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## PMP - Automotive Condensation Particle Counter (CPC) Model 5.430

### Highlights:

- ✓ Single particle counting up to 100,000 particles/cm<sup>3</sup>, up to 20,000 particles/cm<sup>3</sup> with coincidence correction < 10%
- ✓ Counting accuracy ±10%
- ✓ Linearity: R<sup>2</sup> ≥ 0.98 for 1 to 20,000 particles/cm<sup>3</sup>
- ✓ Counting efficiency within 50 ± 12% at 23 nm and ≥ 90% at 41 nm
- ✓ Fast response time T90 < 3 seconds
- ✓ Butanol safety features (anti-spill, odor removal, saturator shutter)
- ✓ Monitoring of peak height assures highest data quality

### Applications:

- ✓ Engine emissions for Euro 5 certification
- ✓ Testing of Diesel particulate filter
- ✓ Particle counter in dilution systems
- ✓ High resolution concentration time series in driving cycles

### High accuracy stationary particle counter for automotive emission measurements

in compliance with the GRPE particle measurement program (PMP) for EURO 5 Regulation 83.



- The GRIMM model 5.430 Condensation Particle Counter (CPC) was developed to measure Diesel emissions according to the EURO 5 Regulation 83.
- In addition to the already well established condensate removal and anti-spill saturator design <sup>1)</sup> this unit features a novel saturator shutter, which enables the transport of the CPC without the need for removing or drying the saturator.
- This full flow CPC contains several design improvements for the automotive user, such as a fast response to concentration changes (T90), and easy maintenance.
- Due to its rugged design the model 5.430 can be easily incorporated into test racks for Euro 5 compliance testing.

<sup>1)</sup> first introduced by GRIMM Aerosol Technik

## System Description

### Measuring Principle

The sample air is continuously drawn into the CPC and saturated with Butanol vapour in the heated saturator chamber. Then, aerosol particles and Butanol vapour pass through the cooled condenser unit, where the Butanol vapour condenses on the particles that act as condensation nuclei. This process increases the size of each individual nanoparticle to approximately  $10\ \mu\text{m}$ . Such large droplets can be conveniently detected by light scattering.

Unlike other models, CPCs for PMP measurements are operated with a reduced difference between saturator and condenser temperature. As result the minimum detectable particle size ( $D_{50}$ ) is increased to  $23\ \text{nm}$ , which means that such a CPC only counts carbonaceous particles with a solid core but not the undesired smaller volatile particles.

*Within the self tests, the CPC also supervises the size of the Butanol droplets to ensure a proper condensation process.*

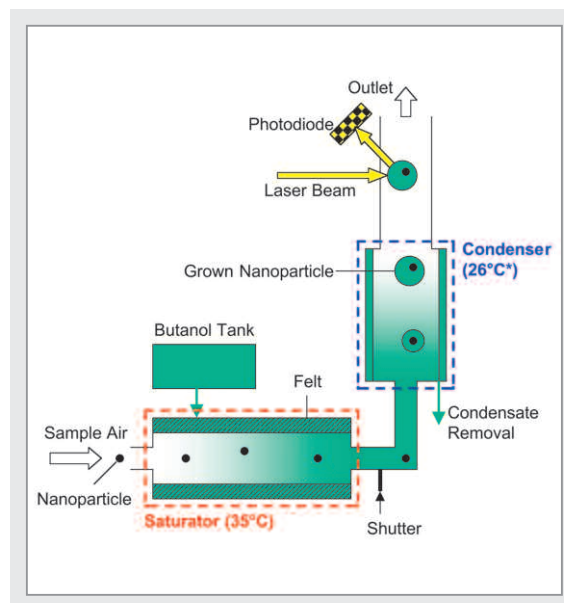
Light scattering works in such a way that the droplet enters the laser illuminated optical volume. Each droplet passing the laser beam generates scattered light that is collected with a mirror onto a photodiode at  $90^\circ$  scattering angle. The signal is converted to an electrical pulse and counted.

Each particle is counted individually (single count mode) while the complete flow of the sample air ( $0.6\ \text{L/min}$ ) is used for the detection of particles (full flow sampling). The flow rate is controlled with differential pressure sensors across a temperature-controlled orifice.

The measured concentration is transmitted online to the computer via the USB interface.

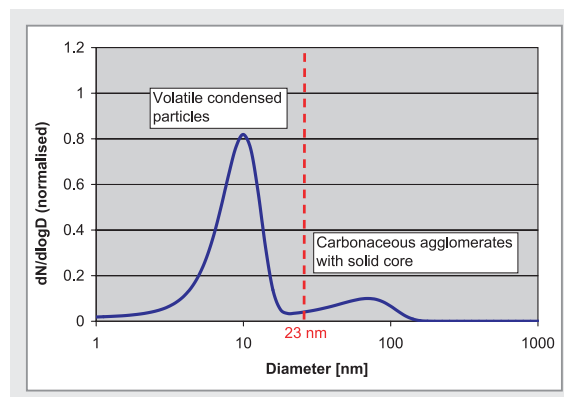
### Calibration

Every GRIMM model 5.430 is carefully tested to guarantee full compliance with PMP regulation. During calibration the candidate CPC is operated in parallel with a Faraday Cup Electrometer (FCE) that serves as a primary reference. Both counters - candidate CPC and reference FCE - are supplied with identical concentra-



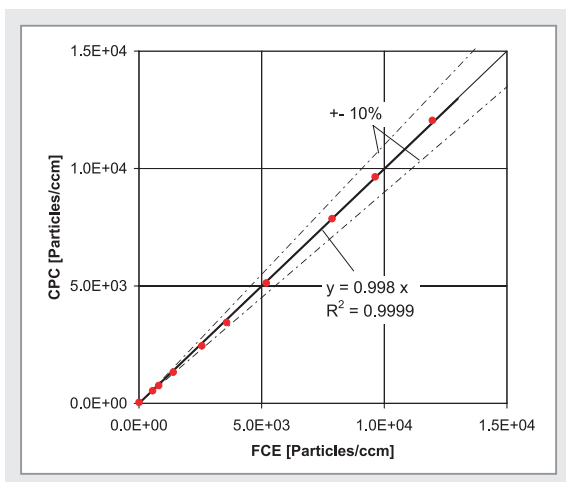
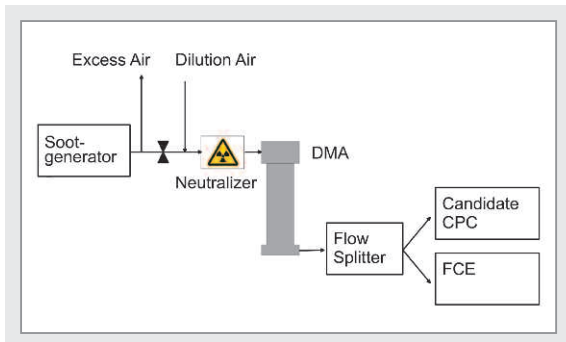
Schematic of a thermal diffusion – laminar flow CPC.

\* Condenser temperature is continuously adapted to ambient pressure.



Number size distribution of Diesel engine exhaust (reproduced from Kittelson 2004). A PMP-CPC must only count carbonaceous particles with solid core, i.e. particles larger than  $23\ \text{nm}$ .

# Calibration and Complete Emission Test System

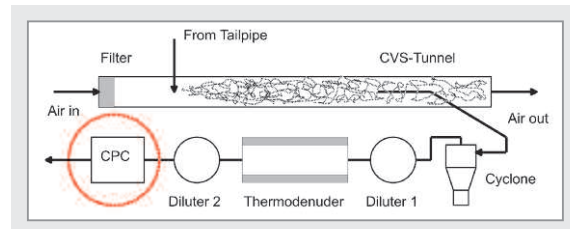


Setup and results for the **calibration of the CPC model 5.430**.

Number concentrations measured by the CPC are then evaluated against the concentrations measured by the reference FCE. The graph above shows the excellent correlation between CPC (y-axis) and FCE (x-axis).

## PMP Measurements

Most often the GRIMM model 5.430 PMP-CPC is used as a detection system in combination with an engine exhaust dilution system. The typical setup consists of a CVS tunnel (measurements directly from the tail pipe are possible as well), a cyclone to remove the main fraction of coarse particles, and a two stage dilution system with the removal of volatile compounds in a thermodenuder.



The CPC in the complete setup for PMP measurements.

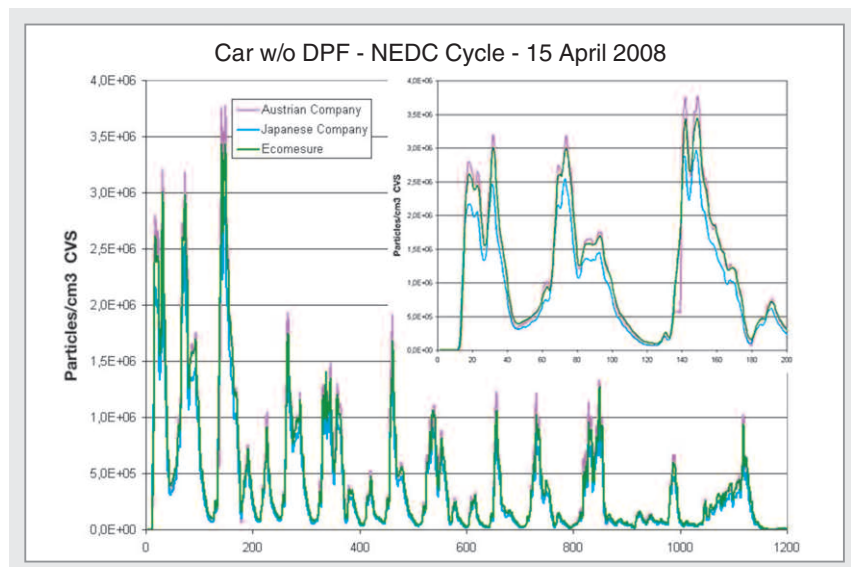
If you are interested in a **complete emission test system**, please contact GRIMM as well.



Courtesy of Ecomasure, France

Above: Example of a complete PMP rack with CVS tunnel in the back

Right: Data from the official test at UTAC (homologation laboratory of French Transport Ministry) in April 2008. Note: Ecomasure used the Grimm PMP-CPC, the other two participants used TSI.



## Specifications

### Model 5.430 Stationary Condensation Particle Counter for Automotive Applications

THE alternative to the TSI Model 3790 Engine Exhaust Condensation Particle Counter

#### Particle Detection <sup>1)</sup>

Concentration Range	0 – 20,000 particles/cm <sup>3</sup> (single particle counting with coincidence correction < 10%)
Concentration Accuracy	Better than ± 10%
Concentration Linearity	R <sup>2</sup> ≥ 0.98 for 1 to 20,000 particles/cm <sup>3</sup>
Counting Efficiency at 23 nm	50 ± 12%, independent of altitude above sea level
Counting Efficiency at 41 nm	> 90%, independent of altitude above sea level
Response Time	T90 ≤ 3 seconds
False Background Counts	Less than 0.001 particles/cm <sup>3</sup>
Readability	0.1 particles/cm <sup>3</sup>

#### Liquid System

Working Fluid	1-Butanol (Reagent-grade p.A.)
Condensate Removal	Continuous drain with a micro-pump into drain bottle

#### Air Flow System

Sample Flow Rate	0.6 L/min (0.021 cfm)
Pump	Optional internal pump or external vacuum source
Flow Control	Volumetric flow through temperature stabilised critical orifice
Suited Aerosol Carrier Gas	Air and inert gases

#### Communications

RS-232	9-pin D connector
Data Output	ASCII based command set
Status Indication	4 LEDs with 3 colors
Software	Optional GRIMM 5.475 Windows software

#### Operating Conditions

Ambient Temperature	10 to 40°C (41 to 104°F)
Ambient Humidity	0 to 95% RH, noncondensing
Ambient Pressure	60 to 105 kPa
Power Requirements	<150 W max. with pump 85-264 VAC wide range power supply, 47-440 Hz, or 120-370 VDC
Dimensions (H x W x D)	22.6 x 25.4 x 22.3 cm (8.9 x 10.0 x 8.8 in)
Weight	9 kg (20 lbs) including pump

<sup>1)</sup> Calibration is performed with soot particles from a Combustion Aerosol Standard (CAST) against a reference Faraday Cup Electrometer (FCE) with classified particles from a Differential Mobility Analyzer.

Further information is available upon request.

#### Publications

ECE / TRANS / WP. 29 / 2008 / 62, 10. April 2008  
ED 4738 / 2004 / PNC - Issue 5 by AEA Energy & Environment  
B. Giechaskiel et al. 2008. Calibration of PMP Condensation Particle Number Counters: Effect of material on linearity and counting efficiency, LB NA 23495 EN C

Just give us a call or visit our website.

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