Automotive Particle Emissions:
Recent and Upcoming Regulatory Developments in the EU

After the introduction of particle number (PN) emission limits for positive ignition light duty vehicles according to the principle "petrol = diesel" (i.e. 6×10^{11} #/km applicable by 1 September 2017/18 for new type approvals/all new vehicles) by Regulation (EC) 459/2012 the European regulation addressing particulate emissions, defined by Euro 6 (light duty) and VI (heavy duty) requirements, at a first glance appears to be settled for the next couple of years.

However, not quite: albeit the installation of closed wall flow particle filters (DPFs) for compression ignition vehicles and engines, which are equally efficient on the test cycle and under real driving conditions, seems to be ensured for current engine technologies, this might not be the case in the future. There are also some concerns about the catalytic creation of small (volatile?) particles downstream of the DPF, the science of which needs to be carefully observed by the regulator in the interest of public health. DPF tampering and defaults are addressed by vehicle on-board-diagnosis (OBD), which will identify also partial DPF failures (normally requiring on-board soot sensors) as from the 2017/18 dates for Euro 6 vehicles and 3 years earlier for Euro VI. But it should not be forgotten that the real effects of OBD for avoiding high pollutant emissions due to failing technology not only depend on the vehicle design but also on the readiness of the driver to follow up OBD warnings and on careful periodic vehicle inspections.

For particle emissions of positive ignition vehicles the relevance of ultra-small particles (sub 23 nm), which are not caught by the current PMP measurement procedure, as well as their chemical and physical particularities that may result in increased health hazards, need to be analysed. Particle emissions of port-fuel injection positive ignition vehicles currently are not regulated and are subject to a regulatory review in the coming years. But most importantly real driving PN emissions (RDE) of positive ignition vehicles must be carefully controlled by a specific test procedure to be applied as from the 2017/18 according to Regulation (EC) 459/2012. Although particle filters (GPFs) are expected to be used on positive ignitions as well in the future, PN emissions of these vehicles will be largely controlled by internal engine measures, the operation of which may be less effective outside the test cycle. They are therefore prone to defeat strategies (by intention or negligence) similar to those we see today for controlling NOx emissions in many diesel vehicles. Currently the development of RDE type approval test procedures in Europe is mainly driven by the need to bring down NOx emissions of diesel vehicles on the road. If in this context portable emission measurement systems (PEMS) will be employed, it would be highly desirable to have PN measurement equipment useable for the same purpose. The Commission will launch a call for a respective

measurement programme and encourages interested potential suppliers of PEMS equipment for PN emissions to participate.

And what about retrofits reducing particle emissions of existing vehicles? Since there is no scientific consensus on the environmental/health benefits of open filters and the installation of closed wall flow filters is hardly cost-effective, the Commission currently does not propose a retrofit strategy for light duty vehicles on the EC level, even such programmes exist in some Member States. The situation is different for heavy duty vehicles and non-road mobile machinery, where the Commission strongly supports the development of an UNECE Regulation harmonising retrofit systems for reducing particle and NOx emissions. Such standard could be used for mutual recognition between Member States, which is important e.g. for granting reduced road tolls to international operators of retrofitted vehicles. In addition it could become a minimum standard for granting national financial incentives according to the provisions of Article 10(2) of Euro VI Regulation (EC) 595/2009. Work on the standard was started in 2009 and it should be finalised and adopted at the UNECE level by January 2014.

Another important topic in the future may be particle emissions from non-combustion sources, such as break and tyre wear. There is scientific evidence that via a complex particle generation – settling – crumbling – re-suspension mechanism eventually very small nano-particles may be released to the ambient air and their numbers may exceed the combustion generated particles in some areas. However the details, the magnitude and environmental/health relevance of this process are not clear at the current stage. A study by the JRC should first identify the relevance of these particles for the environment and human health, if necessary define technical requirements on vehicle components and develop respective test procedures. Given that this process is in an early stage, regulatory application of any new requirements before 2020 appears to be unlikely.

European Commission

Enterprise and Industry
Directorate-General

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16. ETH Conference on Combustion Generated Nano-particles
Zurich, 25 – 27 June 2012

Particulate emissions: legal topics at EU

- PM / PN generated from combustion: legal challenges
- Retrofit strategies and support by legislation
- Particulate emissions from other sources: future legislation?

Euro 5/6 (LD), Euro VI (HD)

	PM (CI)	PN (CI)	PM (PIDI)	PN (PIDI)
Euro 5	5 mg/km	6 x 10^{11} #/km	5 mg/km	-
Euro 6b > 31/8/2014, 2015	5 mg/km	6 x 10^{11} #/km	5 mg/km	6 x 10^{12} #/km
Euro 6c > 31/8/2017, 2018	5 mg/km	6 x 10^{11} #/km	5 mg/km	6 x 10^{11} #/km
Euro VI >31/12/2012, 2013	10 mg/kWh	8 x 10^{11} #/kWh (WHSC) 6 x 10^{11} #/kWh (WHTC)	10 mg/kWh	still to be defined

CI: compression ignition, PIDI: positive ignition & direct injection

PM: particle mass, PN: particle number

Euro 5/6 (LD), Euro VI (HD)

Robust PM/PN emission limits: is the story finished?

➢For CI vehicles: legislation currently effectively mandates closed wall flow filters (DPF):

- Future engine developments?
- Particles catalytically generated downstream of DPF (volatile?)?
- DPF defaults occurring in use including tampering: cracks, holes, etc.

⇓

OBD threshold limits			
Euro VI-A > 31/12/2012, 2013 Pressure drop performance monitoring (60%)	Euro VI –B, C >31/8/2014, 2015 25 mg/kWh	Euro 6-1 OBD, >31/8/2014, 2015 25 mg/km	Euro 6-2 OBD >31/8/2017, 2018 12 mg/km
Euro VI, Euro 6-2 OBD: subject to review for technical feasibility, but currently binding law Euro VI-B, C and Euro 6-2 OBD: DPF partial failure monitoring expected to require on-board soot sensor: driver warning & in-service inspection			

Euro 5/6 (LD), Euro VI (HD)

Robust PM/PN emission limits: is the story finished?

➢For PI vehicles: not quite

- Non-volatile sub-23 nm particles: health effects & measurement techniques (PMP work)
- Chemical composition, physical properties (size ⇔ surface ⇔ health)
- Port fuel injection vehicles (?) => high off-cycle PN emissions in enrichment phases
- Real driving emissions: PN abatement via filter (GPF) vs. internal engine measures

Real Driving Emissions

Current discussion driven by high NOx emissions but also applicable to PN emissions if controlled by internal engine measures

"Traditional" test cycles do not deliver real driving emissions of criteria pollutants (CO, HC, NOx, PM/PN)

<=>

- Limited duration, no "full" coverage of real driving conditions
- "Idealised" test conditions for the sake of high repeatability& reproducibility, least challenging for emission control
- Fully pre-defined test conditions, cycle beating, i.e. emission control less effective at real driving than on test cycle by design or by "negligence"

Real Driving Emissions

"Not-to-exceed (NTE)" test procedures

- In principle "full" coverage of real driving conditions (ambient conditions/history, engine map, …)
- Test conditions not predefined, limited quantitative repeatability& reproducibility of measured emissions
- Certain boundary conditions, trip requirements (e.g. engine loads)
- Statistical evaluation of test results
- Compliance factors (>1) reflecting certain lack of measurement accuracy and statistical uncertainties of results with respect to real driving emissions

=> High degree of repeatability/reproducibility of pass/fail test result

Examples: Portable Emission Measurement Systems (PEMS), randomised test cycles

Real Driving Emissions: state of play

Decision on development of test method by end June 2012:

	Initial type approval	In-service conformity	Member State surveillance
(1)	PEMS	PEMS	PEMS
(2)	PEMS or random test cycle, choice of the manufacturer	PEMS	PEMS or random test cycle
(3)* (still to be assessed with respect to necessary public resources)	PEMS or random test cycle, choice of the manufacturer	PEMS or random test cycle, choice of the manufacturer	PEMS or random test cycle, strong role

Real Driving PN Emissions

Regulation (EC) 459/2012:

"until 1 September 2017/18 a type approval test method ensuring the effective limitation of the number of particles emitted by vehicles under real driving conditions shall be implemented"

Test cycles	PEMS
- Randomized or series of fixed cycles?	- Challenge: equipment for PN emission measurement
- Consistency with RDE measurement procedures used for other pollutants (NOx, CO, …)	- PMP method probably not possible on-board of vehicle
- Minimize test burden	- Wanted: on-board measurement method that can be correlated with PMP method "sufficiently well" according to NTE principle (lack of accuracy ⇔ compliance factor)

And the existing vehicles: retrofits???

- Particle reduction retrofits: “open” vs. “closed” filters
- No consensus on the environmental/health benefits of open filters
- Closed filters require regeneration management & changes to vehicle ECU => “high” costs
- Cost-efficiency of closed filter retrofits to light duty vehicles at least questionable => no current EC initiatives (but national, e.g. DE)
- Heavy duty vehicles (HDV) and non-road mobile machinery (NRMM): closed filter retrofits can be cost-efficient!
- EC supports development of UNECE Regulation for high quality retrofits to HDV and NRMM:

- Basis for mutual recognition between Member States (e.g. motorway toll)

- Defines minimum retrofit standards for national financial incentives according to Article 10(2) of Euro VI Regulation 595/2009/EC?

UNECE Regulation on retrofit emission control

- Sponsored by CH and NL, strongly supported by EC
- Work started in 2009
- Applies to HDV and NRMM
- Addresses retrofits for NOx and PM emission controls
- Addresses two stringency levels of emission controls
- Adoption foreseen by January 2014

PN emissions from non-combustion sources

- Increasing evidence that there may be high amounts of non-volatile nano-particles created from break and tyre wear
- Particle generation – settling – crumbling –re-suspension on the road (to be studied in detail)
- JRC study to be launched in 2012:
  - **Environmental/health relevance (mainly literature research)**
  - **Technical requirements on vehicle components (?)**
  - **Development of type approval test procedures**

NB: regulatory application before 2020 unlikely!

Conclusions

- **Still a lot to do**
- **Focus on PN emissions**
- **Focus on real driving emissions**
- **Focus on new sources of particle generation**

Thank you!

Thank you for your attention!

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