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CERTIFICATION PROCEDURES FOR INNOVATIVE TECHNOLOGIES IN LIGHT DUTY VEHICLES

Transmitted by the Expert from the Netherlands

1. DEVELOPMENT OF NEW CERTICATION PROCEDURES FOR INNOVATIVE TECHNOLOGIES

At the 41st meeting of GRPE the French delegation proposed to set up a working group for the development of new certification procedures for innovative technologies, such as hybrid vehicles. The Dutch delegation has expressed its willingness to support this proposal and to partake in the work. As a first contribution the Dutch delegation offers this discussion document.

In the development of certification procedures for innovative technologies basically two different approaches are possible:

- One approach is to identify the Regulations that are affected by the different new technologies and the elements of those Regulations that need to be adapted. This is done in section ‘2’. One can then attempt to find solutions for the problems identified. In this way the existing legislation is ‘repaired’ to the extent needed.
- The other approach is to design a new formulation altogether that will care for both the conventional technologies and the innovative technologies. This is a more elaborate but also a more fundamental solution. The arguments for a fundamental solution are given under ‘3’ below.

Both of these approaches have their advantages and disadvantages.

At first sight the ‘repair’ option seems the most attractive since it would require less effort and (very important) less time to complete. On the other hand it may lead to less satisfactory compromises. It also brings the risk of a necessity of more repairs when still newer technologies are developed.

The new procedure approach may be expected to have a wider application with less compromises, and less need for further repair in the near future. The present procedure stems in origin from 1968 and should really be regarded as superseded, even for conventional technologies. On the other hand the development of a completely new procedure requires time and effort.

To the extent that time is short a third solution may be envisaged:

- Repair the existing procedures to the extent that technologies that may be expected to appear on the market soon may be homologated and at the same time start a longer term project for a more fundamental solution.

The Dutch delegation feels that the question of how to approach the subject should be addressed first, before any effort is made to accommodate innovative technologies.

2. INVENTORY OF NECESSARY ADAPTATIONS OF ECE REGULATIONS FOR ADVANCED POWERTRAINS

An inventory of ECE Regulations that will have to be adapted in order to let them apply to hybrid (electric) vehicles and fuel cell vehicles, is summarised in the following table. Numbers in the table refer to the listed remarks. For abbreviations see section 5.
In table 1 a vehicle with a combustion engine with a starter alternator that also provides extra torque and/or permits regenerative braking, is considered to be a HEV. This is not an official distinction, but by using this

definition an engine with a starter/alternator without torque assist and/or regenerative braking (ICE+SA) falls within the definitions of the existing regulations, even if a start stop strategy for the engine is used.

Applies to	L,M,N,O	M,N,O	M,N	M1,N1	M1,N1	M,N	M,N	M1,N1
Reg. No.	**10**	**13**	**51**	**68**	**83**	**85**	**100**	**101**
Subject	EMC	Braking	Noise emissions	Max. speed	Emissions	Power curve	BEV	Fuel, energy, CO_2
ICE+SA			6					
BEV	3, 8		6					15
Mech Hybrid	1	7, 10		7	7, 14, 15, 16			7, 14, 15, 16
HEV	1, 3, 8, 17	7, 9	1, 5, 6, 17	5, 7	5, 7, 14, 15, 16	12	5, 13	5, 7, 14, 15, 16
FCEV	2, 8	9	4, 6	11	11, 14, 15, 16		13	11, 14, 15, 16

Table 1. Matters that require modifications of the regulations

Remark:
1. In hybrid vehicles, it is not always possible to control the motor speed as prescribed
2. The possibility of the presence of a fuel cell and a reformer should be added
3. The battery charger, if present, should be named as an electrical/electronic subassembly
4. The word engine should be replaced by power source to include fuel cells
5. The text should be adapted to vehicles with 2 or more driver selectable driving modes
6. Attention has to be paid to electrically driven hydraulic pumps, e.g. for steering or braking
7. Hybrid (electric) vehicles should be added to the definitions
8. Electric regenerative braking should be tested on immunity to electromagnetic waves
9. The additional requirements for electric vehicles should concern all vehicles with electric regenerative braking
10. A section with requirements for vehicles with regenerative braking, other then electrical, should be added
11. Fuel cell vehicles should be added to the definitions
12. The text does apply to series hybrid powertrains but not to other forms of hybrid powertrains, e.g. engines with integrated electric motor
13. The Regulation should also concern the construction and functional safety of HEVs and FCEVs
14. A ΔSOC correction procedure has to be added
15. Regenerative braking should be specified more exactly
16. Self-discharge or energy use of storage devices should be taken into account
17. For some HEVs the engine speed in the stationary vehicle depends on the SOC and cannot be controlled by persons

Priority

In table 2 the priority of the actions is given. Generally speaking the actions for HEVs have high priority while actions for FCEVs and mechanical hybrids have low priority. Nevertheless, a lot of the actions for HEVs also apply on FCEVs. Regulations 83, 85 and 101 have the most impact and should get highest priority. Regulation 85 is important because the power of an engine has to be defined for the other regulations.

Applies to	L,M,N,O	M,N,O	Cars	M1,N1	M1,N1	M,N	M,N	M1,N1
Reg. No.	**10**	**13**	**51**	**68**	**83**	**85**	**100**	**101**
Subject	EMC	Braking	Noise	Max.	Emissions	Power	BEV	Fuel,

			emissions	speed		curve		energy, CO2
ICE+SA			3					
BEV	3		3					3
Mech Hybrid	4	4		4	3			3
HEV	2	2	2	2	1	1	2	1
FCEV	4	4	4	4	4		4	4

Table 2. Priorities of the actions, 1 = highest priority

Complexity
Table 3 shows the complexity of the necessary actions. Especially the ΔSOC correction procedure for emissions will take many measurements. Another difficult task is incorporating driver selectable modes into the Regulations 83 and 101.

Applies to	L,M,N,O	M,N,O	Cars	M1,N1	M1,N1	M,N	M,N	M1,N1
Reg. No.	**10**	**13**	**51**	**68**	**83**	**85**	**100**	**101**
Subject	EMC	Braking	Noise emissions	Max. speed	Emissions	Power curve	BEV	Fuel, energy, CO2
ICE+SA			*					
BEV	*		*					**
Mech Hybrid	*	**		*	***			***
HEV	*	*	**	**	****	***	**	****
FCEV	*	*	*	*	***		*	***

Table 3. Complexity of the actions, more stars is more complex

Some explanation concerning R85
In an engine with a integrated starter/alternator that also gives torque assist, the total power of those two components is dependent on the battery SOC, but not of the vehicle speed. The power curve can be determined unambiguously with a constant voltage source instead of a battery. In practice, using a constant voltage source may be rather complex since the vehicle's battery management system may interpret this as an system error.

Cars with a starter/alternator without torque assist cause no special problems for power curves measurements, because the S/A is just a component that replaces the starter motor and the generator. The power curve of the engine remains unchanged.

In more complex hybrid vehicles measuring the power curve is also more complex. For example, the power curve of the Toyota Prius combustion engine can be measured without the electric motor or generator. It is not possible to measure the power curve of the combustion engine and the electric motor as one, because this power curve depends on the speed of the vehicle and the battery SOC. The power curve of entire powertrain, measured at the wheels also depends on the SOC of the battery. This power curve is therefore a system characteristic, not a component characteristic.
However, if a constant voltage source is used, the dependence on the battery does not play a part. In that case the power curve can be considered a component characteristic, but only if power is measured at the wheels and the component is the entire powertrain and provided that the hybrid system controller accepts the constant voltage source.

What is already done
From 1997 to 2000, there has been a Dutch project and and a European project (called Matador) concerning procedures for measuring the fuel consumption and emissions of hybrid vehicles.

Within the Matador project an inventory was made of all the technical problems associated with these measurements and the necessary changes of the Regulations 83 and 101. It was concluded that for these regulations solutions for the driver selectable modes, the regenerative braking, self discharge of the energy storage component and the ΔSOC correction should be found.
The report of the Dutch project on the pragmatic procedures for HEVs has suggested solutions for the ΔSOC problem while measuring the fuel consumption. This solution was used as input to the Matador project, which included it with some changes in the Matador end report. This solution is a recommendation and has no formal status.
For all the other problems mentioned in table 1, including the ΔSOC correction for emissions, solutions still have to be found.

Possible contributions by working group members
One of the most complex tasks to be performed is to check whether the proposed ΔSOC correction method for measured fuel consumption also applies to measured emissions. To do this, many measurements are necessary to determine the relation between ΔSOC and the produced emissions. These measurements should preferably be done on hybrid vehicles, but it is also possible to measure combustion engines in simulated hybrid use. Working group members should have the necessary equipment to perform these measurements.

To correct the error in measuring energy from regenerative braking, a method has to be developed to measure this amount of energy. Working group members should have the experience and the equipment necessary to develop such a method.

Safety aspects
Apart from aspects concerning exhaust emissions and fuel consumption (or energy use), it should be noted that safety aspects play an important role in the new technologies. These too should be subjected to consideration.

3. A MORE FUNDAMENTAL APPROACH

Instead of ‘repairing’ existing homologation procedures to accommodate the technology-specific measurement problems of electric, hybrid or fuel cell vehicles, also a more fundamental approach can be envisaged. The structure of current procedures has been designed for the internal combustion engine vehicle as we have known it over the last four decades. Each new technology added to this vehicle has required complex adaptations of the procedures. The question is whether such ‘repairs’ are still technically possible, practical and adequate if one wants to adapt existing procedures to deal with advanced propulsion systems. As an example the graphical ΔSOC correction method, that is found to work well for measuring energy consumption of hybrids does not seem to suffice for measuring emissions due to a larger apparently random spread in measured emission values as a function of ΔSOC.

From the results of the EU-funded MATADOR project two important conclusions can be drawn:

- The magnitude of various technology-specific measurement problems of electric, hybrid or fuel cell vehicles is to a large extent related to the current structure of homologation procedures. An important aspect is the use of a relatively short test cycle that is not representative for real-world driving. E.g., the effect of a ΔSOC-variation on measured energy consumption and emissions is strongly reduced when a longer and more dynamic test cycle is used. A longer cycle assures that the thermal engine of a hybrid vehicle does actually switch on during the test and that the energy consumed and the emissions produced with the engine on are weighted in the final results in a representative way. Including a standstill period in the test procedure will e.g. allow the measurement of standstill energy consumption due to battery heating or self-discharge.
- Many measurement problems of advanced propulsion vehicles will in fact also be found in advanced conventional vehicles. The ΔSOC-problem of hybrids is the result of a decoupling of instantaneous energy consumption and emissions from the instantaneous road load. This problem is also found in conventional vehicles with regenerating particulate filters or storage catalysts. Other problems are e.g. related to the

introduction of driver selectable modes, the sensitivity of emissions to small variations in the execution of the test and the energy consumption of auxiliaries during standstill of the vehicle.

The severity of technology-specific measurement problems and consequently the amount and technical complexity of technology-specific test procedures may be greatly reduced by designing an appropriate structure for a new generation of homologation procedures that is able to provide an adequate framework for dealing with all the new propulsion technologies that may come to the market in the next decades.

An important problem with ‘repairing’ existing procedures is that the repairs often require complex definitions of the different propulsion technologies as well as complex test methods involving the measurement of many in-vehicle parameters (e.g. battery voltage and current, power train control parameters, etcetera). In a new homologation procedure framework the vehicle should be considered as a black box as much as possible. Only the interactions with the vehicle’s environment should determine the categorisation and the required technology specific measurement procedures.

As already stated, an important ingredient of the new structure for homologation procedures is the selection of a (set of) driving cycle(s) that is representative for actual use of LD-vehicles. This not only requires that the cycle has representative average dynamics, but also that the cycle has a representative mix of road types (urban, rural and highway) and that the cycle has a representative length.

Another important ingredient should be to redefine how one deals with vehicle conditioning, measurement accuracy and reproducibility. For conventional vehicles the allowed tolerances already cause significant variations in the test results. For hybrids, with discrete switching actions (e.g. ICE on or off) in response to external parameters (e.g. road load) or internal parameters (e.g. battery SOC), the effects are found to be even more dramatic.

All in all defining a new structure for homologation procedures may result in test results that are more representative of the energy consumption and emissions of vehicles in real use and that can be used as a basis for acually comparing rather tha just homologating vehicles with different propulsion technologies. In this way a new structure of homologation procedures will allow the definition of more market-oriented, technology-independent policy instruments to promote clean and energy efficient vehicles.

The development of test procedures that are representative for actual use of the vehicles is not only relevant to governments but is also in the interest of the automotive manufacturers. Their main concern is to develop vehicles that meet the expectations of customers. Design criteria and development targets can only be formulated in a consistent way when the performance demands of homologation procedures and emission legislation are in correspondence with the performance demands set by customer expectations and the actual applications for which vehicles are designed. This requires adequate technology assessment instead of e.g. just worst case homologation: for technology assessment a real-world testing situation is needed, whereas for homolgation an assessment of the worst case situation may be adequate.

4. RECOMMENDATIONS

The following recommendation is made:
The working group, proposed by the French delegation is installed. Its mandate for the first half year is recommended to define a plan of action. More specifically a choice will have to be made between:

1) A ‘repair’ approach (as indicated in section 2)
2) A ‘fundamental’ approach (as indicated in section 3)
3) A temporary repair, with a parallel action for a longer duration fundamental approach

The group should come with a recommendation in the GRPE meeting of Januari 2002. On the basis of that recommendation the final mandate can be formulated.

5. ABBREVIATIONS

The following abbreviations are used for the various possible technologies:

– ICE	Internal combustion engine
– SA	Starter/alternator (whether or not for limited electrical power boost)
– ICE+SA	Combination of an internal combustion engine with a starter / alternator used for a start/stop strategy, but without additional power boost and/or regenerative braking (otherwise it is regarded as a HEV)
– BEV	Battery electric vehicle
– HEV	Hybrid electric vehicle
– FCEV	Fuel cell electric vehicle
– Mech Hybrid	Mechanical hybrid
– SOC	State of charge of the energy buffer (such as e.g. an electric battery)
– ÄSOC	Change in the state of charge, representing a positive or negative item in the energy balance