Discussion document for the GRPE subgroup handling the development of a Regulation for the approval of retrofit exhaust gas after treatment systems – Chairman's views.

Main principles:

1. The Regulation should be technology neutral as far as possible.
2. The requirements should be based on the performance of the Best Available Technology, as well as enabling engines of vehicles or machines to be upgraded to (at least) the next higher emission class.

Questions to be discussed.

A. What shall be the **scope** of the draft Regulation?

Issue 1. Do we develop an approval scheme for systems for HD on road diesel engine vehicles or also for off road diesel engine applications. The basic after treatment technology is the same; the operating conditions may however be quite different.
Proposed solution: we aim at both applications, and try to combine as many aspects of the test procedure as possible, to reduce the cost of certification.
Light duty applications are not envisaged, because of their unfavourable cost benefit ratio, which makes retrofit relatively unattractive.

Issue 2. Most retrofit systems now on the market aim at reducing the mass and number of particulates emitted. Air Quality problems are however also existing for NO_2 in some regions. So there is a potential need for retrofit systems reducing NO_x and/or NO_2.
Existing approval schemes in some contracting parties are limited to the reduction of particles emissions. Some regulatory authorities are working on the development of an approval scheme for systems reducing the emissions of NO_x as well as PM.
Proposed solution: an approval scheme for systems that either:
1. Reduce PM
2. Reduce PM and not significantly increase the direct emission of NO_2;
3. Reduce PM as well as NO_x and thus NO_2

B. **Environmental classification** of vehicles and machines

Issue 3. Many contracting parties classify their motor vehicles and machines according to the series of amendments or euro class they fulfilled when they were first registered or put into use. This classification is subsequently used for the calculation of emissions of the vehicle fleet, the taxation of individual vehicles and/or the access to environmental zones. After retrofitting these vehicles or engines the classification is adapted accordingly to the environmental performance of the retrofitted vehicle or engine.
For this reason retrofit performance requirements shall deliver approvals containing the information needed to upgrade the environmental classification of the vehicle or engine which is retrofitted with the approved systems.

Issue 4. In some cases only a limited reduction of the emissions of particles is needed to upgrade a vehicle type to the next higher Euro class. Such a limited reduction may be achieved by a catalyst type or 'flow through' type of trap. It is proposed to exclude such low efficiency traps by requiring a high filtering efficiency. This is legitimized by the wish to apply the best available technology and achieve the best value for money.

C. Determination of the **scope of application** of systems

Issue 5. **Applicable test cycle**
Assuming an adequate dimensioning of the trap in relation to the size and power of the engine, the filtering efficiency of state of the art wall flow type particulate traps is largely independent of the technology of the engine on which they are installed, and also largely independent of the duty cycle. This means that it might be possible to test a trap using an engine intended for use in on road HD applications in a transient on road test cycle, and use the test results to determine the scope of application of this type of trap on off road diesel engined machines. It may prove to be difficult to run a transient test cycle on an older engine design. This poses a problem if you need a trap to upgrade such an older design to a more modern design which should be tested transiently. Suggestions are welcomed.

Issue 6 Definition of engine families and trap families
We should explore the possibility to calculate whether a type of filter of which the efficiency has been demonstrated to be > x% is capable of upgrading an engine approved according to the y series of amendments to Regulation 49 to the y+1 series of amendments concerning the emissions of particulates, instead of having to having to demonstrate this for any trap-engine combination, thus reducing the administrative and testing burden for industry without additional environmental benefit. For contracting parties applying environmental classification of vehicles or machines, adequate proof shall be presented that a vehicle or machine meets the particulate or NOx limit value for the next higher environmental class, without negatively affecting the other regulated emissions such that they would exceed their applicable limit values.
Trap families may constitute of traps having a varying cross section area, but identical length, cell width, filtering characteristics and catalytic coating (if any).

D. Secondary emissions

Issue 7. **Secondary emissions due to catalytic activity**
Whenever catalytic processes are involved in the after treatment systems, there is the risk of the formation of undesirable secondary emissions, exceeding the non regulated emissions of the original engine without after treatment. This could be the increased direct emission of NO_2, intentionally caused by an oxidation catalyst for continuously regeneration purposes, or the formation of all kinds of toxic hydrocarbons. The Swiss-German VERT requirements and procedures have shown that requirements on the control of toxic hydrocarbons are practicable and feasible.
Increased direct NO_2 emissions only pose an environmental problem if they are emitted in an area where ambient air quality requirements for NO_2 are not fulfilled. It should therefore be up to the authorities to decide to include or exclude traps with increased direct NO_2 emissions in there retrofit programs.

E. Durability

Issue 8. **Durability**
For the user as well as for the environment it is necessary that the particulate traps will effectively reduce emissions for an extended period of time and/or mileage, when used and maintained according to the instructions of the manufacturer. Long term performance may be affected by gradual deterioration, or by sudden defects occurring stochastically. Durability can be verified before granting type approval using an extended durability test, or as a specified obligation to manufacturers, to be checked afterwards, as usually done in the UN-ECE Regulations under the 1958 Agreement.
Proposed solution: accept both approaches as equivalent methods.

In both schemes the manufacturer shall replace traps failing during the durability period at no cost to the user if it can be shown that the engine and trap have been used and maintained according to the instructions of the manufacturer.

Issue 9. **Durability in service**

UN-ECE Regulations usually contain a provision stating that a vehicle or system shall be designed such that it is durable and will function irrespective of the vibrations to which it is subjected. This is generally perceived as a qualitative in use compliance provision. This qualitative provision might be translated in a more quantitative requirement, such as a maximum failure rate during normal operation.

This requirement could be monitored through I&M programs, the results of which shall be collected by the manufacturer and reported to the type approval authority. This approach of course depends on the way how periodic inspections of vehicles or machines are organized in contracting parties. Without these results gained in I&M programs, the manufacturer shall provide for other methods and procedures to monitor in use performance of retrofit systems. This may include the use of information provided by on board diagnostic equipment of retrofitted vehicles or machines, monitoring the behaviour of the trap and its regeneration. Failure to meet the in use durability requirements should mean withdrawal of the approval, without the obligation for the manufacturer to replace all traps that have been installed. He shall just replace the individual traps which fail the annual or biannual short test if such tests are carried out.

F. Technology

Issue 10. **Euro VI equivalent technology only?**

To ensure that EURO VI[1] requirements are fulfilled after retrofitting a EURO V engine, or the stage IIIB requirements for NRMM after retrofitting a stage IIIA NRMM, it has to be verified that the system successfully reduces particulate mass and/or numbers to an extent necessary to meet EURO VI or stage IIIB requirements. With state of the art wall flow traps this is generally considered possible. For NO_x it is however questionable whether it is possible to upgrade a Euro V or earlier engine to a Euro VI level without total redesigning the engine. Upgrading NO_x emissions of Euro II and III to IV or V is not easy, but achievable by retrofitting SCR or maybe EGR.

Issue 11. Back pressure and fuel consumption increase.

To limit the possible increase in fuel consumption and related CO_2-emissions due to the retrofitting of emission reduction systems this increase shall be measured and regulated. Experience with existing schemes has proved that the increase can be limited to < 2%, provided the systems are well designed and dimensioned. Back pressure due to inadequate regeneration or build up of ashes shall be monitored.

Issue 12. Bypassing and flow direction by design

Most experts think it undesirable to accept bypassing of the trap during exceptional conditions for safety reasons. Arguments for this position are: valves used for bypassing would rarely be used and would therefore be unreliable. Furthermore the reason for bypassing would be a threat of filter blocking, which would be duly detected by the OBD system to take remedial measures.

A design has been observed in which the periodic cleaning of the ashes would be performed by reversing the filter element. This would appear an attractive, simple and cheap method, but it would mean that the potentially very toxic ash based particles would be emitted after all the effort to trap them. Reversing the element should be prevented by design restrictions which make it impossible to fit the element in a reversed position. This provision should of course be worded in a technology neutral way.

G. Efficiency

Issue 13. PM reduction efficiency

To upgrade an older diesel engine to the Euro VI level of PM emissions, the filtering efficiency should be at least ca. 95% in particulate mass and > 95% in particulate numbers.

[1] Or its corresponding series of amendments to UN-ECE Regulation R49

For contracting parties using environmental classification of vehicles and machines the traps shall reduce the particulate emissions of a specific engine type or engine family to a level which fulfils the requirement of at least the next higher vehicle or machine class. The requirements for particulate numbers will apply to all particulate size classes 20 – 300 nm, to ensure that the reduction of particulate numbers is achieved for a wide range of engine types, irrespective of the size distribution of their particulate emission.
For systems with periodical active regeneration the emissions during regeneration shall not exceed specific limit values.

Issue 14. NOx reduction efficiency
Recent research using PEMS has shown low NO_x reductions for SCR equipped trucks in driving conditions with relatively low engine loads (e.g. urban driving). To ensure adequate NO_x reduction in most practical conditions of use, and not only in the on average high engine load of the ETC and ESC cycle, it is proposed to add a provision requiring a specific NOx-reduction during low engine load vehicle or machine operation. This would of course mean that retrofitted vehicles might outperform OEM equipped vehicles during specific operation conditions. Is there an objection to that? We should closely watch the progress in the second stage comitology directive for Euro VI.

H. Test procedure

Issue 14. Suggested test procedure.
The way to pick test engines and to establish engine families could largely be copied from Annex XXVII of the German road traffic regulations.

The procedural steps that could be envisaged are:

1. Pick a test engine that will cover the maximum possible engine family. This engine will likely be a Euro III HD on road diesel engine, because Euro III is the most likely candidate engine to be retrofitted in the next few years.
2. Pick a test trap of the trap family with the dimensions compatible with the test engine.
3. After degreening, perform the basic tests: particulate number and particulate mass emissions and secondary emissions in a test cycle applicable to the engine type you want to upgrade to, most likely the ETC or the WHDC test cycle. Traps primarily for machine applications may either be tested on the ETC or the transient NRMM test cycle. Verify the trap's capability to upgrade the test engine to the next higher Euro class.
4. Perform the durability test on the test trap, either [2000] hours in practical application, or during [100] transient cycles.
5. Test the test trap again on the test engine or test machine, verifying the particulate mass and particulate number efficiency.
6. Determine the trap family and the engine family.