

Proposal for a supplement to the 12 series of amendments to UN Regulation No. 13 (Heavy vehicle braking)

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The text reproduced below was prepared by the expert from the European Association of Automotive Suppliers (CLEPA) to include in UN Regulation No. 13 requirements for the type approval of Electro-Mechanical Braking (EMB) systems as state-of-the-art braking systems. This document supersedes the working document ECE/TRANS/WP.29/GRVA/2021/24 and the informal document and GRVA-14-12.

The modifications to the current text of the Regulation are marked as follows:

- modifications already included in GRVA-14-12 in **black bold** for new and ~~striketrough~~ for deleted characters
- newly agreed modifications in **blue**
- text still under discussion and not yet agreed is marked:
 - in **red** for text already contained in GRVA-14-12
 - in **pink** for newly added text

I. Proposal

Contents, Annex 8 title, amend to read:

“8. Provisions relating to specific conditions for **compressed-air braking systems fitted with** spring braking systems”

Paragraph 2.21.4., amend to read:

“2.21.4. *"Electric state of charge (SOC)"* means the instantaneous ratio of electric quantity of energy stored in a ~~traction~~ battery relative to the maximum quantity of electric energy which could be stored in this battery.”

Paragraph 2.31., amend to read:

“2.31. *"Reference braking forces"* means the braking forces of one axle generated at the circumference of the tyre on a roller brake tester, relative to brake actuator pressure **or brake demand value respectively** and declared at the time of type approval.”

Insert new paragraphs 2.44. to 2.56., to read:

2.44. "Electro-mechanical brake" means a friction brake where electrical power only is converted to actuating forces by purely mechanical means.

2.45. "Electro-mechanical braking system" (EMB system) means a service braking system which is equipped with electro-mechanical brakes on all axles.

2.46. "Wheel brake demand value" means the demand value for the braking force of a single wheel brake being electrically actuated.

2.47. The “performance of an electrical energy storage device” means both its energy **storage capacity [J] and its ability to provide electrical power [W].**

2.48. The “usable performance” means the portion of the performance of an electrical energy storage device that is actually available **to the supplied system (e.g. the system may not use the maximum theoretical performance).**

- 2.49. “*Actual Electric Usable Performance (AEUP)*” is the instantaneous per centage value **of maximum usable performance at the time.**
- 2.50. “*AEUPW*” means the low performance level of an electrical energy storage device established according to paragraph 5.2.1.13.1. (b).
- 2.51. “*P_w*” [W] means the low electrical supply power warning as required by paragraph 5.2.1.35.12. in the case of an electro-mechanical braking system.
- 2.52. “*Energy source*” means a device that both generates and provides energy required for the braking system.
- 2.53. “*Electrical energy storage device*” means an energy reserve comprising a device, or combination of individual devices, each capable of storing an electrical charge and provide electrical power in the transmission of a braking system. Storage devices which are connected in series and/or parallel for the purpose of supplying a single braking circuit, shall be considered as one electrical energy storage device within this Regulation.
- 2.54. “*Electrical supply device*” means a device (e.g. battery, REESS, DC/DC converter, generator, fuel-cell or a combination of these components) that supplies electrical power to the braking system's electrical energy storage device(s).
- 2.55. “*Certified Usable Performance (CUP)*” means the maximum usable performance of an electrical energy storage device available for an electro-mechanical braking system determined at the time of type approval.
- 2.56. “*Minimum Required Usable Performance (MRUP)*” means the minimum usable performance of an electrical energy storage device available for an electro-mechanical braking system to fulfil the relevant requirements of this Regulation.”

Paragraph 5.1.4.5.1., amend to read:

- “5.1.4.5.1. The data of the compressed-air **or electro-mechanical** braking system for the functional and efficiency test shall be specified at the vehicle in a visible position in indelible form, or made freely available in another way (e.g. handbook, electronic data record).”

Insert new paragraph 5.1.4.5.3., to read:

- “5.1.4.5.3. **For power-driven vehicle equipped with electro-mechanical braking system the vehicle manufacturer shall describe, at the time of type approval, the procedure by which it can be checked that the warning signals AEUPW and P_w (respectively defined in 2.50. and 2.51. are operational and fulfil the requirements of this regulation. The procedure may be initiated e.g. by triggering an internal self-check routine that may include external actions by the operator.**”

Renumber current paragraphs 5.1.4.6.2. and 5.1.4.6.3. as new paragraphs 5.1.4.6.1.1. and 5.1.4.6.1.2. to read:

- “5.1.4.6.1.1. Reference braking forces are to be determined for a brake actuator pressure range from 100 kPa to the pressure generated under Type-0 conditions for each axle. The applicant for type approval shall nominate reference-braking forces for a brake activator pressure range from 100 kPa. These data shall be made available, by the vehicle manufacturer, according to paragraph 5.1.4.5.1. above.
- 5.1.4.6.1.2. The reference braking forces shall be declared such that the vehicle is capable of generating a braking rate equivalent to that defined in Annex 4 of this Regulation for the relevant vehicle (50 per cent in the case of vehicles of category M₂, M₃, N₂, N₃, O₃ and O₄ except semi-trailers, 45 per cent in the case of semi-trailers), whenever the measured roller braking force, for each axle

irrespective of load, is not less than the reference braking force for a given brake actuator pressure within the declared operating pressure range¹.”

Insert new paragraph 5.1.4.6.2. to read:

“5.1.4.6.2. Reference braking forces for electro-mechanical braking system using a roller brake tester shall be defined according to the following requirements.

5.1.4.6.2.1. It shall be possible on the vehicle to evaluate the relationship between the brake demand value(s) (e.g. as a percent value, voltage, etc.) and the measured braking force on a roller brake tester. The vehicle manufacturer shall describe the method by which this can be realized, and make this information available freely by e.g. handbook, electronic data record etc.

5.1.4.6.2.2. Reference braking forces are to be determined for each axle for a brake demand value from zero to a value corresponding to a braking force generated under Type-0 conditions. The applicant for type approval shall nominate these reference braking forces. These data shall be made available by the vehicle manufacturer, according to paragraph 5.1.4.5.1. above.

5.1.4.6.2.3. The reference braking forces shall be declared such that the vehicle is capable of generating a braking rate equivalent to that defined in Annex 4 of this Regulation for the relevant vehicle (50 per cent in the case of vehicles of category M₂, M₃, N₂, and N₃) whenever the measured roller braking force, for each axle irrespective of load, is not less than the reference braking force for a given brake demand value within the declared operating brake demand value range¹.”

Paragraph 5.2.1.2.7.2., amend to read:

“5.2.1.2.7.2. If the service braking force and transmission depend ... below. In case of compressed-air braking systems, in each service braking circuit in at least one of the air reservoirs a device for draining and exhausting is required in an adequate and easily accessible position;”

Insert new paragraph 5.2.1.2.7.2.3

“5.2.1.2.7.3. Notwithstanding the provisions of paragraph 5.2.1.2.7.2. above, in an electro-mechanical braking system that depends exclusively on the use, controlled by the driver, of an energy reserve, there shall be at least two completely independent braking circuits, each provided with its own transmission having either two independent energy reserves (one for the control and one for energy transmission) or a single independent energy reserve for the transmission of the braking circuit; each of these braking circuit may act on the brakes of one or more wheels. This shall not be construed as a departure from the requirements of paragraph 5.2.1.8. of the Regulation.

It shall be ensured that, in the event of a failure of a braking circuit, the brakes supplied by the remaining independent braking circuit(s) are so selected as to be capable of ensuring the prescribed degree of secondary braking without endangering the stability of the vehicle during braking; in addition, the actual usable electrical performance (AEUP) of each of the aforesaid energy reserves shall be permanently monitored. Under the condition defined in paragraph 5.2.1.13., the monitor shall activate the required warning device.”

Renumber existing paragraph 5.2.1.2.7.3. as 5.2.1.2.7.4.

¹ For the purpose of periodic technical inspection, the minimum limit braking rate values defined for the whole vehicle may need adjustment to reflect national or international in-service requirements.

Paragraph 5.2.1.5., amend to read:

“5.2.1.5. Where use is made of energy other than the muscular energy of the driver, there need not be more than **one supply of such energy (hydraulic pump, air compressor, electrical supply device, etc.).** The means by which the device constituting that **supply, if it** is driven, shall be as safe as practicable.”

Paragraph 5.2.1.5.1., amend to read:

“5.2.1.5.1. In the event of failure in any part of the transmission of a braking system, the feed to the part not affected by the failure shall continue to be ensured if required for the purpose of halting the vehicle with the degree of effectiveness prescribed for residual and/or secondary braking. This condition shall be met by ~~means of devices which can be easily actuated when the vehicle is stationary, or by~~ automatic means.”

Insert a new paragraph 5.2.1.5.4., to read:

“5.2.1.5.4. **However, as an alternative to the provisions of paragraphs 5.2.1.5.1. and 5.2.1.5.2., for an electro-mechanical braking system these requirements are considered to be met if the requirements of paragraph 5.2.1.5.4.1. are satisfied.**

5.2.1.5.4.1. After any single transmission failure it shall still be possible after eight full-stroke actuations of the service braking system control, to achieve, at the ninth application, at least the performance prescribed for the secondary braking system or, where secondary performance requiring the use of stored energy is achieved by a separate control, it shall still be possible after eight full-stroke actuations to achieve, at the ninth application, the residual performance prescribed in paragraph 5.2.1.4. of this Regulation. Each full-stroke application shall be for a duration of at least 7.0 seconds with there being an interval of no more than 9.0 seconds between the release of the brake control and its subsequent actuation.”

Paragraph 5.2.1.8.1.1., amend to read:

“5.2.1.8.1.1. A difference in transverse braking pressures **or wheel brake demand value on any axle** of:

- (a) 25 per cent of the higher value for vehicle decelerations $\geq 2 \text{ m/s}^2$;
- (b) A value corresponding to 25 per cent at 2 m/s^2 for decelerations below this rate.”

Paragraph 5.2.1.13.1., amend to read:

“5.2.1.13.1. Any vehicle fitted with a service brake actuated from an energy **reserve** shall, where the prescribed secondary braking performance cannot be obtained by means of this braking system without the use of the stored energy, be provided with a warning device, in addition to a pressure gauge, where fitted, giving an optical or acoustic signal **at the latest** when the stored energy, in any part of the system, falls to a value at which without re-charging of the **reserve** and irrespective of the load conditions of the vehicle:

- a) **For braking systems other than an electromechanical braking system**, it is possible to apply the service brake control a fifth time after four full-stroke actuations and obtain the prescribed secondary braking performance (without faults in the service brake transmission and with the brakes adjusted as closely as possible);
- b) **For electromechanical braking systems, the actual usable electrical performance (AEUP), in any part of the system, falls to a value at which:**
 - **the prescribed service braking performance cannot be achieved, or**

- **it is still possible to apply the service brake control a fifth time after four full-stroke actuations and obtain at least the secondary braking performance**

whichever occurs first.

This warning device shall be directly and permanently connected to the circuit. The red warning signal specified in paragraph 5.2.1.29.1.1 shall be used as the optical warning signal. When the engine is running, **or during a run cycle (e.g. in case of a vehicle propelled by an electric motor)**, under normal operating conditions and there are no faults in the braking system, as is the case in approval tests for this type, the warning device shall give no signal **except during the time required for charging the energy reserve(s) after each new engine start/run cycle.**

5.2.1.13.1.1. However, in the case of vehicles which are only considered to comply with the requirements of paragraph 5.2.1.5.1 of this Regulation by virtue of meeting the requirements of paragraph 1.2.2 of Part C of Annex 7 to this Regulation, the warning device shall consist of an acoustic signal in addition to an optical signal. These devices need not operate simultaneously, provided that each of them meet the above requirements and the acoustic signal is not actuated before the optical signal. The red warning signal specified in paragraph 5.2.1.29.1.1 shall be used as the optical warning signal.

5.2.1.13.1.2. This acoustic device may be rendered inoperative while the handbrake is applied and/or, at the choice of the manufacturer, in the case of automatic transmission the selector is in the ‘Park’ position.”

Insert new paragraph 5.2.1.13.2., to read:

“5.2.1.13.2. In addition, any vehicle equipped with an electromechanical braking system shall be equipped to determine and display the “actual electrical usable performance (AEUP)” of each of the electrical energy storage devices. [This shall be expressed as a percentage of the certified usable performance of the electric storage device.] The indicators for each AEUP value may share a common space in accordance with UN Regulation 121. They need not be permanently visible, however they must be visible immediately to the driver in response to a manual demand at any time that the ignition/start switch is in the "on" (run) position. Furthermore, the actual usable electrical performance [percentage value of stored energy] in each of the electrical energy storage devices shall be displayed automatically on activation of the AEUP_w warning described in paragraph 5.2.1.13.1. above.”

Paragraph 5.2.1.18., amend to read:

“5.2.1.18. In the case of a vehicle authorized to tow a trailer of category O₃ or O₄ **which is equipped with a compressed-air braking system**, its braking system shall satisfy the following conditions:”

Paragraph 5.2.1.26.3., amend to read:

“5.2.1.26.3. Auxiliary equipment may be supplied with energy from the electric transmission of the parking braking system provided that the supply of energy is sufficient to allow the actuation of the parking braking system in addition to the vehicle electrical load under non-fault conditions. In addition, where the energy reserve is also used by the service braking system, the requirements of paragraph 5.2.1.27.7. **or in the case of electro-mechanical braking systems paragraph 5.2.1.35.16. respectively** shall apply.”

Paragraph 5.2.1.27., amend heading to read:

“5.2.1.27. Special additional requirements for service braking systems with electric control transmission **except electro-mechanical braking systems”**

Paragraph 5.2.1.29.4. to 5.2.1.29.4.3., recalled for easy convenience:

5.2.1.29.4. *Except where stated otherwise:*

5.2.1.29.4.1. *A specified failure or defect shall be signalled to the driver by the above-mentioned warning signal(s) not later than on actuation of the relevant braking control;*

5.2.1.29.4.2. *The warning signal(s) shall remain displayed as long as the failure/defect persists and the ignition (start) switch is in the "on" (run) position; and*

5.2.1.29.4.3. *The warning signal shall be constant (not flashing).*

Insert new paragraph 5.2.1.29.4.4., to read:

“5.2.1.29.4.4. In the case of an electromechanical braking system employing an electrical energy storage device (or devices) it shall be ensured that the value of electrical performance at which the warning signal required by paragraph 5.2.1.35.9. and 5.2.1.35.10. is activated, is respected despite the effect of environmental conditions (e.g., temperature) and ageing. The manufacture shall show to the satisfaction of the type-approval authority, how this is achieved.”

Insert new paragraph 5.2.1.35., to read:

“5.2.1.35. Special additional requirements for service braking systems with electro-mechanical braking system with electric transmission

5.2.1.35.1. For electro-mechanical braking systems, the requirements of this paragraph 5.2.1.35. apply instead of those of paragraph 5.2.1.27. above.

5.2.1.35.2. The performance of the electrical energy storage device(s) shall be sufficient to ensure the residual performance as laid down in paragraph 2.4. of Annex 4 to this Regulation by the actuation of the service brake control when the vehicle is capable of driving.

5.2.1.35.3. The functionality of the system triggering the warning levels $AEUP_w$ and P_w shall be described by the vehicle manufacturer together with the documentation package required in Annex 18 of this Regulation to the Technical Service.

5.2.1.35.4. With the parking brake released, the service braking system shall be able to generate a static total braking force at least equivalent to that required by the prescribed Type-0 test, even when the ignition/start switch has been switched off and/or the key has been removed. In the case of power-driven vehicles equipped with an interface according to paragraph 5.1.3 and authorized to tow trailers of category O₃ or O₄, such vehicles shall provide a full control signal for the service braking system of the trailer. It should be understood that sufficient energy is available in the energy transmission of the service braking system.

5.2.1.35.5. For an electrical energy storage device feeding only the electric control transmission, the full control range of the service braking system shall be guaranteed after the following test procedure.

This test shall be carried out starting from the nominal value of the energy level and the electrical energy storage device not being fed. With the control transmission in operation, the braking control shall be kept released for at least 20 minutes before performing 20 full stroke application of the brakes, with an application time of 7 seconds and a released time of 9 seconds between each actuation.

This requirement shall not be construed as a departure from the requirements of Annex 7, Part D, paragraph 1.

In order to avoid the activation of the red warning signal due to the excessive consumption of electrical energy of the electrical energy transmission, the electrical energy transmission may be switched off.

5.2.1.35.6. In the case that the electrical energy storage devices are providing electrical energy for the electrical control and electrical energy

transmission, the requirements of paragraph 1.2.1. of Part D of Annex 7 shall apply.

- 5.2.1.35.7. As an alternative to the requirements of Annex 7, Part D, paragraph 1.2., electrical energy storage devices that provide power only to the control transmission of the braking system may satisfy the following requirement. **If the energy in an electrical energy storage device falls to a value at which the function or performance of a control transmission will be affected**, the control transmission shall be provided with the power necessary for its correct operation directly from the electrical supply device. It should be understood that there is no fault or failure of the electrical supply device. This alternative power supply shall be provided automatically no later than on the actuation of the control. The energy value at which this alternative supply is required shall be declared by the vehicle manufacturer to the type-approval authority / technical service and the transition verified at the time of type-approval. In addition, this condition shall be signalled to the driver by use of the red warning signal specified in paragraphs 5.2.1.29.1.1.
- 5.2.1.35.8. The electrical energy storage devices may be used also by other vehicle systems as long as the energy consumption of these systems cannot cause the reserves of energy to fall under a level which ensures the prescribed service braking performance.
- 5.2.1.35.9. **A warning signal shall be displayed when the energy storage capacity of the electrical energy storage device(s) is not sufficient to fulfil the requirements of Annex 7, Part D, paragraph 1.2.1.** The yellow warning signal described in paragraph 5.2.1.29.1.2. shall be used.
- 5.2.1.35.10. **A warning signal shall be displayed when the electrical energy level in the electrical energy storage device(s) is insufficient for more than 60 seconds to fulfil the prescribed braking performance in Annex 7, Part D, paragraph 1.2.1.** The yellow warning signal described in paragraph 5.2.1.29.1.2. shall be used.
- 5.2.1.35.11. **The warning signal may not be displayed as specified above in case the electrical performance of the electrical storage of a given braking circuit would fall below the minimum required usable performance value (as specified by the manufacturer in paragraph 1.2.2. of Annex 7, Part D), provided the following conditions are all fulfilled:**
- (a) **The other braking circuit has a sufficient performance to ensure the requirements of paragraph 1.2.1. of Annex 7, Part D are fulfilled,**
 - (b) **The ageing of that circuit remains within the maximum ageing defined by the manufacturer,**
 - (c) **The stability of the vehicle during braking is not endangered.**
- As soon as condition (a) and/or (b) is no longer fulfilled, the yellow warning signal described in paragraph 5.2.1.29.1.2. shall be displayed.**
- The maximum ageing of the electrical storage as specified in item (b) above shall be demonstrated to the technical services (e.g. based on validation test reports).**
- The stability of the vehicle during braking required in item (c) shall be demonstrated to (tested by) the technical services in the worst cases.**
- 5.2.1.35.12. In the case that the supply of power requested by the electrical energy storage device(s) cannot be met by the electrical supply device and delivered power falls below 90 % of currently requested, a power warning (P_w) to the driver shall be activated no later than 5 s after the appearance/detection. The yellow warning signal specified in paragraph 5.2.1.29.1.2. may be used.

- 5.2.1.35.13. The functions to monitor the ageing and charging of the electrical energy storage devices shall be checked at the time of type approval. The method by which this check is carried out shall be agreed between the vehicle manufacturer and technical service. The values of **CUP, MRUP, AEUP_w** etc, specified by the manufacturer and verified in the assessment, shall be declared in Annex 2 paragraph 17.x.
- 5.2.1.35.14. In the case where the braking system of the vehicle shares the same electrical supply device as other vehicle systems and there is low power available from that device, the braking system shall have priority. However, if that electrical supply device also supplies the steering equipment, the steering shall have priority over the braking system in accordance with UN Regulation 79.
- 5.2.1.35.15. The red warning signal specified in paragraph 5.2.1.29.1.1. shall be activated when the service braking performance is not anymore ensured by at least two independent service braking circuits from each achieving the prescribed secondary or residual braking performance.
- 5.2.1.35.16. If auxiliary equipment is supplied with energy from the same electrical energy storage device(s) as the electric transmission, it shall be ensured that the supply of energy (in the case of a driven energy source with the engine running at a speed not greater than 80 per cent of the maximum power speed) is sufficient to fulfil the prescribed deceleration values by either provision of an energy supply which is able to prevent discharge of these reserves when all auxiliary equipment is functioning or by automatically switching off pre-selected parts of the auxiliary equipment at a level above the critical level referred to in paragraph 5.2.1.13.1. (b) of this Regulation such that further discharge of these reserves is prevented. Compliance may be demonstrated by calculation or by a practical test. In the case of power-driven vehicles equipped with an interface according to paragraph 5.1.3 and authorized to tow a trailer of category O₃ or O₄ the energy consumption of the trailer shall be taken into account by a load of 400 W if this consumption is provided by the electrical energy storage device(s).
- 5.2.1.35.17. A failure within the electric transmission,² that affects the function and performance of systems addressed in this Regulation shall be indicated to the driver by the red or yellow warning signal specified in paragraphs 5.2.1.29.1.1. and 5.2.1.29.1.2., respectively, as appropriate. When the prescribed service braking performance can no longer be achieved (red warning signal), failures resulting from a loss of electrical continuity (e.g. breakage, disconnection) shall be signalled to the driver as soon as they occur, and the prescribed residual braking performance shall be fulfilled by operating the service braking control in accordance with paragraph 2.4. of Annex 4 to this Regulation. These requirements shall not be construed as a departure from the requirements concerning secondary braking.
- 5.2.1.35.18. In the case of a single temporary failure (< 40 ms) within the electric control transmission, excluding its energy supply, (e.g. non-transmitted signal or data error) there shall be no distinguishable effect on the service braking performance.
- 5.2.1.35.19. In the case of a power-driven vehicle, electrically connected to a trailer via an electric control line, a clear warning shall be provided to the driver whenever the trailer provides the failure information that the stored energy in any part of the service braking system on the trailer falls below the warning level, as specified in paragraph 5.2.2.16. below. A similar warning shall also be provided when a continuous failure (> 40 ms) within the electric control transmission of the trailer, excluding its energy

² Until uniform test procedures have been agreed, the manufacturer shall provide the Technical Service with an analysis of potential failures within the **electrical transmission** and their effects. This information shall be subject to discussion and agreement between the Technical Service and the vehicle manufacturer.

reserve, precludes achievement of the prescribed service braking performance of the trailer, as specified in paragraph 5.2.2.15.2.1. below. The red warning signal specified in paragraph 5.2.1.29.2.1. shall be used for this purpose.

- 5.2.1.35.20. In the case of a failure in the electric control transmission of the service braking system of a towing vehicle equipped with an electric control line according to paragraph 5.1.3.1.2. or 5.1.3.1.3., the full actuation of the brakes of the trailer shall remain ensured.
- 5.2.1.35.21. If the auxiliary equipment is supplied with energy from the electric transmission, the following requirements shall be fulfilled.
- 5.2.1.35.21.1. In the event of a failure in the energy source or electrical supply device, whilst the vehicle is in motion, the energy in the electrical energy storage device(s) shall be sufficient to actuate the brakes when the control is applied.
- 5.2.1.35.21.2. In the event of a failure in the energy source or electrical supply device, whilst the vehicle is stationary and the parking braking system applied, the energy in the electrical energy storage device(s) shall be sufficient to actuate the lights even when the brakes are applied.”

Annex 2,

Insert a new paragraph 17., to read:

- “17. Additional information in the case of power-driven vehicle equipped with an electro-mechanical braking system (‘EMB’)**
- 17.1. Vehicle is/is not² equipped with an electro-mechanical braking system**
- 17.2. In the case where a towing vehicle is equipped with an electro-mechanical braking system the vehicle is/is not² authorized to tow a trailer with a compressed-air braking system**
- 17.3. Low electrical performance levels AEUP_w in J and W respectively for the energy reserve(s) of each service braking circuit.**
- 17.4. Certified Usable Performance (CUP) in J and W respectively for the energy reserve(s) of each service braking circuit.**
- 17.5. Minimum Required Usable Performances (MRUP) in J and W respectively for the energy reserve(s) of each service braking circuit.**
- 17.6. Low electrical performance levels AEUP_w in J and W respectively for the energy reserve(s) of each service braking circuit.**
- 17.7. The maximum charging power in W for the energy reserve(s) of each service braking circuit**

Annex 4,

Paragraph 1.2.11., amend to read:

- “1.2.11. Status of the energy reserve during the Annex 4 tests:**
 - a) For a vehicle with electrically actuated service brakes powered from traction batteries (or an auxiliary battery) which receive(s) energy only from an independent external charging system, these batteries shall, during braking performance testing, be at an average of not more than 5 per cent above that state of charge at which the brake failure warning prescribed in paragraph 5.2.1.27.6 is required to be given.
If this warning is given, the batteries may receive some recharge during the tests, to keep them in the required state of charge range.

- b) For a vehicle with an electro-mechanical braking system, and without a simulated failure, the energy in the electrical storage devices shall be kept above $AEUP_w$ limit.

Insert a new paragraph 1.3.3., to read:

- 1.3.3.** In the case of a braking system configured according to paragraph 5.2.1.2.7.3., where the braking for a particular wheel (or wheels) may, under a fault condition, compromise the symmetrical distribution of the braking effort between the wheels of one and the same axle, the vehicle shall satisfy the requirements of paragraph 2.5. of Annex 4.
Where the methodology for ensuring the safe behaviour of the vehicle under this condition relies on an electrical/electronic control strategy, the robustness of the function shall be assessed according to Annex 18.

Paragraph 1.5.1.7.2., amend to read:

"In the case of vehicles equipped with hydraulically operated disc brakes **or electrically controlled adjustment mechanisms** no setting requirements are deemed necessary."

Insert new paragraphs 2.5. and 2.5.1., to read:

- 2.5.** Behaviour of the vehicle during a brake transmission failure.
- 2.5.1.** For vehicles configured according to paragraph 5.2.1.2.7.3. of this Regulation, the directional stability of the vehicle under the worst-case fault condition, established under Annex 18, shall be checked.
The fault condition shall be evaluated under the conditions of the Type-0 test using a traffic lane not exceeding 3.5 meters in width. For safety, this evaluation may require several tests at incremental speeds up to that required for the Type-0 test. Steering correction is permitted, if the angular rotation of the steering control does not exceed 120° during the initial two seconds of braking, and not more than 240° in total, to maintain the vehicle in lane.

Insert a new paragraph 4.1.4., to read:

- "4.1.4.** In the case of vehicles fitted with an electro-mechanical braking system, the requirements of paragraph 4.1.1. above are considered to be satisfied if, in an emergency manoeuvre, the deceleration of the vehicle or the clamp force at the least favourable brake, reaches a level corresponding to the prescribed performance within 0.6 second."

Annex 7,

Insert new Part D, to read:

- "D.** Electro-mechanical braking system
- 1.** Capacity of electrical energy storage devices
- 1.1.** General
- 1.1.1.** Vehicles **equipped with an EMB** shall be equipped with electrical energy storage devices of a capacity meeting the requirements of paragraph 1.2. of this annex (Part D).
- 1.1.2.** Electrical energy storage devices that provide power only to the control transmission of the braking system may, as an alternative, satisfy the requirements of paragraph 5.2.1.35.7. to this Regulation.
- 1.1.3.** It shall be possible to easily identify the electrical energy storage devices of the different braking circuits.
- 1.2.** Power-driven vehicles

- 1.2.1. **The energy storage capacity [J] of the electrical energy storage device(s) shall be such that, when it is fully charged, as a minimum, after eight full-stroke actuations of the service braking system control the performance (at the ninth braking) at least fulfils the specified secondary braking performance. Additionally, it shall be such that, on at least the first actuation, the prescribed performance of the service braking system can be achieved.**
- 1.2.2. The value(s) of the **energy level in the electrical energy storage device(s)** of each braking circuit, available to satisfy the condition of paragraph 1.2.1. above, shall be specified by the manufacturer as the minimum energy **storage capacity (i.e. the energy value of MRUP)**.³
- 1.2.3. Testing shall be performed in conformity with the following requirements:
- 1.2.3.1. The initial value of electrical energy in each of the electrical energy storage device(s) of each braking circuit shall be no greater than the **specified values of energy specified in 1.2.2. (i.e. the energy value of MRUP)**. The electrical energy storage devices shall not be supplied with further energy during the test.
The procedure by which the electrical energy storage devices are prepared for this test shall be agreed between the manufacturer and the type-approval authority. This procedure shall be recorded in the test report and included in the type-approval documentation.
- 1.2.3.2. Each full-stroke application shall be for a duration of at least 7.0 seconds **with an** interval of no more than 9.0 seconds between the release of the brake control and its subsequent actuation.
- 1.2.3.3. Each full stroke actuation shall cause a power demand on the electrical energy storage devices equivalent to that required to provide maximum performance from the service braking system. It shall be ensured that the energy provided to the brake system transmission during this test is provided only by the electrical energy storage devices.
- 1.2.3.4. In the case of power-driven vehicles to which the coupling of a trailer is authorized and with a pneumatic control line, the supply line shall be stopped and a compressed-air reservoir of 0.5 litre capacity shall be connected directly to the coupling head of the pneumatic control line. Before each braking actuation, the pressure in this compressed-air reservoir shall be completely eliminated. After **8 full stroke actuations**, at the additional (ninth) actuation of the service braking system control, the energy level supplied to the pneumatic control line shall not fall below a level equivalent to one-half the figure obtained at the first brake actuation.
- 1.2.3.5. It shall be ensured that the energy consumed by the service braking is not reduced by energy saving functions when carrying out the test during standstill compared to a driving situation.
- 1.2.3.6. The capability to achieve the prescribed secondary braking performance shall be confirmed by dynamic testing in accordance with Annex 4, using only the electrical energy available from the electrical energy storage devices at the completion of the relevant tests of paragraph 1.2.3. above. However, the requirement of Annex 4, paragraph 2.2.5. to simulate a failure into the braking system shall not apply.
- 1.2.3.7. **The capability to achieve the prescribed service braking performance at the first actuation shall be confirmed by the type 0 dynamic testing in**

³ The value of the minimum required usable performance shall be stated in the approval document.

accordance with Annex 4, with an initial level of energy in the electrical energy storage devices not greater than the specified values of energy specified in 1.2.2. (i.e. the energy value of MRUP).

2. Capacity of the electrical supply device

2.1. General

The energy supply device (including the energy source, if fitted) shall meet the requirements set forth in the following paragraphs. Testing shall be performed in conformity with the following requirements:

2.2. Conditions of measurement

2.2.1. The capacity of the energy supply device shall be assessed using the procedures of paragraph 1.5.1. of Annex 4 (Type-I test) and paragraph 1.5.3.1. (Hot performance). Contrary to the requirements of the Type-I test, in all cases the number of brake actuations shall be 20.

2.2.2. This test may be conducted under static conditions. In this case the duration of the braking event, the energy consumed by the braking system and the interval between braking events, shall be determined during the dynamic Type-I and hot performance tests of Annex 4.

- a) In the case of vehicles of categories M₃ N₂ and N₃, the energy provided to the electrical energy storage device(s) during the static test shall be equivalent to the value of the energy provided by the electrical supply device to the electrical energy storage device(s) during 20 actuations of the dynamic Type-I followed by one actuation of the hot performance test of Annex 4.
- b) In the case of vehicles of categories M₂ and N₁, the brake actuations 16 to 20 shall be of the same duration and with an equivalent energy demand to that of actuation number 15. The interval between brake actuations shall be the same. The energy provided to the electrical energy storage device(s) during the static test shall be equivalent to the mean value of the energy provided by the electrical supply device to the electrical energy storage device(s) during 15 actuations of the dynamic Type-I followed by one actuation of the hot performance test of Annex 4.

2.2.3. At the commencement of the test:

- a) (The maximum performance of the electrical supply device shall be ensured ...)
- b) the energy level in the electrical energy storage devices shall not exceed the value of the minimum required usable performance as confirmed by paragraph 1.2. above.

2.2.4. For vehicles authorized to tow a trailer of category O₃ or O₄, the electrical requirement of the trailer shall be represented by an electrical demand of 400 W. This demand shall be applied either directly to the electrical supply device or to the reserve of energy used for the trailer supply (indirect supply), whichever is appropriate. This requirement shall not apply if the electrical demand of the trailer is provided from a source that is neither directly nor indirectly maintained by the electrical supply device.

Where the energy supply device provides power for other vehicle systems, including auxiliary systems, and where they will not impose a power demand during the Type-I test procedure, the manufacturer shall declare the total power demand of those systems and this shall be represented during the test by an equivalent electrical demand on the electrical supply device.

The total power demand shall be continuously present throughout the test procedure.

- 2.2.5.** The energy level in the electrical energy storage device(s) during, and on completion of, the test defined in paragraph 2.2. above, shall not fall to the [AEUP_w] value as described in paragraph 5.2.1.13.1. (b) of this Regulation.
- 2.2.6.** The value of the power supplied by the electrical supply device shall not fall to a level at which the warning signal [P_w] required by paragraph 5.2.1.35.12 is activated.
- 3. Capacity of pneumatic energy sources**
- In the case of vehicles to which the coupling of a trailer with a compressed-air braking system is authorized, also the following provisions apply:
- 3.1. Definitions**
- 3.1.1.** "p" = is the pressure in the pneumatic energy storage device(s) of an attached trailer with the capacity of at least the volume defined by paragraph 3.2.4.
- 3.1.2.** "p₃" = 450 kPa
- 3.1.3.** "p₄" = 700 kPa
- 3.1.4.** "t₄" is the time required for the relative pressure (of the attached trailer energy storage device with a volume as defined in paragraph 3.2.4.) to rise from 0 to p₃, and "t₅" is the time required for the relative pressure to rise from 0 to p₄.
- 3.2. Conditions of measurement**
- 3.2.1** In all cases, the speed of the compressor shall be that obtained when the engine is running at the speed corresponding to its maximum power or at the speed allowed by the governor.
- 3.2.2.** During the tests to determine the time t₄ and the time t₅, the pneumatic energy storage device(s) for auxiliary equipment shall be isolated.
- 3.2.3.** In case that the supply line is not only fed directly by the energy source but also from an energy storage device of the motor vehicle, also the pressure in this compressed-air reservoir shall be completely eliminated.
- 3.2.4.** The trailer shall be represented by a pneumatic energy storage device whose maximum relative pressure p (expressed in kPa / 100) is that which can be supplied through the towing vehicle's supply circuit and whose volume V, expressed in litres, is given by the formula $p \times V = 20 R$ (R being the permissible maximum mass, in tonnes, on the axles of the trailer).
- 3.3. Interpretation of results (Conditions of measurement as per paragraph 3.2.)**
- 3.3.1** The time t₄ recorded for the least-favoured energy storage device shall not exceed 6 minutes.
- 3.3.2** The time t₅ recorded for the least-favoured energy storage device shall not exceed 9 minutes.
- 3.4. Additional test**
- 3.4.1.** If the power-driven vehicle is equipped with one or more pneumatic energy storage devices for auxiliary equipment, an additional test shall be performed during which no irregularity shall occur in the operation of the valves controlling the filling of the pneumatic energy storage device(s) for auxiliary equipment.

- 3.4.2. **In the event of a failure in the pneumatic auxiliary equipment it shall be prevented that this failure cannot cause a pressure drop in the supply line (if present) below the pressure of 650 kPa.**
- 3.4.3. **It shall be verified during the aforesaid test that the time t_5 necessary to raise the pressure from 0 to p_4 in the attached trailer energy storage device is less than:**
- 3.4.3.1. **11 minutes.**
- 3.4.3.2. **The test shall be performed with all air reservoirs installed in the towing vehicle and with an attached trailer energy storage device of a volume as defined in paragraph 3.2.4.”**

Annex 8

Amend title to read:

Provisions relating to specific conditions for **compressed-air braking systems fitted with spring braking systems**

Annex 13

Paragraph 5.1.1.3., amend to read:

- 5.1.1.3 **The supply to the energy transmission storage device(s) shall then be cut off.**

Paragraph 5.1.1.4., amend to read:

- 5.1.1.4. The service braking control device shall then be fully actuated four times in succession with the vehicle stationary. **In the case of an electro-mechanical braking system, each full-stroke application shall be for a duration of at least 7.0 seconds with there being an interval of no more than 9.0 seconds between the release of the brake control and its subsequent actuation.**

Appendix 2

Paragraph 1.1.3., amend to read:

- 1.1.3. A number of tests at increments of line pressure / *wheel brake demand value* shall be carried out to determine the maximum ...

II. Justification

A. Regulation

(a) Paragraph 2.21.4.

1. The "*State of Charge (SOC)*" is commonly defined as the *instantaneous ratio of electric quantity of energy stored in a device* (also compare definitions in UN Global Technical Regulation No. 20 and UN Regulation No. 100).

2. In order to make use of the SOC definition in other requirements (in Regulation No. 13) not related to the traction battery, the word "*traction*" is deleted from the definition of paragraph 2.21.4.

3. By this deletion it is possible to also make use of this definition for devices other than the traction battery (e.g. see current requirement 5.2.1.7.2.1. and new table of paragraph 5.1.4.5.3.).

(b) Paragraph 2.31.

4. Due to the new proposed EMB requirements (see paragraphs 5.1.4.6.2.2. and 5.1.4.6.2.3.), the wording "or brake demand value respectively" is added.

(c) Paragraph 2.44.

5. This definition is inserted for clarification. In order to distinguish which requirements are related to the whole electro-mechanical braking system (see definition in paragraph 2.45.) and which requirements are related only to the electro-mechanical brake.

(d) Paragraph 2.45.

6. This definition is inserted to make the difference clear of what is commonly understood under an 'EBS system' where the control is generated and processed as an electrical signal in the control transmission and the electrical output signals to devices which generate actuating forces produced from stored or generated pneumatic energy (in contrast to an electro-mechanical braking system which is actuated by electrical energy).

(e) Paragraph 2.46.

7. The wheel brake demand value for the single wheel brake is derived from the driver's brake demand value taking into account e.g. the loading conditions of the vehicle. This value determines the actual braking force (e.g., see also k-measurement procedure, paragraph 1.1.3. of Annex 2, Appendix 2).

(f) Paragraph 2.50.

8. This warning level $AEUP_w$ is required by paragraph 5.2.1.13.1. (b) and must be made available by the vehicle manufacturer according to paragraph 5.1.4.5.3.

(g) Paragraph 2.51.

9. This warning signal P_w is required by paragraph 5.2.1.35.12. The proper functioning of this warning must be checked during type approval (according to paragraph 5.1.4.5.3.).

(h) Paragraph 2.52.

10. Although the term "*energy source*" is used often in the current version of UN Regulation No. 13, it is not defined (however, it is defined in the agricultural braking Regulation (EU) 2015/68). With the introduction of the new term 'electrical supply device' (paragraph 2.54.) it is seen as necessary to make the distinction clear between them. However, this definition should not imply that the 'energy source' in an electro-mechanical braking system is required equipment (see also 'electrical supply device', paragraph 2.54.); i.e. an electro-mechanical

braking system may or may not include an 'energy source' in addition to an 'electrical supply device'.

(i) **Paragraph 2.53.**

11. In contrast to pneumatic or hydraulic energy storage devices, EMB systems have in them different kinds of energy storage devices (**e.g. batteries, ultracapacitors**).

This paragraph also clarifies when single storage components (e.g. cells or modules) electrically connected (series/parallel combinations) together and are seen as one single electrical energy storage device.

(j) **Paragraph 2.54.**

12. The definition of "*electrical supply device*" clarifies that it may be e.g. an electrical energy storage device, a generator (*energy source*) or something else that supplies electrical power to the braking system's electrical energy storage device(s). Its electrical supply is monitored and its insufficient performance indicated by a warning signal (see paragraph 5.2.1.35.12).

(k) **Paragraph 2.56.**

13. The MRUP defines the minimum energy and power required to perform the prescribed braking performance taking also into account the degradation (e.g. by ageing) of the storage device performance.

(l) **Paragraph 5.1.4.5.1.**

14. The wording "*or electro-mechanical*" is added. It is seen that data for the functional and efficiency test shall also be made available for an electro-mechanical braking system.

(m) **Paragraph 5.1.4.5.3.**

15. In the case of conventional vehicles, the proper functioning of the compressed-air braking systems can be practically checked. E.g., the pressure in the air reservoirs can be reduced (by e.g. venting or successive brake applications with the engine stopped) and increased. By external tools the respective pressures can be measured and the reaction of the braking system (e.g. display of warning signals) can be observed.

16. However, in the case of EMB vehicles, without having a direct access to the electrical energy storage device and electrical supply device and having no means to manipulate the energy level of these devices during a periodical technical inspection (PTI), a procedure similar to conventional vehicles with pneumatic braking systems is not possible.

17. Therefore, for checking the braking system during PTI, a procedure is proposed by which it can be checked that the warning signals SUB_w and P_w are operational and fulfil the requirements of this regulation.

This means checking that

(a) the warning signals SUB_w and P_w are not defect and will illuminate when required (i.e. are operational),

(b) the warning signals illuminate correctly as required by paragraphs 5.2.1.13.1. (b) and 5.2.1.35.12 respectively (i.e. fulfil the requirements of this regulation).

18. This may be done by a visual check of the warning signals on the dashboard, after a specific checking procedure (e.g. a specific static test routine) was initiated during PTI (for example by service brake application(s) by the operator.

(n) **Paragraphs 5.1.4.6.1.1. and 5.1.4.6.1.2.**

19. These renumbered paragraphs are identical to former paragraphs 5.1.4.6.2. and 5.1.4.6.3.

(o) **Paragraphs 5.1.4.6.2. to 5.1.4.6.2.3.**

20. For an electro-mechanical braking system, the relationship between the brake actuator pressure and the braking force does not exist. Instead of the 'brake actuator pressure' the parameter 'brake demand value' is used in determining the reference braking forces during a roller brake tester.

21. The manufacturer shall declare the relationship between the braking forces and the wheel brake demand value e.g. as a percent value or a voltage value.

22. During the periodical inspection, it shall be possible for the tester to monitor the wheel brake demand value on the vehicle itself. This may be done e.g. by showing this value by a display on the dashboard in the cab.

23. Apart from the different parameter 'brake demand value' instead of 'brake actuator pressure' and the deletion of the category O-vehicles, the requirements of the new inserted paragraph 5.1.4.6.2. relating to electro-mechanical braking systems are the same as for compressed-air braking systems.

(p) **Paragraph 5.2.1.2.7.2.**

24. The addition in the last sentence of the wording "*In case of compressed-air braking systems*" is only a clarification that this requirement is only applicable for these kinds of braking systems.

(q) **Paragraph 5.2.1.2.7.3.**

25. This new proposed requirement corresponds to the requirement of paragraph 5.2.1.2.7.2 addressing all braking systems that depend exclusively on the use of an energy reserve controlled by the driver.

26. However, in order not to be design restrictive and to reflect the state-of-art of the development of electro-mechanical braking system, the new added paragraph 5.2.1.2.7.3. also permits - in contrast to the requirement of paragraph 5.2.1.2.7.2 - that e.g. only one or more wheel brake(s) is/are provided with energy either by an energy reserve providing electrical power to the whole transmission or separately to the electric control and separately to the energy transmissions of a braking circuit.

27. Recognising that these systems may employ multiple energy reserves. This proposal makes clear that a common low energy warning device may be used but that the energy in each reserve must be monitored separately.

(r) **Paragraph 5.2.1.5.**

28. By replacing "source" with "supply" which can mean either "source" or "electrical supply device" different brake technologies are covered without design restrictions.

(s) **Paragraph 5.2.1.5.1.**

29. The current wording of paragraph 5.2.1.5.1 was formulated about 50 years ago. The optional permitted possibility to adjust the braking system *when the vehicle is stationary after a failure has been occurred*, does not reflect the state-of-art and should therefore no longer be allowed.

30. This amendment also reflects the situation that an electro-mechanical braking system may have e.g. a 'multi-circuit supply protection electronics' fulfilling paragraph 5.2.1.5.1. by automatic means (as it is the case with conventional compressed-air braking systems).

(t) **Paragraph 5.2.1.5.4.**

31. Electro-mechanical braking systems (such as hydraulic braking systems) do not have multi-protection valves which are normally fitted to compressed-air braking systems for which the requirements of paragraphs 5.2.1.5.1. and 5.2.1.5.2. apply. Therefore, in analogy to paragraph 5.2.1.5.3. (hydraulic braking systems), the requirements of paragraphs 5.2.1.5.4. and 5.2.1.5.4.1. are added. Analogue to paragraph 5.2.1.27.3., the last sentence was added

for clarification of the test procedure (see also the Justification as to the test requirement of paragraph 1.2.3.2. of Annex 7, Part D).

(u) **Paragraph 5.2.1.8.1.1.**

32. Since an EMB system is not a compressed-air braking system it does not use different brake pressures for brake force compensation. A brake system using other energy sources as air should also be allowed to determine the brake force imbalance (caused by the deterioration or defect within the braking system) by controlling the difference in transverse wheel brake demand value.

(v) **Paragraph 5.2.1.13.1.**

33. Paragraph 5.2.1.13.1 (b). is based on the current requirements of paragraph 5.2.1.13.1 demanding a warning when the energy level falls below a critical value. However, the warning level required by paragraph 5.2.1.13.1 (b). is different from that of the current paragraph 5.2.1.13.1. (now, new requirement 5.2.1.13.1 (a)).

34. The warning level of paragraph 5.2.1.13.1 (a) can be freely chosen by the vehicle manufacturer as long as the specified test condition of this requirement is met (i.e. “giving an optical or acoustic signal when the stored energy, in any part of the system, falls to a value at which without re-charging of the reserve and irrespective of the load conditions of the vehicle, it is possible to apply the service brake control a fifth time after four full-stroke actuations and obtain the prescribed secondary braking performance ...”).

35. Thus, a vehicle manufacturer may declare that a red warning signal is illuminated:

36. i) When the prescribed service braking performance is no longer to be ensured (which seems to be the usual case) **or**

37. -ii) The vehicle manufacturer declares a warning level **below** the level **i**). In this case, even when the prescribed service braking performance is not ensured anymore no warning may be given to the driver. In the case of conventional EBS braking systems, paragraph 5.2.1.13.1 would therefore also be fulfilled if a vehicle would drive for hours with the red warning signal illuminated due to an insufficient energy level.

38. The new proposed requirement of paragraph 5.2.1.13.1 (b) corresponds to the “state-of-the-art safety standard” “i” and is seen as an appropriate safety level to be required for electro-mechanical braking systems.

(w) **Paragraph 5.2.1.13.2.**

39. In order that the driver can - at any time - check the actual electrical usable performance (AEUP) it is required that this value shall not only be displayed automatically on activation of the AEUP_w warning signal but also in response to the manual demand of the driver.

(x) **Paragraph 5.2.1.18.**

40. The addition of the wording "*with a compressed-air braking system*" is necessary since a power-driven vehicle cannot be authorized to a trailer of category O₃ or O₄ with an electro-mechanical braking system since for these types of trailer braking systems neither the relevant braking requirements nor an appropriate standardized interface exist.

(y) **Paragraph 5.2.1.26.3.**

41. Paragraph 5.2.1.27. does not address electro-mechanical braking systems. Due to the new proposed EMB requirements, the wording "*or in the case of electro-mechanical braking systems paragraph 5.2.1.35.16. respectively*" is added.

(z) **Paragraph 5.2.1.27.**

42. Since many requirements of this paragraph cannot be fully applied to EMB vehicles the current paragraph 5.2.1.27. is split up in two parts, namely of a paragraph addressing braking systems with non-electrical energy transmission (e.g. compressed-air braking systems - current paragraph 5.2.1.27.) and the new paragraph 5.2.1.35. "Special additional

requirements for service braking systems with electro-mechanical braking system with electric transmission" (including both: electric control and energy transmission).

(aa) Paragraph 5.2.1.35

43. See above Justification as to paragraph 5.2.1.27

(ab) Paragraph 5.2.1.35.2.

44. This requirement ensures that it is not possible that a vehicle with an EMB systems can be driven on public roads without any service braking capabilities. Thus, this requirement reflects the situation that also power-driven vehicles with conventional braking systems cannot either be operated on public roads with the complete loss of the service braking system.

(ac) Paragraph 5.2.1.35.3.

45. In order to avoid design restrictive requirements, manufacturers are required to provide documentation on the parameters and a description of the function triggering these warnings.

(ad) Paragraph 5.2.1.35.4.

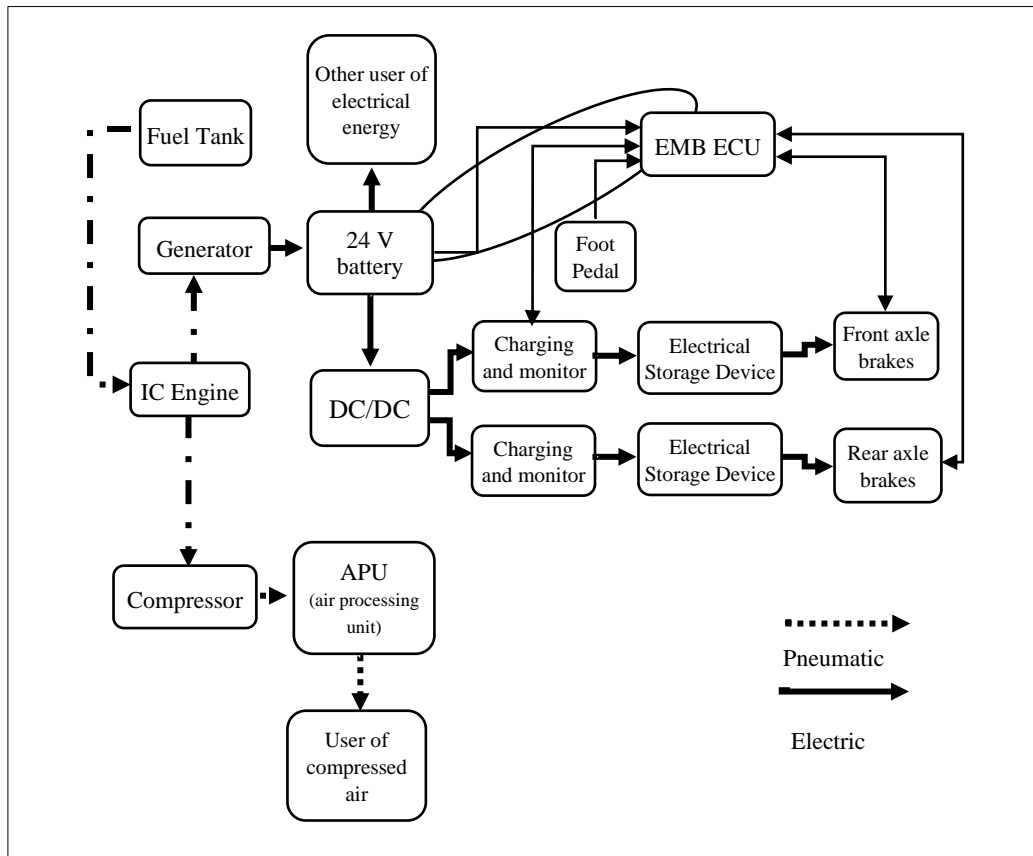
46. This paragraph corresponds to paragraph 5.2.1.27.1. The adding of the wording "*equipped with an interface according to paragraph 5.1.3. and*" clarifies that EMB motor vehicle are only permitted to tow trailers when they are equipped with an interface for trailers having a compressed-air braking system, see also comment as to paragraph 5.2.1.18.

(ae) Paragraph 5.2.1.35.5.

47. This requirement is similar to that in paragraph 5.2.1.27.5. but adapted to electro-mechanical braking systems. Paragraph 5.2.1.35.5. addresses a configuration of an electro-mechanical braking system where an electrical energy storage device (e.g. battery) only supplies electrical energy to the control transmission (but not also to the electrical energy transmission); as an exemplary simplified braking system see figure below.

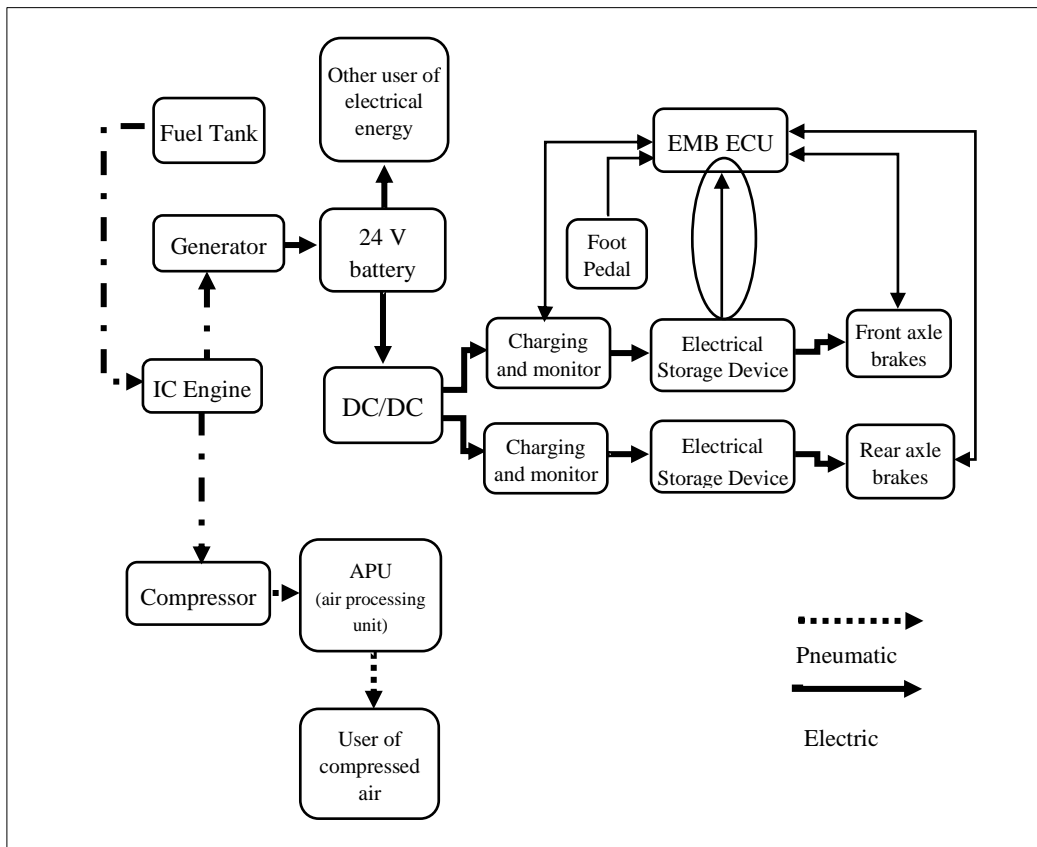
48. The added test condition of "**With the control transmission in operation, the braking control shall be kept released for 20 minutes before performing 20 full stroke application ...**" takes into account of an EMB control system where the duration of the actuation time of the braking control is the most relevant test condition and not the number of brake actuations. In such braking systems electric energy is consumed during application and during the release of the braking control.

49. Since paragraph 5.2.1.35.5. defines only a test procedure for the required energy reserve of the control and not the energy transmission, it is permissible to switch off the electrical energy transmission during the test procedure in order to avoid the activation of the red warning signal due to the excessive consumption of electrical energy due to the 20 brake applications of the electrical energy transmission.



(af) Paragraph 5.2.1.35.6.

50. In contrast to paragraph 5.2.1.35.5., this requirement addresses a configuration of an electro-mechanical braking system where energy storage devices are providing electrical energy for the electrical control and electrical energy transmission; as an exemplary simplified braking system see figure below.



(ag) Paragraph 5.2.1.35.7.

51. The newly added paragraph 5.2.1.2.7.3 permits for electro-mechanical braking system that the **control** transmission uses a **separate** energy storage device and not an energy storage device which is commonly feeding the electric control and energy transmission of a brake circuit (as required by 5.2.1.2.7.2 for non-EMB vehicles).

52. As alternative to the requirements of Annex 7, Part D, paragraph 1.2, paragraph 5.2.1.35.7. offers a requirement demanding an alternative power supply when an electrical energy storage device, that provides power only to the control transmission, fails.

(ah) Paragraph 5.2.1.35.8.

53. The paragraph ensures that if the electrical energy storage devices are used also by other vehicle systems (e.g. automatic traction control or other auxiliary systems) then the energy consumption of these systems shall not cause the reserves of energy to fall under a level which ensures the prescribed service braking performance as per the minimum performance requirements defined by these regulation.

(ai) Paragraph 5.2.1.35.12.

54. This paragraph describes an additional warning (as compared to conventional braking system) for the driver in case that the supply of power is insufficient.

(aj) Paragraph 5.2.1.35.15.

55. This requirement is essentially a copy of paragraph 5.2.1.27.6. This requirement was introduced into UN R13 in the nineties (initiated by the passenger car industry) to avoid the situation that a driver may not get any warning when a vehicle (with a heavy front brake

performance bias on the front axle) fulfils the prescribed service braking performance even in cases when one braking circuit fails completely.

(ak) Paragraph 5.2.1.35.16.

56. This requirement is similar to paragraph 5.2.1.27.7. However, since paragraph 5.2.1.35. covers not only the control transmission (as only covered by paragraph 5.2.1.27.) but also the electrical transmission, the electrical energy storage device for the whole transmission of the service braking system must be addressed by this paragraph. In consequence of this, the required warning level is that required by paragraph 5.2.1.13.1. (b) (analogue to paragraph 5.2.1.13.1. (a) (addressing the electrical energy storage device for the whole transmission of the service braking system).

57. The energy consumption of the trailer shall only be considered if it is provided by the electrical energy storage device(s).

(al) Paragraph 5.2.1.35.17.

58. This requirement is identical with paragraph 5.2.1.27.3 except that this requirement covers the whole electric transmission and not only the electric control transmission as addressed in paragraph 5.2.1.27.3.

(am) Paragraph 5.2.1.35.18.

59. This requirement is identical with paragraph 5.2.1.27.2.

60. Since this requirement addresses only a failed or interrupted data transmission of the control signal, such a failure or interrupted data transmission is not relevant to be considered for the energy transmission.

(an) Paragraph 5.2.1.35.19.

61. Except for the added and clarifying wording "*In the case of*" at the beginning of the text, this requirement is identical with paragraph 5.2.1.27.4.

(ao) Paragraph 5.2.1.35.20.

62. This requirement is identical with paragraph 5.2.1.27.9. In contrast to paragraph 5.2.1.18.2. which requires *partial* or *full* actuation of the trailer brakes, this paragraph requires that the full actuation of the trailer brakes remain ensured in the case of a failure in the electric control transmission of the service braking system.

(ap) Paragraph 5.2.1.35.21.

63. This paragraph is an adaption of paragraph 5.2.1.27.8. However, this paragraph refers to the **whole** electrical transmission (and **not only** to the electric **control** transmission). Instead of an energy source (EBS vehicles) the electrical energy may be supplied in the case of an electro-mechanical braking system by the "electrical supply device". Therefore, also the wording of paragraph 5.2.1.27.8. was modified.

B. Annex 2

(a) Paragraph 17.

64. The new paragraph 17 is added due the new requirements with regard to electro-mechanical braking systems.

C. Annex 4

(a) Paragraph 1.5.1.7.2.

65. Electrically controlled adjustment mechanisms measure and control the clearance between pad and disc constantly.

(b) Paragraph 1.3.3.

66. This test requirement demands that e.g., a failure on a single wheel on a high- μ surface where a very high braking force may be generated and may cause a severe condition with regard of stability, is assessed; see also Justification as to paragraph 2.5 below.

(c) Paragraph 2.5.

67. The proposal for paragraph 5.2.1.2.7.3. permits individual transmissions to be used for each wheel. The requirements of the existing paragraph 5.2.1.8. require that the braking effort across an axle is symmetric, it does not consider the failed condition. The loss of brake effort (complete or partial) can have a significant impact on vehicle stability under braking with a risk of loss of control.

68. Paragraphs 1.3.3. and 2.5. of Annex 4 ensure that there is an integrated control strategy to ensure that the driver can maintain vehicle control under fault/failure conditions.

(d) Paragraph 4.1.4.

69. Since for EMB systems the special response time Annex 6 is not applicable, paragraph 4.1.4. is formulated like paragraph 4.1.3. for hydraulic systems which also do not fall under the scope of Annex 6.

D. Annex 7

(a) Part D

70. With the development of electro-mechanical brakes there is the need to be able to homologate systems using stored electrical energy.

71. In Annex 7 currently there exists only requirements for pneumatic, vacuum and hydraulic systems (Part A to C) using stored energy but there are no corresponding requirements for braking systems using electrical energy storage devices.

72. In Part D the basic principles of parts A to C are applied. However, due to significant differences of EMB systems with conventional braking system (e.g. non-considered EMB trailer interface and the possibility of vehicles to be equipped without a generator), certain modifications have been introduced in this Part D.

(b) Paragraph 1.2.3.1

73. The initial value of electrical energy in the electrical energy storage device(s) of each braking circuit is a value at the time of the test (it is not a characteristic of e.g. the battery of an individual braking circuit, while MRUP is a fixed characteristic of such a battery).

74. A possible test procedure might be:

75. - To determine the initial electrical performance level by discharging each electrical energy storage device until the warning signal required by paragraph 5.2.1.35.9. of this Regulation is activated.

76. - Recharging of each electrical energy storage device until the warning signal is extinguished, at which point the energy supply shall be stopped.

77. - It must be ensured that the electrical energy storage device(s) for each braking circuit is/are conditioned at the minimum required usable performance level declared in paragraph 1.2.2. above.

78. - The electrical energy storage devices are not supplied with further energy.

(c) Paragraph 1.2.3.2

79. As in paragraph 5.2.1.27.5 of UN R13, paragraph 1.2.3.2. defines what is meant by a “full-stroke actuation”.

80. However, deviating from the 20 seconds full application time required by paragraph 5.2.1.27.5., a time of 7.0 seconds is proposed as a more realistic time requirement.

81. The number "20" was set in square bracket for a long time in the nineties when paragraph 5.2.1.27.5 was under discussion. No one - at that time - had an idea what the appropriate number would be.

82. Since the electrical energy consumption for the electrical control transmission of a "conventional" EBS vehicle is comparatively low in relation to the available electrical energy, the relatively high number "20" was chosen to avoid any discussion.

83. However, the situation is completely different for EMB braking systems which also requires energy for the actuation of the brakes where the energy consumption can be considerable.

84. Furthermore, the test procedure of the eight full stroke actuations of paragraph 1.2.1. with an electro-mechanical braking system cannot be directly compared to a **conventional pneumatic** braking system, where:

(a) no additional energy is required to keep the braking force constant which, however, may be the case with an electro-mechanical braking system,

(b) the brake performance is reduced at each brake application in contrast to an electro-mechanical braking system where the braking force at the first brake application will be similar to that of the ninth brake application.

85. In order to find a justifiable time requirement, a completely extreme and even unrealistic worst-case scenario is considered in which a motor vehicle with a braking system with the minimum prescribed service braking performance of only 5 m/s² is braked to standstill on a downhill with an 18 per cent gradient (the largest slope assumption in UN R13) at a speed of 80 km/h. Under these extreme conditions the actual deceleration (neglecting any running resistances) would be 3.26 m/s², resulting in a braking time of **6.81 s** (compared to 4.44 s on a flat road).

86. Assuming the two cases:

(a) A solo vehicle with a Gross Vehicle Weight (GVW) of 26 t (engine power of 330 kW) and;

(b) A vehicle combination of 40 t (engine power of 500 kW),

87. Driving down the gradient of 18 per cent and additionally accelerated by the engine with an acceleration of about 1.1 m/s² and considering - as a worst-case scenario - also the running resistances in the order of 0.14 m/s², then the time needed to accelerate these vehicles again to the speed of 80 km/h would be **8.1 s** (a) and **8.2 s** (b) respectively.

88. Taking these worst-case scenarios into account, a brake application time of 7.0 seconds followed by an unbraked interval of 9.0 seconds is therefore proposed for the test procedure according to paragraph 1.2.1.

89. The reduced application time of 7.0 seconds is proposed to cover also electro-mechanical braking system which - in contrast to a conventional pneumatic braking system - also consumes energy during the brake application time after the brake force has already been fully applied.

90. Since, in an electro-mechanical braking system, the stored electrical energy does not only provide energy for the control but also for the much more consuming energy transmission, the reduced application time of 7.0 seconds is considered a more realistic value than the 20 s duration time as required by paragraph 5.2.1.27.5 of UN R13.

(d) **Paragraph 1.2.3.3.**

91. Whereas paragraph 1.2.3.1 demands that the electrical energy storage devices shall not be supplied with further energy, paragraph 1.2.3.3 demands that only the electrical energy storage devices provide energy to the brake system transmission.

(e) **Paragraph 1.2.3.4.**

92. The requirement of paragraph 1.2.3.4. corresponds to paragraph 1.2.2.3 of Part A (as amended by Supplement 17 to the 11 series of amendments).

(f) **Paragraph 1.2.3.5.**

93. Electro-mechanical braking systems which also consume energy when they keep the braking force constant may reduce or switch off the energy consumption by the service braking system when the parking brake is applied. Therefore, during this test procedure an energy saving function, if available, shall be disabled.

(g) **Paragraph 2**

94. Annex 7, Part D, Section 2 addresses the ability of the electrical supply device to maintain the electrical reserves of the braking system. Since electrical energy storage device (e.g batteries) cannot be completely depleted like pneumatic or hydraulic energy reservoirs and behave fundamentally differently than these energy storage devices, and since the electrical supply device will normally be an energy storage device rather than an energy source, the test requirements for this Section 2 had to be formulated differently.

95. Testing of the electrical supply device is carried out in a different way to pneumatic or hydraulic systems but it has a similar effect in ensuring that brake energy is maintained at the vehicle.

96. The test requirements for the capacity of the electrical supply device are based on the Type-I test which is a very large energy-consuming test procedure and therefore gives a good representation of the amount of energy expected to be available by the use of the braking system in normal driving.

(h) **Paragraph 2.2.1.**

97. Whereas Type-I deals with the fading characteristics of the brake (“heat capacity test”), this Annex 7 test ensures that the capacity of the electrical supply device is sufficient to provide the needed electrical energy also in a demanding driving situation. To standardize and harmonize the test procedure for all vehicle categories, the number of 20 brake actuations is defined (no brake line fading issue).

(i) **Paragraph 2.2.2.**

98. As an alternative to the dynamic test procedure according to paragraph 2.2.1., the static test can be done at the discretion of the manufacturer by matching the conditions of the dynamic Annex 4 Type-I and hot-performance tests:

- energy consumed by the brakes in each of the cycles
- the duration of brake application
- the energy provided by the electrical supply device to the electrical energy storage devices

(j) **Paragraph 2.2.3.**

99. As to a): The discussion to define an appropriate test condition for the initial test condition for the electrical supply device is still underway.

(k) **Paragraph 2.2.5.**

100. This means when the test defined in paragraph 2.2. above starts at the MRUP energy values for the respective braking circuits that during the 20+1 brake applications, the energy levels in the service braking circuits shall not fall to a level when the warning signal AEUP_w is required to be illuminated.

(l) **Paragraph 2.2.6.**

101. The condition of paragraph 2.2.6. ensures that the energy supply device can continue to provide adequate power to the electrical energy storage devices throughout the test.

(m) **Paragraph 3.**

102. The pressure "p₂" in Part A corresponds to the pressure for achieving the prescribed performance of the service braking system during the Type-O test. Since this pressure is not available for an electro-mechanical braking system, the prescribed maximum supply line pressure of 700 kPa at which the Type O-test has to be carried out (see Annex 4, paragraph 3.1.3.2) has taken to be the pressure p₄. With the supply line pressure of 700 kPa the prescribed service braking performance has to be achieved. Thus, this pressure is the worst-case assumption for achieving the prescribed service braking performance.

103. The pressure p₃ is the rounded 65% value of p₄.

(n) **Paragraph 3.1.4.**

104. In contrast to a compressed-air braking system, an electro-mechanical braking system has no air reservoirs providing energy to the service braking system of the motor vehicle. Therefore, for UN Regulation No. 13 as braking regulation, only the respective filling times for the energy reserves of the braking system of the trailer (represented by the attached trailer energy storage device) has to be considered. The filling behaviour of a possibly existing air reservoir in the motor vehicle is indirectly also considered by the prescribed maximum filling times t₄ and t₅ (as the symbols t₁ to t₃ are already used in Part A of Annex 7, the subsequent indices '4' and '5' are used in this paragraph).

(o) **Paragraph 3.2.**

105. The corresponding requirements as laid down in Part A (paragraph 2.4.) regarding the filling times for the attached trailer volume as defined by paragraph 3.2.4. are taken over.

(p) **Paragraph 3.4.**

106. In paragraph 2.5 of Part A of Annex 7, an additional test is prescribed in case if the power-driven vehicle is equipped with one or more energy storage devices for auxiliary equipment having a total capacity exceeding 20 per cent of the total capacity of the **pneumatic** braking energy storage devices. For an electro-mechanical braking system, an analogue "additional test" requirement is demanded by the newly proposed paragraph 2.5. of Part **D** of Annex 7.

107. This further 'additional test' of paragraph 3.4. is included in Part D of Annex 7 since an **electro-mechanical** braking system may have also **pneumatic** energy storage devices for **auxiliary** equipment fed by the same air compressor providing the air for the compressed-air braking system of the trailer. Thus, this test is added (independent on the size of the air reservoirs of the auxiliary equipment) to limit the maximum permitted filling time when **all** air reservoirs of a vehicle combination are filled up.

(q) **Paragraph 3.4.2.**

108. The performance braking requirements in UN Regulation No. 13 assume at least a pressure of 650 kPa in the supply line. Therefore, a failure in another vehicle system (e.g. air suspension) should not have an effect on the braking system that this assumed minimum pressure level is not anymore available.

109. The philosophy of this requirement is similar to that of the requirement of paragraph 5.2.1.15. in UN Regulation No. 13, where a failure of the trailer's braking system or in the event of an interruption in the supply line cannot cause the performance of the service braking system of the motor vehicle to fall under a certain performance level.

(r) **Paragraph 3.4.3.1**

110. The corresponding requirements as laid down in Part A (paragraph 2.5.2.2) regarding the filling times are taken over (see also the testing conditions defined in paragraph 3.4.3.2.).

E. Annex 8

(a) Title of Annex 8

111. The requirements of Annex 8 assume a fluid to compress the spring in order to release a brake. Therefore, by adding in the heading the words "*compressed-air braking systems fitted with*" the scope of this section is made clear

F. Annex 13

(a) Paragraph 5.1.1.3.

112. The main demand of this requirement is that "**any** energy transmission storage device(s) shall not be charged". The **editorial** amendment of this paragraph makes it clear that also for electro-mechanical braking systems this demand has to be fulfilled and that this requirement cannot be circumvented by these braking systems by only switching of the engine.

(b) Paragraph 5.1.1.4.

113. The second sentence is added to take into account the special characteristics of electro-mechanical braking systems (regarding this clarification, see also the detailed Justification as to paragraph 1.2.3.2. of Annex 7, Part D).

(c) Appendix 2, paragraph 1.1.3.

114. Instead of the 'line pressure' the parameter 'wheel brake demand value' will be used to modify the individual brake forces within the k-measurement procedure.
