WHITEPAPER

THE FUTURE OF PARTICLE NUMBER MEASUREMENT

PRECISE, LOW-MAINTENANCE AND EURO 7-READY

MAHA

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The future of particle number measurement
Precise, low-maintenance and Euro 7-ready

Version 1.02
Date 10. March 2026
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Disclaimer

This white paper has been created on the basis of sound scientific findings, regulatory specifications and practical experience in exhaust gas measurement technology. **MAHA** has long-standing **global experience** in the development and implementation of **testing technologies used in Periodic Technical Inspection (PTI)** and is established as a leading supplier of test benches and exhaust gas measurement systems in many countries across the world.

The information in this document reflects **current developments in particle number (PN) measurement** and provides a comprehensive overview of **measuring methods, legal requirements and technological challenges**. The experience gathered from **thousands of testing systems installed all over the world**, not only in PTI but also in **vehicle development and emissions monitoring**, constitutes an essential basis for the analyses presented here.

For decades, MAHA has been a reliable partner for authorities, testing bodies, research institutes and workshops. The company's exhaust gas analysis technologies meet the strictest legal requirements and are used at leading test labs and PTI stations. Drawing on this long-standing expertise, MAHA is actively contributing to the further development of **legally prescribed emissions testing procedures** and compliance with future **Euro 7 standards**.

All **technological comparisons, regulatory analyses and future forecasts** presented in this document are based on current market developments and data available to the public. The methods and innovations described in this white paper are not exclusively linked to a specific product or system, but are rather meant to provide an **objective overview of the future of particle number measurement and its importance to emission control**.

1 INTRODUCTION

The measurement of particulate emissions in the exhaust gas of combustion engines plays a crucial role in environmental protection, public health and compliance with legal regulations. Whereas gravimetric particulate mass (PM) measurement was long regarded as the standard method to be used, particle number (PN) measurement has established itself as a more precise alternative in recent years. This development can be attributed to the fact that ultrafine particles (UFP, <100 nm) have a significant impact on human health, but cannot be reliably measured using conventional PM measuring methods because of their low mass [2].

International regulatory authorities have responded to this by establishing a standardised methodology for PN measurement with the introduction of the **Particle Measurement Programme (PMP)** under the leadership of the **United Nations Economic Commission for Europe (UNECE)** [3][4]. This methodology is now an integral part of statutory exhaust emission standards in Europe, with countries such as Germany, Belgium and the Netherlands incorporating **particle number measurements into the Periodic Technical Inspection (PTI)** [5]. The goal of these measures is to ensure that diesel particulate filters (DPFs) and other exhaust aftertreatment systems in vehicles function properly and that no unexpectedly high emissions are produced.

The development of precise and stable particle counting methods is a major challenge because many factors such as **particle size, chemical composition and morphology** can influence the capture rate. Over the last few years, various measurement methods have been developed, including **condensation particle counters (CPCs), diffusion charge (DC) sensors** and **electrometer-based methods**. These methods differ in terms of sensitivity, maintenance requirements and suitability for various applications such as PTI testing, mobile emission measurements or test bench testing.

This white paper provides a detailed overview of the scientific principles of particle counting and analyses common measuring methods together with their challenges. It also outlines regulatory developments that are of relevance to future emissions monitoring. In conclusion, it will present **MAHA**'s **PC7.0** particle counter – an innovative and field-proven alternative to existing systems, particularly characterised by its robustness, ease of maintenance and high precision.

2 BASICS OF PARTICLE COUNTING IN THE EXHAUST GAS

2.1 DEFINITION AND PROPERTIES OF EXHAUST PARTICLES

Exhaust particles are produced during the combustion of fuels in engines and consist of a variety of solid and volatile components. They can be divided into three main categories [2]:

- **Nucleation mode (d < 50 nm):** These ultrafine particles are formed through the condensation of volatile substances and often lack a solid carbon structure. Due to their low mass, they are particularly susceptible to dilution and cooling processes and can easily disperse in the ambient air.

- **Accumulation mode (d ≈ 50–200 nm):** These particles consist mainly of soot agglomerates produced during combustion and are usually coated with organic or metallic substances. They are more persistent than nucleation particles and contribute significantly to particulate pollution [4].

- **Coarse particles (d > 200 nm):** These larger particles are mainly created by mechanical abrasion, such as brake and tyre wear, or by deposits in the exhaust system, which can be detached by flow mechanisms [5].

Capturing these particles is crucial, as ultrafine particles of the nucleation and accumulation mode in particular penetrate deep into the lungs and are linked to a variety of health risks, including respiratory and cardiovascular diseases.

2.2 PHYSICAL FOUNDATIONS OF PARTICLE MEASUREMENT

Particle number measurement is based on various physical principles that are used to determine the particle concentration and properties:

- **Electrostatic charge:** Some measurement methods utilise diffusion charging, in which particles are marked by ionic charge and then detected by electric fields.

- **Condensation increase:** In condensation particle counting (CPC), ultrafine particles are enlarged by a condensable liquid (e.g. butanol) so that they can be detected optically.

- **Charge detection:** Electrometer-based sensors measure the electrical charge transported by charged particles and use this to calculate the particle concentration.

- **Optical scattering:** Laser-based sensors detect particles when light scatters on their surface, whereby smaller particles are often detected less efficiently [7].

2.3 FACTORS INFLUENCING PARTICULATE EMISSIONS

The quantity and composition of the emitted particles is influenced by a variety of factors [8]:

- **Fuel type:** Diesel engines generally emit more soot particles than petrol engines, while alternative fuels such as natural gas or hydrogen often generate lower particulate emissions.
- **Combustion technology:** Gasoline direct injection (GDI) engines often produce higher particle numbers than intake manifold injection engines. This is because the fuel is not premixed sufficiently and droplets can form in the combustion chamber [10].
- **Exhaust gas aftertreatment:** Systems such as diesel particulate filters (DPFs) or gasoline particulate filters (GPFs) significantly reduce the number of particles. However, malfunctions or manipulations can make the filters less effective and cause high emissions that go unnoticed [4].
- **Driving conditions:** Cold engine starts, high load conditions or sudden load changes influence particle formation and can lead to increased emissions [11].

2.4 SIGNIFICANCE OF PARTICLE COUNTING COMPARED TO PARTICULATE MASS MEASUREMENT

The conventional measurement of particulate mass (PM) continues to be of regulatory importance, but has several limitations [9]:

- **No differentiation by particle size:** PM measurements cannot differentiate between harmful ultrafine particles and larger particles.
- **Limited sensitivity:** The detection limit of gravimetric measurements is just a few µg/m³, which is often not high enough for modern exhaust systems.
- **Long measurement duration:** PM filters need to be weighed after each measurement. This limits the temporal resolution.

In contrast, particle number (PN) measurement offers several advantages [5]:

- **Better detection of ultrafine particles:** PN measurements focus on size ranges that are particularly relevant for health assessment.
- **Higher temporal resolution:** PN sensors provide continuous measured values, allowing for a more accurate assessment of emissions.
- **Clear correlation with modern emission standards:** PN limit values already form part of European vehicle tests and Periodic Technical Inspections (PTI).

2.5 RESEARCH RESULTS ON PARTICULATE EMISSION AND MEASUREMENT

Scientific studies have shown that particle number measurement permits a more accurate assessment of the impact of vehicle emissions on health and the environment. Key findings include:

- **Publication on a field study in China (2025):** The particulate emission distribution and the systematics of the 'high emitters' were examined. The need for tightening up emissions legislation is outlined [12].

- **Lab study on EURO 5 and EURO 6 vehicles (2022):** In the 56 vehicles examined, it was found that the highest particulate emissions were from petrol engines with intake manifold injection. The outdoor temperature also has a significant influence whereby low temperatures greatly increase PN emissions [13].

- **Article on a field study regarding the influence of driving conditions on petrol engines in China (2022):** Cold start and low speed scenarios were identified as particularly critical in terms of PN emissions, and vehicles with direct injection also exhibited significantly higher emissions than those with multi-point injection [14].

- **Study by Karjalainen et al. (2021):** This study shows that fuel-powered auxiliary heaters (AHs) are a significant source of particulate matter that is often not considered in current regulations [1].

2.6 RELEVANT REGULATORY STANDARDS FOR PARTICLE COUNTING

The introduction of particle number measurements in exhaust gas standards has accelerated considerably in recent years. Important regulations include:

- **PMP protocol (UNECE GRPE):**
  - Developed to supplement gravimetric PM measurement using a standardised PN method.
  - Defines a cut-off limit of **23 nm** for detecting solid particles.
  - PMP-compliant CPCs are employed as a reference method [5].

- **Periodic Technical Inspection (PTI) – Germany, Switzerland, Belgium, Netherlands:**
  - Introduction of limit values of **250,000 #/cm³**, or **1,000,000 #/cm³**

Germany	Euro 6, Euro VI
Switzerland	All diesel vehicles with DPF
Belgium	Euro 5 b, Euro 6
Netherlands	All diesel vehicles with DPF: Euro 3, 4, 5, 6 and Euro VI

  - Objective: Identification of defective or manipulated diesel particulate filters (DPFs).
  - Testing devices must be calibrated in accordance with standards.

- **Euro 6b and future emission standards**:
  - Introduction of PN limits for gasoline direct injection (GDI) engines.
  - Expanded to include **non-exhaust emissions** (brake and tyre wear particles) in Euro 7 [15].

- **ISO 27891:2015 – Calibration of condensation particle counters (CPCs):**
  - Defines standards for CPC-based particle counting.
  - Important basis for PTI and type testing procedures.

These standards emphasise the growing importance of particle counting as a core method of emission control.

3 MEASURING METHODS FOR PARTICLE COUNTING

The number of particles in the exhaust gas is measured using various measurement technologies that differ in terms of **accuracy, sensitivity, measurement complexity and areas of application**. In principle, these methods can be classified into **direct** and **indirect** methods [2].

3.1 DIRECT PARTICLE COUNTING METHODS

Direct methods directly measure the number of particles and provide high-resolution real-time data. They are especially suitable for **type tests, PTI measurements and portable emissions measuring systems (PEMS)** [3].

3.1.1 CONDENSATION PARTICLE COUNTERS (CPCS)

- **Measurement principle:** CPCs use a condensable liquid (e.g. butanol or isopropanol) to expand the smallest particles by condensation so that they can be detected optically [4].

- **Advantages:**
  - High sensitivity for particles ranging from **~7 nm to >1 µm**.
  - **PMP standard method** for PN measurements [5].
  - Reference device for many legal test procedures.

- **Disadvantages:**
  - Regular **refilling of the operating medium required** (additional maintenance).
  - **Temperature-sensitive**, susceptible to evaporation losses.
  - **Response time of approx. 1 second**, limited suitability for transient processes.

3.1.2 DIFFUSION CHARGERS (DCS)

- **Measurement principle:** Particles are marked and separated by **ionic charge**. The resulting charge is measured and converted into a particle count [2].

- **Advantages:**
  - **Robust and compact design**, no liquid required.
  - **Very short warm-up and response times** (millisecond range).
  - Measuring range matched to requirements for PTI exhaust pipe measurement, **high measuring accuracy** in the relevant measuring range

- **Disadvantages:**
  - Dependence on particle charge, precise calibration important.
  - **Lower sensitivity for very small particles (<20 nm)**.

3.1.3 OPTICAL PARTICLE COUNTERS (LASER-BASED PN SENSORS)

- **Measurement principle:** Light is scattered by particles, and the change in intensity of the scattered light is used to determine the number of particles [7].

- **Advantages:**
  - **Real-time measurement with high temporal resolution**.
  - **Compact dimensions**, ideal for mobile applications.

- **Disadvantages:**
  - **Lower precision for small particles (<50 nm)**.
  - Dependent on particle composition and shape.

3.2 INDIRECT METHODS FOR PARTICLE COUNTING

Indirect methods do not measure particles directly. Instead, they calculate the number based on other physical properties [8].

3.2.1 GRAVIMETRIC FILTER MEASUREMENT (PM METHOD)

- **Measurement principle:** Particles are collected on a filter and weighed.

- **Disadvantages for PN measurements**:
  - **No differentiation by particle size**.
  - **High detection limits**, therefore unsuitable for PN regulations.

3.2.2 LASER ABSORBANCE MEASUREMENT (OPACITY TESTS IN THE PTI)

- **Measurement principle:** The attenuation of light caused by soot particles is measured.

- **Disadvantages:**
  - **Not sensitive to ultrafine particles**.
  - **High fluctuations depending on engine type and fuel**.

3.3 COMPARISON OF MEASURING METHODS

METHODS	MEASUREMENT PRINCIPLE	ADVANTAGES	DISADVANTAGES
CPC (PMP reference method)	Condensation of particles for optical detection	Very high sensitivity, standardised	Liquid refill necessary, slow
Diffusion charging (DC)	Particles are charged, charge flow is measured	Maintenance-free, fast response time	Dependent on particle charge
Electrometer (FCE)	Total charge measurement of charged particles	High sensitivity, durable	No size information, pressure-dependent
Optical counting (laser PN)	Light scattering by particles	Compact, real-time measurement	Not sensitive to small particles
Gravimetric filter measurement	Filter collects particles, weight is determined	Standard procedure for PM	Unsuitable for PN, long measurement duration
Laser absorbance measurement	Light absorption by soot particles	Fast, robust	No UFP detection, high measurement uncertainty

This analysis shows that **CPCs remain the established reference devices**, offering the highest accuracy, but requiring a lot of maintenance. **Diffusion charge sensors** (DCs) offer a promising alternative with low maintenance requirements and fast response times. **Electrometers and optical PN sensors** are complementary technologies that have their advantages and disadvantages depending on the application.

As particle number measurement becomes increasingly important in **legal testing procedures (e.g. PTI, RDE, Euro 7)**, it is clear that the choice of a suitable measurement principle will play an even greater role in the future.

4 REGULATORY REQUIREMENTS AND STANDARDS FOR PARTICLE COUNTING

The increasing importance of particle number (PN) measurement as a supplement to traditional particulate mass (PM) measurement has led to a large number of new **legal regulations and technical standards**. These relate not only to the **type testing of new vehicles**, but also to **Periodic Technical Inspections (PTI)** for checking emissions while driving [1][2].

4.1 INTERNATIONAL AND EUROPEAN REGULATIONS

4.1.1 PARTICLE MEASUREMENT PROGRAMME (PMP) – UNECE GRPE

The Particle Measurement Programme (PMP) was developed by the **United Nations Economic Commission for Europe (UNECE)** to establish standardised procedures for particle counting. The most significant result of this initiative was the introduction of **PN measurement as the official test method** for Euro 5 and Euro 6 vehicles [3].

- **Key criteria of the PMP protocol:**
  - **Cut-off size of 23 nm:** Detection of solid particles, while volatile particles are removed by evaporation.
  - **Condensation particle counter (CPC) as a reference method**: Ensuring high sensitivity and reproducibility.
  - **Testing under standardised conditions:** Clear specifications for sampling, dilution and temperature control of the exhaust gas sample [4].

These specifications form the **basis for statutory PN limit values** in the European Union and in other international markets where exhaust emission standards are becoming stricter [5].

4.1.2 EURO 5B, 6B AND UPCOMING EURO 7 STANDARD

Euro 5b:

- Introduction of **PN limits for diesel engines**.

Euro 6b:

- Introduction of **PN limits for gasoline direct injection (GDI) engines**.
- **Particle limit for diesel and petrol engines:** 6×10^{11} particles/km.

Euro 7 (expected for 2027) [16]:

- Extension of the **PN limits to include non-exhaust emissions** (e.g. **tyre and brake wear particles**).
- **Lowering the PN limits for GDI engines** in order to regulate ultra-fine particulate emissions even more strictly.
- **Real-time monitoring of PN emissions with PEMS (portable emission measurement systems)** to ensure that measurements are taken under real driving conditions.

The planned Euro 7 specifications will further tighten the requirements for particle measuring devices and in particular increase the importance of mobile PN measurement systems for **Real Driving Emissions (RDE)** and PTI tests.

4.2 NATIONAL REGULATIONS FOR PARTICLE COUNTING IN THE PTI

Some countries have already included **PN measurements in the Periodic Technical Inspection (PTI)** to be able to detect manipulated or defective diesel particulate filters (DPF) [7].

4.2.1 GERMANY

- Since **January 2023**, it has been mandatory for **Euro 6 diesel cars and vans**.
- **Limit value:** 250,000 particles/cm³.
- **Testing devices:** Must be calibrated and have a **measurement uncertainty of <25%**.

4.2.2 BELGIUM

- **PN measurement added to the PTI on 1 July 2022**.
- **Limit value:** 1,000,000 particles/cm³.

4.2.3 NETHERLANDS

- **PN measurement introduced in January 2023.**
- **Limit value:** 1,000,000 particles/cm³.

4.2.4 SWITZERLAND

- **Switzerland: PN-PTI for diesel engines introduced in 2024**.
- **Limit value:** 250,000 particles/cm^{33}.

4.3 RELEVANT ISO AND DIN STANDARDS FOR PARTICLE COUNTERS

In addition to the legal regulations, there are a number of **technical and calibration standards** that ensure the quality and accuracy of PN measuring devices.

4.3.1 ISO 27891:2015 – CALIBRATION OF CPCs

- Standard for the **calibration of condensation particle counters (CPCs)**.
- Defines requirements for **measurement accuracy, stability and reproducibility**.
- Basis for the **certification of PTI testing devices** in Germany and other European countries.

4.3.2 UNECE R83 – TYPE APPROVAL OF VEHICLES

- Contains **requirements for PN measurements for the homologation of new vehicles**.
- Basis for the **statutory emission tests according to Euro 6d and Euro 7** [5].

Summary and prospects

The regulatory requirements for **particle number (PN) measurement** have become significantly tighter in recent years. **The relevance of PN measurement** within type testing is growing steadily. **There is also increasing global interest in including PN measurement in PTI testing** as a means of preventing manipulation and malfunctions in exhaust aftertreatment systems.

- **PN measurements have now become an integral part of the PTI in Germany, the Netherlands, Switzerland and Belgium.**
- **For the very first time, Euro 7 will also regulate non-exhaust-related particulate emissions (e.g. tyre and brake abrasion).**
- **Technical standards such as ISO 27891 ensure standardised and reliable measurement procedures.**

The continuous development of legal regulations will mean that new **measuring systems offering high precision, long-term stability and low maintenance requirements** will become necessary in order to fulfil the new requirements [9].

5 CHALLENGES IN PARTICLE COUNTING

Particle number measurement places high demands on **measurement technology, environmental conditions and calibration**. Although modern systems offer high accuracy, there are still numerous **external factors** that can influence the measurement result. This section highlights the major **challenges** and their impact on measurement quality [2].

5.1 FACTORS INFLUENCING MEASUREMENT RESULTS

5.1.1 TEMPERATURE AND PRESSURE DEPENDENCE

- Particle concentrations can **vary considerably** depending on **pressure and temperature conditions** during the measurement [3].

- Altitude and weather conditions **(air pressure fluctuations, temperature changes)** have a particular influence on **electrostatic sensors** such as diffusion charge sensors (DC) [4].

- **Solution:**
  - Modern systems rely on **pressure-compensated sensors** or **adaptive algorithms** to compensate for environmental changes [5].
  - **Temperature-stabilised sampling systems** prevent evaporation losses.

5.1.2 DILUTION AND SAMPLE PREPARATION

- In many measuring procedures, the exhaust gas must be **diluted** to protect the sensors from being overloaded.

- **Challenge**: **Uneven dilution** can lead to incorrect measurements by selective removal or modification of particles.

- **Solution:**
  - Using **thermal dilution systems** to **eliminate nucleation particles** and **keep the sample stable for CPC-based measurements**.
  - **Homogenising the sample** to avoid particle losses.

5.1.3 INFLUENCE OF PARTICLE SIZE AND MORPHOLOGY

- **Problem:** Differences in particle shape (**spherical, agglomerated, fractal**) influence the **charge absorption** and thus the **efficiency of electrostatic measurement methods** [6].

- **Practical example:**
  - **Soot particles from diesel engines** have different electrical properties than **condensed oil particles from petrol engines** [17].

- **Solution:**
  - **Standardised calibration procedures with NaCl or DEHS particles** according to **ISO 27891**.
  - **Measurement comparisons with reference instruments** to minimise systematic errors.

5.2 CHALLENGES IN MOBILE PARTICLE COUNTING (RDE & PEMS)

5.2.1 REAL-TIME MEASUREMENTS UNDER REAL DRIVING CONDITIONS

- The measurement of particle numbers in **Real Driving Emissions (RDE)** requires **mobile and robust measuring devices** [8].

- **Problem:**
  - **Transient load changes** and **short peak values** require a **high temporal resolution (<1 second)**.
  - CPCs are **limited in this respect** since their response time is often **>1 second**. Furthermore, CPCs are **not suitable for conducting RDE measurements** due to their sensitivity to vibration and their dependence on temperature and consumable [18].

- **Solution:**
  - Systems with **fast response times** (e.g. diffusion chargers, which are not suitable and not used for RDE) **are becoming more relevant than classic CPCs**.
  - **Robust measuring cells** that are resistant to vibrations and temperature fluctuations.
  - **Automated data correction models** to compensate for the effects of interference in real time.

5.2.2 SENSOR AGEING AND MAINTENANCE

- **Long-term use and high particle loads on particle counters** can lead to **measured value deviations** and **calibration drift**.

- **Problem:**
  - **Deposits in the measuring chamber** (e.g. due to oil mist) distort the results.
  - **Sensors can become 'clogged' from high particle loads** (especially CPCs) [19].

- **Solution:**
  - **Automatic cleaning systems** or **periodic zero-point calibration** (as prescribed for PTI measurements) [4].
  - **Alternative technologies that require less maintenance**, e.g. electrostatic sensors (DC)
    .

5.3 COMPARISON OF LAB-BASED AND REAL LIFE MEASUREMENTS

5.3.1 DIFFERENT RESULTS BETWEEN TEST BENCH AND ON-ROAD TESTS

- **Lab conditions:**
  - **Constant temperature, pre-defined humidity, controlled sampling.**
  - Particle distributions and size distributions are **repeatable** [5].

- **On-road measurements:**
  - **Heavy fluctuations due to driving style, weather and environmental factors.**
  - **Outdoor measurements (e.g. PTI measurements) often lead to higher variations** [20][21].

5.3.2 CALIBRATION AND REFERENCE INSTRUMENTS

- **Challenge:**
  - **Particle counters must be regularly calibrated against reference devices (CPCs, electrometers).**
  - **Deviations between different devices** can lead to incorrect measurement interpretations [22][23].

- **Solution:**
  - Use of **certified PN calibrators** for PTI and research facilities.
  - **Measurement comparisons with standardised aerosols** to minimise systematic errors.

Summary and prospects

- The **ambient conditions** (temperature, pressure, dilution) have a considerable impact on the **accuracy of particle counting**.

- **Mobile PN measurements (PEMS, PTI)** call for **fast, robust and low-maintenance measuring devices**.

- **Regular calibration** and **comparative measurements against reference systems** are essential for reliable PN data.

With the introduction of new **Euro 7 regulations** and increased monitoring by **Real Driving Emissions (RDE)**, particle counting is set to continue evolving. The development of **precise, low-maintenance and real-time-capable PN sensors** will play a key role in the future.

6 INNOVATIVE SOLUTIONS: MET PC7.0 – PARTICLE COUNTING WITH MAHA TECHNOLOGY

The growing demands on **particle number (PN) measurement** in exhaust gas analysis are increasing the need for **precise, reliable and low-maintenance measuring systems.** The **MAHA MET PC7.0 particle counter** offers a pioneering solution for various applications in **vehicle testing, research and emissions monitoring**.

The MET PC7.0 particle counter has been specially developed to overcome the **limitations of classic measuring systems** and provide an efficient alternative to conventional **CPC-based methods**. Thanks to the use of state-of-the-art **electrostatic measuring methods** combined with **smart signal processing**, the MET PC7.0 offers **high precision, short response times and low-maintenance operation**.

6.1 TECHNOLOGICAL DESIGN OF THE MET PC7.0

The MET PC7.0 utilises a **diffusion charge sensor (DC)** with highly sensitive electrometer measurement. The system comprises the following main components:

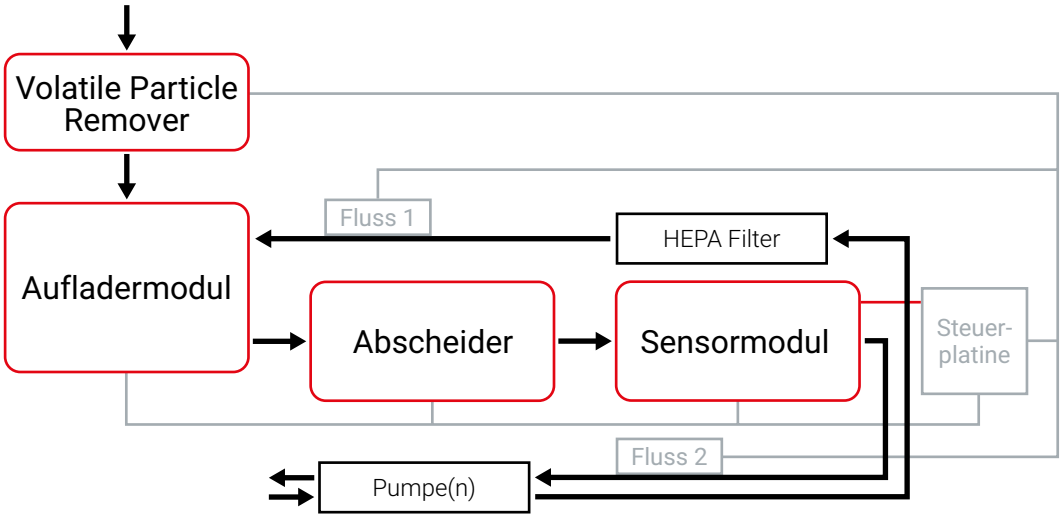

Figure 1: Schematic representation of a particle measuring system consisting of four modules with control PCB and pump(s)

Volatile particle remover (VPR)

The Volatile particle remover (VPR) removes volatile components from the sample gas so that the measurement can be carried out in a legally compliant manner. This is a necessary step because particle measurements must be limited to thermostable, non-volatile particles. With an effectiveness of around 99%, the system exceeds the minimum legal requirements, which in Germany, for instance, are defined as at least 90%.

Advantages:

- Highly efficient removal of volatile components ensures very precise and legally compliant particle measurement

Charging module – diffusion charger (DC)

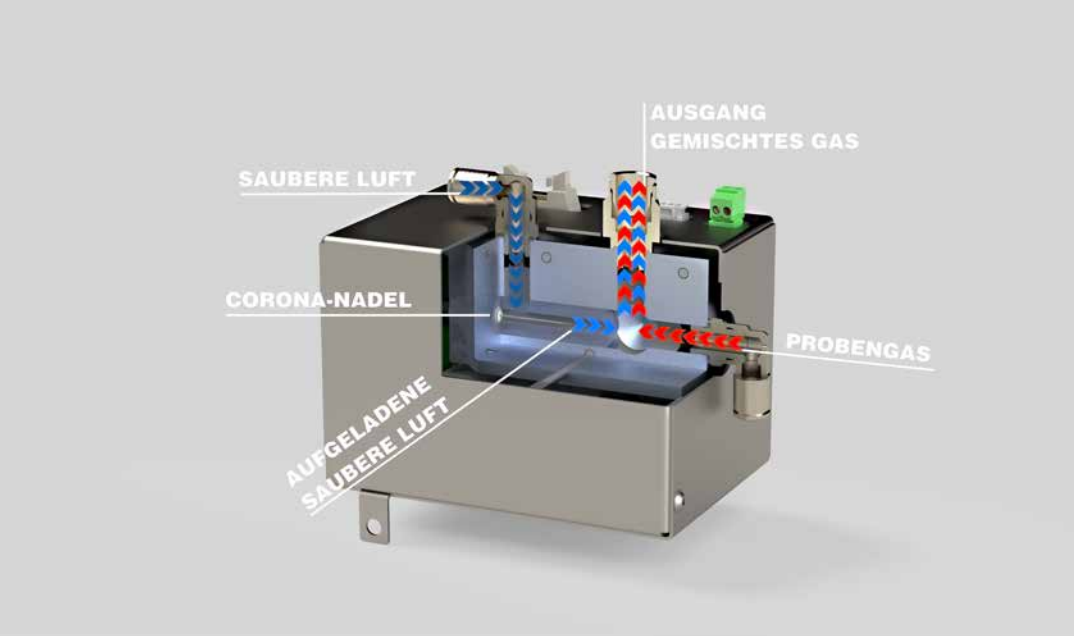

Figure 2: Charging module – diffusion charger (DC)

In the charging module, corona discharge is used to electrically charge the exhaust particles. The Clean Charging technology ensures that ion formation takes place in clean, HEPA-filtered air. This prevents the corona needle from becoming contaminated, thus increasing the service life of the system.

Advantages:

- HEPA-filtered air for generating the ions
- Low-maintenance corona discharge with a long service life
- Self-diagnostics through ion current measurement, even without the presence of particles

Ion/particle separator

Figure 3: Ion/particle separator

The separator separates free ions and certain parts of the charged particles. This facilitates a size-dependent correction of the counting efficiency and a determination of the particle size distribution. The module can also be configured to conduct purely electrical function tests without particles.

Advantages:

- Selective particle size filtering through electrical separation
- Possibility of a function test without particles

Sensor module – Faraday cup electrometer

Figure 4: Sensor module

The sensor module detects the charge induced by charged particles and converts it into a particle number concentration. This is achieved without contact using a Faraday cup, which can measure extremely low currents in the femtoampere range (1 fA = 10^{-15} A).

Advantages:

- Non-contact measurement using a Faraday cup
- Robust and highly precise sensor technology

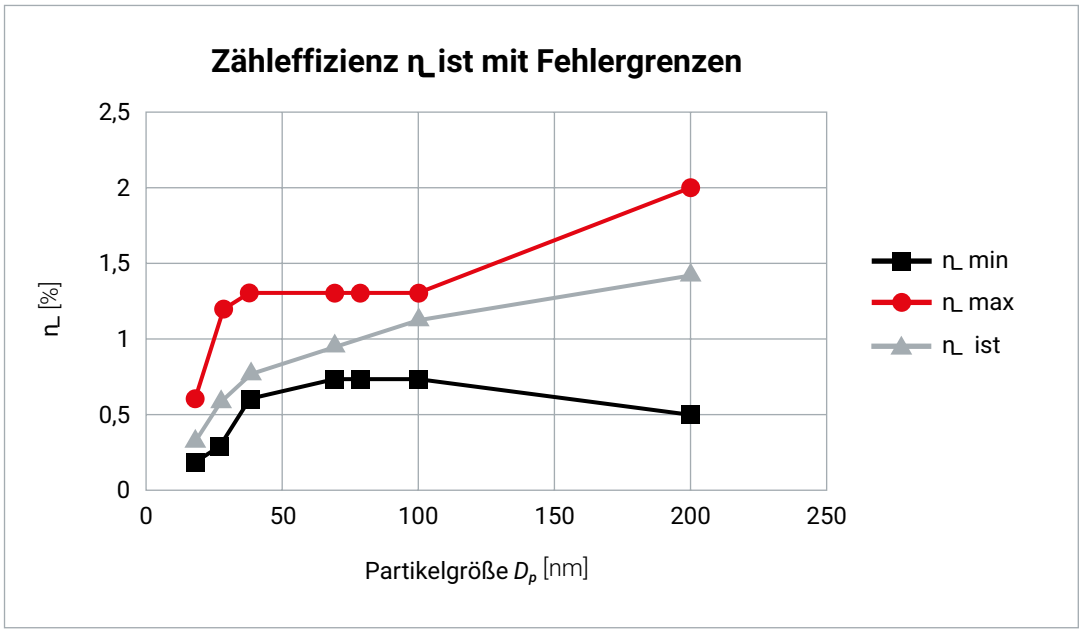

Figure 5: Counting efficiency of our module and the specified limit values η_min and η_max

6.2 ADVANTAGES OF THE MET PC7.0 OVER EXISTING SYSTEMS

FEATURE	MET PC7.0 (MAHA TECHNOLOGY)	CPC
Working principle	Electrostatic charge measurement	Condensation particle counting
Sensitivity	10–500 nm	7–1000 nm
Reaction time	<200 ms	1–2 s
Maintenance requirement	Very low (no consumables)	High (regular refilling with consumable)

The MET PC7.0 boasts an impressively **fast response time**, uses very **robust and precise measurement technology**, requires **no high-maintenance consumables** and **meets all** existing **legal requirements.**

6.3 APPLICATION AREAS OF THE MET PC7.0

The MET PC7.0 is highly versatile and offers precise particle measurement in various scenarios:

PTI test benches

- Determination of the **number of particles in accordance with legal requirements for diesel vehicles** equipped with diesel particulate filters.
- Designed for easy integration into **existing exhaust gas test benches**.

Research & development

- Optimisation of **exhaust gas aftertreatment systems for lower emissions**.
- Diagnostic measurements **to evaluate factors influencing the emission behaviour**.

6.4 COMPARATIVE MEASUREMENTS AND VALIDATION

Lab tests according to PMP standard (23 nm cut-off)

- The MET PC7.0 showed **excellent compliance with PMP-certified CPCs** (deviation <7%).
- **High reproducibility**, especially at low particle concentrations (<10^4 #/cm^3).

Long-term stability tests

- MET PC7.0 has completed over **1000 operating hours without any significant calibration deviations**.
- **Low-maintenance operation**, whereas CPCs require regular refilling with consumables.

6.5 VARIATIONS OF THE MET PC7.0: BASIC AND COMFORT

The MET PC7.0 is available in two versions covering different requirements in particle counting:

MET PC7.0 BASIC

- **Connection** to PC or laptop via **USB-C cable** or **Bluetooth**.
- Test sequences and evaluation via the **MAHA Emission Software (MES)**.
- **Ideal for stationary test benches, mobile use and research labs**.

MET PC7.0 COMFORT

- **Integrated embedded system** that enables **software-supported operation**.

- **No external PC required** – the device can be operated as **'standalone'**.

- **Ideal for mobile applications** and **PTI tests in workshops**.

These two variants allow **the MET PC7.0 to be used efficiently in both classic test benches and mobile testing environments**.

7 SUMMARY AND PROSPECTS

Particle number (PN) measurement has become an essential component of modern exhaust emissions testing. Tighter legal requirements, particularly in the context of the **Periodic Technical Inspection (PTI)** and the introduction of new **Euro 7 standards**, call for precise and reliable measuring systems that are easy to operate.

MAHA MET PC7.0 devices represent a pioneering solution that combines **maximum measuring accuracy with optimum ease of use**. The innovative **electrostatic measuring method** of the MET PC7.0 devices offers a **low-maintenance alternative to conventional CPC-based systems** without compromising on **precision and repeatability**.

7.1 THE KEY BENEFITS OF MET PC7.0 DEVICES

Precise particle measurement for PTI, research and mobile applications

- **Meets all legal requirements** for PN-PTI measurements.

- **Robust measurement technology** that is **highly resistant** to contamination and penetration by liquids.

- **Ideal for workshops, testing organisations and engine developers**.

Two variants offering maximum flexibility

- **BASIC version** with **Bluetooth and USB interface** for **PC-assisted testing using MAHA MES software**.

- **COMFORT version with integrated embedded system** – ideal for **mobile use** and standalone applications.

High stability and low maintenance

- **Unlike CPCs, no consumable is used**, resulting in **longer operating times and no need for maintenance**.

- **Pressure and temperature compensation** for **precise measured values under real conditions**.

Fast measurement times and real-time capability

- **Response time <200 ms**, ideal for **stationary and mobile measurements**.
- **Real-time diagnostics** for efficient test sequences.

7.2 THE FUTURE OF PARTICLE COUNTING WITH MET PC7.0

Integration into networked test benches

- **Connection to digital workshop and inspection systems** through our MES for **seamless testing processes**.

Future-ready

- **The MET PC7.0 is ready for global applications in PTI systems**, even beyond the existing PN-PTI specifications.
- **Can be adapted to future limit values and test standards** for new vehicle technologies.

7.3 CONCLUSION

The MET PC7.0 is more than just another particle counter – it is an efficient, low-maintenance and precise solution for the particle number measurement of tomorrow. Its high flexibility, fast response time and future-proof technology make it the perfect basis for regulatory testing, research and mobile applications.

With MAHA at the forefront of innovation, the MET PC7.0 will make an important contribution to emissions testing and air pollution control.

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About the author

Peter Geigle looks back on more than 25 years of experience in technology and product development. Holding a doctorate in mathematics and a degree in electrical engineering, he has guided numerous companies through their transformation processes and established innovative technologies. His key areas of expertise are the development of new technologies, corporate restructuring and international leadership.

'Learn more about the challenge of precise particle number measurement along with innovative solutions in this white paper.'

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