CAMBUSTION CPMA

Centrifugal Particle Mass Analyzer

Bench-top instrument for classification of aerosol particles by mass : charge ratio

An aerosol particle mass standard for instrument calibration

Determination of particle density and morphology

No loss of mass accuracy at smaller particle sizes

Higher particle throughput at high resolution due to unique design

Introduction

The Cambustion Centrifugal Particle Mass Analyzer (CPMA) is an aerosol classifier which selects particles according to their mass : charge ratio. It produces a monodisperse aerosol based on a mass metric, compared with a DMA which uses an electrical mobility metric.

The CPMA uses opposing electrical and centrifugal force fields to classify aerosol particles, a concept first developed by Ehara *et al.* (J. Aerosol Sci. 1996).

The CPMA's unique design ensures that the classification field is stable across the classification zone, thereby ensuring a high throughput of particles at the selected mass : charge ratio, even at high resolution.

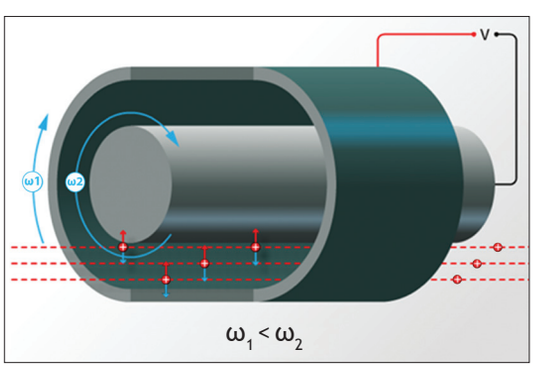
The CPMA was originally conceived by Cambustion in 2004. Since then, through collaboration with the Universities of Cambridge and Alberta, prototype devices have been used in several studies (see reference list).

Following strong customer demand, the CPMA is now part of our aerosol instrumentation range.

Operating Principle

The CPMA's classifier consists of two concentric rotating cylinders, with a variable potential difference between them. Particles which have a higher mass : charge ratio than that selected precipitate on the outer cylinder. Particles which have a lower mass : charge ratio than that selected precipitate on the inner cylinder. Particles which have the selected mass : charge ratio follow a trajectory through the classifier.

Crucially and uniquely to the CPMA, the cylinders may be rotated at slightly different speeds. If the cylinders rotated at the same speed, only particles of the correct mass which also enter along the central trajectory would emerge.



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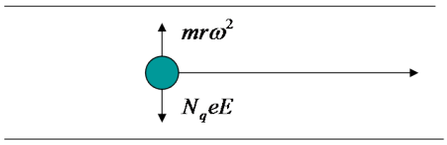
The difference in rotation speed sets up a *stable* centrifugal/electric field across the classification region. A particle of the correct mass:charge ratio will therefore transit the classifier if it enters at any point along the annular radius. This reduces particle losses in the CPMA, even at high resolution.



$$\frac{m}{N_q} = \frac{eV}{r^2\omega^2 \ln\left\{r_o / r_i\right\}}$$

The CPMA is a fundamental standard for particle mass — provided particles are singly charged, the mass setpoint depends on just the set speed and voltage, and the physical dimensions of the classifier. Unlike a DMA, the setpoint does not depend upon the gas properties (such as viscosity and mean free path) or ambient conditions (temperature and pressure), and furthermore is not affected by particle morphology.

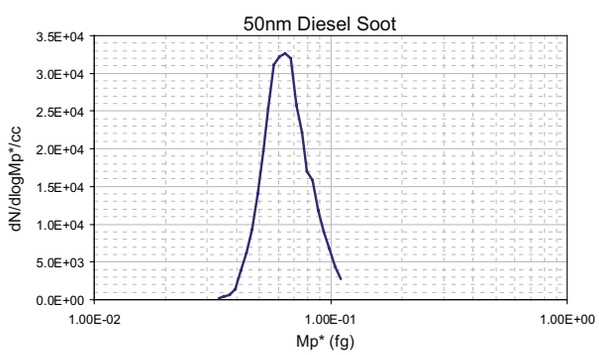
Applications

Monodisperse aerosol selection

With the addition of a neutralizer (or charger), the CPMA may be used as an alternative to a DMA to select a monodisperse aerosol — with high resolution.

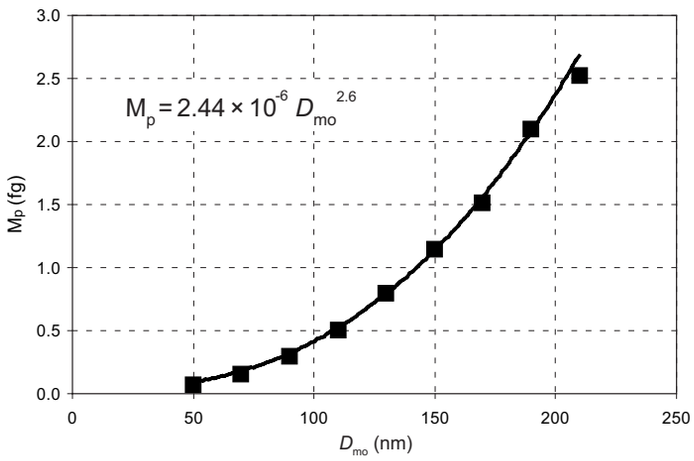
Mass spectral density scan

Add a particle counter (e.g. a CPC or aerosol electrometer), and the mass spectral density may be step-scanned (offline multiple charge correction is required).



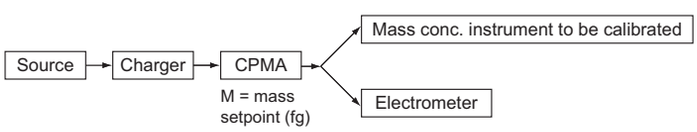
Density and morphology determination

In conjunction with a DMA, it may be used to determine the relationship between size and mass for an aerosol (fractal dimension), thus giving information about particle morphology [e.g. Olfert, Symonds & Collings, 2006]:



As a calibration standard

The CPMA may be used as a calibration standard for other instruments such as aerosol mass spectrometers or black carbon detectors [e.g. Cross *et al.*, 2010]. In combination with a charger and an aerosol electrometer, it may be used as a suspended mass standard [Symonds *et al.*, 2011]:

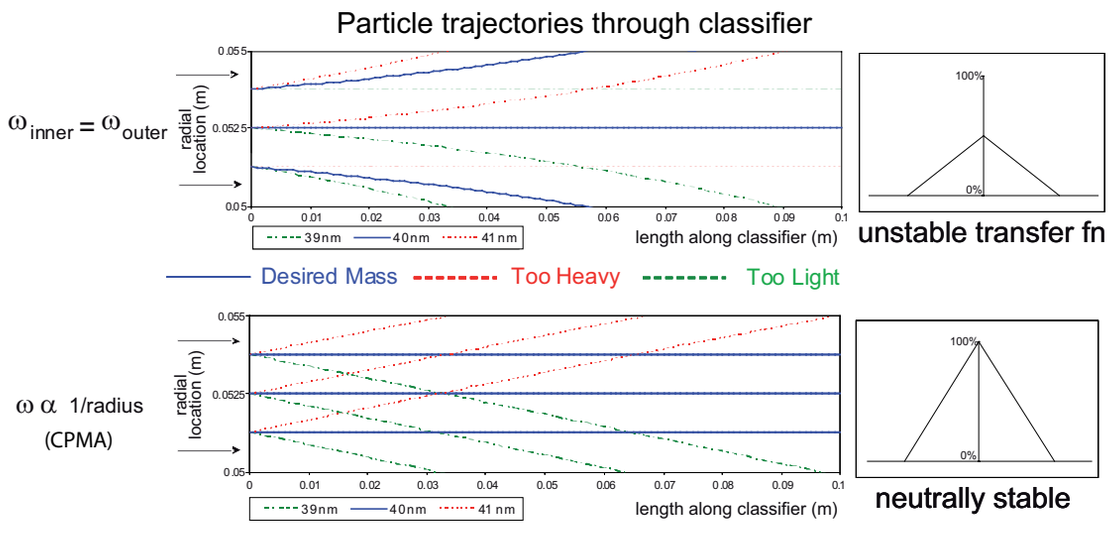


m_{total} = mass *setpoint* × indicated electrometer *concentration* + zero charge correction

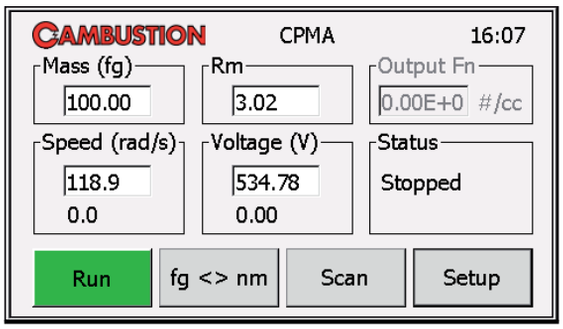
Using this arrangement, it is only necessary to correct for uncharged particles, and these can be minimized by the use of a unipolar charger. The user interface can directly give a fg/cc output when combined with an electrometer.

Software

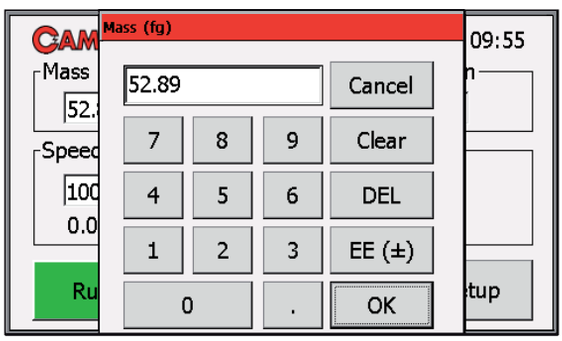
The CPMA is a self-contained bench-top instrument with touch-



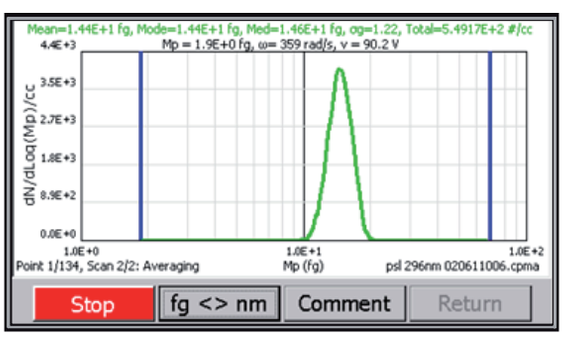
screen interface:



As with most commercial DMAs, the user can directly enter the desired setpoint (in mass or size metrics) and resolution, and the instrument is automatically controlled to give those settings. If a density is supplied, it is simple to switch between mass and size metrics.

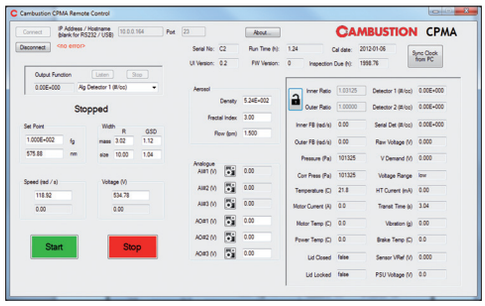


Step-scanning can be performed directly from the instrument, with data being saved to a (supplied) USB flash memory drive:



The CPMA can scan the voltage alone, or both voltage and speed simultaneously which maintains a constant resolution over the scan.

The CPMA is also supplied with PC software including a remote control application, Excel tools for plotting data, and an Application Programming Interface library which allows control of the CPMA from your own programs. An example Excel/VBA project is included to allow automated mass-mobility exponent determination by controlling the CPMA, and a DMA (via an analogue output of the CPMA), with the data automatically scanned into an Excel workbook. The CPMA front panel interface can also be viewed and controlled via a web browser on a device connected to the same network. A remote file access facility allows data files to be accessed via a web browser.

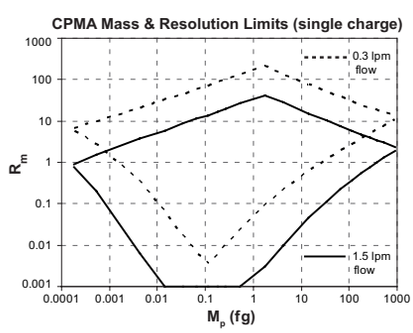


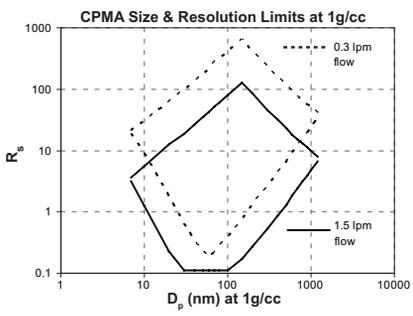
Advantages

- Reduced particle loss due to unique cylinder speed differential
- No loss of mass accuracy at smaller particle sizes
- Stand-alone bench-top instrument with fully integrated touch screen interface, and built-in scan facility
- Simultaneous scanning of speed and voltage for maintenance of a fixed resolution over a scan (or fixed speed scan for increased scan speed)
- Direct entry of mass and resolution; automatic calculation of required speed and voltage
- Sophisticated remote control options, including integration with Excel and user programs; powerful Application Programming Interface
- Highly configurable analogue inputs and outputs
- A direct interface with particle detectors (serial and analogue interfaces)
- Auto-switching dual-range voltage source

Specifications

The absolute limits on the operation range of the CPMA are within the bounds on the diamond shaped areas below, depending on the sample flow:





where : R_m = mass resolution = $\Delta M_{p,FWHM} / M_p^*$

R_s = size resolution = $\Delta D_{p,FWHM} / D_p^*$

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Mass range	0.2 ag* – 1,050 fg (depending on sample flow and desired resolution)
Equivalent diameter range at unit density	7 nm* – 1.3 µm (depending on sample flow and desired resolution)
Rotational speed	500 – 12,000 rpm
Voltage range	0.1 – 1,000 V (auto-switching dual range: 0.1 – ~ 10 V ~10 – 1,000 V)
Classifier dimensions	200 mm × 120 mm (1 mm gap)
Usual sample flow	0.3 – 1.5 lpm (higher flow possible at lower resolution)
Detector input (e.g. for CPC — detector not supplied)	RS232† (×1) or analogue (×2)
Remote external PC interface	Ethernet or RS232† or USB (with supplied adapter) Control via Java web interface, text commands (terminal) or via PC remote application (or user software via API). Remote file access.
Analogue inputs	× 3; ±10 V, 20 kΩ, single ended, configurable for control of any parameter, detector input or data logging
Analogue outputs	× 3; ±10 V, 50 Ω, single ended, output of any parameter, control of DMA voltage
Mass accuracy	5% or better (across the whole size range)
Ambient sensors	Temperature and Pressure
Software supplied	Integrated touchscreen interface Remote control application API dll for user programs Excel Utility and VBA API
Data storage	USB flash memory drive (supplied)
Motor control system	4-quadrant type with active braking
Overall Dimensions & Weight	520 mm w × 460 d × 380 h (inc. feet / handles). 50 kg
Power requirements	90 – 240 VAC, 50/60 Hz, 1,000 W maximum
Auxiliary power out	24 VDC at 0.6 A
Safety features	Guards, full interlocks, overcurrent / short circuit detection & imbalance detection, to BS EN 61010-020:2006

*Note that, as with all particle instrumentation, at smaller particle sizes some diffusion loss is inevitable.

†RS232 port can be used for either detector connection *or* remote control.

Integration with other aerosol equipment (not supplied)

Particle Charger or Neutralizer

Bipolar or unipolar (depending on application); radioactive, X-Ray or corona.

Particle Detector(s) (e.g. CPC or electrometer)

The CPMA can interface with any detector with an analogue output connection, or to most detectors with an RS232 interface, provided that the concentration is returned in text (ASCII) form in response to a simple text command (e.g. "RD").

Differential Mobility Analyzer (for density measurements)

The CPMA can set the voltage of many DMAs via analogue control (if supported by the DMA).

Reference list

A full list of publications which have already made use of CPMA prototypes can be found at:

www.cambustion.com/publications/cpma

Some of these are given below:

• *New Method for Particle Mass Classification - the Couette Centrifugal Particle Mass Analyzer.* J.S. Olfert & N. Collings, J. Aerosol Sci. **36** (11) pp 1338–1352 (2005)

• *The Effective Density and Fractal Dimension of Particles Emitted from a Light-duty Diesel Vehicle with a Diesel Oxidation Catalyst* J.S. Olfert, J.P.R. Symonds & N. Collings, J. Aerosol Sci. **38** (1) pp 69–82 (2007)

• *Density of Particles Emitted from a Gasoline Direct Injection Engine*. J.P.R. Symonds *et al*., *European Aerosol Conference*, Thessaloniki, **T08A017P** (2008)

• *Soot Particle Studies - Instrument Inter-Comparison-Project Overview.* E.S. Cross *et al.*, *Aerosol Science and Technology* **44** pp 592–611 (2010)

• *The Detection Efficiency of the Single Particle Soot Photometer.* J.P. Schwarz *et al*., *Aerosol Science and Technology* **44** pp 612–628 (2010)

• *Mass Measurements with a High-Resolution Particle Mass Classifier.* J.S. Olfert *et al*., *American Association for Aerosol Research Conference*, Portland (2010)

• *Behaviour of Non- and Multiply-Charged Aerosols in the Centrifugal Particle Mass Analyzer*, J.P.R. Symonds *et al*., *American Association for Aerosol Research Conference*, Orlando (2011)

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For more information, a quotation or to see an animation of the CPMA, please visit or contact:

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