

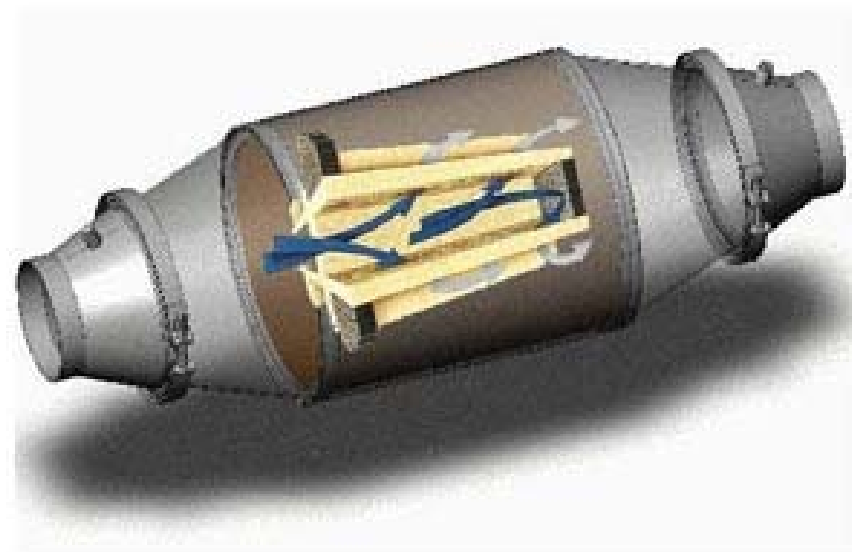


Ruimte en Milieu  
Ministerie van Volkshuisvesting,  
Ruimtelijke Ordening en Milieubeheer

## Common requirements for HD retrofit particulate traps

European Harmonisation

Henk Baarbé





# 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:  $\geq 99\%$  reduction
- Particulate mass:  $\geq 95\%$  reduction
- Avoid secondary emissions
- Reduce fuel economy impact
- Reduce  $\text{NO}_2$  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  $\leq 1\%/year$
- 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:  $\geq 95\%$  based on CPC according to PMP
- ✓ Gaseous emissions during test cycle:
  - no increase of  $\text{NO}_x$ , HC, CO
  - $\Delta \text{NO}_2/\text{NO}_x \leq 20\%$ , preferably less
  - Increase  $\text{CO}_2 \leq 3\%$  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  $\geq 20\%$  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:  $\geq 1000$  h or 100.000 km
- ✓ Life target  $\geq 5000$  h or 500.000 km
- ✓ Maintenance intervals:  $\geq 500$  h
- ✓ Total failure:  $\leq 1\%$  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