge ratio. Outputs from the 22 electrometers are processed in real-time at 10 Hz to provide spectral data and other metrics. To view an animation please visit: www.cambustion.com/dms

The DMS500 operates at fixed pressure to eliminate any concern about online pressure correction algorithms. It samples through a choked orifice to discourage particle agglomeration. This facilitates the wide size range of the instrument, improves time response and isolates the instrument from fluctuating sample pressure.

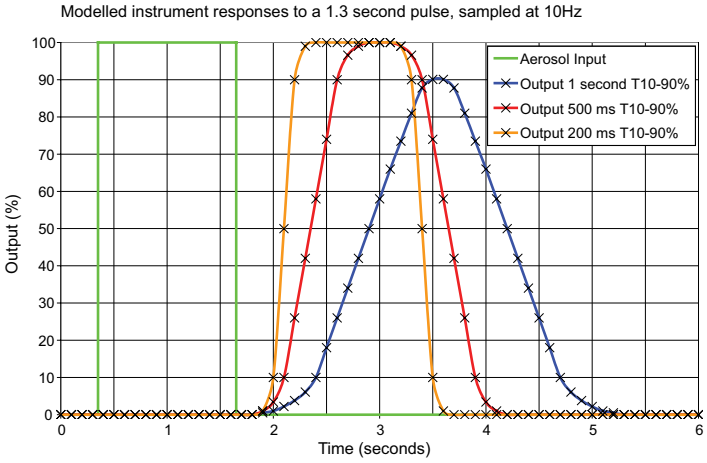
Unique Combination of Real-time Data

Particulate emissions legislation confronts engine developers with two issues. The traditional gravimetric technique for measuring engine particulate emissions is inherently offline, offering no information to engineers regarding emissions performance at different engine conditions. The particle number standard requires measurement of solid particle number.

The DMS500 is uniquely able to output particle size, gravimetrically-correlated mass and particle number correlated with the Euro 6 requirements in real-time. Its integrated sampling system allows it to sample at any point between the exhaust valve and the CVS tunnel, enabling studies of engine and aftertreatment performance.

Fastest Available Time Response

The DMS500 remains the fastest available nanoparticle size spectrometer with an output data rate of up to 10 Hz. However, a fast data rate is not sufficient in itself. Unique design means that the DMS500's response to a step change in concentration ($T_{10–90\%}$) is ~200 ms, or ~300 ms with a 5 m sample line.



An instrument can only be deemed suitable for transient measurements after considering its response to a transient, rather than simply the data logging frequency.

Calibrations for Diesel, GDI and alternative fuels

The difference in combustion processes between gasoline and Diesel results in the production of different particle types:

Nucleation mode

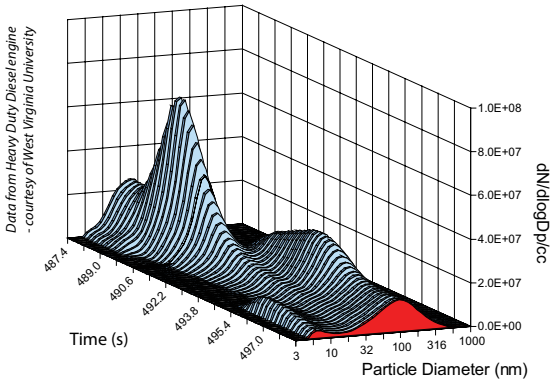
Both gasoline and Diesel engines (including alternative fuels) produce a nucleation mode. This mode consists of small spherical particles typically 5–50 nm in diameter. These particles are composed of condensed liquids such as water, sulphuric acid, fuel, lubricating oil and compounds produced during combustion.

Accumulation mode

Diesel engines inject droplets of fuel into cylinder conditions where the fuel will combust spontaneously. The burning rate is limited by diffusion of oxygen to the surface of the fuel droplet which leads to locally rich combustion. This produces solid primary soot particles (typically 25 nm in diameter). Due to the high concentration these particles adhere to form agglomerates.

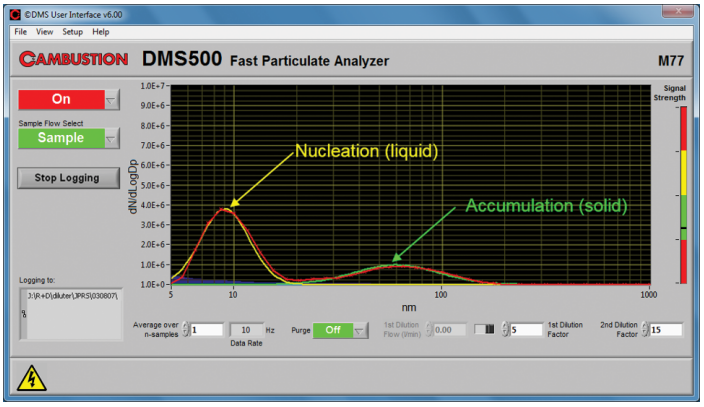
Gasoline engines tend to produce accumulation mode particles which are closer to a spherical morphology. To allow the DMS series instruments to calculate particle mass that correlates with filter paper measurements and particle number that correlates with

Euro 6 requirements, the software separates the nucleation and accumulation modes.



Furthermore, in all unipolar diffusion (corona) charger-based instruments, the different morphologies of accumulation mode particles from different engine types require different calibrations to most accurately give particle mass and number.

The DMS500 can be supplied with calibrations suitable for both Diesel and gasoline particulates which can be switched in software.



In the above example (Diesel engine), the continuous total spectrum in red is accompanied in real-time by the nucleation (volatile) mode in yellow, and accumulation (solid) mode in green.

Each mode is automatically summarised in the data file; recording size, particle number and gravimetrically-correlated mass. These quantities may also be sent to any of four analogue outputs for easy test cell integration. No post-processing of the text output data file is required. A suite of MS Office compatible data presentation tools is provided.

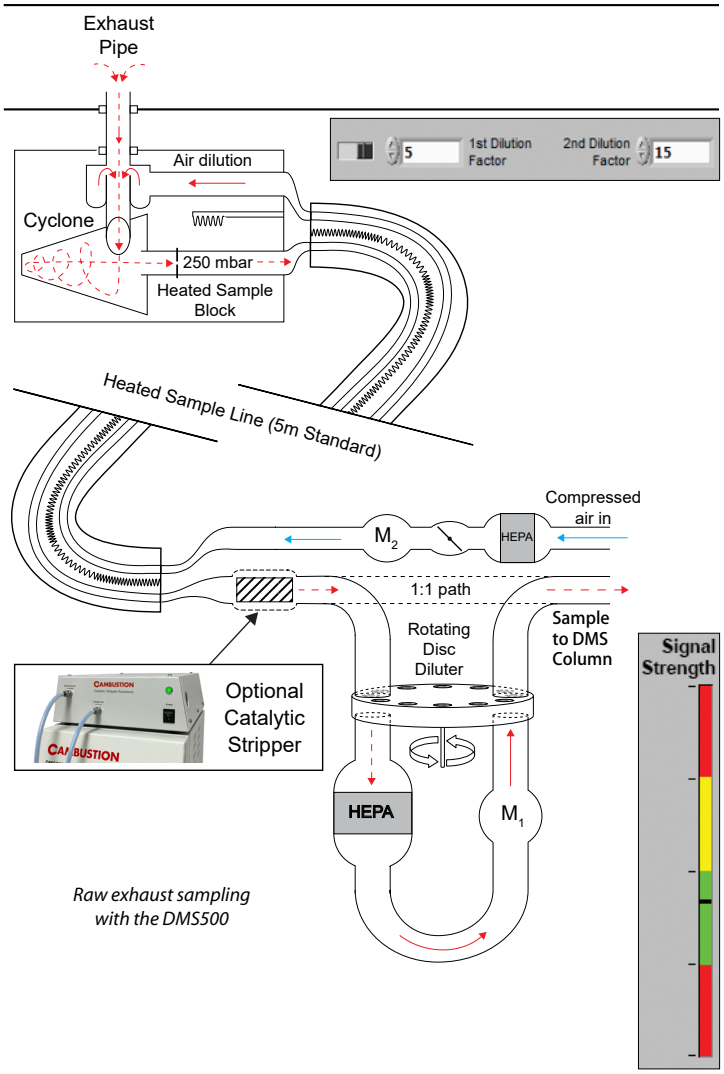
DMS500 shown with other ultra-fast Cambustion analyzers (HC, NO_x, CO & CO_2)

Fully Integrated Conditioning and Dilution system

The DMS500 is fitted with a fully integrated two-stage dilution system specifically for direct engine exhaust measurements.

This provides 1st dilution at the point of sampling to avoid condensation and agglomeration, and a high factor 2nd diluter to allow sampling from a very wide range of concentrations. 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.

An optional Catalytic Stripper removes volatile particles and can be bypassed if desired.



Raw exhaust sampling with the DMS500

The dilution system is calibrated for particle losses during instrument calibration and this correction is automatically applied.

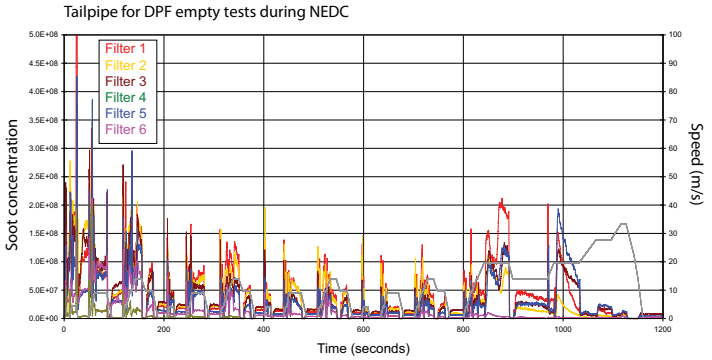
The heated sampling line can operate at up to 191°C allowing sampling directly from the exhaust of an engine with no need for a CVS. This permits measurement either side of a DPF/GPF or a general after-treatment system.

Applications

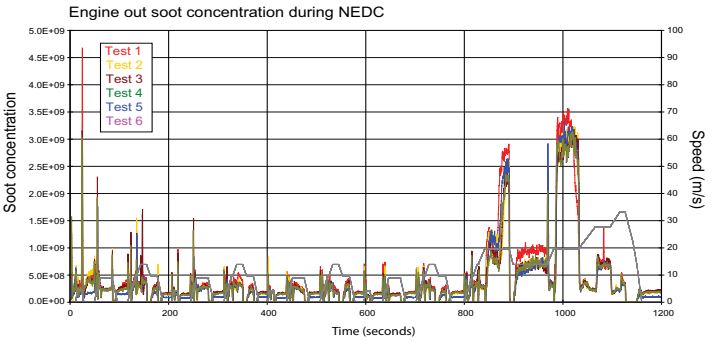
1. Gasoline & Diesel Particulate Filter Evaluation

The DMS500's raw exhaust sampling capability makes it ideal for evaluating DPF or GPF performance. Measurement upstream

of the filter allows calculation of the particle mass and number being presented to the filter, and optimization of engine-out emissions. Downstream measurement allows filter performance to be evaluated, the DMS software producing real-time data for both particle number and particle mass, coupled with particle size spectra.



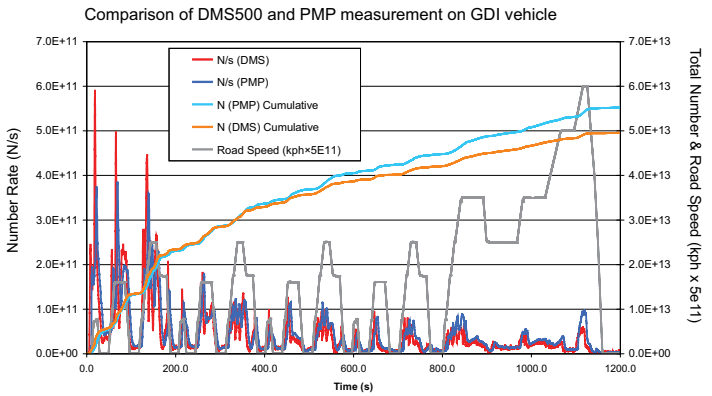
The wide dynamic range of the DMS500 and dilution system allows it to distinguish between filters of differing performance, as well as detecting a failed filter (even though the overall performance may still meet the particle number limit.)



The DMS500's sophisticated analogue inputs allow online correction from a measured concentration in N/cc to number of particles/second (using exhaust flow). Additional use of vehicle speed can show whether engine operating conditions comply with the solid particle limit.

2. GDI Calibration

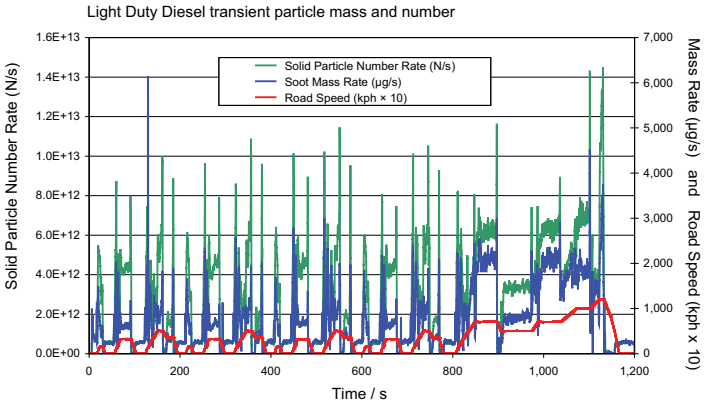
The adoption of GDI technology means that engineers now need to optimise gasoline engines for particulate emissions.



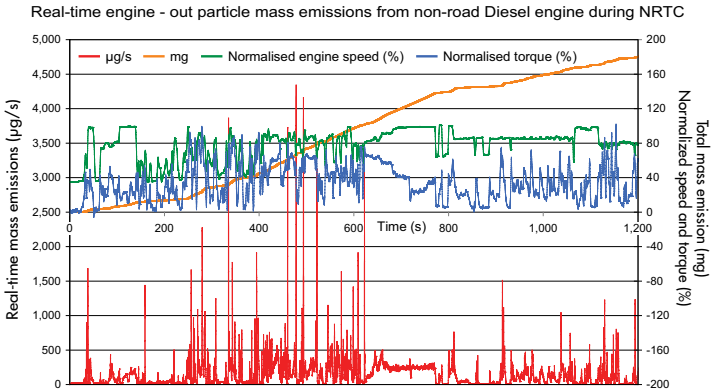
Due to the greater challenge of mixture preparation in GDI, transient engine conditions can lead to very high particle emissions, particularly just after cold start. The DMS500 can identify these transient spikes where slower PMP measurements may not (see also front cover), and can be used to evaluate different calibrations in a time-efficient manner. Even when a GPF is fitted, the reduced soot load means the GPF's efficiency never reaches that of a loaded DPF — optimization of GDI engine-out particle number remains an important task.

3. Diesel Calibration

Diesel engine calibrators now have better control over fuel injection, boost and other parameters affecting emissions. However, during engine transients, parameters such as airflow may be less accurately controlled, leading to poor combustion and resultant particle emissions. Such behaviour may also be very sensitive to external conditions.



As with GDI particle measurement, the DMS500 provides an online output of particle mass and number (including the ability to sample between the engine and the aftertreatment) — aiding engineers in reducing total emissions. The instrument's fast time response is particularly relevant when calibrating for transient cycles, including the Non-Road Transient Cycle.

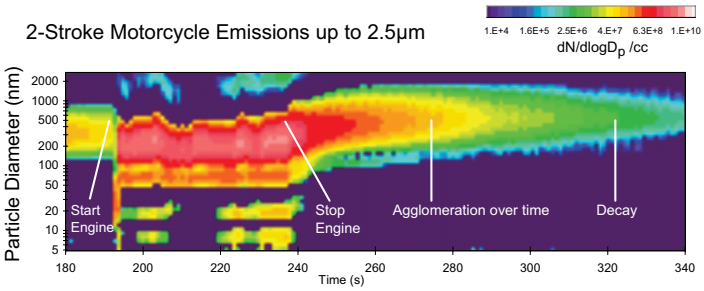


4. Other engine applications

Crankcase emissions may represent a significant source of particles for some engine types. The DMS500's broad size range makes it ideal for studying such emissions which can be highly variable with engine load etc. The DMS500 also offers the ability to characterise devices such as oil mist separators.

This is particularly of interest during GDI engine development, since carbonised deposits can accumulate on the inlet valve stem, which is no longer washed with gasoline as in a PFI engine.

Two stroke engines are often used for lighter vehicles, with an increasing emphasis on GDI to reduce hydrocarbon emissions. The introduction of small amounts of lubricating oil into the combustion air means that crankcase-scavenged two strokes present a unique problem for particle control since they can produce particles greater than 600nm. The DMS500 with its wide size range (up to 2.5µm) is well suited for such an application.



The DMS500 is also capable of measuring the particle concentration upstream and downstream of an EGR cooler, feeding into improved EGR cooler clogging models.

Application Notes

A variety of supporting application notes regarding sampling techniques and correlation data are available at http://www.cambustion.com/applications/DMS

Powerful Test Cell Integration, Easy to Use Software

The DMS500 is designed as a rugged instrument to add particulate monitoring capability to a test cell. Controlled via a dedicated PC, it includes support for the AK protocol (via serial or Ethernet) allowing easy integration with the test cell, including remote control, status monitoring and data output, facilitating projects such as automated mapping.

The DMS500 also offers four channels each of analogue input and output for seamless integration with existing emissions equipment.

Instrument operation will be straightforward for gas analyzer users — PC software includes full error detection and warning. The system requires a stabilisation period of 30 minutes, and zero concentration is set automatically via an internal HEPA filter with no need for access to the sample line.

User-configurable parameters such as dilution factors and sampling rate can be set via the AK interface from the test cell, and data output is also available over AK for test bench recording if required. Rugged metal cased construction gives the DMS500 the durability to operate under industrial conditions yet it remains easily transportable between locations with quick release piping / cabling plus wheels and handles.

The DMS500 is completely controlled from the PC with no need to refer to the front of the instrument. Ethernet communications enable easy switching between different computers.

Enhanced MS Office Data Presentation Tools

DMS500 data files require no post-processing. Each file contains all summary and spectral data. The plain text data files give the flexibility of being readable with MS Excel, MATLAB/Scilab or equivalents. A freely distributable Excel add-in assists with data presentation and produces contour plots / waterfall animations to share with colleagues, with no need for them to install additional proprietary software.

Improved Sensitivity; Wide Dynamic Range

The DMS500 with integrated dilution offers over 9 orders of magnitude in dynamic range (see specifications table). The signal strength indicator guides the operator to set dilution appropriately. Suitable use of the diluter greatly increases the instrument cleaning interval even for engine emissions. An easy-to-use cleaning tool is supplied; cleaning takes around 10 minutes.

The instrument *measures* its own true baseline noise during the automatic zeroing function, plots this on the interface and records to the data file, providing warnings both on screen and in data files when cleaning is required.

Calibration

The DMS500 is traceably calibrated for size against standard polystyrene latex (PSL) spheres and with a variety of representative aerosols through comparison with a differential mobility analyzer (DMA). A traceable standard electrometer is used for number calibration using a methodology similar to that recommended for condensation particle counter (CPC) calibration (as used in the solid particle number counting system). Aerosols used include real soot and volatile sulphuric acid. This final empirical calibration accounts for particle losses inside the instrument. Traceable calibration certificates are provided.

Dual Sampling Accessory (DSA)

This allows automated switching of the DMS500 between two different sample locations (such as pre- and post- DPF/GPF, as in the illustration below).

DMS500 with Dual Sampling Accessory for GPF/DPF studies

For more information see: www.cambustion.com/products/dsa

DMS500 MkII Transient Engine Particulate Analyzer

Specifications:

Particle size range	5nm - 1µm (5nm - 2.5µm option)
Number of Electrometers	22
Size Classification	Electrical Mobility
Dilution Factor Range	÷1 – 3,000
Heated Sample Line	7, 5 or 2 metres length
Maximum 1st Dilution & Heated Line Temperature	191°C
Sample Conditioning	Optional catalytic stripper for volatile particle removal
Roll off function	Software selectable: 23 nm for Euro 6 sub 23 nm for proposed PMP48
Max Sample Temperature	800°C
Minimum Sample Pressure	600 mb (4,200 m / 13,000 ft equivalent)
Sample Flow Rate	8 slpm (1 µm range) at 0 °C + 100 kpa
Instrument Dimensions / Weight	980h × 380w × 520d mm with wheels 80 Kg
External Pump Dimensions / Weight	480h × 330w × 450l with wheels 46 Kg
Analogue / AK Outputs	4 @ 10 Hz; software configurable
Analogue / AK Inputs	4 @ 10 Hz; software configurable
Instrument Zeroing	Automatic; internal HEPA filter
Stabilisation Time	30 minutes from switch on
Spectral Elements	16 or 32 / decade
Output Data Rate	10/sec – 1/min
Time Response	$T_{10\text{-}90\%}$ 200 ms $T_{10\text{-}90\%}$ 300 ms with 5m heated line
Calibrations: Spherical:	By NIST traceable PSL spheres & DMA size-selected NaCl/ H_2SO_4, comparison with standard electrometer
Agglomerate:	DMA size-selected soot, comparison with standard electrometer
Service / Calibration interval	12 months
Warranty Period	12 months (extendable)
Max concentration	1×10^{11} N/cc
PC Interface	Ethernet
Remote Control	AK Protocol (Ethernet)
Controlling Computer	Windows PC (Laptop or Desktop)

Services Required:

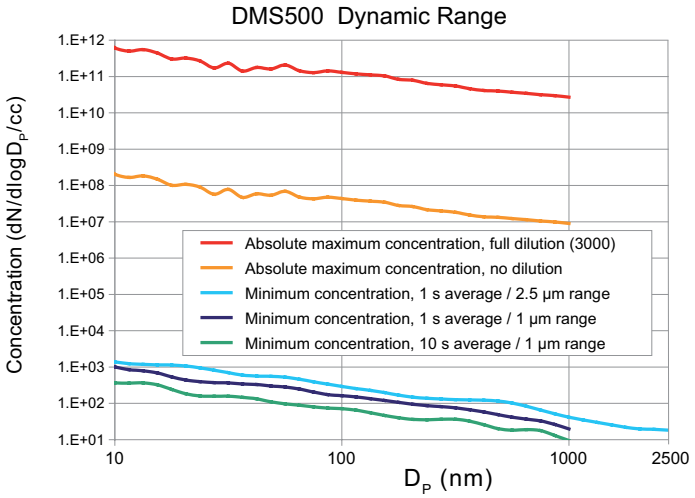
Electrical Supply	110-115 / 220-240 V AC 50/60Hz 1500W (main unit) 750W (pump)
Exhaust pipe connection	6mm or 1/4 inch Swagelok
Compressed Air (for raw exhaust sampling)	Oil-free @ 3–8 bar gauge Dew point 3°C or lower ISO 8573 Class 1.4.1
Extract for vacuum pump exhaust	12 mm internal diameter pipe
Internet connection (recommended)	For remote technical support

Sensitivity (RMS at 1 Hz):

10 nm	1.0×10^3 (dN/dlogD_p /cc)
30 nm	4.0×10^2
100 nm	1.7×10^2
300 nm	8.0×10^1
Sensitivity to typical Diesel accumulation mode (80 nm, σ_g = 1.8)	Number: ~170 N/cc Mass: ~0.5 µg/m³ indicates typical level at which lognormal mode falls below detection threshold

All specifications subject to change without notice.

Aerosol Science Applications



The DMS500 is also suitable for general aerosol science applications. For more information please see our alternative brochure or visit: www.cambustion.com/products/dms500.

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 and application notes please contact:

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