Submitted by the Expert
from the United Kingdom

Capacity of the energy reserve of an electrical braking system.

For braking systems that employ stored energy in their control and/or energy transmission, Regulation 13 (and Regulation 13H) include specific requirements to ensure that the energy storage device is of a suitable capacity. Starting from a nominal value, the reserve of energy in the energy storage device is depleted by a prescribed number of "full-stroke" actuations of the brake control and, at the completion, there must remain sufficient energy for a defined level of brake performance to be achieved.

During the first meeting of the special interest group on electrical braking (EBSIG) clarification was sought on what was meant by the term "full-stroke" actuation.

There was also agreement that, for an electrical brake, the amount of energy consumed by each brake actuation will be dependent on the period of time for which the brake is applied. This differs from a compressed-air (pneumatic) braking system where a specific volume of air is consumed for each application, independent of the time for which the brake is applied.

It is necessary to determine the appropriate time for electrical brake to be applied (and the length of the period between successive actuations).

Full-stroke actuation: What does it mean?

This term is of long standing and is understood to mean that the control is moved to the operating position that represents maximum braking, i.e., the foot pedal is pushed to its maximum point of travel. In a conventional pneumatic system this means that the full pressure, available in the energy storage device(s) at that time, is released into the circuits of the brake transmission.

With the advent of the use of electric control lines, the definition of brake transmission was adapted to distinguish between the energy used for the control of the brake (control transmission) and the energy used to create a mechanical force at the brake (energy transmission). For braking systems employing an electrical control line, an additional test was introduced to establish that the battery supplying the electrical energy to the control line has sufficient capacity. This additional test is only concerned about the reserve of electrical energy for the electric control line; the energy capacity of the reserves for the pneumatic part of the brake system (control and energy transmission) continues to be assessed as before.

It should be understood that a full-stroke application means that:

> The brake control is moved from its position of rest to the furthest point of its range of travel, such that it provides, from the reserve(s) of energy, the maximum energy/power that the components of the brake transmission (control transmission plus energy transmission) are able to consume when operating normally.
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> Strategies and/or functions that are intended to reduce or limit the power available to the brake transmission, below the maximum that may be required in normal use, are to be suppressed during the full-stroke actuation test.

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How long should the brake be applied for during energy capacity tests, and what interval is appropriate between each actuation?

Proposal:

Regulation 13, Annex 7, Part D, paragraph 1.2.3.2.:

"1.2.3.2. Each full-stroke application shall be for a duration of at least **8.0** seconds with an interval of no more than **5.0** seconds between the release of the brake control and its subsequent actuation."

Regulation 13H, Annex 4, [Part B], paragraph [1.2.3.2.]:

"1.2.3.2. Each full-stroke application shall be for a duration of at least **8.0** seconds with an interval of no more than **5.0** seconds between the release of the brake control and its subsequent actuation."

Complimentary requirements will be necessary in other places in the regulations where "full-stroke" actuations are required.

Justification

Application Time.

The task of the EBSIG is to develop proposals that can be introduced into both Regulation 13 and Regulation 13H. It follows that the rationale for the proposals must be valid for each class of power-driven vehicle covered by those regulations.

Informal Document GRVA-15-17 (CLEPA) contains a proposal that the brake application time should be for at least 7.0 seconds, and that there should be an interval between successive applications of the brake of no more than 9.0 seconds. It is explained that these figures are based on the braking behaviour of a 40-tonne vehicle on an 18% gradient and the time it would take to accelerate that vehicle back to it starting speed: Dynamic test conditions.

Effectively, this approach defines a new test condition associated with a particular set of vehicle characteristics. The rationale for these conditions and characteristics is not clear. However, it does not seem reasonable to assess vehicles of category M_1 and N_1 in the same way.

Another approach is to look to the performance tests that already exist within the regulations and determining a brake application time that is aligned to those requirements.

The Type-0 test is the basic brake performance test, and the requirements for all vehicles of category M and N are established within the regulations. The Type-0 test defines the maximum speed at which the test is conducted, together with the minimum mean fully developed deceleration, and maximum stopping distance, that have to be achieved. These variables permit a straightforward calculation of the duration of the braking event. Further, the Type-0 test is conducted under two conditions, one with the engine disconnected and one with the engine connected.

	Category	M_1	M_2	M_3	N_1	N_2	N_3
	Test	Type-0	Type-0	Type-0	Type-0	Type-0	Type-0
Type-0 test with engine dis-connected	V	100 km/h	60 km/h	60 km/h	80 km/h	60 km/h	60 km/h
	s ≤	0.1 v+0.0060 v2	$0.15v + \frac{v^2}{130}$				
	d_m ≧	6.43 m/s²	5.0 m/s²				
Type-0 test with engine connected	Vmax	160 km/h	100 km/h	90 km/h	120 km/h	100 km/h	90 km/h
	s ≤	0.1 v+0.0067 v2	$0.15v + \frac{v^2}{103.5}$				
	d_m ≧	5.76 m/s²	4.0 m/s²				

Table 1: Type-0 speed, deceleration, and stopping distance requirements from Regulation 13 and Regulation 13H.

In terms of braking duration, the Type-0 test with engine connected is the most onerous; it is conducted at a higher speed and with a lower deceleration requirement than the test with the engine disconnected. The proposal is based on the criteria of the "*engine connected"* test.

Calculating a brake application time based upon the speed/MFFD.

Using the test speed and deceleration values of the regulations to calculate the period of brake application appears to offer a solution that is related to an existing requirement. However, the brake application times established in this way would be an underestimation; the deceleration values listed in the regulations are the mean fully developed decelerations which are measured only over part of the period of time that the brake is applied (from 0.8 to 0.1 of the test speed).

Recognising this limitation, it is more appropriate to establish the duration of the braking event by calculating the time taken when braking to achieve the maximum permitted stopping distance. This approach delivers the following values:

	Category	M_1	M_2	M_3	N_1	N_2	N_3
Type-0 test with engine connected	Vmax	160 km/h	100 km/h	90 km/h	120 km/h	100 km/h	90 km/h
	s ≤	187.52 m	111.62 m	91.76 m	157.13 m	111.62 m	91.76 m
	Actual Mean Deceleration	5.27 m/s²	3.46 m/s²	3.41 m/s²	3.54 m/s²	3.46 m/s²	3.41 m/s²
	Brake Application Time	**8.44 s**	**8.04 s**	**7.34 s**	**9.43 s**	**8.04 s**	**7.34 s**

Table 2: Braking time values for Type-0 test (engine connected) based upon maximum permitted stopping distance.

It is worth recalling that the objective is to arrive at a representative time value during which the braking system will be consuming energy.

Type-0 tests are conducted at different speeds according to vehicle type and this impacts on the energy demand of the brakes. However, for the full-stroke actuation test, as described above, the severity is set by the requirement to provide maximum available power to the brakes. This suggests that the speed used to assess the application time for a full-stroke actuation could be normalised.

For vehicles approved according to Regulation 13 (N_1, N_2, N_3, M_2 and M_3) an operational speed of 100km/h is quite typical. It can be seen from *Table 2.*, that with an actual mean deceleration of 3.46 m/s² the braking time from 100 km/h is 8.04 seconds. As the actual mean deceleration is approximately the same for all vehicle types in Regulation 13, it is proposed that the application time, for the purpose of the full-stroke actuation test, is set at 8.0 seconds for all vehicle types.

Regulation 13 H considers vehicles of categories M_1 and N_1. For consistency, the application time for N1 vehicles should be consistent with Regulation 13 – 8.0 seconds.

It is noted that the actual mean deceleration of M_1 vehicles during the Type-0 test is 5.27 m/s². However, because of the higher test speed (160 km/h) the braking time is longer – 8.44 seconds. It would not be reasonable to use 100 km/h as a representative operational speed for an M_1 vehicle and to establish a braking time based upon that figure. While there is an argument for applying a shorter application time for the full-stroke actuation test for these vehicles, again, for consistency, it is proposed that a value of 8.0 seconds is used.

Category	M_1	M_2	M_3	N_1	N_2	N_3
Brake Application Time (rounded)	**8.0 seconds**					

Table 3: Braking time values to be used for "full-stroke" brake actuation according to Regulation 13 and Regulation 13H.

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Interval between full-stroke applications.

The energy storage device capacity test of R13, Annex 7, is undertaken with the supply to the storage device "stopped". It is clear then that the interval between the completion of one full-stroke brake actuation, and the start of another, is not to allow for any replenishment of the reserve of energy. There is no reason to associate the time interval with the running time of the vehicle, or with its energy source/supply. However, the interval is important as it permits the components of the braking system, the actuators, motors, the reserve(s) of energy, etc., to resume an "at rest" or steady state.

With the introduction of an electronic control line into Regulation 13, and the assessment of the capacity of the battery used to provide energy to the control transmission, a period of 5.0 seconds was adopted for the interval between successive brake actuations. While the logic behind this selection is uncertain, it is a value that has served the regulation well for 25 years.

For consistency, and to avoid confusion, it is proposed that the interval between full-stroke brake actuations for the new electrical braking systems is aligned with that associated with electronic control lines – 5.0 seconds.

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