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Portable Particle Counter for Engines with Diesel Particle Filters


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Motivation and objectives

Up to now the measurement of the emissions from engines in vehicles and construction machinery is based on opacimetry. These instruments are successfully used since many years for regulatory applications. During engine inspection on site a short procedure without a test bench is required.

Therefore the free acceleration test is applied. During the free acceleration the accelerator pedal is depressed quickly and hold during a few seconds. The engine increases the revolution from idle to full speed against its inertia and emits a cloud of smoke (figure 1).

New generations of engines or engines equipped with particle filters emit fewer smoke that cannot be measured with opacimeters any more. Now for the in use testing particle measuring instruments are required.

The Swiss administration FOEN and METAS evaluate particle sensitive instrumentation for this and further applications.

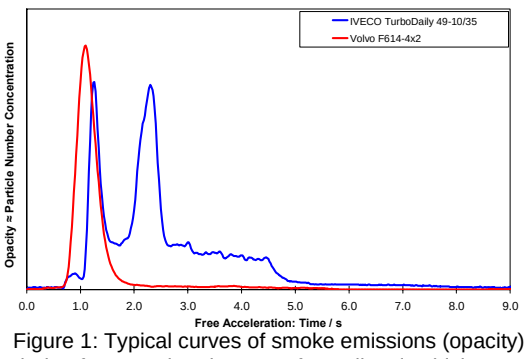

Figure 1: Typical curves of smoke emissions (opacity) during free acceleration test of two diesel vehicles

The measurement of the particle number concentration is establishing as a standard method for exhaust assessment. Future regulations for vehicle emissions will be based on particle number.

This project introduces possible requirements for an instrument measuring the particle number concentration of an engine at a working site, in workshops or in test centres. Therefore the instrument must be rugged, easy to operate, and portable.

Applications of this instrument

Diesel engines emit a large amount of ultrafine solid particles, mainly composed of elementar carbon, that are health hazardous. In order to protect humans, animals and plants from harmful effects of ultrafine particles, the Swiss Authorities are focusing their activities on the abatement of the ultrafine particles from diesel and other combustion processes. The most effective technology to reduce ultra fine particles from in-use diesel engines are closed particle filters. Tested and approved particle filter systems recommended for the retrofit of Diesel engines in Switzerland are published in the FOEN/Suva Filter List. Such a portable particle counter shall improve the monitoring of emission behaviour of installed particle-trap systems or equivalently effective emission curtailment systems and original equipment systems (eg Euro-5).

Following applications are possible:
- Emission monitoring of diesel-powered machines on construction sites
- Failure detection on particle trap systems
- Type-approval and registration
- Comformity of production and in-use compliance of retrofit systems
- Periodical emission inspection of diesel engines for road, non-road mobile, stationary applications and direct-injection gasoline engines
- Inspection of burners and other combustion processes

Acknowledgement

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Modes for Particle Number Measurement

1. Free acceleration
Measurement of the peak concentration or the sum of particles during the acceleration. This instrument continuously follows the curve of the smoke with a defined time constant and calculates either the peak value or the integral over a defined time period (figure 2).

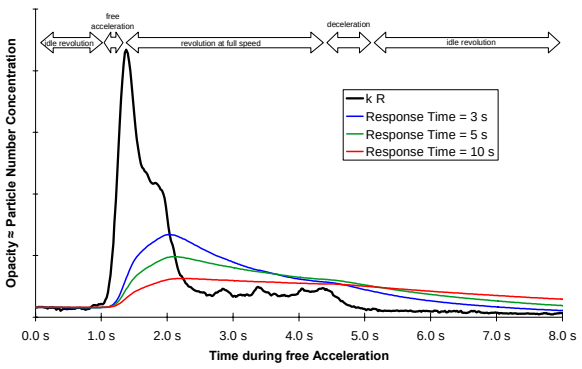

Figure 2: Comparison of the curves of smoke emissions during free acceleration test (black). Measurements with higher response times show smoothed curves. The peak concentration and the total number of particles depend on this response time of the instrument

2. Steady state
Measurement of the actual concentration at steady state or from a collected probe. In the first case the engine is run at a defined and constant load and the instrument measures an average number concentration. In the second case the engine fills a volume during a free acceleration and the instrument measures the homogenized aerosol from that volume immediately afterwards.

Requirements for the instrument

Definition particles:	Solid components of smoke
Particle size:	20 nm to 300 nm
Sampling:	Probe with a constant flow from the exhaust
Probe conditioning:	Continuous flow (e.g. 1 L/min) with dilution (factor > 10) and heating (300 °C ± 5°C during ≥ 0.2 s), in order to get concentrations < 10^4 mL^{-1} and to eliminate condensates
Reference conditions:	100°C und 1013 hPa
Measuring:	Particle number concentration (over above size range)
Resolution:	1 % of the indication
Uncertainty:	± 20 %
Drift:	During a measurement: 5 % / h With restart / zero / cleaning by user: 5 % $year^{-1}$
Resistance:	vibrations, shocks, EMV (cell phones, etc.), heat, humidity, high particle concentrations, etc.
Weight:	< 10 kg
Power Supply:	230 V AC or batteries

Steady State Measurement

Measurand:	Particle Number Concentration
Response Time	< 20 s
Measuring Range:	< 10^2 cm^{-3} to > 10^8 cm^{-3}

Free Acceleration Measurement

Measurand:	Particle Number per acceleration cycle (= integrated concentration over sampling time)
Delay Time:	Time between smoke entry at sampling line and start of detector response < 2 s
Response Time:	Time of 10 % to 90 % response to a step function of particle concentration at entry
Measuring range:	< 100 to > 1 000 000 particles per cycle