TSI PTI-Prototype for PN-Periodic Technical Inspection

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UNDERSTANDING, ACCELERATED

PN Legislation – Off-Road

+ Swiss Ordinance of Air Pollution Control (VAMV) was first to limit PN emissions *in-use*
  - Regulation SR 941.242 mandates compliance testing for off-road vehicles
    → Construction machinery DPFs
  - Previously bi-annual tests with opacimeters
  - Since 2017 prescribes test for PN emissions & certification
    - Limit value of 250,000 particles/cm^3 as pass/fail threshold
  - In future buses & other non-road mobile machinery
    - DPF and **(in-use) filter performance control**

TSI Reference Instrument

Nanoparticle Emission Tester (TSI 3795)

+ PN counting instrument
  - Measurement of ***solid*** particle number concentration only
  - Only certified instrument at this time
    - METAS certification to stringent requirements of Swiss Regulation SR 941.242 (2014) for NRMM

TSI Reference Instrument (2)

Nanoparticle Emission Tester (TSI 3795)

+ Based on CPC technology!
  - Most accurate, true particle counting
  - Link to type approval tests

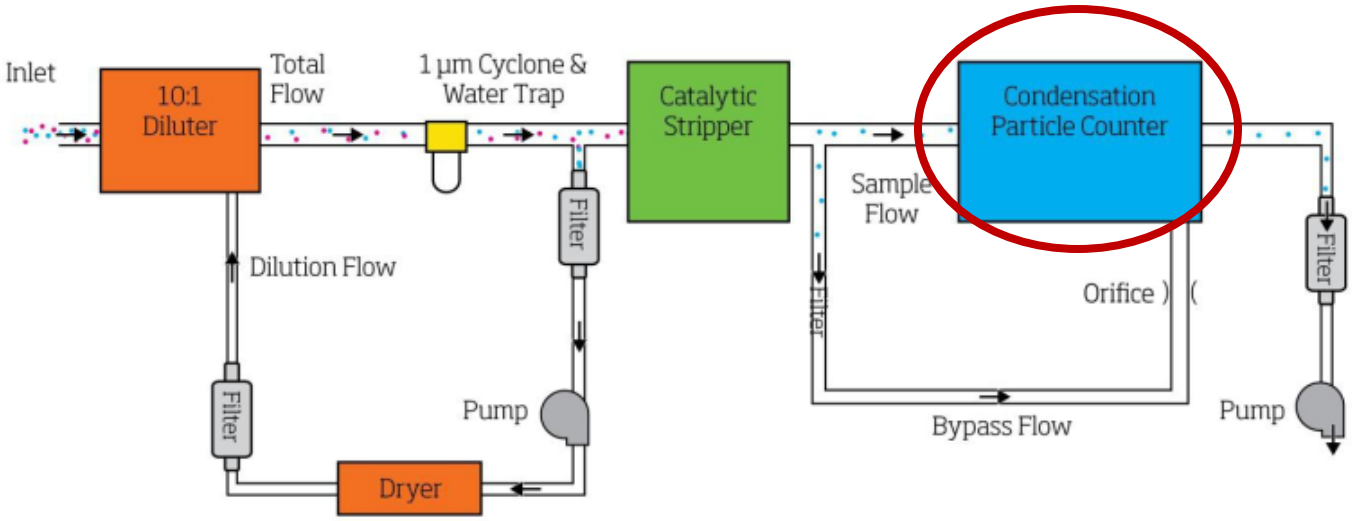
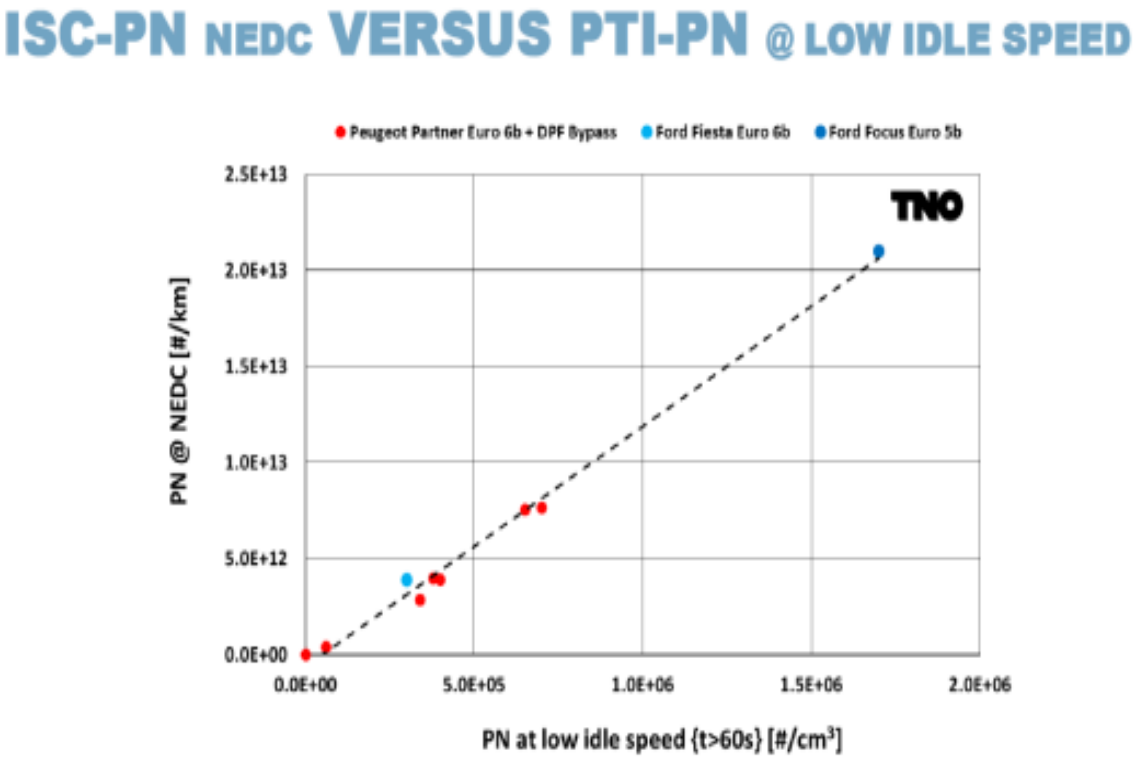


Photo and schematic © TSI Inc.

TSI Reference Instrument (3)

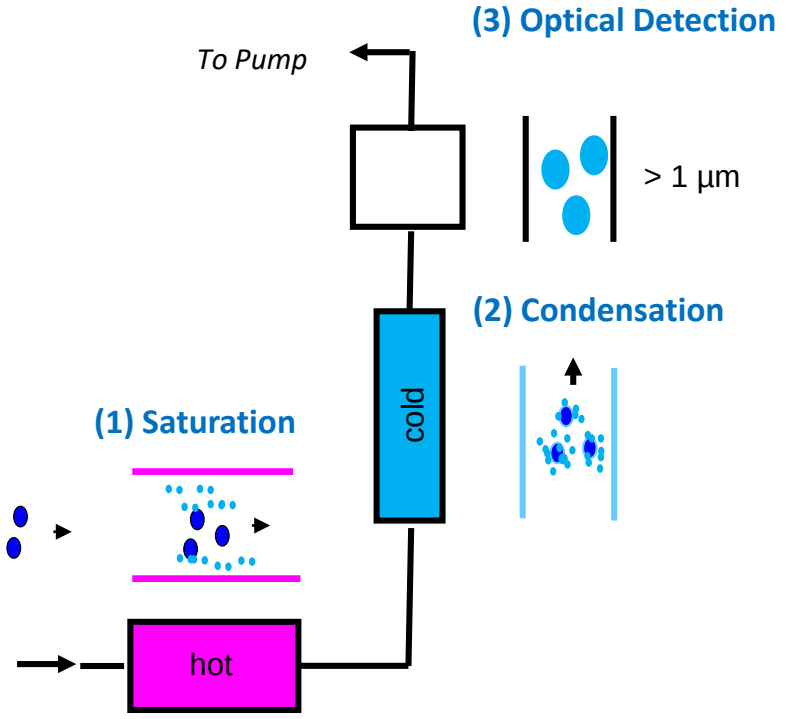
Nanoparticle Emission Tester (TSI 3795)



Source: Presentation at VERT-Forum 2018 by Gerrit Kadijk

Why CPC Technology for PN?

+ **Direct** counting of particles (just like Euro 5/ Euro 6)
  - No assumptions
  - Flow can be measured accurately
  - Pulse height detector for reliable measurements
  - Experience with excluding volatiles
+ **Sensitive** over full size range relevant for this test
+ **Traceable Calibration** is covered by ISO 27891:2015 „*Aerosol particle number concentration — Calibration of condensation particle counters*“

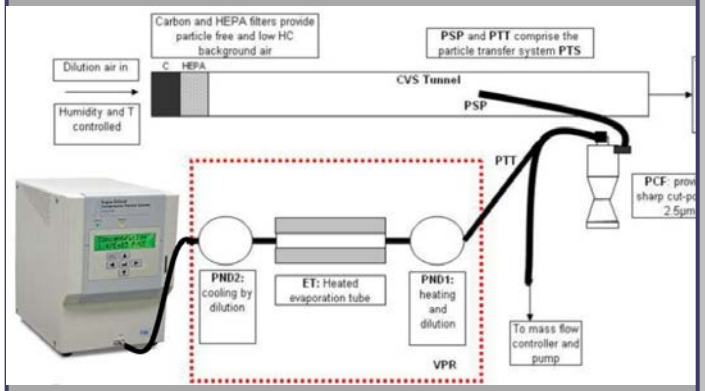


Principle of measurement of a Condensation Particle Counter

Why CPC Technology for PN? (2)

+ Highly reliable based on **>20 years** of experience in engine emission testing

Type approval testing
EURO 5b/6 – Reg. 83/49



Real Driving Emissions
PN-PEMS

Source: www.horiba.com

NRMM - SR 941.242/
Swiss ships SR 747.201.3

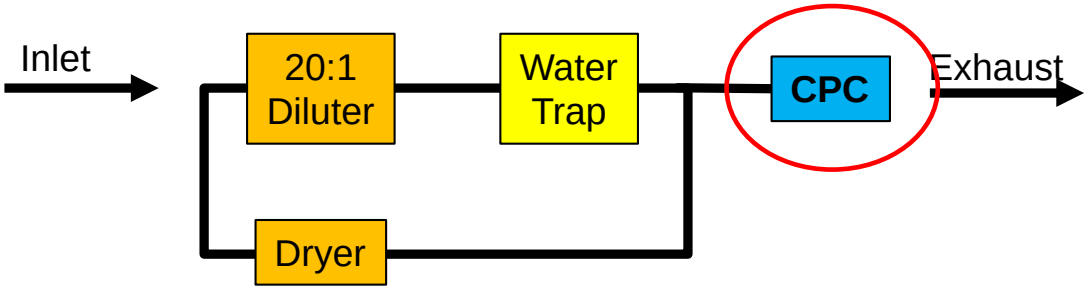
Aircraft emissions SAE E-31

Solid PN >10nm

+ Suitable for Diesel, gasoline, and heavy duty emissions
+ Comparable & defendable results, e.g. from PTI-station to PTI-station

NEW: PTI Prototype from TSI

+ First use: JRC campaign in April
  - Isopropanol-based condensation particle counter (CPC)
  - Integrated, dry 20:1 dilution
  - Probe for tailpipe measurement
  - Water trap

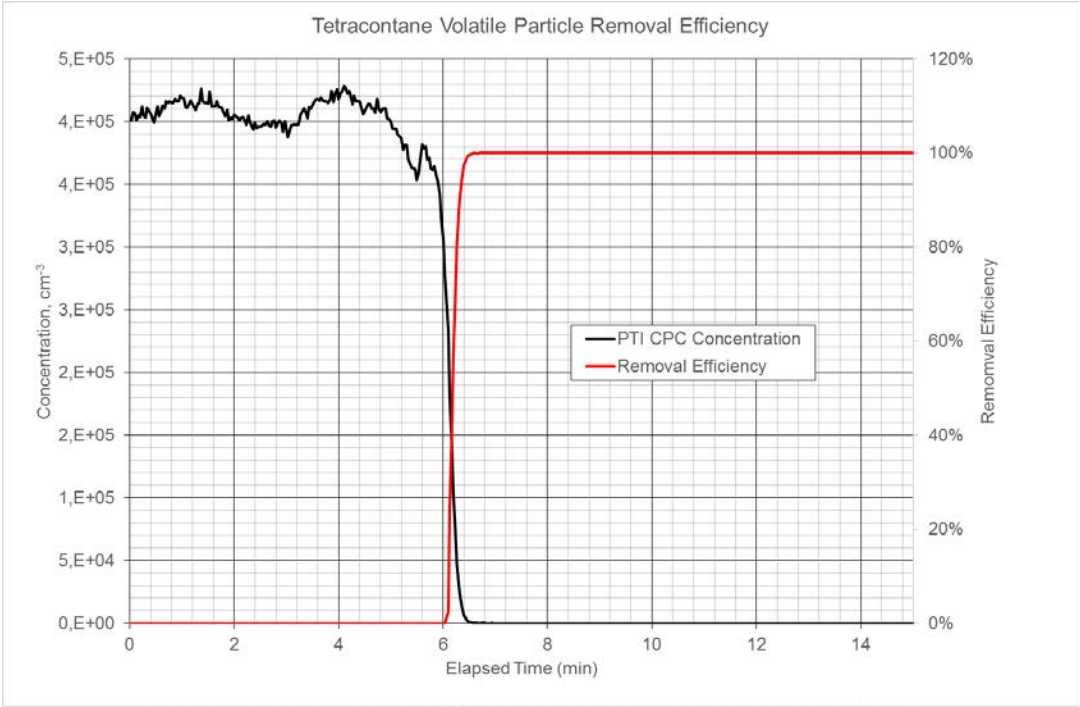


NEW: PTI Prototype from TSI (2)

+ Key features
  - Smaller & lighter
    (<9 kg vs. >13 kg)
  - Battery-powered
    (2x Li-ion, hot-swappable)
  - Touchscreen on device
  - Easy-to-use test mode

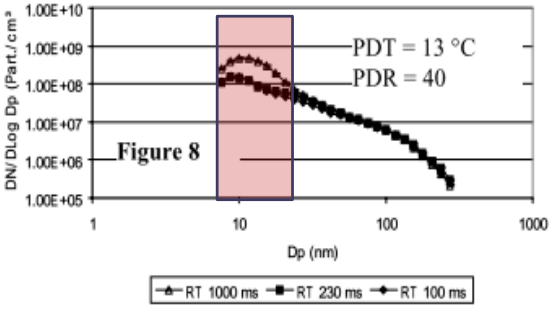
PTI-Prototype: Improvements

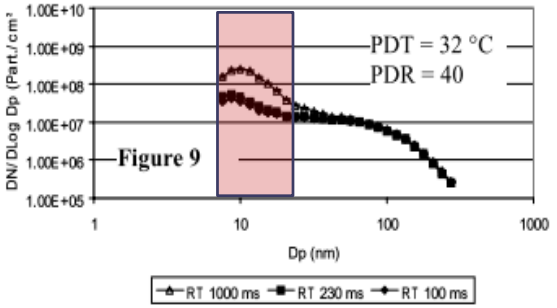
+ Added a catalytic stripper to remove volatile components
+ JRC tests showed evidence of very small particles that were likely volatile (on top of the small solids)

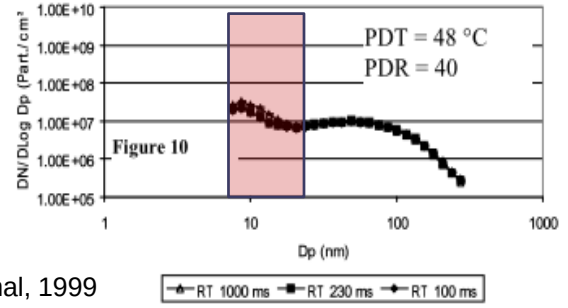


PTI Prototype: Improvements

+ Volatiles can increase PN concentrations by orders of magnitude — *false positives*
+ Volatile substances in combustion emissions *condense* heterogeneously and homogeneously, affecting particle number concentrations



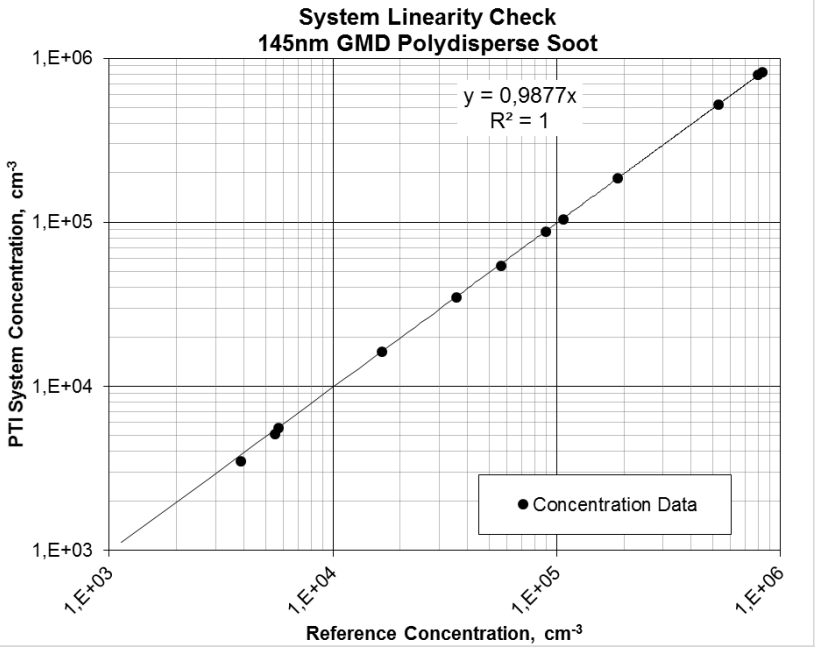




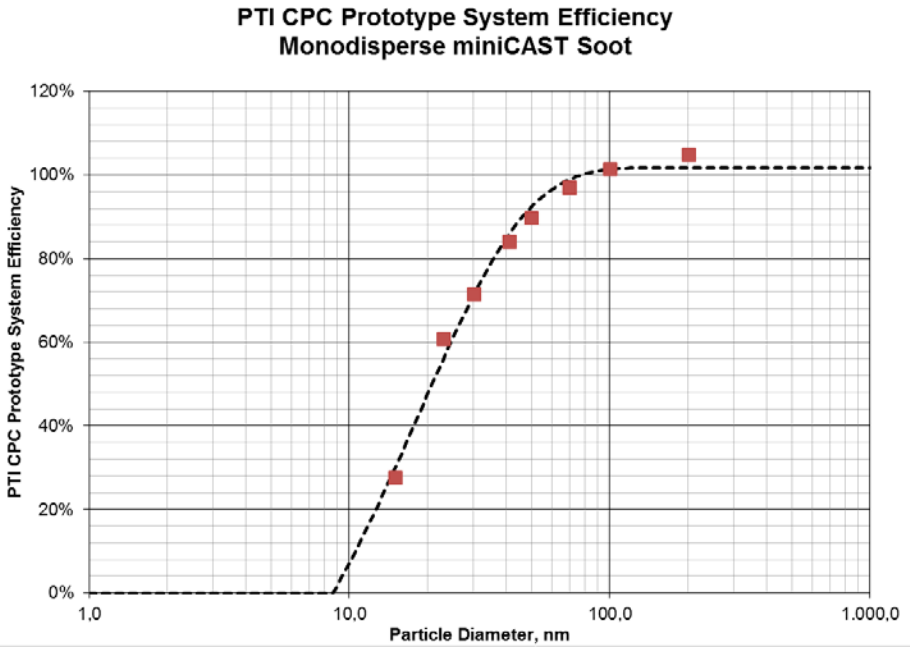
Abdul-Khalek et al., SAE International, 1999

New PTI Prototype with catalytic stripper - Performance

Linearity



Counting Efficiency



D_{50}: 23 nm

Summary

+ Presented an instrument solution for determining PN concentration in tailpipe emissions during PTI
  - for garage shops, service stations and technical inspection facilities
+ Direct counting of particles through proven CPC technology translates to
  - accurate and reliable counting of discrete particles – one-by-one –
  - as in type approval testing according to Euro 5/6 legislations.
  - -> Further homologation

Any Questions?

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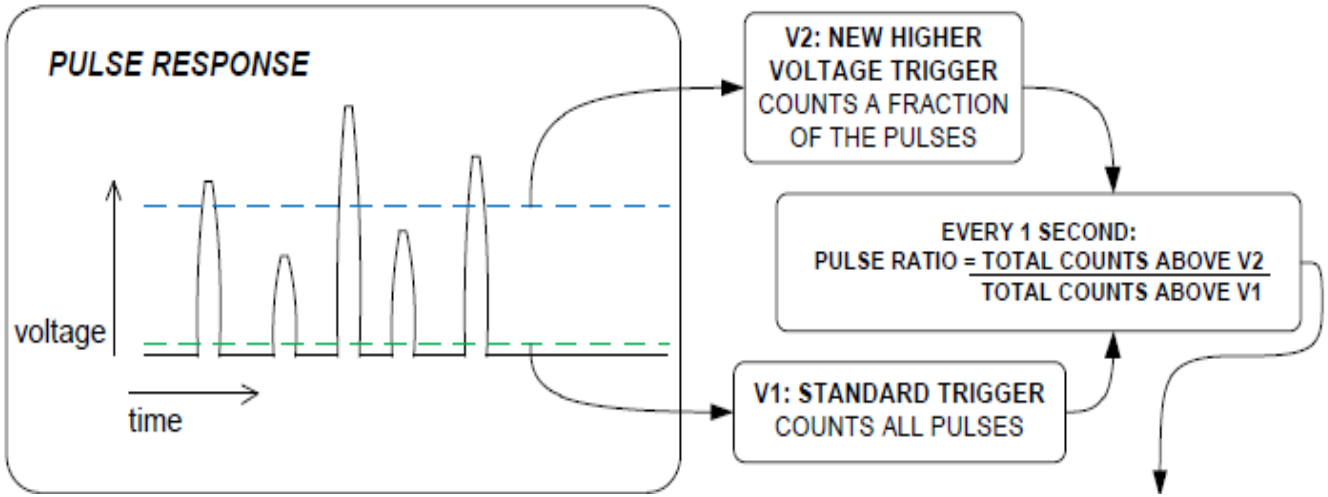
Pulse Height Analyzer



Pulse response
Each particle passing through the optics generates an electric pulse, and the height of the pulse can be correlated to the size of the grown droplet.

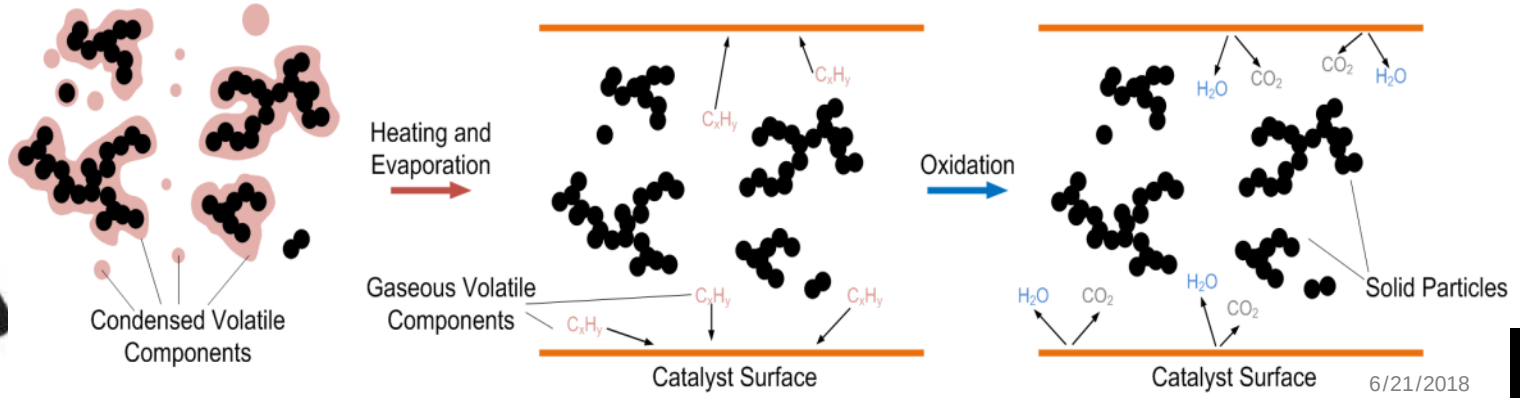
Pulse height error
Under certain conditions, particles do not grow to this droplet size, and as a result, the pulse height is decreased. Certain CPCs include an error/warning which is triggered when pulse height decreases enough to indicate a problem with the measurement early.

Methods of removing volatile particulate matter

+ Volatile particle removal (VPR) tube
  - Evaporates volatile material
  - Uses secondary dilution to prevent re-condensation
  - Possibility of re-nucleation

+ Thermal denuder
  - Evaporates volatile material
  - Volatiles adsorb into activated carbon
  - Needs regeneration

+ **Catalytic stripper**
  - Evaporates volatile material
  - Volatiles are oxidized using a catalyst to prevent them from re-condensing



PTI Prototype: Data Sheet

NANOPARTICLE EMISSION TESTER FOR PERIODIC INSPECTION

PORTABLE, FAST, PASS-FAIL RESULTS

The PTI-PN tester is a light-weight, battery powered, mobile solution for garage shops, service stations and technical inspection facilities to test for nanoparticle emission levels of vehicles. Sampling emissions straight from the tailpipe with a pass/fail result in less than one minute, this tester is perfect for easy Diesel or Gasoline Particle Filter Testing (DPF or GPF).

Evolving from original nanoparticle sensors and sensors for compliance testing, TSI's PTI-PN tester enables the measurement of particle number emissions accurately and reliably. TSI's tester provides touch screen guidance for the technician through the test cycle, step-by-step, ensuring measurements are taken correctly. The test cycle requires the vehicle's engine to be warmed up and in idle conditions and the ambient air measurement precedes the tailpipe emission test. A total of four measurements are taken, each last five seconds where the average of the engine emission test is compared to a pass/fail threshold setting. In addition to the test cycle, manual measurements can be enabled for diagnostic or research purposes.

Features and Benefits

+ Light-weight, battery powered mobile tester
+ Easy Diesel or Gasoline Filter Testing (DPF, GPF)
+ Sample straight from the tailpipe with included probe
+ Pass/fail result in less than a minute
+ Results backed up in internal memory
+ Test Cycle and Manual measurement mode

Sampling	Ambient Air				Tailpipe Emission										
PN Measurement															
Time (seconds)					0	5	10	15	20	25	30	35	40	45	50	55

The time sequence of a pre-defined test cycle in 5-second intervals. Nanoparticles in ambient air are sampled as reference point, before the sampling probe is attached to the tailpipe. Three measurements are recorded at the tailpipe and averaged, and the pass or fail results is based on comparing the average to a defined limit value.

UNDERSTANDING, ACCELERATED

SPECIFICATIONS

NANOPARTICLE EMISSION TESTER FOR PERIODIC INSPECTION

The cost-effective PTI-PN tester is a prototype available for selected cooperation partners involved in the development of supporting and drafting regulations targeting clean emission testing of light-duty vehicles.

Particle Size Range
23 nm to 1 µm

Particle Concentration Range
1,000 to 5,000,000 (5x10⁶) particles/cm³
Single particle counting with continuous live-time coincidence correction

Particle Concentration Accuracy
±20%

False Background Counts
0.01 particles/cm³ based on 12 hour average

Flow System
Sampling flow at probe tip of 0.1 L/min
Tip dilution flow 2 L/min (volumetric)

Liquid System
Isopropyl alcohol (2-Propanol, not included)

Communication Interfaces
Embedded touch-display.
USB type B for external memory drives.

Environmental Operating Conditions
Ambient Temperature 10 to 35°C (50 to 95°F)
Ambient Humidity 0 to 90% RH, noncondensing
Ambient Pressure 75 to 105 kPa (0.75 to 1.05 atm)

Accessories
Included
- Sampling probe 2 m with clamp for tailpipe sampling
- 2 Lithium-ion batteries for operation up to 8 hours
- Charger for batteries: 100 to 240 VAC, 50/60 Hz, 335 W Fill
- Desiccant dryer

Replacement Parts
- Disposable, pre-soaked wicks
- Air filters
- Air dryer cartridges filled with desiccant silica gel

Dimensions (H x W x D)
16 cm x 28 cm x 28 cm (6.2 in. x 11.2 in. x 10.9 in.), not including sampling probe

Weight
< 9 kg (< 19.5 lbs) including batteries

UNDERSTANDING, ACCELERATED

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