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DMS500Mk2

The transient exhaust particle analyser

Capabilities

Particle size distributions
5nm – 1µm
(5nm – 2.5µm option)

Particle number (PN)
selectable 10nm & 23nm roll-offs

Particle mass (PM)

Fastest available time response
for transient calibration / R&D

Optional catalytic stripper
removes volatile particles

Flexible sampling
pre-and post-aftertreatment
tailpipe
CVS

Sub 0°C testing

Altitude testing

Applications

Engine & after-treatment development
PN for Euro 6/7
PM for 1mg/mile

Gas turbine measurements

Fuel and lubricant effects

Alternative fuels
hydrogen
methane
ammonia

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Engine exhaust particles

Combustion of hydrocarbon fuels produces particles which may be a mixture of solid soot and volatile particles (liquid/semi-liquid). The size and number concentration of the particles produced depends on the combustion process, and is affected by fuel type, combustion mode, local air fuel ratio and more.

Emissions legislation

Many different emissions metrics for internal combustion engines exist, including particle mass (PM, expressed as mass/mile or mass/kWh), particle number (PN, expressed as N/km or N/kWh).

Legislation requires compliance under a range of conditions, including real-world driving, high altitude, low temperature, flexible fuels and more. Development for compliance thus benefits from every insight into particle formation available.

Transient test cycles

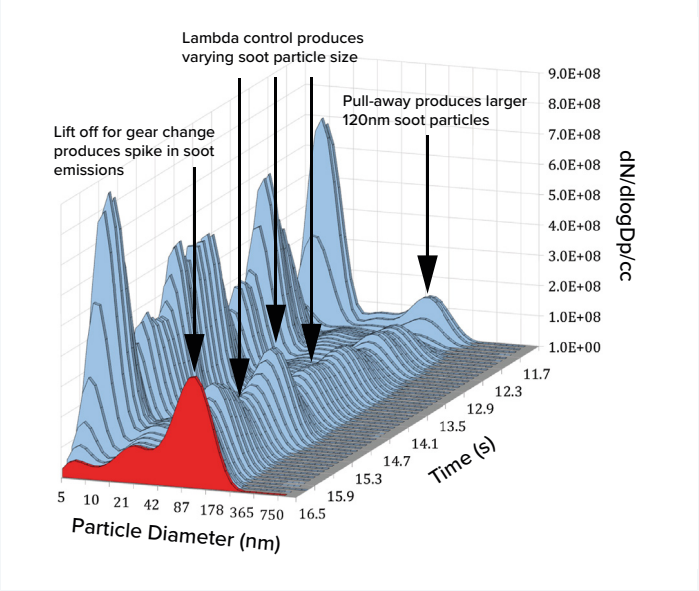
All current legislation recognises that engines are not operated at steady state, and indeed may experience rapid changes in both speed and load. The DMS500 is able to measure and resolve these transients — see Time Response section.

DMS500 Measurements

Particle size

The DMS500 measures the full size distribution between 5nm and 1000 nm (with an extended 5nm — 2500nm option available).

Changes in local air fuel ratio in the combustion region can affect the size of particles produced. Combustion of lubricating oil can produce particles much smaller in size than fuel derived products.



Variations in particle size affect the relationship between PN and PM. Changes in size distribution can also affect the proportion of particles falling within the counting regions for PN (>23 nm for Euro 6 and >10nm for Euro 7). Oil consumption effects may be of particular significance for the 10–23nm size range.

Measurement of the full size distribution enables the DMS500 to provide crucial insights into evolving legislative requirements.

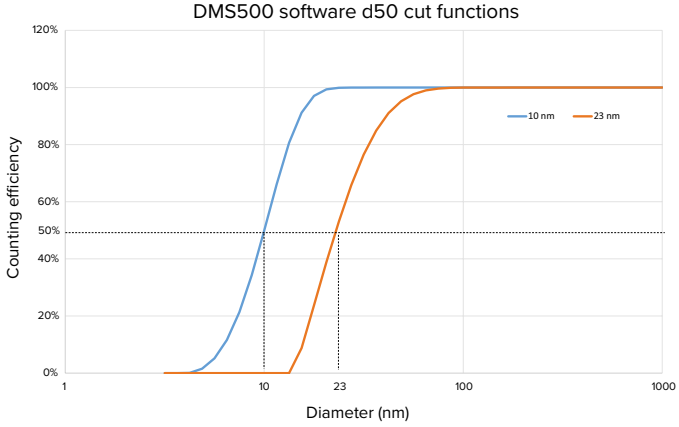
Particle number (PN)

The optional Catalytic Stripper Accessory (CSA) for the DMS500 removes volatile particles from the sample. A catalytic stripper is expected to form part of the Euro 7 measurement technique for PN.

Flexible software allows the DMS500 to output PN with a 23nm “cut” (Euro 6), 10nm (Euro 7) or no cut for research purposes if desired. Users can also compare 10 and 23nm cut data without having to change hardware.

The DMS500 software calculates the total number of particles present (N/cc), which may be converted to N/s, N/kWh or N/km with engine / test bench data.

DMS500 software d50 cut functions



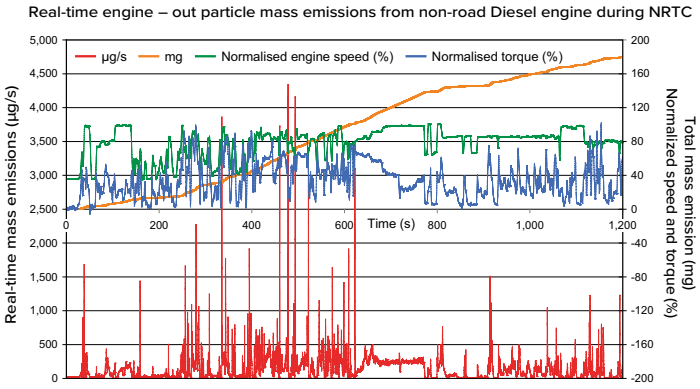
Particle losses are size dependent — measurement of the full size distribution allows automatic correction for transport losses, a correction not possible if only measuring a single concentration.

Unique Combination of Real-time Data

The DMS500 is uniquely able to output particle size, gravimetrically-correlated mass and particle number correlated with the Euro 6 & Euro 7 requirements, from a single instrument and sample point.

Particle mass (PM)

Measurement of the full size distribution allows the DMS500 to output a mass concentration in µg/cc, which may be converted to mg/mile, mg/km or mg/kWh with engine / test bench data.



The optional Catalytic Stripper Accessory (CSA) for the DMS500 removes volatile particles from the sample. This supports enhanced accuracy as mass concentrations fall, including development for 1mg/mile standards.

DMS500 Applications

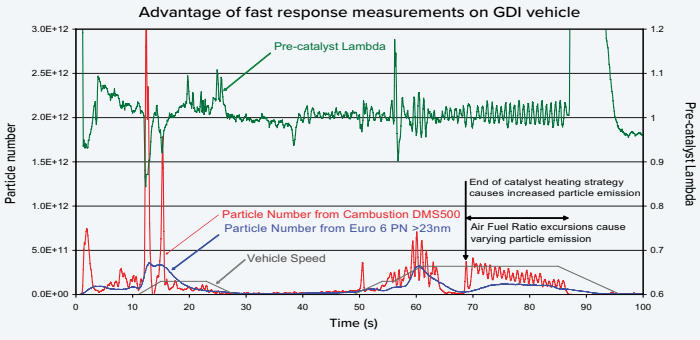
Diesel

The DMS500's measurement of the full particle size, number and mass data offers engineers a complete data set to understand and optimise diesel engine emissions.

DMS500 data is used to develop diesel engines for compliance with mass or number legislation, or to gain deeper understanding of combustion processes / instabilities and performance of external components such as turbochargers.

Spark ignition

Spark ignition engines present combustion challenges, including mixture preparation and cylinder scavenging. GDI engines and alternative fuels such as ethanol blends add to the complexity, and accurate transient calibration of the engine is essential to minimise engine out emissions.



Even when fitted with a Gasoline Particulate Filter, the lower filtration efficiency achieved (due to the difficulty forming a soot cake at higher temperatures in lean conditions) on a spark ignited engine means that optimisation of engine out emissions is crucial as part of emissions compliance.

After-treatment

After-treatment performance varies in real-time, especially after a regeneration of a DPF / GPF. DMS500 data offers engineers information on both the challenge to the after-treatment (in PN or PM terms) and the performance of the after-treatment at reducing tailpipe emissions.

The Dual Sampling Accessory (DSA) allows test bench controlled switching of the DMS500 sample point between pre- and post-after-treatment, while supporting the required changes in dilution.

DMS500 data allows engineers to understand after-treatment filtration efficiency, on a number, mass and even on a size dependent basis.

Alternative fuels

Different fuels have different combustion properties, and can affect particle emissions.

Liquid fuels have different volatilities and spray patterns, and small changes in fuel composition can produce significant shifts in particle number or mass emissions, especially during cold conditions. DMS500 data offers a tool to understand and calibrate out undesirable increases in emissions due to fuel properties.

Other fuels such as methane and hydrogen can still present emissions challenges, including particles from oil consumption. The DMS500's size measurement capability helps engineers understand the new and unique challenges presented by these new fuels.

Altitude testing

Altitude testing increasingly forms part of stringent emissions legislation. The DMS500 is able to measure from conditions equivalent to 4,200m / 13,000ft altitude without special modifications.

Sub 0°C testing

With a fully heated sampling system, the DMS500 is compatible with emissions measurements at −7°C, and even lower temperatures for development. Mixture preparation and combustion can be poor at low temperatures, and the DMS500 allows easy investigation of potential issues, providing detailed data to support development.

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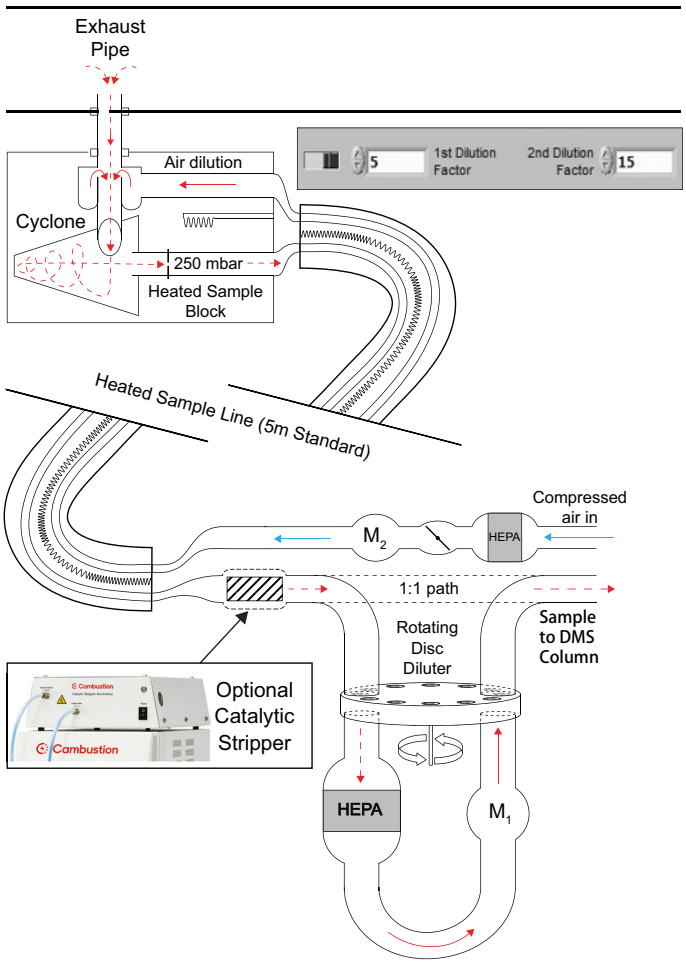
DMS500 Advantages

Fully integrated sample conditioning & dilution

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 user controllable high factor 2nd diluter allows sampling from a very wide range of concentrations.

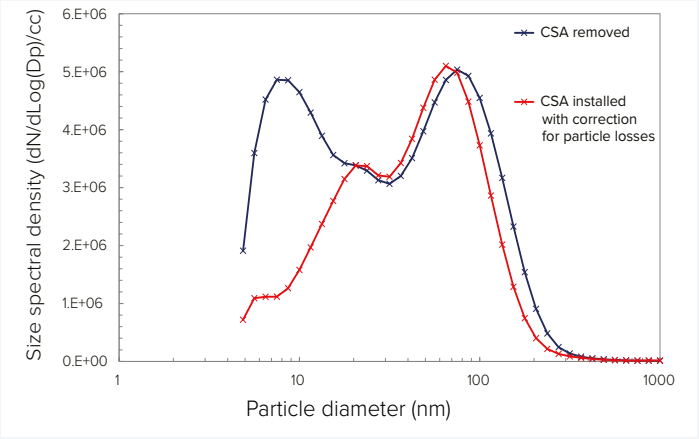
Control of the dilution system is integral to the PC-based user interface and the measured particulate concentration is automatically corrected for the total applied dilution. The dilution system is calibrated for particle losses during instrument calibration and this correction may be automatically applied.

Heated sample lines

The heated sampling line (available in 2, 5 or 7 metre lengths) operates at up to 191°C, allowing sampling directly from the exhaust of an engine with no need for a CVS or partial flow tunnel. This permits measurement either side of a DPF / GPF or a general after-treatment system.

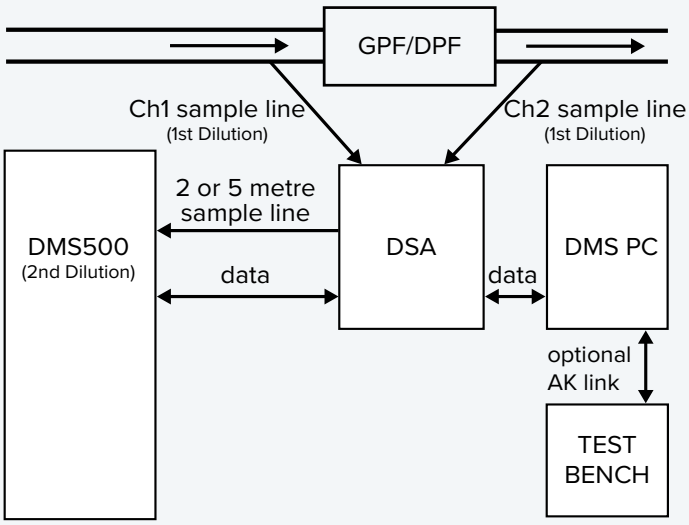
Catalytic Stripper Accessory (CSA)

An optional CSA removes volatiles, supporting Euro 7 development and enhanced mass measurement accuracy at low concentrations. The CSA can be bypassed if required.

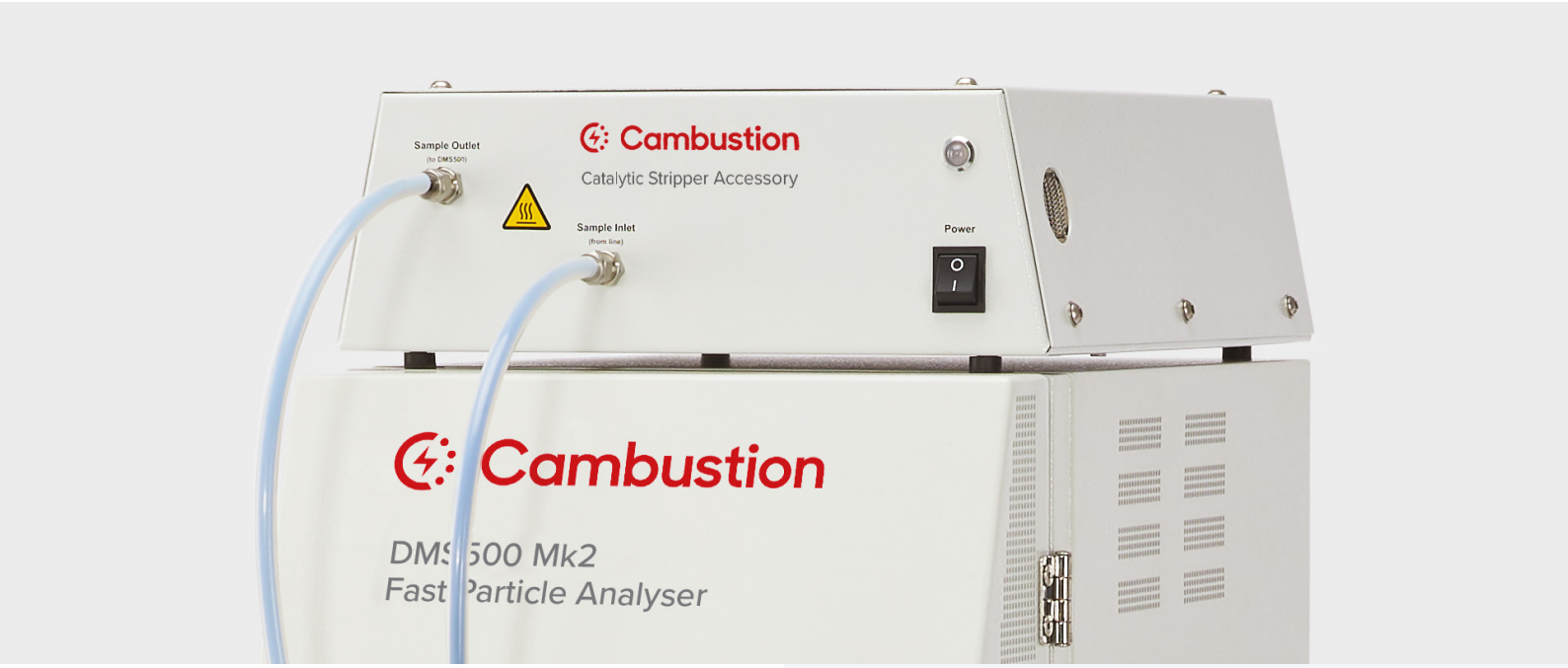


The CSA requires no additional dilution, ensuring measurement sensitivity remains unaffected. The DMS500's fast time response is also not compromised when the CSA is fitted.

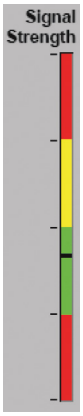
Dual Sampling Accessory (DSA)



The DSA allows automated switching of the DMS500 between two different sample locations (such as pre- and post- DPF/GPF).



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 (or test bench under automatic control) to set dilution appropriately. Use of the diluter ensures long intervals between cleaning, even for high soot applications. An easy-to-use cleaning tool is supplied; cleaning takes around 10 minutes.

The instrument measures its noise during the automatic zeroing function, providing warnings both on screen and in data files when cleaning is required.

Powerful test bench integration, easy-to-use software

The DMS500 is a rugged instrument, and efficiently adds particulate monitoring capability to a test bench. Controlled via a dedicated PC, it includes support for the AK protocol for full test bench integration, including remote control, status monitoring and data output. Alternatively, the DMS500 can be used standalone for flexibility and rapid deployment.

Instrument operation is straightforward — PC software includes full error detection and warning. The system requires a switch on stabilisation period of 30 minutes, and zero concentration is set automatically via an internal HEPA filter.

Rugged metal cased construction gives the DMS500 the durability to operate under industrial conditions yet it remains easily transportable between locations.

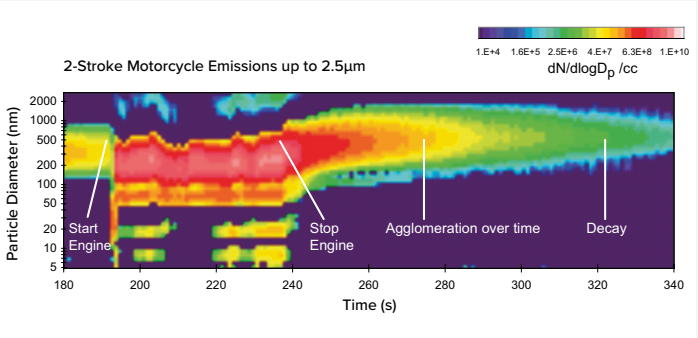
The DMS500 is completely controlled from the PC with no need to refer to the front of the instrument. Ethernet communications enable easy switching between different computers, and the control software may be installed on multiple PCs without requiring additional licences.

Enhanced data presentation tools

DMS500 data files require no post-processing. Each file contains all summary and size data, with flexible user configurable outputs for custom requirements.

The plain text data files are readable in a wide variety of software packages, including loading into test bench data acquisition systems such as STARS Automation, etas INCA and more...

A freely distributable Excel add-in assists with data presentation and produces contour plots / waterfall animations to share with colleagues.



Traceable calibration

The DMS500 is traceably calibrated for size against standard PolyStyrene Latex (PSL) spheres and with a Differential Mobility Analyser (DMA) using a variety of representative aerosols including real soot and volatile sulphuric acid.

A traceable standard electrometer is used for number calibration using a methodology similar to that recommended for condensation particle counter (CPC) calibration.

Traceable calibration certificates are provided.

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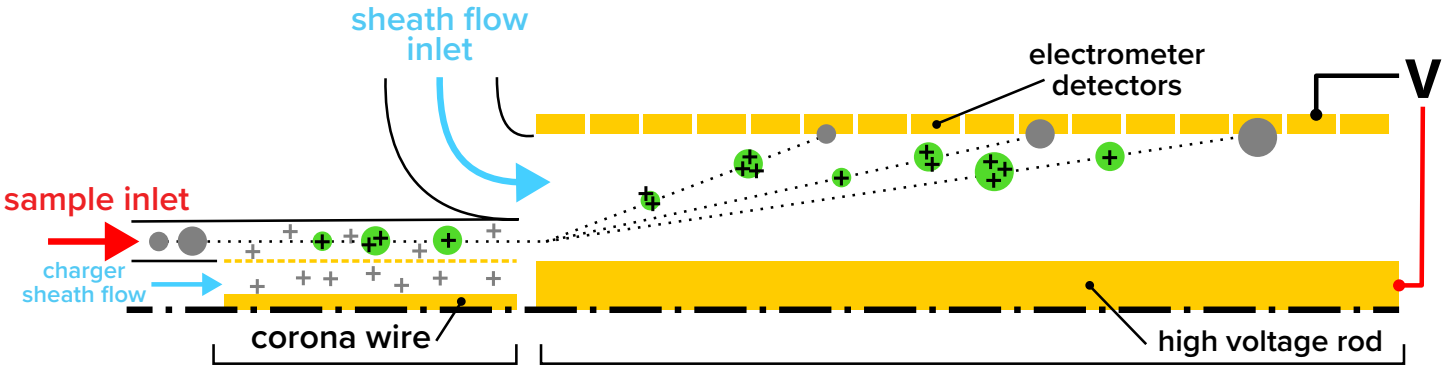


DMS500 Measurement principle

The DMS500 uses a controlled corona discharge to charge incoming particles.

Charged particles are introduced into a classifier with a strong electrical field. The electrostatic force experienced by the charged particles is perpendicular to the flow field and drives them towards the electrometer detectors as they are carried along the classifier.

The speed with which a particle traverses the gap depends on its charge:aerodynamic drag ratio, i.e. its electrical mobility.

Charged particles therefore land on the electrometer detectors at various locations down the classifier, depending upon their electrical mobility.

When a charged particle lands, the charge passes through the electrometer, and the current measured is proportional to the number of particles landing per second.

Data from the 22 electrometer detectors are processed in real-time at 10Hz to provide size and concentration data.

To view an animation visit: **cambustion.com/dms**

The DMS500 operates at a fixed pressure to eliminate any concern about pressure correction algorithms. The sample passes 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.

Fastest available time response

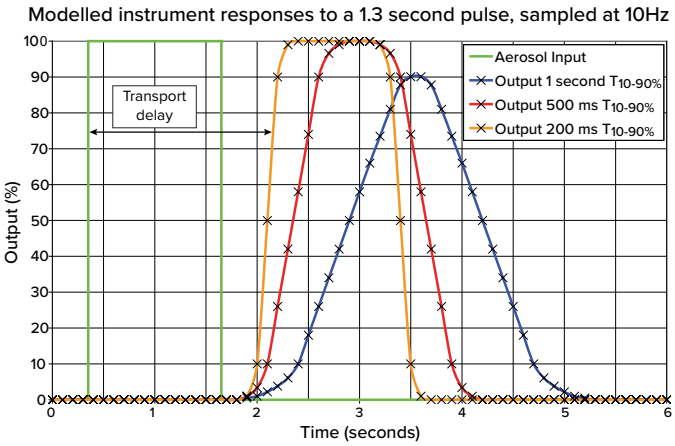
The DMS500 remains the fastest available nanoparticle sizer with a data rate of up to 10Hz.

Data can always be oversampled, however data logging at 10Hz does not yield useful information on events lasting less than 1 second unless the response of an instrument to a step change in concentration ($T_{10\text{-}90\%}$) is significantly faster than 1 second.

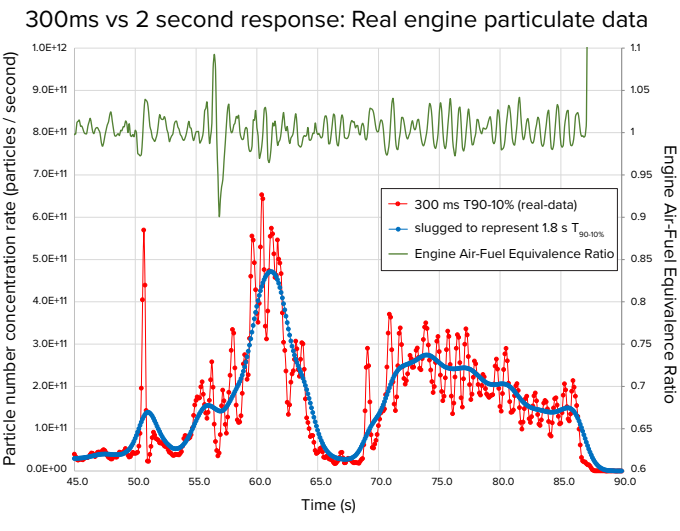
Unique design means that the DMS500's response to a step change in concentration ($T_{10\text{–}90\%}$) is ~200ms, or ~300ms with a 5m sample line and CSA.

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

The graph below illustrates the effect of instrument time response on the ability to resolve a short lived event - with an event duration of 1.3 seconds, a time response significantly faster than 1 second is required to make a true measurement.



The 1 second $T_{10\text{-}90\%}$ data fails to resolve the true maximum concentration.



The above graph shows that only with a 300ms $T_{10\text{-}90\%}$ response are the effects of lambda control resolved — the 1.8s $T_{10\text{-}90\%}$ response does not identify important features, despite an identical data sampling rate.

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DMS500 Mk2 background

The Cambustion DMS500 was the world's first production realtime nanoparticle sizer, introduced in 2002. Now in its second generation, the DMS500 has been adopted as the particulate instrument of choice at research labs, universities and the majority of vehicle OEMs worldwide.

The DMS500 has undergone over 20 years of development as engine testing requirements have evolved; incorporating enhancements such as enhanced sensitivity, a flexible dilution system and a catalytic stripper to support Euro 7 PN projects.

Designed with engine test bench applications 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.

The DMS has been carefully optimised, ensuring inexperienced users can readily operate the instrument and gather relevant data.

Unique and powerful data summary features allow users to easily acquire the output data they need whilst still having access to the full particle size distributions.

The integrated sampling system allows sampling at any point between the exhaust valve and the CVS tunnel, enabling studies of engine and aftertreatment performance.

The DMS500 employs technology described by the following patents: GB2,374,671, GB2,378,510 & US6,828,794.

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Specifications:

Particle size range	5nm – 1µm (5nm – 2.5µm option)
Calibration metric	Electrical Mobility
Dilution factor range	1:1 – 1:3000
Heated sample line	7, 5 or 2 metres length
Maximum 1st dilution and Heated line temperature	191°C
Sample conditioning	Optional catalytic stripper for volatile particle removal
Roll off function / "cut" (software selectable)	23nm d_{50} for Euro 6 10nm d_{50} for proposed Euro 7 no cut for development
Minimum sample pressure	600mb
Maximum altitude	4,200m / 13,000ft
Sample flow rate	8slpm (1µm range) at 0°C & 100kPa
Instrument dimensions / weight	98h x 38w x 52l cm 80Kg
External pump dimensions / Weight	48h x 33w x 45l cm 46Kg
Analogue outputs	4 @ 10 Hz; software configurable
Analogue inputs	4 @ 10Hz; software configurable
Stabilisation time	30 minutes from switch on
Spectral elements	16 or 32 / decade
Output data rate	10/sec – 1/min
Time response: DMS500 DMS500 with 5m line & CSA	$T_{10\text{-}90\%}$ 200ms $T_{10\text{-}90\%}$ 300ms
Service / calibration interval	12 months
Max inlet concentration	1 x 10^{11} N/cc

PC interface	Ethernet
Calibrations: Spherical: Soot agglomerate:	By NIST traceable PSL spheres & DMA size-selected NaCl / H_2SO_4, comparison with standard electrometer DMA size-selected soot, comparison with standard electrometer
Remote control & data acquisition	AK protocol over Ethernet Data logged to local hard disk
Controlling computer	Windows laptop or desktop

Services Required:

Electrical Supply	110-115 / 220-240 V AC 50/60Hz 1,500W (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	12mm internal diameter pipe
Internet connection (recommended)	For remote technical support

Sensitivity (RMS at 1 Hz):

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

All specifications subject to change without notice

Local agents / distributors:

China: li.qiang@cambustion.com

France: arnaud@lvmair.fr

Germany & Austria: office@ms4.info

India: info@tesscorn.com

Cambustion

To learn more, visit:

cambustion.com

or contact: support@cambustion.com

Global HQ | UK

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

Tel. +44 1223 210250
US & Canada: 1-800-416-9304

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