FEATURES AND ADVANTAGES OF A NEW ENGINE EXHAUST CONDENSATION PARTICLE COUNTER (EECPC), TSI MODEL 3790

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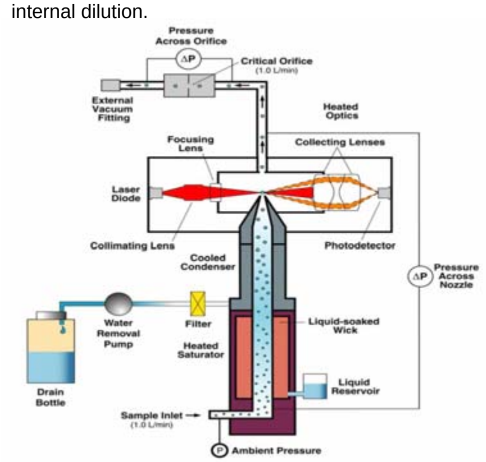
Introduction

The UNECE GRPE Particle Measurement Programme (PMP) recommended that a **Particle Number Counter (PNC)** shall be used to measure the particle number (PN) concentration of diesel exhaust emissions to complement mass-based measurements (GRPE-PMP-17-1). Following this recommendation, the European Commission proposed to add a PN limit value to its Euro 5 Regulation 83 for light-duty diesel vehicles, effective in the fall of 2009. A new PNC has been developed to fulfill all requirements of this regulation. The EECPC Model 3790 is based on the rugged and highly repeatable performance of the CPC 3010D, with several improvements and new performance features.

Principle of Operation

The EECPC Model 3790 is a continuous-flow condensation particle counter (CPC). Supersaturated butanol vapor is used to optically enlarge single particles for detection and counting. In accordance with PMP, the EECPC 3790 uses a full-flow design and no internal dilution.



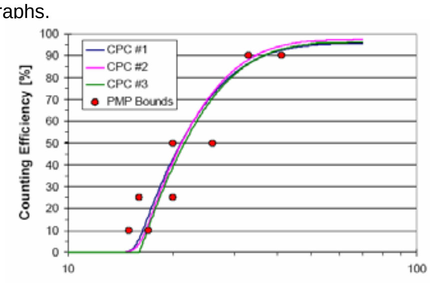
Schematic Diagram of the EECPC 3790

Technical Requirements

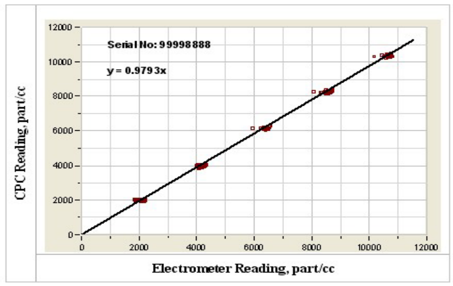
The most important technical requirements for the PNC that must be met are PN concentration range, particle detection efficiency, and linearity response:

Concentration range: 0 to 10,000 particle/cm^3
Detection efficiency: 50% (± 12%) at 23 nm, better than 90% at 41 nm
Linearity response: R^2 >0.97, relative error < ±10% against primary standard

The EECPC Model 3790 fully meets these key requirements, as is demonstrated by the following graphs.



PMP Bounds and Counting Efficiency Curves of Three EECPC's (calibration according to Liu et al.)



Linearity Response Compared to a Reference Electrometer

Coincidence Correction

PMP further specifies that the PNC shall not make use of an algorithm to correct or define the counting efficiency, but shall incorporate a coincidence correction function.

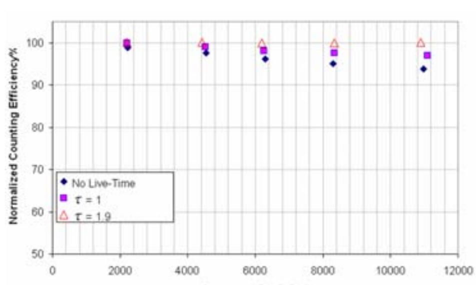
In all single particle counting instruments there is a fraction of time during which the detector is occupied, and no other electronic signals can be processed. During this non-detecting time, additional particle events can not be captured.

In order to accurately represent the concentration of particles, this non-detecting time must be subtracted from the sample time, and the resulting 'live-time' must be used in the concentration calculations. The live time processing can also be interpreted as a first order coincidence correction. In the EECPC, the electronic dead time is measured ten times per second. An experimentally determined dead time scaling factor corrects for pulse shape effects:

$$t_{live} = t_{sample} - (t_{dead} \times \tau)$$

t_{live} electronic 'live-time'
t_{sample} sample time
t_{dead} electronic 'dead-time', measured every Δt = 0.1 s in the EECPC
τ dead time scaling factor, experimentally determined (τ = 1.9)

$$C_D = \frac{\Delta N}{V} \times \frac{\Delta t}{t_{live}} = \frac{\Delta N}{Q \cdot \Delta t} \times \frac{\Delta t}{t_{live}} = \frac{\Delta N}{Q \cdot t_{live}}$$



EECPC Live-Time Processing, Example for 55 nm Particles

Improvements and New Features

Precisely Controlled Operating Temperatures
Temperatures of the condenser, saturator, and optics are measured and controlled using feedback circuitry to ensure reliable operating performance.

Condensate Removal Function
Eliminates build-up of condensed water in the butanol to ensure reliable operating performance.

Anti-Flooding Design
Prevents optics flooding in the event that the EECPC inlet is temporarily blocked for a few seconds.

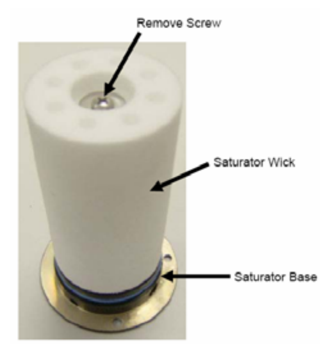
Inlet Pressure Measurement
The EECPC can operate at inlet pressures in the range of 75 to 105 kPa. The inlet pressure is measured by an absolute pressure sensor.

Accurate Flow Control
A critical orifice is used to accurately control the flow. Problems with the aerosol flow are detected by monitoring the pressure drop across the nozzle.

USB and Ethernet Communications
The Model 3790 provides serial & USB communication and an Ethernet port for network connection.

Built-in Data Logging Capabilities
A removable Flash Memory SD Card can be used to store data (e.g. particle concentration and analog input data).

Removable Saturator Wick
The newly designed saturator wick is removable from the bottom panel of the instrument without opening the instrument cabinet.



Summary

The EECPC 3790 is a new designed particle number counting instrument that fulfills all requirements specified in the current proposal for the Euro 5 Regulation 83. The Model 3790 offers important improvements over the CPC 3010D that was previously used for measuring diesel emissions and many new features that make it very reliable and easy to use.

References

GRPE-PMP-17-1 (working paper), Suitability of Particle Number Measurement For Regulatory Use, 2006

Liu, W., Osmondson, B.L., Bischof, O.F. and G.J. Sem, Calibration of Condensation Particle Counters, SAE Paper 2005-01-0189