

## ***EMIS hearing on 19 April 2016***

### **Replies to the Questionnaire to the Joint Research Centre (JRC)**

**1a. What was the timeline of works on the Real-Driving Emissions (RDE) procedure (with exact dates) until the adoption of the 2nd RDE package in October 2015?**

**Response:** At the request of the Commission's policy services, the works started swiftly after the JRC presented the results of the on-road emission tests conducted at the JRC's VELA facilities in Ispra (Italy). The complete timeline of relevant events was as follows:

- **23 November 2010:** The JRC presents the results of the on-road emissions testing of light-duty vehicles in a workshop organised by DGs ENTR and ENV and open to stakeholders. The work started at the JRC in 2007 and included twelve Euro 3, 4 and 5 vehicles and continued until 2010; while the on-road emissions of regulated gaseous pollutants generally remain below the respective emissions limit, the on-road NO<sub>x</sub> emissions of diesel cars exceed the applicable emissions limit by several factors. The manufacturer and type of the cars was not disclosed at the time, but were subsequently disclosed publicly on 13 November 2015.
- **31 January 2011:** DG ENTR (now DG GROW) organises the kick-off meeting of the RDE-LDV working group (Real Drive Emission-Light Duty Vehicle Working Group) whose objective is to develop a complementary test procedure that ensures that the emissions of

regulated pollutants are appropriately controlled under normal conditions of vehicle use. The JRC report 'Analyzing on-road emissions of light-duty vehicles with Portable Emission Measurement Systems (PEMS)' is published.

- **2011-2012:** Four candidate procedures are initially discussed in the RDE-LDV working group:
  - i. multi-cycle test approach like in the US,
  - ii. emissions modelling,
  - iii. random driving cycles,
  - iv. on-road emissions testing with Portable Emissions Measurement Systems (PEMS).

Out of these four procedures, the latter two were assessed in greater detail by the JRC until the end of 2012, as they appeared to be the most promising at the time (see documentation on the CIRCA server).

- **4 February 2013:** The JRC announces in the RDE-LDV working group meeting the publication of a report ('A complementary emissions test for light-duty vehicles: Assessing the technical feasibility of candidate procedures') that summarizes the findings of the comparative assessment of random cycles and on-road emissions testing with PEMS. In the period between November 2012 and February 2013 it became clear that Member States would support the further development of PEMS on-road testing towards a complete RDE test procedure. Random cycle testing was kept as a fall-back option in case particle number (PN) measurement with PEMS equipment turned out not to be feasible.
- **1 October 2013:** The first meeting of a dedicated Task Force for the development of a RDE data evaluation method took place. Three methods were assessed:
  - i. speed-binning that groups instantaneous NO<sub>x</sub> emissions according to the corresponding vehicle speed at speed intervals of 5 km/h and assesses the NO<sub>x</sub> emissions relative to the emitted mass of CO<sub>2</sub> against the CO<sub>2</sub>-specific NO<sub>x</sub> emissions observed during type approval (proposed by TNO),

- ii. power-binning that groups the instantaneous NOx emissions according to the corresponding power at the wheels and normalizes the NOx emissions based on a generic frequency distribution (proposed by TU Graz),
- iii. averaging window method that calculates moving average NOx emissions over windows that represent half of the CO2 mass emitted during type approval with the worldwide harmonized light vehicle test procedures (WLTP) and averaging the NOx emissions of all windows if these fall within an interval of up to 50% of the CO2 emissions observed over the WLTP (proposed by the JRC).

Subsequently the latter two methods were retained by the dedicated Task Force and developed further for application in the RDE test procedure.

- **12-13 June 2014:** First meeting of the drafting committee as subgroup of the RDE-LDV Working Group (Commission with stakeholders) on real driving emissions of light duty vehicles on the drafting of the technical requirements for PEMS equipment. The subsequent meetings of the “drafting group” were chaired by the JRC.
- **October-November 2014:** Completion by the Commission of the first of four regulatory RDE acts making up the full RDE test procedure. The 1<sup>st</sup> regulatory RDE act sets out the RDE test procedure for NOx; the 2<sup>nd</sup> act defines the boundary conditions for the RDE test procedure; the 3<sup>rd</sup> act extends RDE testing to particle numbers and cold start; and the 4<sup>th</sup> act covers in-service conformity.
- **2011-2014:** For the completion of the 1<sup>st</sup> regulatory RDE act, in total around 30 meetings of the RDE working group and 20 meeting of the Task Force on data evaluation took place. In addition, 5 meetings of the drafting group specifying the performance of PEMS equipment were organized.
- **24 March 2015:** At the Technical Committee of Motor Vehicles (TCMV) the support for the 1<sup>st</sup> regulatory RDE act appeared to be insufficient for a qualified majority and as a result the act was not voted by Member States.

- **19 May 2015:** TCMV approves the 1<sup>st</sup> regulatory RDE act. In parallel, the technical work continues with a view to the second regulatory RDE act for defining additional boundary conditions for driving dynamicity and cumulative elevation, as well as on binding conformity factors and implementation date.
- **28 October 2015:** TCMV voting approves the 2<sup>nd</sup> regulatory RDE act.

A more detailed account of the work on the RDE test procedure can be found on the **CIRCABC server of the European Commission**.

**1b. Was the timeline comparable with the one for heavy-duty vehicles?**

**Response:** On-road testing of heavy-duty vehicles (HDV) with PEMS started at the JRC in 2004 following a request from DG ENTR and a clear stakeholder consent to develop a regulatory In-Use test procedure based on PEMS testing; Regulation 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and its implementing Regulation 511/2011 were published 5 and 7 years respectively after initial testing.

On-road testing of light-duty vehicles started at the JRC in 2007 for research and exploratory purposes only. The European Commission required that the applicability of PEMS to a wider range of light-duty vehicles was demonstrated and elevated on-road NOx emissions for Euro 3 to 5 diesel vehicles was established. Once this was achieved, the Commission decided to develop an RDE test procedure in 2011, 5 years passed from the launch of the RDE working group until the publication of the 1<sup>st</sup> regulatory RDE act (i.e., Regulation 2016/427 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6).

**1c. Was there a delay at any stage in setting up the RDE-LDC Expert Group or in the work on RDE? Could the work on RDE have been completed earlier?**

**Response:** The JRC is not aware of any delays in setting up the RDE-LDV working group or in the work on the RDE procedure. The development of the RDE on-road test, as that of any regulatory test procedure, poses technical challenges. For example, PEMS equipment was initially relatively bulky; the emission limits for light-duty vehicles are defined in g/km rather than g/kWh for heavy-duty vehicles, which necessitates the careful designs of boundary conditions and the implementation of data evaluation to ensure vehicles are assessed in a reliable, robust, and fair manner. RDE constitutes the first regulatory on-road test world-wide. From the JRC's perspective as the Commission's science service, the time frame of the technical work appears appropriate.

**1d. When was the technical part of RDE ready?**

**Response:** The technical part of the 1<sup>st</sup> regulatory RDE act was completed in November 2014. A preliminary draft version of the procedure still to be refined had been presented to TCMV on the 15 October 2014. At the TCMV meeting on 24 March 2015, the 1<sup>st</sup> RDE act did not receive sufficient support from Member States for a qualified majority. On 19 May 2015, the first RDE act received the approval of Member States (see section 1.a).

**2. When did the JRC and its European Reference Laboratory for Air Pollution (ERLAP) become aware for the first time of the substantial exceedance of NOx limits by European light duty vehicles? Which Commission DGs did you inform?**

**Response:** The risk that NOx emissions of diesel vehicles would be significantly higher outside the regulatory test cycle was known to the European Commission as well as to a wider audience of stakeholders and based on laboratory tests with alternative driving cycles when the Euro 5/6 Regulation 715/2007 was drafted in 2006. For this reason, the Commission was empowered in the Regulation to "keep under review the test cycles used to measure emissions in order to ensure they reflect real driving emissions. At that time, PEMS equipment that was small enough and could ensure reliable on-road measurements with light duty vehicles was not available. The JRC's Vehicle and Engine Emissions Laboratories (VELA) subsequently started testing light-duty vehicles on the road with PEMS in 2007. A limited number of tested Euro 3 and 4 diesel cars showed elevated on-road NOx emissions. At this time, the introduction of more stringent Euro 5 emission limits were envisaged for 2009 (see Regulation 715/2007). To assess whether problems persisted or were resolved for Euro 5 vehicles, the JRC tested two Euro 5 diesel

cars once these became available on the market in 2009. As the results showed elevated NO<sub>x</sub> emissions also for these vehicles, a report was drafted without delay and communicated in a dedicated meeting on 23 November 2010. DG ENTR and DG ENV, as well as stakeholders, participated in the meeting. The report was published by the JRC in early 2011 and the test results were openly available then ('Analyzing on-road emissions of light-duty vehicles with Portable Emission Measurement Systems (PEMS)').

**3a. In 2013, two years before the Volkswagen scandal, you had warned EU officials of the dangers of defeat devices. What was the basis for your reference to the possible use of defeat devices by car manufactures in your 2013 report?**

**Response:** The 2013 report had the objective to assess random cycles and on-road testing with PEMS as two RDE candidate procedures. The assessment was based on emissions tests conducted at the JRC and expert judgement. The on-road emission measurements reported by JRC did not allow to establish whether the elevated NO<sub>x</sub> emissions were due to insufficient emission control, just "negligent" calibration thereof, or an intentional manipulation of vehicles. The JRC did not have any concrete information that car manufacturers applied illegal defeat strategies at any point in time. Specific search for defeat devices was not in the scope of the JRC work; testing for the existence of illegal defeat devices according to the legal definition would have required a much deeper and more sophisticated analysis, for which resources (e.g. special IT knowledge) were not available.

The JRC was aware of the possibility that defeat devices could, in principle, be applied. In 1998, US-EPA accused several US heavy-duty vehicle manufacturers of violating the Clean Air Act by installing illegal defeat devices. As part of the resulting settlement with the EPA, these manufacturers received heavy fines and were subjected to new emissions standards which included on-road testing. A subsequent law suit in 2001 was settled in 2003 with a general agreement between heavy-duty vehicle manufacturers and EPA on provisions of on-road emissions testing with PEMS. In Europe, Regulation 715/2007 explicitly prohibits defeat devices, thus implicitly deducing that such devices could also be applied in light-duty vehicles, in particular with vehicle control software becoming increasingly sophisticated. Against this background, the 2013 report by the JRC concluded that random cycle testing in the laboratory may be less robust than on-road testing with respect to the application of defeat strategies. This conclusion, alongside the explanations in Box 2 of the 2013 JRC Report, is derived from Regulation 715/2007, past experiences and a risk assessment based on expert judgement and deductive reasoning.

**3b. Which officials and institutions did you approach, when did you alert them, and what were their exact reactions? If Member States or Commission authorities were not alerted, why weren't they?**

**Response:** The Commission services were informed about JRC work and its outcome, as reported in 2011 and 2013. In addition, DG ENTR co-funded the additional 2013 study and DG ENTR staff co-authored the report. Beyond what is written in the 2013 JRC report, the JRC did not alert institutions or Member States as there was no evidence of any concrete application of illegal defeat devices. Moreover, the conclusions of the reports were made public.

**4a. How, in the JRC's view, should a comprehensive RDE-Test cycle look like in Europe, in particular with regard to a credible conformity factor as part of a RDE test procedure?**

**Response:** The provisions of the 1<sup>st</sup> and 2<sup>nd</sup> regulatory RDE acts define a test procedure that is technically feasible and that will in all likelihood substantially decrease the on-road NOx emissions of diesel vehicles compared to the current situation. Recital 14 of the 2<sup>nd</sup> regulatory RDE act provides sufficient grounds for reviewing, and if applicable possibly revising, technical provisions and conformity factors if needed. It needs to be highlighted once again that RDE constitutes the first regulatory on-road test procedure for light-duty vehicles worldwide. With all major elements in place, it is now important to monitor RDE-approved vehicles as soon as these are available on the market. Based on the subsequent insights, the possible need for revisions can be discussed.

**4b. Has this view changed in any way in light of information given by vehicle manufacturers?**

**Response:** The JRC view considers in a first instance the established legislative requirements.

**5a. What are currently best technologies that can be used for detecting a defeat device during conformity test, and which among them would you advise a type approval authority to use?**

**Response:** It is difficult to detect defeat devices by a single emissions test and by testing a single vehicle (abnormal emission patterns may be vehicle specific as a result of a defect or malfunctioning hardware/software). The JRC has proposed a step-wise screening process based on dedicated tests and data analysis. The tests comprise:

- i. laboratory tests under type approval conditions to identify principle compliance with emission limits,
- ii. on-road test within and outside RDE conditions to identify whether deviations from the emissions measured in the laboratory occur; if this is the case
- iii. repeated laboratory testing under type approval conditions with variation in selected test parameters (e.g. test temperature, hot versus cold engine start, modification of selected parts of the driving cycle).

The number of feasible modifications is large, and practical constraints may limit the number of applicable test modifications. In parallel, the results of the on-road test (obtained under point (ii)) can be analysed with a tool developed at the JRC and made available to the Type-Approval Authorities that selects from on-road driving data sets only the pollutant emissions of those vehicle operation points that match the ones observed in the laboratory. If the pollutant emissions on the road under laboratory-like conditions are substantially elevated, this would provide a first indication of the possible existence of defeat devices that could then be further assessed under point (iii) in the laboratory. We would like to highlight that any of the proposed tests may be able to detect emission anomalies, but they need to be complemented by a legal evaluation to establish unlawful application of defeat devices.

A similar approach has now been adopted also by US-EPA. Unpredictable laboratory tests with modified driving profiles or conditions coupled with on-road tests will be used for screening purposes. Once an unusual emission pattern is identified, further investigation would then be carried out. Other technologies like remote sensing devices, On-Board Diagnostics (OBD) data analysis are also being taken into consideration and assessed in order to identify vehicles with high emissions under normal conditions.

**5b. How should a real-world test program be structured, to be able to detect defeat devices?**

**Response:** The JRC would think that the current type approval requirements for testing cars in the laboratory and on the road are fit for purpose. However, even the most rigorous and well-designed type approval procedures will not be sufficient to prevent the use of defeat devices. To ensure effective prevention of defeat devices, in-service conformity testing and proper market surveillance need to be enforced. These provisions will be discussed as part of the 4<sup>th</sup> regulatory RDE act in 2016/2017 and the revision of the type-approval framework.

**5c. What are the further steps the EU should undertake to that effect?**

**Response:** The RDE requirements for the in-service conformity testing and market surveillance will be discussed in 2016/2017. A proposal to revise the type approval framework has already been adopted by College on 27 January 2016. Regarding the RDE test procedure, a review of the procedure is foreseen by Recital 14 of the 2<sup>nd</sup> regulatory RDE act. The JRC and DG GROW are currently in the process of finalising a formal Administrative Agreement (AA) that foresees the review of RDE provisions by the JRC in 2017 and 2018 with the aim to identify the strengths and limitations of the current provisions and establish a list of recommendations. A complementary AA with DG ENV on vehicle testing is also being considered to assess the current emission performance of vehicles on the market and their impact on air quality.

**6a. Could you outline the different types of NOx control technologies available and their respective advantages and disadvantages?**

**Response:** The following technologies are readily available to reduce the NOx emissions of diesel cars:

- NOx control by after-treatment technologies:

Selective Catalytic Reduction (SCR) systems: This technology relies on the reaction between NH<sub>3</sub> (ammonia) and NO<sub>x</sub>, promoted by a specific catalyst. Urea is injected into the stream of exhaust gas in a quantity matching the expected NO<sub>x</sub> emissions. At high temperature, urea decomposes into ammonia, the needed reagent.

- Strengths: High NO<sub>x</sub> reduction efficiency of 95% under optimal working conditions; proven technology in Heavy-Duty and Light-Duty applications, good durability, wide operating temperature range, low thermal ageing, due to the highly effective reduction it allows for simultaneous fuel efficiency improvements through engine downsizing and turbo-charging which increase the emission of NO<sub>x</sub> from the engine before after-treatment;
  - Limitations: The catalyst is more costly than Lean NO<sub>x</sub> Trap (LNT) systems when engines with small displacements are considered, addition of a reactant is required that needs to be refilled in regular intervals; urea tank required which could lead to packaging issues, SCR effectiveness decreases substantially if the catalyst has not reached its operation temperature (actually injection of urea is switched off below exhaust temperatures between 150-200 °C); overdosing of urea can cause ammonia emissions, disposal of used SCR systems.
- Lean NO<sub>x</sub> traps (LNT): A NO<sub>x</sub> trap is a device able to adsorb NO<sub>x</sub> in specific combustion conditions (excess of air). Under rich conditions (excess of fuel), NO<sub>x</sub> are then released and reduced to form N<sub>2</sub>. LNTs need to be regenerated periodically since the NO<sub>x</sub> storage capacity is limited.
- Strength: Somewhat cheaper than SCR, no need for tank to store reactant, no need for frequent refilling.
  - Limitations: Generally lower NO<sub>x</sub> reduction efficiencies of 70% to a maximum of 90% periodic regeneration of LNT comes today at a fuel penalty of few percentage points; NO<sub>x</sub> efficiency depends on triggered regeneration and typically decreases with aging, precise air-fuel management required, could be subjected to poisoning by sulphur, NO<sub>x</sub> trap performance at high temperature/high flow rate operating conditions is still challenging, limited operating temperature range

➤ NOx control by engine measures:

Exhaust Gas Recirculation (EGR): Some exhaust gas is recirculated to the inlet manifold and mixed with the fresh air entering into the engine. This reduces the peak temperature reached in the combustion chamber which has a strong influence on the NOx formation.

- Strengths: readily applied in diesel engines, long-term experience, low costs.
- Limitations: EGR rate tailored to engine operating conditions may vary between 0% and 40% of the intake air volume; EGR can easily be deactivated; high EGR rates can lead to deposits, condensation and may drastically reduce the life time of engines.

➤ Injection timing and delayed fuel injection:

- Strengths: effective reduction of engine out NOx emissions.
- Limitations: Reduced engine efficiency and fuel penalty, electronically controlled fuel metering and timing are required for after-treatment devices with active regeneration.

It is important to note that engine internal NOx reduction measures are generally considered insufficient to achieve RDE requirements. The application of a LNT or SCR or their combination will be necessary to reduce on-road NOx emissions to the required levels. This assessment is confirmed by recent initiatives of car manufacturers that foresee the fleet-wide introduction of SCR technology for diesel cars.

**6b. Can you confirm that the technology necessary to meet legal levels of NOx emissions for diesel cars in real world driving conditions exist?**

**Response:** To the best of our knowledge, technologies are available to reduce the NOx emissions of diesel cars to the specified emission limit under real-world driving conditions. This assertion is supported by experience with Euro 6 light-duty vehicles and Euro 6 heavy-duty vehicles and various stakeholder documents.

**6c. Are there high costs for manufacturers involved? Does it substantially increase the fuel consumption of vehicles?**

**Response:** The answer to this question depends on the definition of “high costs” and “substantially increase”. Cost data are kept confidential by vehicle and component manufacturers for competitive reasons; here only estimates can be provided. The most promising and most likely widely applied NOx after-treatment technology may become Selective Catalytic Reduction (SCR) catalysts. The International Council on Clean Transportation (ICCT - 2012) estimates the costs of an SCR system at 400-600 USD (around 300-460 EUR). In the cost/benefit assessment drafted by the Commission services at the time of adoption of the RDE package, which was based on a 2013 TNO study<sup>1</sup>, the costs of an SCR system was estimated at EUR 417 – 491. At the same time, one should also recall that some of these costs were already incurred for non-RDE certified Euro 6 vehicles (a big majority of vehicles on the market already has a SCR or an LNT installed). We would expect that mass production and technological learning can reduce the costs of catalysts substantially in the future. In addition, consumers may need to refill urea solution at a rate between 1-2 l/1000 km at a price of some 0.6-1.6 EUR/l. SCR systems only incur additional fuel consumption if active heating, e.g., during cold-start is required.

As far as lean NOx traps are concerned, these are available at costs of 258 – 340 EUR (TNO 2013). The trap collects NOx but needs to be regenerated through combustion of additional fuel under rich conditions that reduce the trapped NOx to N<sub>2</sub> and CO<sub>2</sub>. This regeneration may happen every few minutes and comes at a fuel penalty of a few percentage points.

**7a. Which regulatory changes would allow us to reduce air pollutant and greenhouse gas emissions from vehicles?**

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<sup>1</sup> TNO (2013) Implementation of Euro 6 light-duty vehicle pollutant standards and benchmark against other international standards.

Response: From a technical point of view, the greenhouse gas (GHG) and pollutant emissions of vehicles result from a combination of factors, including:

- i. the number of persons using vehicles in each year,
- ii. the yearly distance driven by each person in vehicles,
- iii. the manner each driver uses his vehicle and the driving circumstances (aggressive motorway driving versus stop-and-go city driving), and
- iv. the distance-specific GHG and pollutant emissions of vehicles in use. It should be noted that the vehicles with the lowest pollutant emissions are in general not those with the lowest fuel consumption, unless unconventional vehicles are considered. It should be also taken into consideration that pollutant emissions from vehicles include evaporative emissions (i.e. fuel vapours escaping from the fuel system when the vehicle is parked) and non-exhaust particle emissions (particles generated by brake wear and by the interaction of the tyres with the road).

While the factors listed above are elements that influence the level of emissions, it may not necessarily be possible to address all of them effectively through regulatory measures. In designing such measures it must also be considered what is practically feasible. It is against that background that with regard to pollutant emissions the RDE has been introduced with the view to determine the level of air pollutant emissions in a more effective and realistic way. The core task is now to ensure its full and effective implementation.

As regards CO<sub>2</sub> emissions, the CO<sub>2</sub> emission standards for cars and vans have recently been evaluated and it is evident from that evaluation that the CO<sub>2</sub> regulations have been effective in reducing CO<sub>2</sub> emissions and in driving technology development. This is confirmed not only by the reductions seen in the monitored CO<sub>2</sub> emissions but also through the monitoring of fuel sales performed for the purpose of the UNFCCC.

**7b. Which technical tools would ensure that legal requirements of vehicles are met not only in the laboratory during certification/type-approval testing but throughout the full life cycle of vehicles across a wide range of operating conditions?**

**Response:** The following elements are important:

- Robust and well-designed type approval procedures are important and the introduction and application of RDE is an essential element.
- On-Board Diagnostics (OBD) is another important technical tool to check the proper functioning of the emission control devices. OBD can help in identifying, and consequently improving, the components of a vehicle affecting its emissions that are more subject to faults.
- Introduction and application of in-service conformity and market surveillance testing (technical aspect currently under discussion as part of the 4<sup>th</sup> regulatory RDE act). The proposal of the European Commission for a new Regulation on the approval and market surveillance of motor vehicles is another essential element to ensure an effective control on vehicles once they have been type approved and marketed. The introduction of an in service conformity test for CO2 emissions is foreseen as part of the new type approval framework proposal which will serve as a check on the effectiveness and representativeness of the laboratory test.
- Continuous review of the RDE test procedure and revision of provisions if deemed to be necessary following the requirements of Recital 14 of the 2<sup>nd</sup> regulatory RDE act..
- Law enforcement – without proper enforcement any revisions of technical provisions around the testing of vehicles remain less effective.

**7c. Which policy responses would be the most effective to deal with defeat devices and to improve current compliance and enforcement?**

**Response:** The JRC considers that the RDE test procedure will provide the means for a robust verification of the effectiveness of the pollutant emission reduction and should serve as a deterrent for the application of any defeat devices. Yet, no single type approval test or combination of laboratory tests can ensure that vehicles operate during their entire lifetime according to regulatory requirements. To this end, RDE as an element for in-service conformity testing and proper EU-wide market surveillance is critically important. Both aspects will be discussed and introduced as part of the 4<sup>th</sup> regulatory RDE act in 2016/2017. Furthermore, the proposal of the European Commission for a new type approval framework, which will strengthen the market surveillance and enforcement, is another essential element to ensure an effective control on

vehicles once they have been type approved and marketed. In the context of these activities, it is important to define measures that clearly describe responsibilities and escalation procedures towards the withdrawal of the type approval in case non-compliance is observed.

**8. What was the involvement of the car manufacturers during the development work on RDE? What was the position of the European Automobile Manufacturers' Association (ACEA) with regards to RDE as presented at the RDE-LDV expert group between 2011 and 2015? When did discussions with vehicle manufacturers on draft RDE proposals begin?**

**Response:** ACEA and individual car manufacturers have been participating in the meetings of the RDE working group from the beginning, i.e., 31 January 2011. ACEA members provided several cars and PEMS data to JRC for the different testing campaigns. The contributions of ACEA and individual car manufacturers are documented on the CIRCA server of the European Commission. The position of ACEA and the car manufacturers on the RDE procedure is documented by the various letters and emails on technical and political items communicated with the European Commission. Upon request, JRC can disclose relevant communication with ACEA.

**9. The JRC states in its report of 2011 that emission limits expressed as distance-specific quantities, mg/km, are problematic because they lack a reference to actual engine parameters and insufficiently account for the large variability of on-road driving conditions. Can you clarify what the JRC meant with this? Has the JRC looked further into developing other parameters?**

**Response:** To explain the discussions around the metrics of emission limits, one first has to emphasize that emission limits intend to restrict the mass of pollutants emitted given a certain vehicle utility. For light-duty vehicles it is accepted worldwide that the distance driven by a car is a useful and easily understandable measure of vehicle utility, thus limits are expressed in grams per kilometre worldwide.

For heavy-duty vehicles (HDV), the situation is more complex because these vehicles can be loaded up to several factors of the empty vehicle mass. HDV can be driven long distances or operated without covering much distance, e.g., when collecting garbage, or pumping cement onto construction sites. The driven distance is thus not a good measure of the utility of a heavy-duty vehicle. It is therefore internationally agreed to use engine work or, equivalently, the mass of CO<sub>2</sub> emitted as utility parameter.

Next to these wider considerations, one enters another level of controversy when considering emissions testing with a fixed cycle (thus a fixed and commonly agreed driving pattern) and with PEMS on the road. Fixed driving cycles used in laboratory are defined as time/speed profiles. It is well known that the speed of the vehicle is only roughly correlated to the load of the engine (e.g. the same speed on roads with different slopes will result in a very different load to the engine). For on-road testing, on the contrary, there is little a priori control over how a vehicle is driven or how many stops and traffic jams will be encountered during a trip. The variability of on-road driving can thus introduce uncertainty when evaluating the emissions performance of cars on the road in terms of g/km. One way to address this uncertainty is to express emissions in terms of engine work or fuel consumed (or its equivalent CO<sub>2</sub> mass emitted). This would allow controlling of the amount of work a vehicle has done during a trip and it would also allow a somewhat fairer evaluation of cars equipped with large versus small engines. Options to incorporate alternative metrics into RDE have been discussed and are currently under discussion for the evaluation of cold-start emissions. Yet, any such alternative metrics does ultimately mean that test results need to be linked to the existing emission limits. These are defined in g/km. So far there has not been sufficient support by Member States and other RDE stakeholders to investigate the feasibility of alternative metrics for RDE in greater detail.

**10. Could you please describe in detail all technical justified exceptions/circumstances (within the meaning of art. 5 (2) of regulation (EC) No. 715/2007) which in JRC's view have to be considered as necessary to protect the engine against damage and to ensure safe vehicle operation?**

**Response:** There are indeed circumstances under which a modulation or even a deactivation of emission control systems might be necessary. This could be for example the case at low temperatures where EGR systems might encounter condensation damaging the engine, or when SCR systems haven't reached the operational temperature of the catalyser and the injection of Urea needs to be stopped. For gasoline cars, a remarkable example is when the air/fuel mixture is not kept anymore at the stoichiometric value (typically at high load) to avoid excessive temperature in the catalyst. But there is no general answer regarding the necessity because for each of the possible technical problems leading to such exemptions, a possible technical solution may be found. Therefore such exemptions should be made on a case by case basis, taking into consideration technical progress and the best available technology on the market within the different vehicle categories.

**11a. The JRC has been testing the on-road emissions of light-duty vehicles with PEMS since 2007. Could you explain why in 2015 the industry still claims that PEMS are not reliable and need additional testing, if this is precisely what JRC has been doing for the last 8 years?**

**Response:**

As set out in the response to question 1 b, on-road testing of heavy-duty vehicles (HDV) with PEMS started at the JRC in 2004. On-road testing of light-duty vehicles started at the JRC in 2007 for research and exploratory purposes only as the European Commission required that the applicability of PEMS to a wider range of light-duty vehicles was demonstrated and elevated on-road NOx emissions for Euro 3 to 5 diesel vehicles was established. Once this was achieved, the Commission decided to develop an RDE test procedure in 2011, 5 years passed from the launch of the RDE working group until the publication of the 1<sup>st</sup> regulatory RDE act (i.e., Regulation 2016/427 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6).

The JRC cannot speak on behalf of vehicle manufacturers. The JRC would like to point out first that it has been using and evaluating PEMS equipment; however the JRC does not develop analytical equipment nor improve its measurement performance. To our judgement, PEMS equipment can provide reliable NOx emission measurements under the ambient and operating conditions permitted by RDE within a measurement uncertainty of some 20-30% (i.e., 15-24 mg NOx/km). This relatively high uncertainty relative to laboratory equipment results mainly from the measurement of pollutants over a period of 1.5-2h, which entails the risk of analyser drift. Drift is virtually negligible for laboratory measurements. For more details, we refer to the detailed assessment of PEMS measurement uncertainty presented by the JRC in the RDE meeting on 1 October 2015.

**11b. Based on your experience and technology development in the area would you say that the accuracy of the PEMS within the next 5 years will be high enough to evaluate precisely the on-road emissions of NOx in LDV?**

**Response:** The answer to this question depends on how one defines “high enough” and “precisely”. A few items are important. First it is noteworthy that laboratory equipment is also subject to measurement uncertainty; text voted by Member States in the TCMV effectively accounts for this uncertainty with emissions limit. This means, car manufacturers are required to design their vehicles so that the pollutant emissions plus the measurement uncertainty of the laboratory equipment remain below the emissions limit. Hence, RDE accounts for the additional but not for the absolute measurement uncertainty of the PEMS equipment. Second, the recently published 1<sup>st</sup> regulatory RDE act (Regulation 2016/427) defines performance requirements for PEMS in the context of RDE. These performance requirements were based on existing PEMS technologies. Bilateral discussions between Commission services and PEMS manufacturers revealed that the requirements for analyser drift could be tightened, which may ultimately reduce the measurement uncertainty by some 10-15% points. Further improvement potentials need to be identified in future meetings, e.g. when discussing the revision of RDE conformity factors as envisaged in Recital 14 of the 2<sup>nd</sup> regulatory RDE act.

## References

ICCT (2012): Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles.

Source: [http://www.theicct.org/sites/default/files/publications/ICCT\\_LDVcostsreport\\_2012.pdf](http://www.theicct.org/sites/default/files/publications/ICCT_LDVcostsreport_2012.pdf)