

## New type IV test for vehicles equipped with an electric regenerative endurance braking system

*This proposal implements the principles presented in documents GRVA-01-27 and GRVA-04-30, and includes further improvements from industry, based on input received since GRVA-04. For the best convenience of GRVA experts, some text have been added to provide relevant background.*

### I. Proposal

- 2.21. "Electric regenerative braking" means a braking system which, during deceleration, provides for the conversion of vehicle kinetic energy into electrical energy.
- 2.21.1. "Electric regenerative braking control" means a device which modulates the action of the electric regenerative braking system.
- 2.21.2. "Electric regenerative braking system of category A" means an electric regenerative braking system which is not part of the service braking system.
- 2.21.3. "Electric regenerative braking systems of category B" means an electric regenerative braking system which is part of the service braking system.
- 2.21.4. "Electric state of charge" means the instantaneous ratio of electric quantity of energy stored in the traction battery relative to the maximum quantity of electric energy which could be stored in this battery.
- 2.21.5. "Traction battery" means an assembly of accumulators constituting the storage of energy used for powering the traction motor(s) of the vehicle.

*insert a new paragraph 5.2.1.29.7., to read:*

- 5.2.1.29.7. Vehicles equipped with an electric regenerative braking system of category A or B (as defined in paragraphs 2.21.2. and 2.21.3.), using the alternative Type-IV test defined in paragraph 1.9 of Annex 4, shall warn the driver at the latest when the service braking performance is decreased below the minimum hot performance specified in the type-II test of Annex 4. The yellow warning signal according to paragraph 5.2.1.29.1.2 shall be used.**

**The method to assess the service braking performance [(e.g. by temperature/energy calculation and/or deceleration control)] shall be described by the vehicle manufacturer together with the documentation package required in Annex 18 of this Regulation to the Technical Services.**

#### **Annex 4 - Braking tests and performance of braking systems**

- 1.4. Type-0 test (ordinary performance test with brakes cold)
- 1.4.1.2.2. [...] In the case of a vehicle equipped with an electric regenerative braking system, the requirements depend on the category of this system:
  - Category A: Any separate electric regenerative braking control which is provided, shall not be used during the Type-0 tests.

Category B: The contribution of the electric regenerative braking system to the braking force generated shall not exceed that minimum level guaranteed by the system design.

This requirement is deemed to be satisfied if the batteries are at one of the following state of charge conditions where state of charge<sup>1</sup> is determined by the method set out in Appendix to this annex:

- (a) At the maximum charge level as recommended by the manufacturer in the vehicle specification; or
- (b) At a level not less than 95 per cent of the full charge level, where the manufacturer has made no specific recommendation; or
- (c) At the maximum level which results from automatic charge control on the vehicle, or
- (d) When the tests are conducted without a regenerative braking component regardless of the state of charge of the batteries.

1.5. Type-I test (fade test)

1.5.1. With repeated braking

1.5.1.1. The service braking systems of all power-driven vehicles shall be tested by successively applying and releasing the brakes a number of times [...]

*paragraph 1.5.1.8, amend to read:*

1.5.1.8. For vehicles equipped with an electric regenerative braking system of category B, the condition of the vehicle batteries at the start of the test, shall be such that the braking force contribution provided by the electric regenerative braking system does not exceed the minimum guaranteed by the system design.

This requirement is deemed to be satisfied if the batteries are at one of the state of charge conditions listed in the ~~fourth clause~~ **four clauses** of paragraph 1.4.1.2.2. above.

1.5.3. Hot performance

1.5.3.1.2. For vehicles fitted with an electric regenerative braking system of category A, during brake applications, the highest gear shall be continuously engaged and the separate electric regenerative braking control, if any, shall not be used.

1.5.3.1.3. In the case of vehicles equipped with an electric regenerative braking system of category B, having carried out the heating cycles according to paragraph 1.5.1.6. of this annex, the hot performance test shall be carried out at the maximum speed which can be reached by the vehicle at the end of the brake heating cycles, unless the speed specified in paragraph 1.4.2. of this annex can be reached.

For comparison, the Type-0 test with cold brakes shall be repeated from this same speed and with a similar electric regenerative braking contribution, as set by an appropriate state of battery charge, as was available during the hot performance test.

[...]

The tests may be conducted without a regenerative braking component. In this case, the requirement on the state of charge of the batteries is not applicable.

---

<sup>1</sup> By agreement with the Technical Service, state of charge assessment will not be required for vehicles, which have an on-board energy source for charging the traction batteries and the means for regulating their state of charge.

~~1.6. Type II test (downhill behaviour test)~~

~~Annex 4, insert a new paragraph 1.6.5, to read:~~

~~1.6.5. For vehicles equipped with an electric regenerative braking system, the condition of the vehicle batteries at the start of the test, shall be such that the braking force contribution provided by the electric regenerative braking system does not exceed the minimum guaranteed by the system design.~~

~~This requirement is deemed to be satisfied if the batteries are at one of the state of charge conditions listed in the four clauses of paragraph 1.4.1.2.2. above.~~

1.8. Type-IIA test (endurance braking performance)

Annex 4, insert a new paragraph 1.8.2.4, to read:

1.8.2.4. For vehicles equipped with an electric regenerative braking system, the condition of the vehicle batteries at the start of the test shall be such that the braking force contribution provided by the electric regenerative braking system does not exceed the minimum guaranteed by the system design.

**This requirement is deemed to be satisfied if the batteries are at one of the state of charge conditions listed in the four clauses of paragraph 1.4.1.2.2. above.**

Annex 4, insert a new paragraph 1.9., to read:

1.9. Type-IV test (downhill behaviour and endurance braking performance test for vehicles equipped with an electric regenerative braking)

1.9.1. The requirements of paragraph 1.9.2. ~~above~~ below may be used as an alternative to the Type-IIA test for vehicles listed in paragraph 1.8.1. of this Annex, in case they are equipped with an electric regenerative braking system.

1.9.2. Test conditions and performance requirements

1.9.2.1. Type-II test with increased performance

The vehicle shall fulfil the requirements of the Type-II test, with the exception of the following parameters:

- [The vehicle shall be driven on a [7] per cent down-gradient, instead of the 6 per cent value specified in paragraph 1.6.1.]
- [For the hot performance of the service braking system, the mean fully developed deceleration  $d_m$  (as defined in paragraph 1.6.3.) shall at least be equal to [5m/s<sup>2</sup>].]

1.9.2.2. As an alternative to paragraph 1.9.2.1. above, the following requirements may be used:

1.9.2.2.1. The electric regenerative braking system shall implement technical measures to secure that the necessary retardation capacity in the batteries is available for the vehicle to be able to absorb at least the energy to stabilize speed in the forthcoming (predicted) downhill on the route of the vehicle [that the vehicle may potentially follow].

1.9.2.2.2. The **vehicle equipped with an** electric regenerative braking system shall be able to secure a sufficient retardation ~~capacity in the batteries~~ to ensure the stabilization of the vehicle speed during a Type-II test.

1.9.2.2.3. The driver shall be informed about the available ~~retardation battery~~ capacity prior to the time when the braking force of the electric regenerative braking ~~is can~~ no longer ~~be~~ provided [(e.g. when the battery is fully loaded)].

1.9.2.2.4. Notwithstanding the paragraphs 1.9.2.2.1. to 1.9.2.2.3. above, in case the vehicle is equipped with a supplementary endurance braking system able to absorb kinetic energy of the vehicle independently from the regenerative braking system, the following requirements may be used:

- The electric regenerative braking system shall implement technical measures to secure that the necessary retardation capacity in the batteries of the vehicle is available for the vehicle to be able to absorb at least the ~~fraction-portion~~ of the kinetic energy to stabilize speed in the forthcoming (predicted) downhill on the route of the vehicle [that the vehicle may potentially follow], which is not absorbed by the supplementary endurance braking system.
- The vehicle equipped with an electric regenerative braking system shall be able to secure a retardation [~~capacity in the batteries~~] at least equivalent to the ~~fraction-portion~~ of the kinetic energy necessary to stabilize the vehicle speed during a Type-II test, which is not absorbed by the supplementary endurance braking system.
- The ~~fraction-portion~~ of the energy absorbed by the electric regenerative braking and the relevant control strategies to suitably distribute/phase kinetic energy absorption between the electric regenerative braking system and the supplementary endurance braking system installed on the vehicle shall be described by the vehicle manufacturer to the Technical Service.

1.9.2.2.5. The technical measures taken to safeguard necessary retardation capacity in the batteries shall be described / demonstrated by the manufacturer to the technical service during the inspection of the safety approach as part of the assessment to Annex 18 [CEL]. The general principle of the means available to the driver to control the electric regenerative braking shall also be described (e.g. a separate control, an integrated control with other functions).~~†~~

~~Additionally, the vehicle manufacturer shall provide information about the air and rolling resistance of the vehicle and the total efficiency of the the electric components converting the kinetic energy of the wheels into electric energy in the batteries, provided such parameters are taken into account to fulfil the requirements of paragraphs 1.9.2.2.1., 1.9.2.2.2. and 1.9.2.2.4.~~

1.9.2.3. The vehicle shall fulfil the requirements of type-IIA test as specified above in this regulation. The condition of the vehicle batteries at the beginning of the test shall be such that the retardation capacity available in the batteries is

- at least equivalent to the kinetic energy necessary to pass the Type-IIA test.
- at least equivalent to the ~~fraction-portion~~ of the kinetic energy which is not absorbed by a supplementary endurance braking system fulfilling the requirements of paragraph 1.9.2.2.4. above, and that is necessary to pass the Type-IIA test.

## II. Justification

An electric vehicle with fully loaded traction batteries cannot pass the Type-IIA test, unless (for example) extra-battery capacity (which cannot be used for traction) is added to always ensure the type-IIA equivalent kinetic energy can be absorbed by the batteries. Given the risk to jeopardize the energetic efficiency of these emission-free vehicles, industry is proposing an alternative to Type-IIA test, by creating a new Type-IV test, as per paragraph 1.9.

- Paragraph 5.2.1.29.7. : vehicles using the type-IV test of Annex 4 shall be equipped with a brake estimator alerting the driver in case the efficiency of the brakes falls below the type-II hot performance (3.3m/s<sup>2</sup> for N3, 3.75m/s<sup>2</sup> for M3)
- Paragraph 1.5.1.8. : correction of an editorial mistake in current regulation text
- Paragraph 1.6.5. : same concept as requirement as in paragraph 1.5.1.8 of Type-I fade test
- Paragraph 1.8.2.4. : same concept as requirement as in paragraph 1.5.1.8 of Type-I fade test

- Paragraph 1.9.1 specifies when the type-IV test can be used
- Paragraph 1.9.2.1. : specification of the type-II test with increased performance from slope 6% to 7%, and hot-stop requirement from 3.3m/s<sup>2</sup> for N3 (3.75m/s<sup>2</sup> for M3) to 5m/s<sup>2</sup>, which is the required value of the service braking system in type-0 test. This is a drastic increase of friction brake performance, since it is meant to be applied in the case where the batteries of the electric regenerative braking system is fully charged (i.e. the worst case). With this alternative, the system is not required to preserve any free battery charge for the purpose of retardation, it can fully use the capacity of the battery for the purpose of traction.
- Paragraph 1.9.2.2 is proposing an alternative to the increased type-II performance as per paragraph 1.9.2.1. In this alternative, the system shall implement “smart charging strategies” able predict the potential downhills on the route of the vehicle, e.g. based on the altitude (height), the topology of the roads “around” the vehicle, “geo-fencing” strategies, in order to secure that the vehicle is able to absorb the kinetic energy.
- Paragraph 1.9.2.2.1. : specification of the expected functionality of the smart charging strategy
- Paragraph 1.9.2.2.2. : the vehicle shall be able to secure (for the sole purpose of retardation, if needed to pass the forthcoming downhill) the energy equivalent to the potential energy of a type-II.
- Paragraph 1.9.2.2.3. : the aim of informing the driver of the available-retardation capacity available in the batteries is permit him/her to anticipate and adapt speed prior to the point when the batteries are full, in other terms to handle in the best way the retardation capacity of the vehicle (as he/she does with the available traction energy in the batteries).
- Paragraph 1.9.2.2.4 adapts the requirements to the case where a supplementary retardation means is installed on the vehicle
- Paragraph 1.9.2.2.5. : the smart charging strategies shall be described and assessed according to the CEL-Annex.  
Additionally, the vehicle manufacturer may, in order to pass requirements specifying retardation capacity to be secured in the batteries (1.9.2.2.1, 1.9.2.2.2 and 1.9.2.2.4), account for that the kinetic energy is not only converted into electric energy in the batteries, but is also absorbed by mechanical air and rolling resistance, as well as by the efficiency of the electric components converting kinetic energy transmitted by the wheels into electric energy in the batteries.
- Paragraph 1.9.2.3 requires the application of Type-IIA, starting from a battery charge where the equivalent kinetic energy to the type-IIA is reserved.