

## Simultaneous Comparison of 20 Instrument Candidates for Diesel Particle Measurement

Swiss Contribution to PMP Phase II - June 2002

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The GRPE PMP program, formed in January 2001 and conducted under the auspices of the UNECE WP29/GRPE group, will produce a recommendation for new or additional PM measurement system to be used for EU type approval, testing and development of future emission standards for both light- and heavy-duty vehicles. The new PM measurement methods would include some particle size characterisation parameters to address the nanoparticle emission issue. The objectives of the program are to identify the best metrics for future particle measurements, to determine instruments and methods utilising those metrics, to investigate a test procedure for the measurement of particles during type approval tests and finally, to recommend a suitable test system or systems. The group's recommendation is expected to be ready in late 2003.

Countries participating actively in the PM project are: France, UK, Germany, Sweden, Netherlands and Switzerland. Also Japan is contributing. USA refused to participate, stating that the new EPA 2007 PM measuring method will be sufficient to address health effects. Switzerland on the contrary has made an official statement saying that not only mass but also number of solid particles in the size range of 20 – 300 nm must be measured and curtailed with respect to Swiss legal requirement to minimize carcinogenic air pollutants using best available technology BAT – which are particulate traps with efficiencies of > 99 %. Accordingly on 1.Sept.2002 Switzerland has set into force a trap retrofit regulation for Diesels > 37 kW used in all larger construction operations where traps must be VERT-verified to reach > 95% filtration based on solid particle number definition. While Switzerland is free to regulate retrofit measures in highly polluted areas, type approval for new vehicles must be in accordance to EU-regulations by contract Bern/Brussels which motivates Switzerland to participate in this European task force PMP.

PM is a changing mix of substances of widely different toxicity, unspecific to particle size, phase and solubility and can therefore not be accepted as a metric addressing health effects properly – it is rather misleading medical research and industry. Mass would become an acceptable metric again if it could be measured and regulated specific to particle size-class and to toxicity rated substances as occupational health regulations tend to do.

Particles are airborne, emitted as aerosols, available as aerosols in street canyons and deposited in the lungs according to the laws of aerosol physics. Consequently they should be characterized as aerosol physics teaches. Characteristics (= metrics) are size (mobility diameter, aerodynamic diameter, surface), number and chemical composition.

Solid (insoluble) particles in the size range of 20-300 nm are of particular interest (1) because of their high probability of alveolar deposition, fast penetration into the vascular system and extremely long residence time, (2) because of the fact of the availability of filters as highly efficient and technically proven tools to clean the exhaust gas of Diesel to an extent which is new in air pollutant abatement and 3) because future Diesels with PM-emissions below detection limit of EPA 2007 method will still emit millions of such particles < 100 nm per cm<sup>3</sup>.

Volatile particles on the other hand (mostly soluble condensates of sulphates and hydrocarbons HC) will be more and more disappear to be an emission problem due to the use of sulphur-free fuels, low-sulphur lubricants and oxidation catalysts. It must also be accepted that soluble toxic substances, which are extremely fast distributed via the aqueous phase in the organism and can be phagotized thus disappearing as a threat to the organism must be discussed by their mass in relation to body weight and by their half-time activity which is many orders of magnitude lower than with solid particles. Hence the differentiation between solid-insoluble and volatile-soluble particles must be the first milestone-decision towards a new particle measurement. Mixing those 2 components in measurement as we still do now in regulation will continue to falsify conclusions from epidemiological correlations.

Criteria for new metrology have been set up reflecting the need for measuring these health related particle parameters at type approval conditions for HD and LD-vehicles – keeping in mind that this new metrology should also be able to characterize the ambient aerosol – not forcing us to use different methods for emission and ambient measurements which again makes conclusions from emission to ambient difficult if not impossible.

During PMP Phase I theoretical investigations and literature studies were performed on health effects, aerosol sampling & measuring and possible exhaust gas after-treatment methods – reports in English language are available – followed by screening tests of different sampling and measuring systems at standard and future emission levels and accompanied by the development of a combustion aerosol standard by the Swiss office of measurement and accreditation METAS.

The major contribution of Switzerland within PMP Phase II -2002 is the simultaneous comparison of 20 candidate instruments now offered by the industry. Test period were 3 weeks in June 2002. Aerosol sources were a modern VOLVO HD Diesel with OEM trap installation and the METAS combustion aerosol standard CAST. Engine tests were performed in regulated steady state modes and transient cycles with many repetitions. Repeatability, detection limit, time response and other properties can be evaluated from the enormous amount of data collected. Test site was EMPA, the Swiss national laboratory for material research and testing which is now very busy to evaluate the data to present a report in January 2003.

Results with this new instrumentation are very promising so far. Sensitivity is 2-3 orders of magnitude better than standard gravimetry, all requested properties can be measured, separation of solids and volatiles is perfectly possible on line and particle number emission can be detected within a second following transient cycles. More work will be needed to agree on conventions for calibration methods as usual.

Most of these new instruments – which are not only far better for this purpose but also much less expensive than standard PM-gravimetry - are still in an early stage of development and little money has been spent so far for this important target, which opens scope for improvement in many practical aspects and will result in improved reliability and repeatability.

From here there will be definitely no point of return back to the “classic” method of PM-mass.