

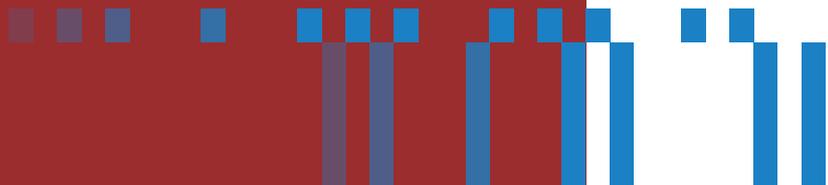


® Knowledge  
Beyond  
Measure.



# Engine Particle Emissions Measurement Solutions

An Industry Leader and Manufacturer of  
Reference Instrumentation



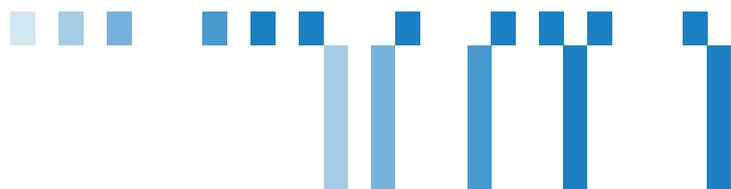
# A Reputable History of Being at the Forefront of Cutting-Edge Instrumentation Technology

For the past 20 years, TSI® has been a key developer and supplier of instrumentation solutions for measuring particulate matter emitted by automotive and heavy-duty internal combustion engines, non-road mobile and stationary machinery, aircraft engines, and marine engines with applications in the areas of:

- Engine development and research
- Type approval particle number measurements
- Engine particle characterization
- Real world field emissions

## Engine Development and Research

Engine developers, diesel and gasoline particulate filter (DPF/GPF) manufacturers, and other automotive component suppliers rely on detailed particle size and concentration data to design and optimize engines or after-treatment equipment for low-emission vehicles. At the same time, as automotive and on-road heavy-duty emissions standards become more stringent, the contribution to pollution from non-road sources such as aircraft and marine engines will continue to increase. TSI's solutions enable researchers and manufacturers to stay on the leading edge of technology to develop cleaner and more fuel-efficient engines.



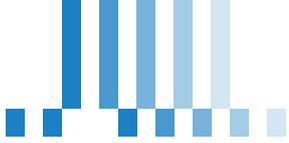


# Type Approval Particle Number (PN) Measurements

TSI® has long been the industry leader in providing condensation particle counters (CPCs) for myriad applications. In fact, it was a TSI® CPC that was considered as the standard reference instrumentation during the development of the UN-ECE-sponsored Particle Measurement Programme (PMP) Informal Group, which contributed significantly to the development of current European number-based emissions regulations. Instrumentation for type approval testing typically use TSI's Engine Exhaust Condensation Particle Counters (EECPC) as part of the complete measuring instrumentation solution used to certify a vehicle via chassis dyno measurements.

# Engine Particle Characterization

Physico-chemical characterization of the particles emitted by internal combustion engines enables researchers understand the structure, morphology, and chemical composition of the particles which influence their behavior and properties. This information can aid engine manufacturers in further reducing particle emissions, help climatologists develop models for atmospheric chemistry, or assist filter manufacturers in designing respirator filters to protect heavy equipment operators, for example. MSP® Corporation, a TSI® company, has long been an industry leader in developing and manufacturing cascade impactors for size-resolved particle sampling, with applications ranging from environmental sources and pharmaceutical aerosols to engine particle emissions.



# Real-World Field Emissions

Assessing emission levels for construction machinery, marine engines, buses, and other vehicles under realistic use conditions has quickly become a popular topic in recent news. The Nanoparticle Emission Tester (3795 NPET) from TSI® was manufactured for this application purpose, which is compliant to the non-road mobile machinery (NRMM) testing protocol defined by Swiss regulation 941.242.

For applications with extremely high particle concentrations, for example in diesel engines not equipped with DPFs, the High-Concentration NPET (3795-HC) was recently developed, and it is used to measure total solid particle concentrations upstream and downstream of engines with DPFs or GPFs, cold start emissions, or biomass combustion emissions beyond the constraints of the current Swiss regulation.

In Germany, the solid particle emissions from wood burning stoves can also be measured with the HC-NPET for meeting the requirements of the German Blue Angel certification ecolabel.

Measures in recent years to improve the representativeness of engine and vehicle testing protocols compared to real-world conditions and to identify vehicles with high emissions has led to the demand for Periodic Technical Inspections (PTI). The implementation of a PTI program for vehicles in several European countries, requires a lower cost, rugged, fast, and simple-to-use solid particle counter that can be deployed in the thousands of emission testing garages throughout these countries. The Dutch government has recently issued regulations for inspection of in-use diesel particle filters using particle number instruments, effective 1 January 2020.



# Advanced Solutions for Particle Number Measurements

## Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer

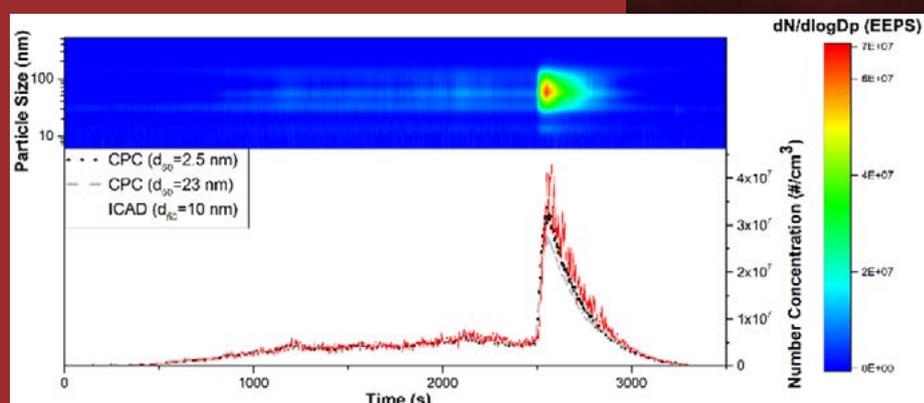
### 3090

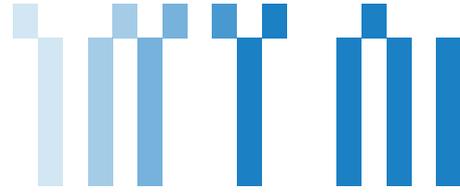
- Provides accurate, time-resolved, particle size distributions with 10 Hz time resolution and 32 channels of size resolution from 5.6 nm and 560 nm
- Measures the real-time particle number size distributions with high accuracy during transient conditions
- The EEPS™ spectrometer measurements correlate very well with those made by the more conventional Scanning Mobility Particle Sizer (SMPS) when measuring engine emissions at steady operating conditions
- Many of the major automotive companies are already using the EEPS™ spectrometer in their test cell facilities

### Application Example

As one example of its many applications, the 3090 EEPS spectrometer has been used to track the transient burst of particle emissions commonly seen during DPF regeneration (see Figure 1). Not only can the total number emissions be measured, but also the size distribution, which is essential to know for developing improved engine control strategies and after treatment devices.

Figure 1. Particle size distribution and number concentration after regeneration of DPF on a Diesel Euro 3 engine (51st PMP Meeting, Brussels, Nov 2019, Sureal23 Project)





# Porous Tube Thermodiluter (PTT)

## 3098

Upcoming post EURO 6/VI particle number regulations will demand accurate sub-23nm engine exhaust particle measurements. For this specific purpose TSI has recently introduced the Porous Tube Thermodiluter (PTT) 3098; a turn-key sample conditioning solution designed to accompany the EEPS spectrometer (see Figure 2).

The 3098 offers two independently user-adjustable dilution stages based on the porous tube diluter design (this type of diluter has been recommended by recent Horizon 2020 European projects).

A catalytic stripper sits between the dilution stages, permitting measurement of only solid particles as required by current particle number regulations.

- The system has been fully characterized for particle losses
- Comes complete with a user-friendly unified software control solution that also has AK protocol functionality for test cell integration.

Together, the 3090 EEPS and the 3098 PTT create a full turn-key system known as the model 3095 Engine Exhaust Particle Measurement System. This easy-to-use, industry-robust solution, is the ideal tool for measurement of raw engine combustion aerosols before and/or after a particle filter.

Figure 2. 3095 Engine Exhaust Particle Measurement System (3090 EEPS Spectrometer and 3098 Porous Tube Thermodiluter.)

# An Industry Leader in Providing Condensation Particle Counters (CPCs) for Myriad Applications

## Engine Exhaust Condensation Particle Counter

### EECPC 3790A

This latest-generation 3790A EECPC detects nanoparticles (as mandated by Euro 5/6 and Euro VI regulations) and is often combined with two diluters and a volatile particle remover (VPR) for making PMP-compliant solid particle number emission measurements.

## The 10 nm Version of this Engine Exhaust Condensation Particle Counter

### EECPC 3790A-10

With this new 3790A-10 version available in advance of the upcoming post UNECE Euro 6/VI legislation for cars and trucks, automotive manufacturers and supporting suppliers have the necessary tools to develop their new solutions ahead of time and before the new regulations are enforced.

The table below compares the 23 nm 3790A EECPC and the 10 nm 3790A-10 EECPC

EECPC Model	3790A	3790A-10
Purpose	PMP-compliant for current Euro 6/VI Regulations	PMP-compliant for upcoming post Euro 6/VI Regulations
Efficiency Near Cutpoint	50% ± 12% at 23nm	65% ± 15% at 10nm
Efficiency Plateau	> 90%	> 90%
Concentration Range	0 to 1x10 <sup>4</sup> particles/cm <sup>3</sup>	0 to 5x10 <sup>4</sup> particles/cm <sup>3</sup>
Concentration Accuracy	± 10% at ≤ 1x10 <sup>4</sup> particles/cm <sup>3</sup>	± 10% at ≤ 5x10 <sup>4</sup> particles/cm <sup>3</sup>
Response Time	< 5s (~3s)	< 5s (~3s)
Aerosol Flow Rate	1000 cm <sup>3</sup> /min	1000 cm <sup>3</sup> /min



# Impactors for Size-Resolved Particle Sampling

## NanoMOUDI™ Impactor 125R

- Used to identify key molecular markers that allows for discrimination of particles according to their source, including providing information on fuel and lubricant usage, engine size, and engine operating regime
- Size-segregated particle samples can be collected in 13 size fractions between 10 nm and 10  $\mu\text{m}$ , for subsequent physical and chemical characterization
- This system has been used in the HORIZON 2020 project PEMS4Nano focused on the development of portable devices, to detect particles down to 10 nm for Real Driving Emission applications



# Real-World. Field Emissions. Trusted Measurements.

## Nanoparticle Emission Tester

### NPET 3795

This rugged, portable instrument, is used to assess emission levels under realistic conditions for: construction machinery, marine engines, buses, and other non-road engines.

- Free-measurement mode to enable continuous number concentration measurements
- Features a test cycle mode, which is compliant to the non-road mobile machinery (NRMM) testing protocol defined by Swiss regulation 941.242
- Approved for verifying compliance with Swiss regulation SR 747.201.3 for marine diesel engines equipped with particulate filters
- Operates safely down to  $-10^{\circ}\text{C}$  and up to 3,000 m altitude
- Due to its degree of sensitivity, it enables detection of elevated number concentrations caused by small cracks or leaks within diesel particle filters, which cannot be detected using conventional opacimeters

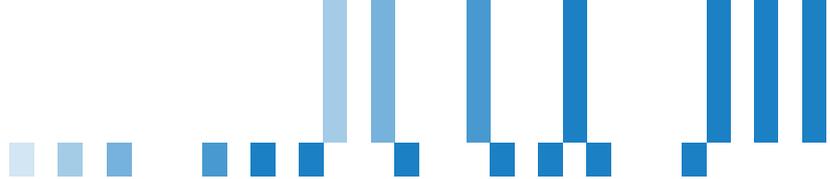
## High-Concentration Nanoparticle Emission Tester

### NPET 3795-HC

For applications with extremely high particle concentrations, for example in diesel engines not equipped with DPFs, the 3795-HC is the instrument of choice.

- Measure up to 100 million particles per cubic centimeter
- Measure total solid particle concentrations upstream and downstream of engines with DPFs or GPFs, cold start emissions, or biomass combustion emissions beyond the constraints of the current Swiss regulation
- Measure solid particle emissions to enable manufacturers to develop new solutions ahead of time and before new regulations are enforced.
- Measure solid particle emissions from wood burning stoves (meeting requirements of the Blue Angel certification ecolabel)





## Periodic Technical Inspections (PTI)

Since 2016, TSI® has been working with a group of scientists and policy makers from Switzerland, Germany, Belgium and Netherlands to develop a new solution for upcoming PTI programs. The motivation for this new instrument was to have a tool for rapidly verifying if DPFs are performing adequately during the life cycle of the vehicle and, additionally, to identify high-polluting vehicles with defective DPFs.

Please refer to table below to determine the appropriate TSI® instrument based on your specific application requirements:

Measure with:	EEPMS 3095 (EEPS™/PTT)	NPET 3795-HC	NPET 3795
Application	Research and Development	Non-road mobile machinery and marine diesel engines. METAS approved	Pre/post DPF/GPF PN measurements
Size Resolution	32 size intervals (16 channels per decade)	N/A	N/A
Particle Size Range	5.6 nm to 560 nm	23 nm to 1 µm	23 nm to 1 µm
Concentration Range	>1x10 <sup>4</sup> particles/cm <sup>3</sup> @ 10:1 dilution to 1x10 <sup>9</sup> particles/cm <sup>3</sup> @ 500:1 dilution	1,000 to 5x10 <sup>6</sup> particles/cm <sup>3</sup>	2,000 to 1x10 <sup>8</sup> particles/cm <sup>3</sup>
Dilution Ratio	10 to 500 (user adjustable)	10 (fixed)	200 (fixed)
Time Resolution	10 Hz	1 Hz	1 Hz
Volatile Particle Remover	Catalytic Stripper	Catalytic Stripper	Catalytic Stripper

Solid Particle Counting and Sizing Systems available from TSI



Learn more at  
**[tsi.com/engineemissions](https://www.tsi.com/engineemissions)**

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