Common requirements for HD retrofit particulate traps

European Harmonisation

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Health effects or AAQ?

• Maximum health effects or upgrading to a higher Euro class?
• Emphasis on Particle Mass or number?
Heavy Duty retrofit DPF

Evaluation criteria

• Health effects or Air Quality?
• Technology
• Quality definition
• Cost effectiveness
• Reliability and emission stability
• Energy consumption
Health effects

• Eliminate solid particles 20 – 300 nm
• UN-ECE PMP-method
• Both particulate mass and particulate number
Technology

WHO rule: no safe exposure level:

use Best Available Technology!

- Particulate number: > 99% reduction
- Particulate mass: > 95% reduction
- Avoid secondary emissions
- Reduce fuel economy impact
- Reduce NO$_2$ increase
- Reliable regeneration capabilities
Quality definition

- Filtration efficiency
- Independent of engine characteristics and engine application
- Test on one typical HD diesel engine in a steady state cycle is sufficient
- Further tests in transient cycle if desired for determining scope of application (engine types or engine families)
Cost effectiveness

• WHO: overall health cost Particulate Matter $\sim$ € 300/kg
• Additional climate change savings
• Abatement cost PM today € 30 to € 50/kg
• Increasing DPF production numbers will further reduce abatement cost
Reliability and emission stability

- Emission stability $\leq 3\%$
- Failure rate $\leq 1\%/\text{year}$
- Needed: OBM, OBD, IUC, COP, training/tools and appropriate fuels and lubricants
Energy consumption (penalty)

• Fuel consumption penalty $\leq 2\%$
• Back pressure critical factor
• Back pressure monitoring with OBD
Requirements and recommendations

• Mandatory requirements to achieve BAT and maximum health effects
• Recommendations for the successful implementation of retrofit schemes
Requirements (1)

- System definition: *particle filter + regeneration elements and controls*
- OBM and OBD: monitoring pressures and temperatures, 3 month memory, tamper proof. Signalling malfunctions.
- Flow direction defined by design to prevent reversing the filter element
- Diagnostic access point up stream filter
- Fuel borne catalyst: safety requirements
Requirements (2)

- No bypass permitted
- Visible and durable identification plate
- Back pressure limits 50 mbar (new) and 200 mbar (aged) at highest no load rpm (95 percentile)
- Adequate technical documentation
- Verification tests on modern DI diesel engine.
- Highest space velocity and temperature specified by the DPF manufacturer.
Requirements (3)

- **Initial verification filter test**
  - Test cycle: ESC operating points 1, 10, 11 and 13
  - Sample treatment according to PMP protocol
  - Particulate number 20 – 300 nm mobility size (min. 5 classes): $\geq 97\%$ reduction in each class, loaded as well as after regeneration
  - Particulate number transient peaks during regeneration: $\geq 90\%$ reduction
Requirements (4)

✓ Efficiency during free acceleration: ≥ 95% based on CPC according to PMP

✓ Gaseous emissions during test cycle:
  • no increase of NO\textsubscript{x}, HC, CO
  • Δ NO\textsubscript{2}/NO\textsubscript{x} ≤ 20%, preferably less
  • Increase CO\textsubscript{2} ≤ 3% at each operating point
Requirements (5)

- Secondary emissions test (if catalysis involved): no relevant increase of any toxic substances.
  - Not relevant: less than 3 times the detection limit
  - Substances to be specified in annex
Requirements (6)

• Evaluation of regeneration behaviour:
  – Soot loading to >20% back pressure increase
  – Degussa regeneration cycle for passive regeneration systems
  – Particulate number efficiency > 90% during regeneration
  – Gaseous emissions: no increase (with the exception of some CO)
Requirements (7)
Endurance test (2000 h) in real world mobile application
- Must include all filter elements
- System sealed by inspectors
- 3 inspections (at zero, 1000 and 2000 h)
- Ash cleaning once permitted
- Back pressure monitoring (second by second) and logging (per minute) $\leq 200$ mbar 95 percentile
Requirements (8)

- Verification filter test after endurance test:
  - Procedures and requirements identical to initial verification test (excluding verification of secondary emissions)
Requirements (9)

Durability and service intervals:

- Interval between ash cleanings: $\geq 1000 \text{ h or } 100,000 \text{ km}$
- Life target $\geq 5000 \text{ h or } 500,000 \text{ km}$
- Maintenance intervals: $\geq 500 \text{ h}$
- Total failure: $\leq 1\% \text{ per year}$
- End of life: environmentally friendly recycling according to technical description
Verification procedure

- Verification tests by authorised laboratory
- Verification and de-verification of DPF systems is listed in official and public documents
- Manufacturer (holder of the verification) shall report annually on failures
In use performance check
✓ Authority tests at least 3 in-use DPF annually of each family of DPF
✓ In case of doubt the sample is extended
✓ Test of opacity and back pressure
✓ Comparison of results with figures in PET document
Conformity of Production

- Assessment of the quality control system of the manufacturer, including basis filtration tests and regeneration performance
- Initial audit, before granting type approval
- Periodic audits to assess the manufacturers’ efforts on monitoring of adequate filtration and regeneration
Durability requirements

- Useful life between ash cleanings: $\geq 1000$ h or 100,000 km
- Useful life of the system: $\geq 5000$ hrs of 500,000 km
- Maintenance intervals: $> 500$ hrs.
- Total failures: $< 1\%$ per year
De-verification

• De-verification by the authority based on:
  • annual failure reports (failure rate > 3%)
  • in use performance checks (insufficient emission stability)
  • Inadequate conformity of production
  • Analysis of statistical fleet monitoring for regeneration performance, back pressure and failures
  • After de-verification: systems already installed may remain in use
Recommendations

Certification of Conformity (1)

• Each system should be accompanied by Certificate of Conformity issued by the manufacturer

• Acceptance test: opacity, back pressure and nearby noise, before and after installation

• Initial and periodic measurements carried out by retrofitter or by the owner, provided they use equipment that is annually calibrated by the supervising authority.
Recommendations

• **Certification of Conformity (2)**
  
  ✓ Emission document and label characterizing vehicle and DPF
  
  ✓ Containing emission values and running number
  
  ✓ Signed by retrofitter and vehicle owner
Recommendations

Inspection and maintenance (1)

✓ Periodic Emission Test (PET) by owner or retrofitter

✓ Interval 12 months or other, depending on application

✓ Opacity during free acceleration or torque converter stall

✓ Use of officially calibrated instruments
Recommendations

- **Inspection and maintenance (2)**
  - Data logger download to allow later analysis
  - Maintenance and ash cleaning according to manufacturers’ manual
  - Test and maintenance data recorded on PET-document, provided by the authorities
Safety issues (1)

- Principle: no additional risk to the owner, the operator, any third party and the environment
- Hot surface protection
- Engine manufacturers tolerance
- No obstruction of vision
- Back pressure (95% percentile) < 200 mbar
Safety issues (2)

• 2 year warranty for function and performance

• Guaranteed compatibility of engine and FBC
Candidate engines

- All 4-stroke diesel provided properly maintained and lube oil consumption < 1% of fuel consumption
- 2-stroke diesel and 4-stroke diesel with open EGR are more sensitive to increased back pressure
Thank you for your attention