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UN Regulation No 13-H – Uniform provisions concerning the approval of passenger cars with regard to braking [2026/502]

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1. Scope

1.1. This Regulation applies to the braking of vehicles of categories M_1 and N_1 ([1]).

1.2. This Regulation does not cover:

1.2.1. Vehicles with a design speed not exceeding 25 km/h;

1.2.2. Vehicles fitted for invalid drivers;

1.2.3. The approval of the Electronic Stability Control (ESC) and Brake Assist System(s) (BAS) of the vehicle.

1.2.4. Vehicles which are not equipped with manual braking controls intended for use during normal operation.

2. Definitions

For the purposes of this Regulation:

2.1. "*Approval of a vehicle*" means the approval of a vehicle type with regard to braking.

2.2. "*Vehicle type*" means a category of vehicles which do not differ in such essential respects as:

2.2.1. The maximum mass, as defined in paragraph 2.11. below;

2.2.2. The distribution of mass among the axles;

2.2.3. The maximum design speed;

2.2.4. A different type of braking equipment, with more particular reference to the presence or otherwise of equipment for braking a trailer or any presence of electric braking system;

2.2.5. The engine type;

2.2.6. The number and ratios of gears;

2.2.7. The final drive ratios;

2.2.8. The tyre dimensions.

2.3. "*Braking equipment*" means the combination of parts whose function is progressively to reduce the speed of a moving vehicle or bring it to a halt, or to keep it stationary if it is already halted; these functions are specified in paragraph 5.1.2. below. The equipment consists of the control, the transmission, and the brake proper.

([1]) This Regulation offers an alternative set of requirements for category N_1 vehicles to those contained in UN Regulation No 13. Contracting Parties that apply both UN Regulation No 13 and this Regulation recognize approvals to either Regulation as equally valid. M_1 and N_1 categories of vehicles are defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3), document ECE/TRANS/WP.29/78/Rev.6, para. 2 – www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html.

2.4. "*Control*" means the part actuated directly by the driver to furnish to the transmission the energy required for braking or controlling it. This energy may be the muscular energy of the driver, or energy from another source controlled by the driver, or a combination of these various kinds of energy.

2.5. "*Transmission*" means the combination of components comprised between the control and the brake and linking them functionally. The transmission may be mechanical, hydraulic, pneumatic, electric or mixed. Where the braking power is derived from or assisted by a source of energy independent of the driver, the reserve of energy in the system is likewise part of the transmission.

The transmission is divided into two independent functions: the control transmission and the energy transmission. Whenever the term "transmission" is used alone in this Regulation, it means both the "control transmission" and the "energy transmission":

2.5.1. "*Control transmission*" means the combination of the components of the transmission which control the operation of the brakes, including the control function and the necessary reserve(s) of energy;

2.5.2. "*Energy transmission*" means the combination of the components which supply to the brakes the necessary energy for their function, including the reserve(s) of energy necessary for the operation of the brakes.

2.6. "*Brake*" means the part in which the forces opposing the movement of the vehicle develop. It may be a friction brake (when the forces are generated by friction between two parts of the vehicle moving relatively to one another); an electrical brake (when the forces are generated by electro-magnetic action between two parts of the vehicle moving relatively to but not in contact with one another); a fluid brake (when the forces are generated by the action of a fluid situated between two parts of the vehicle moving relatively to one another); or an engine brake (when the forces are derived from an artificial increase in the braking action, transmitted to the wheels, of the engine).

2.7. "*Different types of braking equipment*" means equipment which differ in such essential respects as:

2.7.1. Components having different characteristics;

2.7.2. A component made of materials having different characteristics, or a component differing in shape or size;

2.7.3. A different assembly of the components.

2.8. "*Component of the braking equipment*" means one of the individual parts which, when assembled, constitutes the braking equipment.

2.9. "*Progressive and graduated braking*" means braking during which, within the normal operating range of the device, and during actuation of the brakes (see paragraph 2.16. below):

2.9.1. The driver can at any moment increase or decrease the braking force by acting on the control;

2.9.2. The braking force varies proportionally as the action on the control (monotonic function);

2.9.3. The braking force can be easily regulated with sufficient precision.

2.10. "*Laden vehicle*" means, except where otherwise stated, a vehicle so laden as to attain its "maximum mass".

2.11. "*Maximum mass*" means the maximum mass stated by the vehicle manufacturer to be technically permissible (this mass may be higher than the "permissible maximum mass" laid down by the national administration).

2.12. "*The distribution of mass among the axles*" means the distribution of the effect of the gravity on the mass of the vehicle and/or its contents among the axles.

2.13. "*Wheel/axle load*" means the vertical static reaction (force) of the road surface in the contact area on the wheel/wheels of the axle.

2.14. "*Maximum stationary wheel/axle load*" means the stationary wheel/axle load achieved under the condition of the laden vehicle.

2.15. "*Hydraulic braking equipment with stored energy*" means a braking equipment where energy is supplied by a hydraulic fluid under pressure, stored in one or more accumulator(s) fed from one or more pressure pump(s), each fitted with a means of limiting the pressure to a maximum value. This value shall be specified by the manufacturer.

2.16. "*Actuation*" means both application and release of the control.

2.17. "*Electric regenerative braking*" means a braking system which, during deceleration, provides for the conversion of vehicle kinetic energy into electrical energy.

2.17.1. "*Electric regenerative braking control*" means a device which modulates the action of the electric regenerative braking system;

2.17.2. "*Electric regenerative braking system of category A*" means an electric regenerative braking system which is not part of the service braking system;

2.17.3. "*Electric regenerative braking system of category B*" means an electric regenerative braking system which is part of the service braking system;

2.17.4. *"Electric State of Charge (*SOC*)"* means the instantaneous ratio of electric quantity of energy stored in an electrical storage device (e.g., battery, capacitor, etc.) relative to the maximum quantity of electric energy which could be stored in this device;

2.17.5. "*Traction battery*" means an assembly of accumulators constituting the storage of energy used for powering the traction motor(s) of the vehicle.

2.18. "*Phased braking*" is a means which may be used where two or more sources of braking are operated from a common control, whereby one source may be given priority by phasing back the other source(s) so as to make increased control movement necessary before they begin to be brought into operation.

2.19. "*Nominal value*" definitions for braking reference performance are required to put a value on the transfer function of the braking system, relating output to input for vehicles individually.

2.19.1. "*Nominal value*" is defined as the characteristic which can be demonstrated at type approval and which relates the braking rate of the vehicle on its own to the level of the braking input variable.

2.20. "*Automatically commanded braking*" means a function within a complex electronic control system where actuation of the braking system(s) or brakes of certain axles is made for the purpose of generating vehicle retardation with or without a direct action of the driver, resulting from the automatic evaluation of on-board initiated information.

2.21. "*Selective braking*" means a function within a complex electronic control system where actuation of individual brakes is made by automatic means in which vehicle retardation is secondary to vehicle behaviour modification.

2.22. "*Braking signal*": logic signal indicating brake activation as specified in paragraph 5.2.22. of this Regulation.

2.23. "*Emergency braking signal*": logic signal indicating emergency braking as specified in paragraph 5.2.23. of this Regulation.

2.24. "*Identification code*" identifies the brake discs or brake drums covered by the braking system approval according to this Regulation. It contains at least the manufacturer's trade name or trademark and an identification number.

2.25. *'Automated Driving System (ADS)'* means the vehicle hardware and software that are collectively capable of performing the entire Dynamic Driving Task (DDT) on a sustained basis.

2.25.1. *'Dynamic Driving Task (DDT)'* means the real-time operational and tactical functions required to operate the vehicle.

2.26. "*Brake demand value*" means the demand value for the braking force of a single wheel, or axle, being electrically actuated.

2.27. The "*performance of an electrical storage device*" means its ability to provide power (W) and quantity of energy (Wh) when fully charged.

2.28. "P_w" (W) means the low electrical supply power warning as required by paragraph 5.2.24.9. in the case of an electrical transmission braking system.

2.29. "*Energy source*" means a device that both generates and provides energy required for the braking system.

2.30. "*Electrical storage device*" means a device, or combination of individual devices, each capable of storing an electrical charge and of providing electrical power to the braking system transmission. Electrical 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 storage device within this Regulation.

2.31. The "*effect of ageing*" is quantifying the irreversible degradation of the performance of an electrical storage device, due to e.g., the effects of time, use, and environmental exposure.

2.32. "*Electrical supply*" means a device (e.g. battery, REESS, generator, fuel-cell or a combination of these components) that supplies electrical power to the braking system's electrical storage device(s).

2.33. "*Energy Management System*" means, an electrical device(s), being part of, or used by, an electrical transmission braking system, that monitors critical variables that impact on the performance and state of the electrical storage devices (e.g., voltage, temperature, internal resistance, effect of ageing, state of charge, power consumption, charging cycles, etc.) and deduces the actual capability of the devices to fulfil the performance requirements of this Regulation.

2.34. "*Electrical Transmission Braking System*" (ETBS) means a braking system where the service braking force, and transmission, depend exclusively on the use, controlled by the driver, of energy provided from electrical storage devices.

2.35. "*Auxiliary equipment*" means, for the purposes of this Regulation, the collective of systems, functions, or components, including those that are essential to the operation of the vehicle, that are supplied with energy from the same energy reserves as the braking system.

2.36. The "*state of an electrical storage device*" means its ability to provide power (W) and quantity of energy (Wh) at the time.

2.37. *"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.

3. Application for approval

3.1. The application for approval of a vehicle type with regard to braking shall be submitted by the vehicle manufacturer or by his duly accredited representative.

3.2. It shall be accompanied by the under-mentioned documents in triplicate and by the following particulars:

3.2.1. A description of the vehicle type with regard to the items specified in paragraph 2.2. above. The numbers and/or symbols identifying the vehicle type and the engine type shall be specified;

3.2.2. A list of the components, duly identified, constituting the braking equipment;

3.2.3. A diagram of assembled braking equipment and an indication of the position of its components on the vehicle;

3.2.4. Detailed drawings of each component to enable it to be easily located and identified.

3.3. A vehicle, representative of the vehicle type to be approved, shall be submitted to the Technical Service conducting the approval tests.

4. Approval

4.1. If the vehicle type submitted for approval pursuant to this Regulation meets the requirements of paragraphs 5. and 6. below, approval of that vehicle type shall be granted.

4.2. An approval number shall be assigned to each type approved, its first two digits shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval. The same Contracting Party shall not assign the same number to the same vehicle type equipped with another type of braking equipment, or to another vehicle type.

4.3. Notice of approval or of refusal of approval of a vehicle type pursuant to this Regulation shall be communicated to the Parties to the Agreement which apply this Regulation by means of a form conforming to the model in Annex 1 to this Regulation and of a summary of the information contained in the documents referred to in paragraphs 3.2.1. to 3.2.4. above, the drawings supplied by the applicant for approval being in a format not exceeding A4 (210 × 297 mm), or folded to that format, and on an appropriate scale.

4.4. There shall be affixed, conspicuously and in a readily accessible place specified on the approval form, to every vehicle conforming to a vehicle type approved under this Regulation, an international approval mark consisting of:

4.4.1. A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval ([2]) and of

4.4.2. The number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle prescribed in paragraph 4.4.1. above.

4.5. If the vehicle conforms to a vehicle type approved under one or more other Regulations, annexed to the Agreement, in the country which has granted approval under this Regulation, the symbol prescribed in paragraph 4.4.1. above, need not be repeated; in such a case, the Regulation and approval numbers and the additional symbols of all the regulations under which approval has been granted in the country which has granted approval under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in paragraph 4.4.1. above.

4.6. The approval mark shall be clearly legible and be indelible.

4.7. The approval mark shall be placed close to or on the vehicle data plate.

4.8. Annex 2 to this Regulation gives examples of arrangements of approval marks.

5. Specifications

5.1. General

5.1.1. Braking equipment

5.1.1.1. The braking equipment shall be so designed, constructed and fitted as to enable the vehicle in normal use, despite the vibration to which it may be subjected, to comply with the provisions of this Regulation.

5.1.1.2. In particular, the braking equipment shall be so designed, constructed and fitted as to be able to resist the corroding and ageing phenomena to which it is exposed.

5.1.1.3. Brake linings shall not contain asbestos.

5.1.1.4. The effectiveness of the braking equipment shall not be adversely affected by magnetic or electrical fields. This shall be demonstrated by fulfilling the technical requirements and respecting the transitional provisions of UN Regulation No 10 by applying:

(a) The 03 series of amendments for vehicles without a coupling system for charging the Rechargeable Electric Energy Storage System (traction batteries);

(b) The 04 series of amendments for vehicles with a coupling system for charging the Rechargeable Electric Energy Storage System (traction batteries).

5.1.1.5. A failure detection signal may interrupt momentarily (< 10 ms) the demand signal in the control transmission, provided that the braking performance is thereby not reduced.

([2]) The distinguishing numbers of the Contracting Parties to the 1958 Agreement are reproduced in Annex 3 to the Consolidated Resolution on the Construction of Vehicles (R.E.3), document ECE/TRANS/WP.29/78/Rev. 6, Annex 3 – www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html.

5.1.2. Functions of the braking equipment

The braking equipment defined in paragraph 2.3. of this Regulation shall fulfil the following functions:

5.1.2.1. Service braking system

The service braking system shall make it possible to control the movement of the vehicle and to halt it safely, speedily and effectively, whatever its speed and load, on any up or down gradient. It shall be possible to graduate this braking action. The driver shall be able to achieve this braking action from his driving seat without removing his hands from the steering control.

5.1.2.2. Secondary braking system

The secondary braking system shall make it possible by application of the service brake control to halt the vehicle within a reasonable distance in the event of failure of the service braking system. It shall be possible to graduate this braking action. The driver shall be able to obtain this braking action from his driving seat without removing his hands from the steering control. For the purposes of these provisions it is assumed that not more than one failure of the service braking system can occur at one time.

5.1.2.3. Parking braking system

The parking braking system shall make it possible to hold the vehicle stationary on an up or down gradient even in the absence of the driver, the working parts being then held in the locked position by a purely mechanical device. The driver shall be able to achieve this braking action from his driving seat.

5.1.3. The requirements of Annex 8 shall be applied to the safety aspects of all complex electronic vehicle control systems, including those defined in an independent regulation, which provide or form part of the control transmission of the braking function, included those which utilize the braking system(s) for automatically commanded braking or selective braking.

However, vehicles equipped with systems or functions, including those defined in an independent regulation, which use the braking system as the means of achieving a higher level objective, are subject to Annex 8 only insofar as they have a direct effect on the braking system. If such systems are provided, they shall not be deactivated during type approval testing of the braking system.

5.1.4. Provisions for the periodic technical inspection of braking systems

5.1.4.1. It shall be possible to assess the wear condition of the components of the service brake that are subject to wear e.g. friction linings and drums/discs (in the case of drums or discs, wear assessment may not necessarily be carried out at the time of periodic technical inspection). The method by which this may be realized is defined in paragraphs 5.2.11.2. of this Regulation.

5.1.4.2. It shall be possible to verify, in a frequent and simple way, the correct operational status of those complex electronic systems which have control over braking. If special information is needed, this shall be made freely available.

5.1.4.2.1. Where the operational status is indicated to the driver by warning signals, as specified in this Regulation, it shall be possible at a periodic technical inspection to confirm the correct operational status by visual observation of the warning signals following a power-on.

5.1.4.2.2. At the time of type approval, the means implemented to protect against simple unauthorized modification of the operation to the verification means chosen by the manufacturer (e.g. warning signal) shall be confidentially outlined. Alternatively, this protection requirement is fulfilled when a secondary means of checking the correct operational status is available.

5.1.4.2.3. It shall be possible to generate maximum braking forces under static conditions on a rolling road or roller brake tester.

5.1.4.3. Data for braking systems

5.1.4.3.1. The data of the electrical transmission 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).

5.1.4.3.2. For power-driven vehicle equipped with an electrical transmission braking system the vehicle manufacturer shall describe, at the time of type approval, the procedure by which it can be checked that the detection means triggering the warning signals specified in paragraphs 5.2.24.6., 5.2.24.7. and 5.2.24.9. are operational.

5.1.4.4. Reference braking forces

5.1.4.4.1. Reference braking forces for an electrical transmission braking system using a roller brake tester shall be defined according to the following requirements.

5.1.4.4.1.1. It shall be possible to evaluate the relationship between the brake demand value(s) and the measured braking force on a roller brake tester. The brake demand value(s) shall be displayed on the vehicle and easily readable from the driver's seat during the roller brake test (e.g., using a menu system, automatic demand, etc.). The vehicle manufacturer shall describe how to display those values and make this information available according to paragraph 5.1.4.3.1. above.

5.1.4.4.1.2. 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 5.1.4.3. above.

5.1.4.4.1.3. The reference braking forces shall be declared such that the vehicle is capable of generating a braking rate equivalent to that defined in Annex 3 of this Regulation for the relevant vehicle 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 range ([3]).

5.2. Characteristics of braking systems

5.2.1. The set of braking systems with which a vehicle is equipped shall satisfy the requirements laid down for service, secondary and parking braking systems.

5.2.2. The systems providing service, secondary and parking braking may have common components so long as they fulfil the following conditions:

5.2.2.1. There shall be at least two controls, independent of each other and readily accessible to the driver from his normal driving position. Every brake control shall be designed such that it returns to the fully off position when released. This requirement shall not apply to a parking brake control when it is mechanically locked in an applied position;

5.2.2.2. The control of the service braking system shall be independent of the control of the parking braking system;

([3]) 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.

5.2.2.3. The effectiveness of the linkage between the control of the service braking system and the different components of the transmission systems shall not be liable to diminish after a certain period of use;

5.2.2.4. The parking braking system shall be so designed that it can be actuated when the vehicle is in motion. This requirement may be met by the actuation of the vehicle's service braking system, even partially, by means of an auxiliary control;

5.2.2.5. Without prejudice to the requirements of paragraph 5.1.2.3. of this Regulation, the service braking system and the parking braking system may use common components in their transmission(s), provided that in the event of a failure in any part of the transmission(s) the requirements for secondary braking are still ensured;

5.2.2.6. In the event of breakage of any component other than the brakes (as defined in paragraph 2.6. above) and the components referred to in paragraph 5.2.2.10. below, or of any other failure of the service braking system (malfunction, partial or total exhaustion of an energy reserve), that part of the service braking system which is not affected by the failure, shall be able to bring the vehicle to a halt in the conditions prescribed for secondary braking;

5.2.2.7. If service braking is ensured by the action of the driver's muscular energy assisted by one or more energy reserves, secondary braking shall, in the event of failure of that assistance, be capable of being ensured by the driver's muscular energy assisted by the energy reserves, if any, which are unaffected by the failure, the force applied to the service brake control not exceeding the prescribed maximum;

5.2.2.8. If the service braking force and transmission depend exclusively on the use, controlled by the driver, of an energy reserve, there shall be at least two completely independent energy reserves, each provided with its own transmission, likewise independent; each of them may act on the brakes of only two or more wheels so selected as to be capable of ensuring by themselves the prescribed degree of secondary braking without endangering the stability of the vehicle during braking; in addition, each of the aforesaid energy reserves shall be equipped with a warning device as defined in paragraph 5.2.14. below;

5.2.2.9. If the service braking force and transmission depend exclusively on the use of an energy reserve, one energy reserve for the transmission is deemed to be sufficient, provided that the prescribed secondary braking is ensured by the action of the driver's muscular energy acting on the service brake control and the requirements of paragraph 5.2.5. below are met;

5.2.2.10. Certain parts, such as the pedal and its bearing, the master cylinder and its piston or pistons, the control valve, the linkage between the pedal and the master cylinder or the control valve, the brake cylinders and their pistons, and the lever-and-cam assemblies of brakes, shall not be regarded as liable to breakage if they are amply dimensioned, are readily accessible for maintenance, and exhibit safety features at least equal to those prescribed for other essential components (such as the steering linkage) of the vehicle. Any such part as aforesaid whose failure would make it impossible to brake the vehicle with a degree of effectiveness at least equal to that prescribed for secondary braking shall be made of metal or of a material with equivalent characteristics and shall not undergo notable distortion in normal operation of the braking systems.

5.2.3. The failure of a part of a hydraulic transmission system shall be signalled to the driver by a device comprising a red tell-tale signal lighting up before or upon application of a differential pressure of not more than 15.5 bar between the active and failed brake equipment, measured at the master cylinder outlet and remaining lit as long as the failure persists and the ignition (start) switch is in the "On" (run) position. However, a device comprising a red tell-tale signal lighting up when the fluid in the reservoir is below a certain level specified by the manufacturer is permitted. The tell-tale signal shall be visible even by daylight; the satisfactory condition of the signal shall be easily verifiable by the driver from the driver's seat. The failure of a component of the device shall not entail total loss of the braking equipment's effectiveness. Application of the parking brake shall also be indicated to the driver. The same tell-tale signal may be used.

5.2.4. Where use is made of energy other than the muscular energy of the driver, there need not be more than one supply (energy source or electrical supply, as relevant) of such energy (hydraulic pump, air compressor, etc.), but the means by which the device constituting that supply is driven shall be as safe as practicable.

5.2.4.1. 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 secondary braking. This condition shall be met by means of devices which can easily be actuated when the vehicle is stationary, or by automatic means.

5.2.4.2. Furthermore, storage devices located down-circuit of this device shall be such that in the case of a failure in the energy supply after four full-stroke actuations of the service brake control, under the conditions prescribed in paragraph 1.2. of Annex 4 to this Regulation, it is still possible to halt the vehicle at the fifth application, with the degree of effectiveness prescribed for secondary braking.

5.2.4.3. However, for hydraulic braking systems with stored energy, these provisions can be considered to be met provided that the requirements of paragraph 1.3. of Annex 4 to this Regulation, are satisfied.

5.2.4.4. However, as an alternative to the provisions of paragraphs 5.2.4.1. and 5.2.4.2., for an electrical transmission braking system these requirements are considered to be met if the requirements of paragraph 5.2.4.4.1. are satisfied.

5.2.4.5. After any single transmission failure it shall still be possible after eight full actuations of the service braking system control, to achieve, at the ninth application, at least the performance prescribed for the secondary braking system. Each full actuation shall be as specified in Annex 4 Part B paragraph 1.2.3.3.

5.2.5. The requirements of paragraphs 5.2.2., 5.2.3. and 5.2.4. above shall be met without the use of any automatic device of a kind such that its ineffectiveness might pass unnoticed through the fact that parts normally in a position of rest come into action only in the event of failure in the braking system.

5.2.6. The service braking system shall act on all wheels of the vehicle and shall distribute its action appropriately among the axles.

5.2.7. In the case of vehicles equipped with electric regenerative braking systems of category B, the braking input from other sources of braking, may be suitably phased to allow the electric regenerative braking system alone to be applied, provided that both the following conditions are met:

5.2.7.1. Intrinsic variations in the torque output of the electrical regenerative braking system (e.g. as a result of changes in the electric state of charge in the traction batteries) are automatically compensated by appropriate variation in the phasing relationship as long as the requirements ([4]) of one of the following annexes to this Regulation are satisfied:

Annex 3, paragraph 1.3.2., or

Annex 6, paragraph 5.3. (including the case with the electric motor engaged), and

wherever necessary, to ensure that braking rate[3] remains related to the driver's braking demand, having regard to the available tyre/road adhesion, braking shall automatically be caused to act on all wheels of the vehicle.

([4]) The Type Approval Authority, which is to grant approval, shall have the right to check the service braking system by additional vehicle test procedures.

5.2.7.2. Compensation provided, at any time, to ensure that the braking rate ([5]) of the vehicle remains related to the driver's braking demand, shall be declared. The manufacturer shall provide the Technical Service with a description of the compensation function(s), including the limits of operation, and the strategy that ensures this compensation does not compromise the safety of the vehicle, its occupants, or other road users.

5.2.8. The action of the service braking system shall be distributed between the wheels of one and the same axle symmetrically in relation to the longitudinal median plane of the vehicle.

Compensation and functions, such as anti-lock, which may cause deviations from this symmetrical distribution shall be declared.

5.2.8.1. Compensation by the electric control transmission for deterioration or defect within the braking system shall be indicated to the driver by means of the yellow warning signal specified in paragraph 5.2.21.1.2. below. This requirement shall apply for all conditions of loading when compensation exceeds the following limits:

5.2.8.1.1. 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 ≥ 2 m/s^2;

(b) A value corresponding to 25 per cent at 2 m/s^2 for decelerations below this rate.

5.2.8.1.2. An individual compensating value on any axle:

(a) > 50 per cent of the nominal value for vehicle decelerations ≥ 2 m/s^2;

(b) A value corresponding to 50 per cent of the nominal value at 2 m/s^2 for decelerations below this rate.

5.2.8.2. Compensation as defined above, is permitted only when the initial brake application is made at vehicle speeds greater than 10 km/h.

5.2.9. Malfunctions of the electric control transmission shall not apply the brakes contrary to the intentions of the driver or ADS.

5.2.10. The service, secondary and parking braking systems shall act on braking surfaces connected to the wheels through components of adequate strength.

Where braking torque for a particular axle or axles is provided by both a friction braking system and an electrical regenerative braking system of category B, disconnection of the latter source is permitted, providing that the friction braking source remains permanently connected and able to provide the compensation referred to in paragraph 5.2.7.1. above.

However, in the case of short disconnection transients, incomplete compensation is accepted, but within 1s, this compensation shall have attained at least 75 per cent of its final value.

Nevertheless, in all cases, the permanently connected friction braking source shall ensure that both the service and secondary braking systems continue to operate with the prescribed degree of effectiveness.

Disconnection of the braking surfaces of the parking braking system shall be permitted only on condition that the disconnection is controlled by the driver from his driving seat or from a remote control device, or by an ADS, by a system incapable of being brought into action by a leak.

([5]) The Type Approval Authority, which is to grant approval, shall have the right to check the service braking system by additional vehicle test procedures. The assessment of the function shall be recorded in the test report.

The remote control device mentioned above shall be part of a system fulfilling the technical requirements of an ACSF of Category A as specified in the 02 series of amendments to UN Regulation No 79 or later series of amendments.

5.2.11. Wear of the brakes shall be capable of being easily taken up by means of a system of manual or automatic adjustment. In addition, the control and the components of the transmission and of the brakes shall possess a reserve of travel and, if necessary, suitable means of compensation such that, when the brakes become heated, or the brake linings have reached a certain degree of wear, effective braking is ensured without immediate adjustment being necessary.

5.2.11.1. Wear adjustment shall be automatic for the service brakes. Automatic wear adjustment devices shall be such that after heating followed by cooling of the brakes, effective braking is still ensured. In particular the vehicle shall remain capable of normal running after the tests conducted in accordance with Annex 3, paragraph 1.5. (Type-I test).

5.2.11.2. Checking the wear of the service brake friction components

5.2.11.2.1. It shall be possible to easily assess this wear on service brake linings from the outside or underside of the vehicle, without the removal of the wheels, by the provision of appropriate inspection holes or by some other means. This may be achieved by utilizing simple standard workshop tools or common inspection equipment for vehicles.

Alternatively, a sensing device per wheel (twin wheels are considered as a single wheel), which will warn the driver at his driving position when lining replacement is necessary, is acceptable. In the case of an optical warning, the yellow warning signal specified in paragraph 5.2.21.1.2. below may be used.

5.2.11.2.2. Assessment of the wear condition of the friction surfaces of brake discs or drums may only be performed by direct measurement of the actual component or examination of any brake disc or drum wear indicators, which may necessitate some level of disassembly. Therefore, at the time of type approval, the vehicle manufacturer shall define the following:

(a) The method by which wear of the friction surfaces of drums and discs may be assessed, including the level of disassembly required and the tools and process required to achieve this;

(b) Information defining the maximum acceptable wear limit at the point at which replacement becomes necessary.

This information shall be made freely available, e.g. vehicle handbook or electronic data record.

5.2.12. In hydraulic-transmission braking systems, the filling ports of the fluid reservoirs shall be readily accessible; in addition, the receptacles containing the reserve fluid shall be so designed and constructed that the level of the reserve fluid can be easily checked without the receptacles having to be opened, and the minimum total reservoir capacity is equivalent to the fluid displacement resulting when all the wheel cylinders or calliper pistons serviced by the reservoirs move from a new lining, fully retracted position to a fully worn, fully applied position. If these latter conditions are not fulfilled, the red warning signal specified in paragraph 5.2.21.1.1. below shall draw the driver's attention to any fall in the level of reserve fluid liable to cause a failure of the braking system.

5.2.13. The type of fluid to be used in hydraulic transmission braking systems shall be identified by the symbol in accordance with Figure 1 or 2 of Standard ISO 9128:2006 and the appropriate DOT marking (e.g. DOT 3). The symbol and the marking shall be affixed in a visible position in indelible form within 100 mm of the filling ports of the fluid reservoirs; additional information may be provided by the manufacturer.

5.2.14. Warning device

5.2.14.1. 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 an indication of the available energy (e.g. a pressure gauge) where fitted, giving an optical or, except for an electrical transmission braking system, an acoustic signal at the latest when the stored energy (or the state of an electrical storage device, as relevant) in any part of the system, falls to a level at which without re-charging of the reserve and irrespective of the load conditions of the vehicle:

(a) For braking systems other than an electrical transmission 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;

(b) For electrical transmission braking systems, the prescribed service brake performance cannot be achieved, or it is still possible to apply the service brake control a fifth time after four full ([6]) actuations and obtain at least the secondary braking performance, whichever occurs first,

Without faults in the service brake transmission and with the brakes adjusted as closely as possible.

This warning device shall be directly and permanently connected to the circuit. The red warning signal specified in paragraph 5.2.21.1.1. 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, as relevant.

5.2.14.2. However, in the case of vehicles which are only considered to comply with the requirements of paragraph 5.2.4.1. of this Regulation by virtue of meeting the requirements of paragraph 1.3. of Annex 4 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 meets the above requirements and the acoustic signal is not actuated before the optical signal. The red warning signal specified in paragraph 5.2.21.1.1. below shall be used as the optical warning signal.

5.2.14.3. In addition, for vehicles equipped with an electrical transmission braking system, there shall be an acoustic signal that is activated no later than 60 seconds after the activation of the red warning signal required by paragraph 5.2.14.1.(b) or on the first application of the service brake control after activation of that red warning signal, whichever occurs first.

Vehicles which rely for their propulsion on energy from an electrical storage device or devices, shall be deemed to comply with this requirement if the energy to the traction motor(s) is stopped before the energy in the electrical storage device(s) has fallen to a level at which the red warning signal is activated.

5.2.14.4. This acoustic device may be rendered inoperative while the parking brake is applied and/or, at the choice of the manufacturer, in the case of automatic transmission the selector is in the "Park" position.

5.2.14.5. In addition, any vehicle equipped with an electrical transmission braking system shall have an indicator reflecting the effect of ageing on each of the electrical storage devices. This requirement shall not apply to a traction battery that also has the function of an energy storage device (within the meaning of Annex 4, part B).

([6]) A full actuation means the actuation of the control in accordance with Annex 4, Part B, paragraph 1.2.3.3. for a duration of 8.0 seconds or for a time T as described in that paragraph.

The indicators for electrical storage devices may share a common space in accordance with UN Regulation No 121. They need not be permanently visible; however, they shall 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.

The indicator shall provide at least four different levels of ageing above the level at which a maintenance of the electrical storage device(s) is recommended. This fifth level shall be given before the warning signal required by 5.2.24.6. is activated. The different levels above this indication shall be evenly distributed with respect to the performance of the electrical storage devices.

5.2.15. Without prejudice to the requirements of paragraph 5.1.2.3. above, where an auxiliary source of energy is essential to the functioning of a braking system, the reserve of energy shall be such as to ensure that, if the engine stops or in the event of a failure of the means by which the energy source is driven, the braking performance remains adequate to bring the vehicle to a halt in the prescribed conditions. In addition, if the muscular effort applied by the driver to the parking braking system is reinforced by a servo device, the actuation of parking braking shall be ensured in the event of a failure of the servo device, if necessary by using a reserve of energy independent of that normally supplying the servo device. This reserve of energy may be that intended for the service braking system.

5.2.16. The pneumatic/hydraulic/electrical auxiliary equipment shall be supplied with energy in such a way that during its operation, the prescribed deceleration values can be reached and that, even in the event of damage to the source of energy, the operation of the auxiliary equipment cannot cause the reserves of energy (i.e. reserve within reservoir, accumulator, or electrical storage devices ([7])) feeding the braking systems to fall below the level indicated in paragraph 5.2.14. above.

5.2.17. In the case of a motor vehicle equipped to tow a trailer with electric service brakes, the following requirements shall be met:

5.2.17.1. The power supply (generator and battery) of the motor vehicle shall have a sufficient capacity to provide the current for an electric braking system. With the engine running at the idling speed recommended by the manufacturer and all electrical devices supplied by the manufacturer as standard equipment of the vehicle switched on, the voltage in the electrical lines shall at maximum current consumption of the electrical braking system (15 A) not fall below the value of 9.6 V measured at the connection. The electrical lines shall not be capable of short circuiting even when overloaded;

5.2.17.2. In the event of a failure in the motor vehicle's service braking system, where that system consists of at least two independent units, the unit or units not affected by the failure shall be capable of partially or fully actuating the brakes of the trailer;

5.2.17.3. The use of the stop-lamp switch and circuit for actuating the electrical braking system is permissible only if the actuating line is connected in parallel with the stop-lamp and the existing stop-lamp switch and circuit are capable of taking the extra load.

5.2.18. Additional requirements for vehicles equipped with electric regenerative braking systems.

5.2.18.1. Vehicles fitted with an electric regenerative braking system of category A.

5.2.18.1.1. The electric regenerative braking shall only be activated by reduction of the acceleration demand and/or the gear neutral position.

([7]) It is understood that an electric control transmission, according to paragraph 5.2.20., is not equipped with an electrical storage device within the meaning of this regulation.

5.2.18.2. Vehicles fitted with an electric regenerative braking system of category B.

5.2.18.2.1. It shall not be possible to disconnect, partially or totally, one part of the service braking system other than by automatic means. This should not be construed as a departure from the requirements of paragraph 5.2.10. above;

5.2.18.2.2. The service braking system shall have only one control device;

5.2.18.2.3. The service braking system shall not be adversely affected by the disengagement of the motor(s) or by the gear ratio used;

5.2.18.2.4. If the operation of the electric component of braking is ensured by a relation established between information coming from the control of the service brake and the braking force to the wheels which of it results, a failure of this relation leading to the non-respect of the prescriptions of distribution of braking among the axles (Annex 5 or 6, which is applicable) shall be warned to the driver by an optical warning signal at the latest when the control is actuated and having to remain lit as long as this defect exists and that the switch of "contact" is in the position "Go".

5.2.18.3. For vehicles fitted with an electric regenerative braking system of either category, all the relevant prescriptions shall apply except paragraph 5.2.18.1.1. above. In this case, the electric regenerative braking may be actuated by reduction of the acceleration demand and/or the gear neutral position. Additionally, the action on the service braking control shall not reduce the above braking effect generated by the reduction of the acceleration demand.

5.2.18.4. The operation of the electric braking shall not be adversely affected by magnetic or electric fields.

5.2.18.5. For vehicles equipped with an anti-lock device, the anti-lock device shall control the electric braking system.

5.2.18.6. The state of charge of the traction batteries is determined by the method set out in Appendix 1 to Annex 3 to this Regulation ([8]).

5.2.19. Special additional requirements for the electric transmission of the parking braking system:

5.2.19.1. In the case of a failure within the electric transmission, any unintended actuation of the parking braking system shall be prevented;

5.2.19.2. In the case of an electrical failure in the control or a break in the wiring within the electric control transmission between the control and the ECU directly connected with it, excluding the energy supply, it shall remain possible to apply the parking braking system from the driver's seat and thereby be capable of holding the laden vehicle stationary on an 8 per cent up or down gradient. Alternatively, in this case, an automatic actuation of the parking brake is allowed when the vehicle is stationary, provided that the above performance is achieved and, once applied, the parking brake remains engaged independently of the status of the ignition (start) switch. In this alternative, the parking brake shall be automatically released as soon as the driver or ADS starts to set the vehicle in motion again. The engine/manual transmission or the automatic transmission (park position) may be used to achieve or assist in achieving the above performance.

([8]) 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.

5.2.19.2.1. A break in the wiring within the electrical transmission, or an electrical failure in the control of the parking braking system shall be signalled to the driver by the yellow warning signal specified in paragraph 5.2.21.1.2. When caused by a break in the wiring within the electrical control transmission of the parking braking system, this yellow warning signal shall be signalled as soon as the break occurs.

In addition, such an electrical failure in the control or break in the wiring external to the electronic control unit(s) and excluding the energy supply shall be signalled to the driver by flashing the red warning signal specified in paragraph 5.2.21.1.1. as long as the ignition (start) switch is in the "On" (run) position including a period of not less than 10 seconds thereafter and the control is in the "On" (activated) position.

However, if the parking braking system detects correct clamping of the parking brake, the flashing of the red warning signal may be suppressed and the non-flashing red signal shall be used to indicate "parking brake applied".

Where actuation of the parking brake is normally indicated by a separate red warning signal, satisfying all the requirements of paragraph 5.2.21.2. below, this signal shall be used to satisfy the above requirement for a red signal.

5.2.19.3. 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 5.2.20.6. or, in the case of electrical transmission braking systems, paragraph 5.2.24.12. respectively shall apply.

5.2.19.4. After the ignition/start switch which controls the electrical energy for the braking equipment has been switched off and/or the key removed, it shall remain possible to apply the parking braking system, whereas releasing shall be prevented.

However, the parking braking system may also be released when this action is part of an operation of a remote control system fulfilling the technical requirements of an ACSF of Category A as specified in the 02 series of amendments to UN Regulation No 79 or later series of amendments.

5.2.20. Special additional requirements for service braking systems with electric control transmission except electrical transmission braking systems:

5.2.20.1. With the parking brake released, the service braking system shall be able to fulfil the following requirements:

(a) With the propulsion system on/off control in the "On" ("Run") position, generate a static total braking force at least equivalent to that required by the Type-0 test for service braking performance as prescribed in paragraph 2.1. of Annex 3 to this Regulation;

(b) During the first 60 seconds after the propulsion system on/off control has been deactivated to the "Off" or "Lock" position and/or the ignition key has been removed, three brake applications shall generate a static total braking force at least equivalent to that required by the Type-0 test for service braking performance as prescribed in paragraph 2.1. of Annex 3 to this Regulation; and

(c) After the period mentioned above, or as from the fourth brake application within the 60 second period, whichever occurs first, generate a static total braking force at least equivalent to that required by the Type-0 test for secondary braking performance as prescribed in paragraph 2.2. of Annex 3 to this Regulation.

It should be understood that sufficient energy is available in the energy transmission of the service braking system.

5.2.20.2. 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.

5.2.20.3. A failure within the electric control transmission ([9]), not including its energy reserve, 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 5.2.21.1.1. and 5.2.21.1.2. below, 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 secondary braking performance shall be fulfilled by operating the service braking control in accordance with paragraph 2.2. of Annex 3 to this Regulation.

5.2.20.4. In the event of a failure of the energy source of the electric control transmission, starting from the nominal value of the energy level, the full control range of the service braking system shall be guaranteed after twenty consecutive full stroke actuations of the service braking control. During the test, the braking control shall be fully applied for 20 seconds and released for 5 seconds on each actuation. It should be understood that during the above test sufficient energy is available in the energy transmission to ensure full actuation of the service braking system. This requirement shall not be construed as a departure from the requirements of Annex 4.

5.2.20.5. When the battery voltage falls below a value nominated by the manufacturer at which the prescribed service braking performance can no longer be guaranteed and/or which precludes at least two independent service braking circuits from each achieving the prescribed secondary braking performance, the red warning signal specified in paragraph 5.2.21.1.1. below shall be activated. After the warning signal has been activated, it shall be possible to apply the service braking control and obtain at least the secondary performance prescribed in paragraph 2.2. of Annex 3 to this Regulation. It should be understood that sufficient energy is available in the energy transmission of the service braking system.

5.2.20.6. If auxiliary equipment is supplied with energy from the same reserve as the electric control transmission, it shall be ensured that, with the engine running at a speed not greater than 80 per cent of the maximum power speed, the supply of energy is sufficient to fulfil the prescribed deceleration values by either provision of an energy supply which is able to prevent discharge of this reserve when all auxiliary equipment is functioning or by automatically switching off pre-selected parts of the auxiliary equipment at a voltage above the critical level referred to in paragraph 5.2.20.5. above of this Regulation such that further discharge of this reserve is prevented. Compliance may be demonstrated by calculation or by a practical test. This paragraph does not apply to vehicles where the prescribed deceleration values can be reached without the use of electrical energy.

5.2.20.7. If the auxiliary equipment is supplied with energy from the electric control transmission, the following requirements shall be fulfilled:

5.2.20.7.1. In the event of a failure in the energy source, whilst the vehicle is in motion, the energy in the reservoir shall be sufficient to actuate the brakes when the control is applied;

5.2.20.7.2. In the event of a failure in the energy source, whilst the vehicle is stationary and the parking braking system applied, the energy in the reservoir shall be sufficient to actuate the lights even when the brakes are applied.

([9]) Until uniform test procedures have been agreed, the manufacturer shall provide the Technical Service with an analysis of potential failures within the control transmission and their effects. This information shall be subject to discussion and agreement between the Technical Service and the vehicle manufacturer.

5.2.21. The general requirements for optical warning signals whose function is to indicate to the driver certain specified failures (or defects) within the braking equipment of the motor vehicle, are set out in the following sub-paragraphs. Other than as described in paragraph 5.2.21.5. below, these signals shall be used exclusively for the purposes prescribed by this Regulation.

5.2.21.1. Motor vehicles shall be capable of providing optical brake failure and defect warning signals, as follows:

5.2.21.1.1. A red warning signal, indicating failures defined elsewhere in this Regulation within the vehicle braking equipment which preclude achievement of the prescribed service braking performance and/or which preclude the functioning of at least one of two independent service braking circuits;

5.2.21.1.2. Where applicable, a yellow warning signal indicating an electrically detected defect within the vehicle braking equipment, which is not indicated by the red warning signal described in paragraph 5.2.21.1.1. above.

5.2.21.1.3. The warning signals required by this paragraph shall employ the brake system malfunction symbol listed in UN Regulation No 121.

5.2.21.2. The warning signals shall be visible, even by daylight; the satisfactory condition of the signals shall be easily verifiable by the driver from the driver's seat; the failure of a component of the warning devices shall not entail any loss of the braking system's performance.

5.2.21.3. Except where stated otherwise:

5.2.21.3.1. 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;

5.2.21.3.2. 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

5.2.21.3.3. The warning signal shall be constant (not flashing).

5.2.21.3.4. In the case of an electrical transmission braking system employing an electrical storage device (or devices) it shall be ensured that the value of electrical performance at which the warning signal required by paragraph 5.2.24.6. and 5.2.24.7. is activated, is respected despite the effect of environmental conditions (e.g., temperature) and ageing. The manufacture shall show to the satisfaction of the Technical Service, how this is achieved.

5.2.21.4. The warning signal(s) mentioned above shall light up when the electrical equipment of the vehicle (and the braking system) is energised. With the vehicle stationary, the braking system shall verify that none of the specified failures or defects are present before extinguishing the signals. Specified failures or defects which should activate the warning signals mentioned above, but which are not detected under static conditions, shall be stored upon detection and be displayed at start-up and at all times when the ignition (start) switch is in the "On" (run) position, as long as the failure or defect persists.

5.2.21.5. Non specified failures (or defects), or other information concerning the brakes and/or running gear of the power-driven vehicle, may be indicated by the yellow signal specified in paragraph 5.2.21.1.2. above, provided that all the following conditions are fulfilled:

5.2.21.5.1. The vehicle is stationary;

5.2.21.5.2. After the braking equipment is first energised and the signal has indicated that, following the procedures detailed in paragraph 5.2.21.4. above, no specified failures (or defects) have been identified; and

5.2.21.5.3. Non-specified faults or other information shall be indicated only by the flashing of the warning signal. However, the warning signal shall be extinguished by the time when the vehicle first exceeds 10 km/h.

5.2.22. Generation of a braking signal to illuminate the stop lamps.

5.2.22.1. Activation of the service braking system by the driver shall generate a signal that will be used to illuminate the stop lamps.

5.2.22.2. Requirements for vehicles equipped with an Automated Driving System, automatically commanded braking and/or regenerative braking which produce a retarding force (e.g. upon release of the accelerator control) ([10]).

Deceleration demanded by an Automated Driving System, automatically commanded braking and/or regenerative braking	
≤ 1.3 m/s²	> 1.3 m/s²
May generate the signal	Shall generate the signal

Once generated, the signal shall be kept as long as a deceleration demand persists. However, the signal may be suppressed at standstill or when the deceleration demand falls below 1.3 m/s² or that value which generated the signal, whichever is lower.

An appropriate measure (e.g. switch-off-hysteresis, averaging, time delay) shall be implemented in order to avoid fast changes of the signal resulting in flickering of the stop lamps.

5.2.22.3. Activation of part of the service braking system by "selective braking" or by functions whose primary intention is not to decelerate the vehicle (e.g. slight actuation of the friction brakes to clean the discs) shall not generate the signal mentioned above ([11]).

5.2.22.4. The signal shall not be generated when retardation is solely produced by the natural braking effect of the engine, air-/rolling resistance and/or road slope.

5.2.23. When a vehicle is equipped with the means to indicate emergency braking, activation and de-activation of the emergency braking signal shall only be generated by the application of the service braking system when the following conditions are fulfilled ([8]):

5.2.23.1. The signal shall not be activated when the vehicle deceleration is below 6 m/s² but it may be generated at any deceleration at or above this value, the actual value being defined by the vehicle manufacturer.

The signal shall be de-activated at the latest when the deceleration has fallen below 2.5 m/s².

5.2.23.2. The following conditions may also be used:

(a) The signal may be generated from a prediction of the vehicle deceleration resulting from the braking demand respecting the activation and de-activation thresholds defined in paragraph 5.2.23.1. above;

or

(b) The signal may be activated at a speed above 50 km/h when the antilock system is fully cycling (as defined in paragraph 2. of Annex 6).

The signal shall be deactivated when the antilock system is no longer fully cycling.

([10]) At the time of type approval, compliance with this requirement shall be confirmed by the vehicle manufacturer.
([11]) During a "selective braking" event, the function may change to "automatically commanded braking".

5.2.24. Special additional requirements for electrical transmission braking systems.

5.2.24.1. When the state of the electrical storage device(s) is insufficient to ensure the secondary performance as laid down in paragraph 2.2. of Annex 3 to this Regulation by the actuation of the service brake control the release of the parking braking system shall be prevented.

5.2.24.2. With the parking brake released, the service braking system shall:

(a) With the propulsion system on/off control in the "On" ("Run") position, generate a static total braking force at least equivalent to that required by the Type 0 test for service braking performance as prescribed in paragraph 2.1. of Annex 3 to this Regulation,

(b) During the first 60 seconds after the propulsion system on/off control has been deactivated to the "Off" or "Lock" position and/or the ignition key has been removed, three brake applications shall generate a static total braking force at least equivalent to that required by the Type 0 test for service braking performance as prescribed in paragraph 2.1. of Annex 3 to this Regulation, and

(c) After the period mentioned above, or as from the fourth brake application within the 60 second period, whichever occurs first, generate a static total braking force at least equivalent to that required by the Type 0 test for secondary braking performance as prescribed in paragraph 2.2. of Annex 3 to this Regulation.

It should be understood that sufficient energy is available in the energy transmission of the service braking system.

5.2.24.3. For an electrical 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 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 actuations of the service brakes control, with a released time of 5.0 seconds between each actuation.

This requirement shall not be construed as a departure from the requirements of Annex 4, Part B, 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.

5.2.24.4. In the case that the electrical storage devices are providing electrical energy for the electrical control and electrical energy transmission, the requirements of paragraph 1.2.1. of Part B of Annex 4 shall apply.

5.2.24.5. As an alternative to the requirements of Annex 4, Part B, paragraph 1.2., electrical 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 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 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 5.2.21.1.1.

5.2.24.6. A warning signal shall be displayed no later than when the effect of ageing on the electrical storage device(s) is such that its performance is not sufficient to fulfil the requirements of Annex 4, Part B, paragraph 1.2.1. The yellow warning signal described in paragraph 5.2.21.1.2. shall be used.

5.2.24.7. A warning signal shall be displayed no later than when the state of the electrical storage device(s) is insufficient for more than 60 seconds to fulfil the prescribed braking performance in Annex 4, Part B, paragraph 1.2.1. The yellow warning signal described in paragraph 5.2.21.1.2. shall be used.

5.2.24.8. There shall be an energy management system for the electrical storage devices of the transmission.

5.2.24.8.1. The energy management system shall be capable of continuously assessing the electrical storage devices, to determine their ability to deliver to the brake transmission the needed power, over time, to fulfil the performance requirements of this Regulation and, where appropriate, of activating the warning signals required by this Regulation.

If the assessment is not complete at the time that the start/run switch is moved to the on (run) position, a red warning signal shall be activated and shall remain active until the safe status of the electrical transmission braking system has been confirmed. The red warning signal prescribed in paragraph 5.2.21.1.1. may be used. This requirement shall apply even after a maintenance operation on the electrical storage device and/or the energy management system (e.g. the replacement/temporary disconnection of an electrical storage device, or the replacement of the energy management system itself).

The method by which the energy management system determines the safe status, including after maintenance, shall be described by the manufacturer at the time of type approval. Compliance with these requirements shall be demonstrated to the satisfaction of the Technical Service, including an assessment according to Annex 8.

5.2.24.8.2. It shall be demonstrated that the energy management system accurately identifies the condition at which the warning signals required by this Regulation are activated.

The Technical Service shall take account of the influence of the individual variables used by the energy management system, on both the performance and the state of the electrical storage device(s).

The Technical Service shall verify that the accuracy of the energy management system is ensured under all operating conditions (for example different environmental conditions) that can reasonably be foreseen by reviewing the documentation provided by the manufacturer and performing tests of the energy management system in different conditions (e.g., changes in temperature).

5.2.24.8.3. In the context of the assessment described in paragraph 5.2.24.8.2., the manufacturer shall provide the following information as part of the documentation required by Annex 8, paragraph 3:

(a) Regarding the Energy Management System:

(i) A detailed overview of the energy management system, explaining its architecture, components, and functionality.

(ii) A description of how the system monitors electrical storage devices.

(iii) Sufficient information about the energy management system strategy to illustrate the algorithms and logic used to assess the state and the performance of electrical storage devices.

(iv) A list of all the input variables considered by the energy management system in assessing the state and the performance of the electrical storage devices.

(v) A sensitivity analysis showing how each of the listed variables affects the ability of the energy management system to accurately identify when a warning signal shall be activated.

(b) Regarding the relevant verification testing the documentation shall include:

(i) The thresholds, or criteria, that trigger the warning signals described in paragraph 5.2.21.1.1. and paragraph 5.2.21.1.2.

(ii) Results of verification testing to assess the accuracy of the energy management system.

(iii) Data on different operating conditions, such as temperature or battery ageing.

(iv) An outline of the boundary conditions that could impact the accuracy of the energy management system (e.g., temperature, aging characteristics).

(v) In response to paragraph 3.4.4. of Annex 8, a description of the strategy in the event of a failure of the energy management system, or of an input channel to the energy management system, when relevant to the braking functionality.

(vi) When applicable, the procedures for updating the energy management system and ensuring its ongoing maintenance.

(vii) The appropriate testing procedures to be taken into account when performing the relevant verification testing to assess compliance with paragraph 5.2.24.6. and paragraph 5.2.24.7.

5.2.24.8.4. In the event of a failure of the energy management system or an input channel of the energy management system that prevents the assessment of the state of the energy storage device(s), a red visual warning signal, accompanied by an audible signal, shall be activated at the moment of the detection of the failure (i.e. a first time in operation then at each start-up thereafter). The operation of the acoustic signal may be temporary, but the visual warning must remain active as long as the failure persists. The red warning signal prescribed in paragraph 5.2.21.1.1. may be used for visual alert. If the manufacturer's failure strategy affects braking functionality, details shall be given in the documentation required in paragraph 5.2.24.8.3.

Even in the event of the failure described above, if the energy management system is still able to assess the status of the electrical storage device(s), it is sufficient to use only the yellow warning signal specified in paragraph 5.2.21.1.2.

5.2.24.9. In the case that the supply of power requested by the electrical transmission cannot be met by the electrical supply, a power warning (P_w) to the driver shall be activated no later than 5.0 s after the appearance/detection. The yellow warning signal specified in paragraph 5.2.21.1.2. may be used.

The functionality of the system triggering the warning level P_w shall be described by the vehicle manufacturer as part of the documentation package required in Annex 8 of this Regulation to the Technical Service.

5.2.24.10. In case auxiliary equipment is supplied from the same electrical storage device(s) as the braking system, and in the event of a failure of the electrical supply (including the energy source, if fitted) that is providing energy to this electrical storage device(s) the:

— Auxiliary equipment shall be switched off, and/or

— The vehicle shall be automatically brought to standstill,

Before the critical level referred to in paragraph 5.2.14.1.(b) of this Regulation is reached.

In either case, the operation of auxiliary equipment required to satisfy subject to the performance requirements of another safety-related UN regulation shall not be affected.

In the case of a vehicle that is not equipped with an onboard electrical supply (e.g. an electric vehicle with a traction battery having the function of an energy storage device) the mitigation required by this paragraph shall also be applied before the critical level referred to in paragraph 5.2.14.1.(b) of this Regulation is reached, or following a failure that would prevent the traction battery from providing power to the braking system.

5.2.24.11. The red warning signal specified in paragraph 5.2.21.1.1. 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 braking performance.

5.2.24.12. The electrical supply shall be able to ensure that the state of the electrical storage device(s) remains sufficient to fulfil the prescribed service braking performance.

Additionally, in case the auxiliary equipment is supplied from the same electrical supply (including the energy source, if fitted) as the braking system, the requirement above shall be fulfilled even when all the auxiliary equipment is functioning. Where two or more auxiliary equipment cannot operate simultaneously (e.g. the climate control system cannot provide both heating and cooling at the same time), only the highest power consuming system, function, or component, shall be considered during the assessment. The manufacturer shall declare the total power demand of the auxiliary equipment and provide evidence to justify the exclusion of any auxiliary equipment.

This shall be assessed in accordance with the requirements set out in Annex 4, part B, Section 2 of this regulation.

In the case of a vehicle that is powered by an internal combustion engine, and which has a driven electrical energy source (e.g. an alternator), to maintain the electrical supply, compliance with this paragraph may be assessed with the engine running at a speed not greater than 80 per cent of the maximum power speed.

5.2.24.13. A failure within the electric transmission ([12]), 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 5.2.21.1.1. and 5.2.21.1.2., 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 secondary braking performance shall be fulfilled by operating the service braking control in accordance with paragraph 2.2. of Annex 3 to this Regulation.

5.2.24.14. 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.

5.2.24.15. If the auxiliary equipment is supplied with energy from the electric transmission, the following requirements shall be fulfilled.

5.2.24.15.1. In the event of a failure in the energy source or electrical supply, whilst the vehicle is in motion, the energy in the electrical storage device(s) shall be sufficient to satisfy the brake performance requirements defined in paragraph 5.2.14.1.(b).

([12]) 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.

Where that electrical supply also has a role as an electrical storage device for one circuit of the transmission, a failure of that supply shall not affect ability of the electrical storage device of another circuit to provide the power necessary to achieve the prescribed secondary brake performance.

5.2.24.15.2. In the event of a failure in the energy source or electrical supply, whilst the vehicle is stationary and the parking braking system applied, the energy in the electrical storage device(s) shall be sufficient to actuate the lights even when the brakes are applied.

5.2.24.16. Low Energy Emergency Function

5.2.24.16.1. Within 60 seconds of the activation of the acoustic warning signal required by paragraph 5.2.1.14.1.2., there shall be an automatic function to progressively reduce the vehicle's speed such that it cannot exceed 20 km/h. Once the vehicle has come to a standstill, it shall be prevented from rolling away and there shall be sufficient electrical power available for it to be possible to apply the parking brake.

5.2.25. Power-driven vehicles of category M_1 and N_1 equipped with temporary-use spare wheels/tyres shall satisfy the relevant technical requirements of Annex 3 to UN Regulation No 64.

5.3. Special Provisions for vehicles equipped with an Automated Driving System

The braking equipment of any vehicle equipped with an Automated Driving System, other than Automated Lane Keeping Systems as defined in UN Regulation No 157, shall fulfil the following requirements.

5.3.1. An ADS may control the vehicle's braking equipment providing that the ADS is designed to comply with relevant national and/or international technical regulations and relevant national legislation governing operation, and providing that its activation is restricted by technical means to the jurisdiction(s) where these apply. Compliance with this requirement shall be declared by the manufacturer at the time of the application for approval.

5.3.2. Compliance with the applicable performance requirements of this UN Regulation whilst the ADS is active shall be demonstrated in accordance with Annex 8.

5.3.2.1. The transmission links between the ADS and the braking equipment (excluding the ADS itself), are subject to the requirements of Annex 8.

5.3.3. Whilst the ADS is active, detected faults as specified in this UN Regulation shall be transmitted to the ADS.

6. Tests

Braking tests which the vehicles submitted for approval are required to undergo, and the braking performance required, are described in Annex 3 to this Regulation.

7. Modification of vehicle type or braking system and extension of approval

7.1. Every modification of the vehicle type or of its braking system shall be notified to the Type Approval Authority which approved the vehicle type. That Authority may then either:

7.1.1. Consider that the modifications made are unlikely to have an appreciable adverse effect and that in any case the vehicle still meets the requirements; or

7.1.2. Require a further report from the Technical Service responsible for carrying out the tests.

7.2. Notice of confirmation, extension, or refusal of approval shall be communicated by the procedure specified in paragraph 4.3. above, to the Parties to the Agreement which apply this Regulation.

7.3. The Type Approval Authority issuing the extension of approval shall assign a series of numbers to each communication form drawn up for such an extension.

8. Conformity of production

The conformity of production procedures shall comply with those set out in the Agreement, Schedule 1 (E/ECE/TRANS/505/Rev.3) with the following requirements:

8.1. A vehicle approved to this Regulation shall be so manufactured as to conform to the type approved by meeting the requirements set forth in paragraph 5. above;

8.2. The Type Approval Authority which has granted type approval may at any time verify the conformity control methods applied in each production facility. The normal frequency of these verifications shall be once every two years.

9. Penalties for non-conformity of production

9.1. The approval granted in respect of a vehicle type pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 8.1. above are not complied with.

9.2. If a Contracting Party to the Agreement which applies this Regulation withdraws an approval it has previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation by means of a copy of the communication form conforming to the model in Annex 1 to this Regulation.

10. Production definitively discontinued

If the holder of the approval completely ceases to manufacture a type of vehicle approved in accordance with this Regulation, he shall so inform the Type Approval Authority which granted the approval. Upon receiving the relevant communication, that Authority shall inform thereof the other Parties to the Agreement applying this Regulation by means of copies of a communication form conforming to the model in Annex 1 to this Regulation.

11. Names and addresses of the Technical Services conducting approval tests, and of Type Approval Authorities

The Contracting Parties to the Agreement applying this Regulation shall communicate to the United Nations secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Type Approval Authorities which grant approval and to which forms, certifying approval or extension or refusal or withdrawal of approval, issued in other countries, are to be sent.

12. Transitional provisions

12.1. General

12.1.1. Contracting Parties applying this Regulation may grant type approvals according to any preceding series of amendments to this Regulation.

12.1.2. Contracting Parties applying this Regulation shall continue to grant extensions of existing approvals to any preceding series of amendments to this Regulation.

12.2. Transitional provisions for the 01 series of amendments

12.2.1. As from 1 September 2018, no Contracting Party applying this Regulation shall refuse to grant or refuse to accept type approvals to this Regulation as amended by the 01 series of amendments.

12.2.2. Even after 1 September 2018, Contracting Parties applying this Regulation shall continue to accept type approvals granted to the 00 series of amendments to this Regulation.

However, Contracting Parties applying this Regulation shall not be obliged to accept, for the purpose of national or regional type approval, type approvals to the 00 series of amendments to this Regulation for vehicle types not fitted with a Vehicle Stability Function (as defined in UN Regulation No 13) or ESC and BAS.

12.2.3. As from 1 September 2018, Contracting Parties applying this Regulation shall grant type approvals only if the vehicle type to be approved meets the requirements of this Regulation as amended by the 01 series of amendments.

12.2.4. Contracting Parties applying this Regulation shall not refuse to grant extensions of type approvals for existing types, regardless of whether they are fitted with a Vehicle Stability Function (as defined in UN Regulation No 13) or ESC and BAS or not, on the basis of the provisions valid at the time of the original approval.

12.3. Transitional provisions for the 02 series of amendments

12.3.1. As from the official date of entry into force of the 02 series of amendments, no Contracting Party applying this Regulation shall refuse to grant or refuse to accept type approvals under this Regulation as amended by the 02 series of amendments.

12.3.2. As from the official date of entry into force of the 02 series of amendments, Contracting Parties applying this Regulation shall grant type approvals for a vehicle equipped with an electrical transmission braking system only if the vehicle type to be approved meets the requirements of this Regulation as amended by the 02 series of amendments.

12.3.3. As from 1 September 2028, Contracting Parties applying this Regulation shall not be obliged to accept type approvals to the preceding series of amendments, for a vehicle type having a braking system equipped with an electronic control system, first issued after 1 September 2028.

12.3.4. As from 1 September 2030, Contracting Parties applying this Regulation shall not be obliged to accept type approvals issued to the preceding series of amendments to this Regulation.

12.3.5. Notwithstanding paragraph 12.3.4., Contracting Parties applying this Regulation shall continue to accept type approvals issued according to the preceding series of amendments to this Regulation, for the vehicles which are not affected by the changes introduced by the 02 series of amendments.

12.3.6. Notwithstanding the transitional provisions above, Contracting Parties whose application of this Regulation comes into force after the date of entry into force of the most recent series of amendments are not obliged to accept type approvals which were granted in accordance with any of the preceding series of amendments to this Regulation/ are only obliged to accept type approval granted in accordance with the 02 series of amendments.

ANNEX 1

Communication (*)

(Maximum format: A4 (210 × 297 mm))



Issued by: Name of administration:
.....
.....
.....

Concerning (2): Approval granted
Approval extended
Approval refused
Approval withdrawn
Production definitively discontinued

of a vehicle type with regard to braking, pursuant to UN Regulation No 13-H

Approval No. ..... Extension No. .....

1. Trade name or mark of the vehicle .....

2. Vehicle type .....

3. Manufacturer's name and address .....

4. If applicable, name and address of manufacturer's representative .....

.....

5. Mass of vehicle .....

5.1. Maximum mass of vehicle .....

5.2. Minimum mass of vehicle .....

6. Distribution of mass of each axle (maximum value) .....

7. Make and type of brake linings, discs and drums:

7.1. Brake linings

7.1.1. Brake linings tested to all relevant prescriptions of Annex 3 .....

7.1.2. Alternative brake linings tested in Annex 7 .....

(*) At the request of (an) applicant(s) for UN Regulation No 90 approval, the information shall be provided by the Type Approval Authority as contained in Appendix 1 to this annex. However, this information shall not be provided for purposes other than UN Regulation No 90 approvals.
(1) Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see provisions in the Regulation).
(2) Strike out what does not apply.

7.2. Brake disc and drums

7.2.1. Identification code of brake discs covered by the braking system approval

.....

7.2.2. Identification code of brake drums covered by the braking system approval .....

.....

8. Engine type .....

9. Number and ratios of gears .....

10. Final drive ratio(s) .....

11. If applicable, maximum mass of trailer which may be coupled .....

11.1. Unbraked trailer .....

12. Tyre dimension .....

12.1. Temporary-use spare wheel / tyre dimensions .....

12.2. Vehicle meets the technical requirements of Annex 3 to UN Regulation No 64:

..... Yes/No ([2])

13. Maximum design speed .....

14. Brief description of braking equipment .....

14.1. Vehicle is equipped with an ADS: .....yes/no

15. Mass of vehicle when tested:

	Laden (kg)	Unladen (kg)
Axle No 1		
Axle No 2		
Total		

16. Result of the tests:

Test Speed (km/h)	Measured performance	Measured force applied to control (daN)

16.1. Type-0 tests: .....

Engine disconnected .....

Service braking (laden) .....

Service braking (unladen) .....

Secondary braking (laden) .....

Secondary braking (unladen) .....

16.2. Type-0 tests: .....

Engine connected .....

Service braking (laden) .....

Service braking (unladen) .....

(In accordance with paragraph 2.1.1.(B) of Annex 3) .....

16.3. Type-I tests: .....

Preliminary snubs (to determine pedal force) .....

Hot performance (1st stop) .....

Hot performance (2nd stop) .....

Recovery performance .....

16.4. Dynamic parking brake performance .....

17. Result of the Annex 5 performance tests .....

18. Vehicle is / is not (2) equipped to tow a trailer with electrical braking systems

19. Vehicle is / is not (2) equipped with an anti-lock system

19.1. The vehicle fulfils the requirements of Annex 6: Yes / No (2)

19.2. Category of anti-lock system: category 1 / 2 / 3 (2)

20. Additional information in the case of power-driven vehicle equipped with an electrical transmission braking system.

20.1. Vehicle is/is not (2) equipped with an electrical transmission braking system.

21. Adequate documentation according to Annex 8 was supplied in respect of the following system(s): Yes / No / Not applicable (2)

22. Vehicle submitted for approval on .....

23. Technical Service responsible for conducting approval .....

24. Date of report issued by that Service .....

25. Number of report issued by that Service .....

26. Approval granted / refused / extended / withdrawn ([2])

27. Position of approval mark on the vehicle .....

28. Place .....

29. Date .....

30. Signature .....

31. The summary referred to in paragraph 4.3. of this Regulation is annexed to this communication

ANNEX 1 – Appendix

List of vehicle data for the purpose of UN Regulation No 90 approvals

1. Description of the vehicle type .....

1.1. Trade name or mark of the vehicle, if available .....

1.2. Vehicle category .....

1.3. Vehicle type according to UN Regulation No 13-H approval .....

1.4. Models or trade names of vehicles constituting the vehicle type, if available .....

.....

1.5. Manufacturer's name and address

2. Make and type of brake linings, discs and drums:

2.1. Brake linings

2.1.1. Brake linings tested to all relevant prescriptions of Annex 3 .....

2.1.2. Alternative brake linings tested in Annex 7 .....

2.2. Brake disc and drums

2.2.1. Identification code of brake discs covered by the braking system approval .....

.....

2.2.2. Identification code of brake drums covered by the braking system approval .....

.....

3. Minimum mass of vehicle .....

3.1. Distribution of mass of each axle (maximum value) .....

4. Maximum mass of vehicle .....

4.1. Distribution of mass of each axle (maximum value) .....

5. Maximum vehicle speed .....

6. Tyre and wheel dimensions .....

7. Brake circuit configuration (e.g. front/rear or diagonal split) .....

8. Declaration of which is the secondary braking system .....

9. Specifications of brake valves (if applicable) .....

9.1. Adjustment specifications of the load sensing valve .....

9.2. Setting of pressure valve .....

10. Designed brake force distribution .....

11. Specification of brake .....

11.1. Disc brake type (e.g. number of pistons with diameter(s), ventilated or solid disc) .....

11.2. Drum brake type (e.g. duo servo, with piston size and drum dimensions) .....

.....

11.3. In case of compressed air brake systems, e.g. type and size of chambers, levers, etc. .....

12. Master cylinder type and size .....

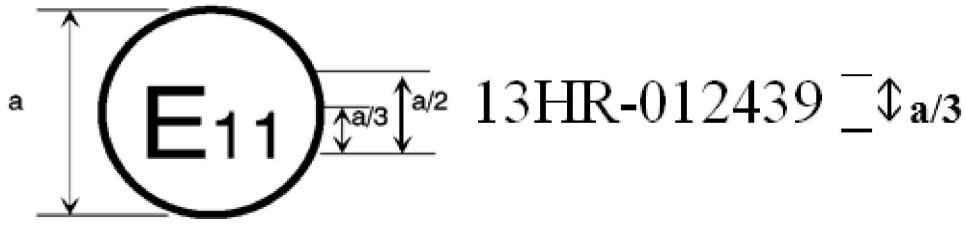
13. Booster type and size .....

ANNEX 2

Arrangements of approval marks

Model A

(See paragraph 4.4. of this Regulation)

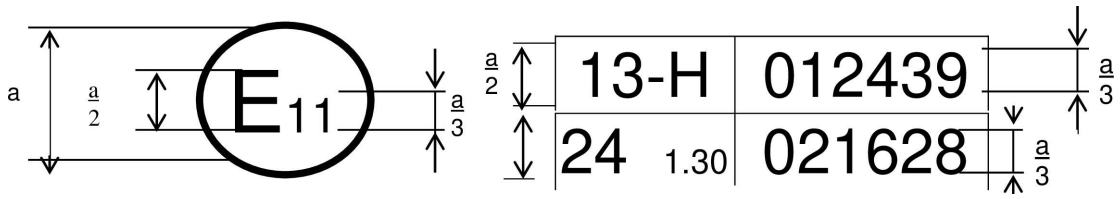


a = 8 mm min.

The above approval mark affixed to a vehicle shows that the vehicle type concerned has, with regard to braking, been approved in the United Kingdom (E 11) pursuant to UN Regulation No 13-H under approval number 012439. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of the 01 series of amendments to UN Regulation No 13-H.

Model B

(See paragraph 4.5. of this Regulation)



a = 8 mm min.

The above approval mark affixed to a vehicle shows that the vehicle type concerned has been approved in the United Kingdom (E 11) pursuant to Regulations Nos 13-H and 24 ([1]). (In the case of the latter Regulation the corrected absorption coefficient is 1.30 m^{-1}). The approval numbers indicate that, at the dates when the respective approvals were given, UN Regulation No 13-H included the 01 series of amendments and UN Regulation No 24 included the 02 series of amendments.

([1]) This number is given merely as an example.

ANNEX 3

Braking tests and performance of braking systems

1. Braking tests

1.1. General

1.1.1. The performance prescribed for braking systems is based on the stopping distance and the mean fully developed deceleration. The performance of a braking system shall be determined by measuring the stopping distance in relation to the initial speed of the vehicle and/or by measuring the mean fully developed deceleration during the test.

1.1.2. The stopping distance shall be the distance covered by the vehicle from the moment when the driver begins to actuate the control of the braking system until the moment when the vehicle stops; the initial speed shall be the speed at the moment when the driver begins to actuate the control of the braking system; the initial speed shall not be less than 98 per cent of the prescribed speed for the test in question.

The mean fully developed deceleration (d_m) shall be calculated as the deceleration averaged with respect to distance over the interval v_b to v_e, according to the following formula:

$$d_m = \frac{v_b^2 - v_e^2}{25.92\ (s_e - s_b)}$$

Where:

v_o = initial vehicle speed in km/h,

v_b = vehicle speed at 0.8 v_o in km/h,

v_e = vehicle speed at 0.1 v_o in km/h,

s_b = distance travelled between v_o and v_b in metres,

s_e = distance travelled between v_o and v_e in metres.

The speed and distance shall be determined using instrumentation having an accuracy of ±1 per cent at the prescribed speed for the test. The d_m may be determined by other methods than the measurement of speed and distance; in this case, the accuracy of the d_m shall be within ±3 per cent.

1.2. For the approval of any vehicle, the braking performance shall be measured during road tests conducted in the following conditions:

1.2.1. The vehicle's condition as regards mass shall be as prescribed for each type of test and be specified in the test report;

1.2.2. The test shall be carried out at the speeds prescribed for each type of test; if the maximum design speed of a vehicle is lower than the speed prescribed for a test, the test shall be performed at the vehicle's maximum speed;

1.2.3. During the tests, the force applied to the brake control in order to obtain the prescribed performance shall not exceed the maximum force laid down;

1.2.4. The road shall have a surface affording good adhesion, unless specified otherwise in the relevant annexes;

1.2.5. The tests shall be performed when there is no wind liable to affect the results;

1.2.6. At the start of the tests, the tyres shall be cold and at the pressure prescribed for the load actually borne by the wheels when the vehicle is stationary;

1.2.7. The prescribed performance shall be obtained without locking of the wheels at speeds exceeding 15 km/h, without deviation of the vehicle from a 3.5 m wide lane, without exceeding a yaw angle of 15° and without abnormal vibrations;

1.2.8. For vehicles powered completely or partially by an electric motor (or motors), permanently connected to the wheels, all tests shall be carried out with these motor(s) connected;

1.2.9. For vehicles as described in paragraph 1.2.8. above, fitted with an electric regenerative braking system of category A, behaviour tests shall be carried out on a track with a low adhesion coefficient (as defined in paragraph 5.2.2. of Annex 6) at a speed equal to 80 per cent of the maximum speed but not exceeding 120 km/h, to check that stability is retained.

1.2.9.1. Moreover, for vehicles fitted with an electric regenerative braking system of category A, transient conditions as gear changes or accelerator control release shall not affect the behaviour of the vehicle in condition described in paragraph 1.2.9. above;

1.2.10. In the tests provided in paragraphs 1.2.9. and 1.2.9.1. above wheel locking is not allowed. However, steering correction is permitted if the angular rotation of the steering control is within 120° during the initial 2 seconds and not more than 240° in all;

1.2.11. Status of the energy reserve during the Annex 3 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 5.2.20.5. 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 electrical transmission braking system, and without a simulated failure, the state of the electrical storage devices shall be kept above the level specified in paragraph 5.2.14.1.(b).

1.3. Behaviour of the vehicle during braking

1.3.1. In braking tests, and in particular in those at high speed, the general behaviour of the vehicle during braking shall be checked.

1.3.2. Behaviour of the vehicle during braking on a road on which adhesion is reduced shall meet the relevant requirements of Annex 5 and/or Annex 6 to this Regulation.

1.3.2.1. In the case of a braking system according to paragraph 5.2.7. of this Regulation where the braking for a particular axle (or axles) is comprised of more than one source of braking torque, and any individual source can be varied with respect to the other(s), the vehicle shall satisfy the requirements of Annex 5, or alternatively, Annex 6 under all relationships permitted by its control strategy ([1]).

1.4. Type-0 test (ordinary performance test with cold brakes)

1.4.1. General

1.4.1.1. The average temperature of the service brakes on the hottest axle of the vehicle, measured inside the brake linings or on the braking path of the disc or drum, is between 65 and 100 °C prior to any brake application.

([1]) The manufacturer shall provide the Technical Service with the family of braking curves permitted by the automatic control strategy. These curves may be verified by the Technical Service.

1.4.1.2. The test shall be conducted in the following conditions:

1.4.1.2.1. The vehicle shall be laden, the distribution of its mass among the axles being that stated by the manufacturer; where provision is made for several arrangements of the load on the axles the distribution of the maximum mass among the axles shall be such that the mass on each axle is proportional to the maximum permissible mass for each axle;

1.4.1.2.2. Every test shall be repeated on the unladen vehicle; there may be, in addition to the driver, a second person on the front seat who is responsible for noting the results of the test;

1.4.1.2.3. 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 condition is deemed to be satisfied if the state of charge of the batteries is in one of the following conditions:

(a) At the maximum charge level recommended by the manufacturer, as listed in the vehicle specification;

(b) At a level not less than 95 per cent of the full charge level, where the manufacturer has made no specific recommendation;

(c) At a maximum level resulting 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.

1.4.1.2.4. The limits prescribed for minimum performance, both for tests with the vehicle unladen and for tests with the vehicle laden, shall be those laid down hereunder; the vehicle shall satisfy both the prescribed stopping distance and the prescribed mean fully developed deceleration, but it may not be necessary to actually measure both parameters;

1.4.1.2.5. The road shall be level; unless otherwise specified each test may comprise up to six stops including any needed for familiarization.

1.4.2. Type-0 test with engine disconnected, service braking in accordance with paragraph 2.1.1.(A) of this annex.

The test shall be carried out at the speed prescribed, the figures prescribed in this connection being subject to a certain margin of tolerance. The minimum performance prescribed shall be attained.

1.4.3. Type-0 test with engine connected, service braking in accordance with paragraph 2.1.1.(B) of this annex.

1.4.3.1. The test shall be carried out with the engine connected, from the speed prescribed in paragraph 2.1.1.(B) of this annex. The minimum performance prescribed shall be attained. This test is not run if the maximum speed of the vehicle is ≤ 125 km/h.

1.4.3.2. The maximum practical performance figures shall be measured, and the behaviour of the vehicle shall be in accordance with paragraph 1.3.2. of this annex. However, if the maximum speed of the vehicle is greater than 200 km/h, the test speed shall be 160 km/h.

1.5. Type-I test (fade and recovery test)

1.5.1. Heating procedure

1.5.1.1. The service brakes of all vehicles shall be tested by successively applying and releasing the brakes a number of times, the vehicle being laden, in the conditions shown in the table below:

Conditions

v_1 (km/h)	v_2 (km/h)	Δt (sec)	n
80 % $v_{max} \leq 120$	0.5 v_1	45	15

Where:

v_1 = initial speed, at beginning of braking

v_2 = speed at end of braking

v_{max} = maximum speed of the vehicle

n = number of brake applications

Δt = duration of a braking cycle: time elapsing between the initiation of one brake application and the initiation of the next

1.5.1.2. If the characteristics of the vehicle make it impossible to abide by the duration prescribed for Δt, the duration may be increased; in any event, in addition to the time necessary for braking and accelerating the vehicle, a period of 10 seconds shall be allowed in each cycle for stabilizing the speed v_1.

1.5.1.3. In these tests, the force applied to the control shall be so adjusted as to attain a mean deceleration of 3 m/s^2 during every brake application; two preliminary tests may be carried out to determine the appropriate control force.

1.5.1.4. During brake applications, the highest gear ratio (excluding overdrive, etc.) shall be continuously engaged.

1.5.1.5. For regaining speed after braking, the gearbox shall be used in such a way as to attain the speed v_1 in the shortest possible time (maximum acceleration allowed by the engine and gearbox).

1.5.1.6. For vehicles not having sufficient autonomy to carry out the cycles of heating of the brakes, the tests shall be carried out by achieving the prescribed speed before the first braking application and thereafter by using the maximum acceleration available to regain speed and then braking successively at the speed reached at the end of each 45 second cycle duration.

1.5.1.7. 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 as listed in paragraph 1.4.1.2.3. above.

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

1.5.2. Hot performance

1.5.2.1. At the end of the Type-I test (test described in paragraph 1.5.1.) the hot performance of the service braking system shall be measured in the same conditions (and, in particular, at a constant control force no greater than the mean force, or brake demand value, actually used) as for the Type-0 test with the engine disconnected (the temperature conditions may be different).

Any system or function that provides compensation for a loss of brake performance due to heat fade shall be inoperative during this test.

1.5.2.2. This hot performance shall not be less than 75 ([2]) per cent of that prescribed, nor less than 60 per cent of the figure recorded in the Type-0 test with the engine disconnected.

1.5.2.3. 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 braking control, if any, not used.

1.5.2.4. 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 2.1.1.(A) of this annex can be reached.

For comparison, a later 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.

Following the recovery process and test, further reconditioning of the linings shall be permitted before the test is made to compare this second cold performance with that achieved in the hot test, against the criteria of paragraphs 1.5.2.2. or 1.5.2.5. of this annex.

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.

1.5.2.5. In the case of a vehicle which satisfies the 60 per cent requirement specified in paragraph 1.5.2.2. of this annex, but which cannot comply with the 75[2] per cent requirement of paragraph 1.5.2.2. of this annex, a further hot performance test may be carried out using a control force not exceeding that specified in paragraph 2. of this annex. The results of both tests shall be entered in the report.

1.5.3. Recovery procedure

Immediately after the hot performance test, make four stops from 50 km/h with the engine connected, at a mean deceleration of 3 m/s^2. Allow an interval of 1.5 km between the start of successive stops. Immediately after each stop, accelerate at maximum rate to 50 km/h and maintain that speed until making the next stop.

1.5.3.1. Vehicles equipped with an electrical regenerative braking system of Category B may have their batteries recharged or replaced by a charged set. In this case, further reconditioning of the linings shall be performed in order to complete the recovery procedure.

The procedures may be conducted without a regenerative braking component.

([2]) This corresponds to a stopping distance of $0.1\ v + 0.0080\ v^2$ and a mean fully developed deceleration of 4.82 m/s^2.

1.5.4. Recovery performance

At the end of the recovery procedure, the recovery performance of the service braking system shall be measured in the same conditions as for the Type-0 test with the engine disconnected (the temperature conditions may be different), using a mean force on the control, which is not more than the mean control force used in the corresponding Type-0 test.

This recovery performance shall not be less than 70 per cent, nor more than 150 per cent, of the figure recorded in the Type-0 test with the engine disconnected.

1.5.4.1. For vehicles equipped with an electrical regenerative braking system of category B, the recovery test shall be made with no regenerative braking component, i.e. under the conditions of paragraph 1.5.4. above.

After the further reconditioning of the linings, a second repeat Type-0 test shall be made from the same speed and with no electric regenerative braking contribution as in the recovery test with the engine/motors disconnected, and comparison shall be made between these test results.

The recovery performance shall not be less than 70 per cent, nor more than 150 per cent of the figure recorded in this final repeat Type-0 test.

2. Performance of braking systems

2.1. Service braking system

2.1.1. The service brakes shall be tested under the conditions shown in the following table:

(A)	Type-0 test with engine disconnected	v s ≤ d_m ≥	100 km/h 0.1 v + 0.0060 v^2 (m) 6.43 m/s^2
(B)	Type-0 test with engine connected	v s ≤ d_m ≥	80 % v_{max} ≤ 160 km/h 0.1 v + 0.0067 v^2 (m) 5.76 m/s^2
		f	6.5 – 50 daN

Where:

v = test speed, in km/h

s = stopping distance, in metres

d_m = mean fully developed deceleration, in m/s^2

f = force applied to foot control, in daN

v_{max} = maximum speed of the vehicle, in km/h

2.1.2. In the case of a motor vehicle authorized to tow an unbraked trailer, the minimum Type-0 performance of the combination shall not be less than 5.4 m/s^2 in both the laden and unladen conditions.

The combination performance shall be verified by calculations referring to the maximum braking performance actually achieved by the motor vehicle alone (laden) during the Type-0 test with the engine disconnected, using the following formula (no practical tests with a coupled unbraked trailer are required):

$$d_{M+R} = d_M \bullet \frac{P_M}{P_M + P_R}$$

Where:

d_{M+R} = calculated mean fully developed deceleration of the motor vehicle when coupled to an unbraked trailer, in m/s^2

d_M = maximum mean fully developed deceleration of the motor vehicle alone achieved during the Type-0 test with engine disconnected, in m/s^2

P_M = mass of the motor vehicle (laden)

P_R = maximum mass of an unbraked trailer which may be coupled, as declared by the motor vehicle manufacturer

2.2. Secondary braking system

2.2.1. The performance of the secondary braking system shall be tested by the Type-0 test with the engine disconnected from an initial vehicle speed of 100 km/h and a force applied to the service brake control not less than 6.5 daN and not exceeding 50 daN.

2.2.2. The secondary braking system shall give a stopping distance not exceeding the following value:

$$0.1\ v + 0.0158\ v^2\ (m)$$

and a mean fully developed deceleration not less than 2.44 m/s^2 (corresponding to the second term of the above formula).

2.2.3. The secondary braking effectiveness test shall be conducted by simulating the actual failure conditions in the service braking system.

2.2.4. For vehicles employing electric regenerative braking systems, the braking performance shall additionally be checked under the two following failure conditions:

2.2.4.1. For a total failure of the electric component of the service braking output.

2.2.4.2. In the case where the failure condition causes the electric component to deliver its maximum braking force.

2.3. Parking braking system

2.3.1. The parking braking system shall be capable of holding the laden vehicle stationary on a 20 per cent up or down gradient.

2.3.2. On vehicles to which the coupling of a trailer is authorized, the parking braking system of the motor vehicle shall be capable of holding the combination of vehicles stationary on a 12 per cent up or down gradient.

2.3.3. If the control device is manual, the force applied to it shall not exceed 40 daN.

2.3.4. If it is a foot control device, the force exerted on the control shall not exceed 50 daN.

2.3.5. A parking braking system which has to be actuated several times before it attains the prescribed performance is admissible.

2.3.6. To check compliance with the requirement specified in paragraph 5.2.2.4. of this Regulation, a Type-0 test shall be carried out, with the engine disconnected, at an initial test speed of 30 km/h. The mean fully developed deceleration on application of the control of the parking brake system and the deceleration immediately before the vehicle stops, shall not be less than 1.5 m/s^2. The test shall be carried out with the laden vehicle. The force exerted on the braking control device shall not exceed the specified values.

3. Response time

3.1. Where a vehicle is equipped with a service braking system which is totally or partially dependent on a source of energy other than the muscular effort of the driver, the following requirements shall be satisfied:

3.1.1. In an emergency manoeuvre, the time elapsing between the moment when the control device begins to be actuated and the moment when the braking force on the least favourable placed axle reaches the level corresponding to the prescribed performance shall not exceed 0.6 seconds;

3.1.2. In the case of vehicles fitted with hydraulic braking systems, the requirements of paragraph 3.1.1. above are considered to be satisfied if, in an emergency manoeuvre, the deceleration of the vehicle or the pressure at the least favourable brake cylinder, reaches a level corresponding to the prescribed performance within 0.6 seconds;

3.1.3. In the case of vehicles fitted with an electrical transmission braking system, the requirements of paragraph 3.1.1. above are considered to be satisfied if, in an emergency manoeuvre, the deceleration of the vehicle at the least favourable brake, reaches a level corresponding to the prescribed performance within 0.6 second.

ANNEX 3 – Appendix

Procedure for monitoring the state of battery charge

This procedure is applicable to vehicle batteries used for traction and regenerative braking.

The procedure requires the use of a bi-directional DC Watt-hour meter or a bi-directional DC Ampere-hour meter.

1. Procedure

1.1. If the batteries are new or have been subject to extended storage, they shall be cycled as recommended by the manufacturer. A minimum 8-hour soak period at ambient temperature shall be allowed after completion of cycling.

1.2. A full charge shall be established using the manufacturer's recommended charging procedure.

1.3. When the braking tests of paragraphs 1.2.11., 1.4.1.2.3., 1.5.1.6., 1.5.1.7. and 1.5.2.4. of Annex 3 are conducted the watt-hours consumed by the traction motors and supplied by the regenerative braking system shall be recorded as a running total which shall then be used to determine the state of charge existing at the beginning or end of a particular test.

1.4. To replicate a level of state of charge in the batteries for comparative tests, such as those of paragraph 1.5.2.4. of Annex 3, the batteries shall be either recharged to that level or charged to above that level and discharged into a fixed load at approximately constant power until the required state of charge is reached. Alternatively, for vehicles with battery powered electric traction only, the state of charge may be adjusted by running the vehicle. Tests conducted with a battery partially charged at their start shall be commenced as soon as possible after the desired state of charge has been reached.

ANNEX 4

Provisions relating to energy sources and energy storage devices (energy accumulators)

A. Hydraulic braking systems with stored energy

1. Capacity of energy storage devices (energy accumulators)

1.1. General

1.1.1. Vehicles on which the braking equipment requires the use of stored energy provided by hydraulic fluid under pressure shall be equipped with energy storage devices (energy accumulators) of a capacity meeting the requirements of paragraphs 1.2. or 1.3. of this annex;

1.1.2. However, the energy storage devices shall not be required to be of a prescribed capacity if the braking system is such that in the absence of any energy reserve it is possible with the service brake control to achieve a braking performance at least equal to that prescribed for the secondary braking system;

1.1.3. In verifying compliance with the requirements of paragraphs 1.2., 1.3. and 2.1. of this annex, the brakes shall be adjusted as closely as possible and, for paragraph 1.2. of this annex, the rate of full-stroke actuations shall be such as to provide an interval of at least 60 seconds between each actuation.

1.2. Vehicles equipped with a hydraulic braking system with stored energy shall meet the following requirements:

1.2.1. After eight full-stroke actuations of the service brake control, it shall still be possible to achieve, on the ninth application, the performance prescribed for the secondary braking system.

1.2.2. Testing shall be performed in conformity with the following requirements:

1.2.2.1. Testing shall commence at a pressure that may be specified by the manufacturer but is not higher than the cut-in pressure ([1]);

1.2.2.2. The energy storage device(s) shall not be fed; in addition, any energy storage device(s) for auxiliary equipment shall be isolated.

1.3. Vehicles equipped with a hydraulic braking system with stored energy which cannot meet the requirements of paragraph 5.2.4.1. of this Regulation shall be deemed to satisfy that paragraph if the following requirements are met:

1.3.1. After any single transmission failure it shall still be possible after eight full-stroke actuations of the service brake control, to achieve, at the ninth application, at least the performance prescribed for the secondary braking system.

1.3.2. Testing shall be performed in conformity with the following requirements:

1.3.2.1. With the energy source stationary or operating at a speed corresponding to the engine idling speed, any transmission failure may be induced. Before inducing such a failure, the energy storage device(s) shall be at a pressure that may be specified by the manufacturer but not exceeding the cut-in pressure;

1.3.2.2. The auxiliary equipment and its energy storage devices, if any, shall be isolated.

([1]) The initial energy level shall be stated in the approval document.

2. Capacity of hydraulic fluid energy sources

2.1. The energy sources shall meet the requirements set out in the following paragraphs.

2.1.1. Definitions

2.1.1.1. "p_1" represents the maximum system operational pressure (cut-out pressure) in the energy storage device(s) specified by the manufacturer.

2.1.1.2. "p_2" represents the pressure after four full-stroke actuations with the service brake control, starting at p_1, without having fed the energy storage device(s).

2.1.1.3. "t" represents the time required for the pressure to rise from p_2 to p_1 in the energy storage device(s) without application of the brake control.

2.1.2. Conditions of measurement

2.1.2.1. During the tests to determine the time t, the feed rate of the energy source shall be that obtained when the engine is running at the speed corresponding to its maximum power or at the speed allowed by the over-speed governor.

2.1.2.2. During the test to determine the time t, energy storage device(s) for auxiliary equipment shall not be isolated other than automatically.

2.1.3. Interpretation of results

2.1.3.1. In the case of all vehicles, the time t shall not exceed 20 seconds.

3. Characteristics of warning devices

With the engine stationary and commencing at a pressure that may be specified by the manufacturer but does not exceed the cut-in pressure, the warning device shall not operate following two full-stroke actuations of the service brake control.

B. Electrical transmission braking system

1. Performance of electrical storage devices

1.1. General

1.1.1. Vehicles equipped with an electrical transmission braking system shall be equipped with electrical storage devices of a performance meeting the requirements of paragraph 1.2. of this annex (Part B).

1.1.2. Electrical storage devices that provide power only to the control transmission of the braking system may, as an alternative, satisfy the requirements of paragraph 5.2.24.7. to this Regulation.

1.1.3. It shall be possible to easily identify the electrical storage devices of the different braking circuits.

1.2. Vehicles equipped with an electrical transmission braking system with stored energy shall meet the following requirements:

1.2.1. The performance of the electrical storage device(s) shall be such that, as a minimum, after eight full actuations of the service braking system control (as described in paragraph 1.2.3.3. below) the performance (at the ninth braking) at least fulfils the requirements specified for secondary braking. 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. Testing shall be performed in conformity with the following requirements:

1.2.2.1. At the commencement of the test, the state of the electrical storage device(s) of each braking circuit shall be such that the necessary condition to display the yellow warning signal specified in paragraph 5.2.24.7. is fulfilled. Additionally, the state shall not be higher than the value which can be delivered by an electrical storage device whose performance has degraded to a point where the warning specified in 5.2.24.6. is displayed.

In the case that a traction battery also has the function of an energy storage device (within the meaning of this Annex), the state of the traction battery at the commencement of the test may be such that the battery can no longer provide power to the traction motors. This condition may be a result of the actual capability of the traction battery being insufficient, or when of the control strategy of the vehicle suspends the supply of energy to the traction motor(s).

1.2.3. The electrical storage devices shall not be supplied with further energy during the test.

1.2.3.1. The procedure by which the electrical storage devices are prepared for this test shall be agreed between the manufacturer and the type-approval authority technical service. This procedure shall be recorded in the test report and included in the type-approval documentation.

1.2.3.2. Each full actuation shall be for a duration of at least 8.0 seconds with an interval, specified by the vehicle manufacturer, of at least 5.0 seconds between the release of the brake control and its subsequent actuation.

The vehicle manufacturer may provide cooling to the electromechanical actuators during the static phase of the test.

1.2.3.3. Each actuation shall cause a demand (a_{ref}) on the brake actuators necessary to deliver the maximum possible deceleration designed to be delivered by the system in the Type 0 condition (e.g. cold brakes, Type 0 speed, laden, fully charged electrical storage devices), limited to 8.0 m/s^2.

The demand value to the brake actuators may be reduced to a lower value $a_{reduced}$, while not being lower than the prescribed service braking deceleration. In this case, the duration T of each full stroke actuation shall be increased as per according to the following formula below:

$$T = a_{ref} / a_{reduced} \times 8 \text{ seconds}$$

The method by which the demand is calibrated to deliver a_{ref} or $a_{reduced}$, as relevant, shall be agreed between the between the manufacturer and the technical service. This procedure shall be recorded in the test report and included in the type-approval documentation.

It shall be ensured that the energy provided to the brake system transmission during this test is provided only by the electrical storage devices.

1.2.3.4. It shall be ensured that, when carrying out the test during standstill compared to a driving situation, the energy consumed by the service braking system is not reduced below the demand specified in paragraph 1.2.3.3. by energy saving functions.

1.2.3.5. The capability to achieve the prescribed secondary braking performance (at the ninth actuation of the brake control) shall be confirmed by dynamic testing in accordance with Annex 3, using only the electrical energy available from the electrical storage devices at the completion of 8 full ([2]) actuations performed in static condition (i.e. with the vehicle at standstill), in the test conditions specified in the relevant tests of paragraph 1.2.3. above. However, the requirement of Annex 3, paragraph 2.2.3. to simulate a failure into the braking system shall not apply.

As an alternative to the dynamic testing above, the ninth actuation of the brake control may be done in static condition. The vehicle manufacturer shall provide evidence that the power provided over the time of the actuation is sufficient to at least achieve the prescribed secondary braking performance in the test condition of Annex 3. The method used to construct this evidence (e.g. based on the comparison of the power consumed by the brake actuators with the value measured during a dynamic test) shall be agreed between the manufacturer and the technical service and verified by the technical service, recorded in the test report and included in the type-approval documentation.

1.2.3.6. The capability to achieve the prescribed service braking performance at the first actuation shall be confirmed by the Type-0 dynamic testing in accordance with Annex 4, with an initial level of energy in the electrical storage devices not greater than the specified values of energy specified in paragraph 1.2.2.1.

As an alternative to the dynamic testing above, the actuation of the brake control may be done in static condition. The power necessary to deliver this performance shall be determined using the same procedures as those described in paragraph 1.2.3.6.

2. Capacity of the electrical supply

2.1. General

The electrical supply (including the energy source, if fitted) shall meet the requirements set forth in the following paragraphs.

In the case that a traction battery also has the function of an electrical storage device (within the meaning of this Annex), without a source to replenish the traction battery (i.e. beside regenerative braking), the requirements below shall not apply, for the relevant circuit(s).

Testing shall be performed in conformity with the following requirements:

2.2. Conditions of measurement

2.2.1. The capacity of the electrical supply shall be assessed using the procedures of paragraph 1.5.1. of Annex 3 (Type-I test) and paragraph 1.5.2.1. (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 3.

The brake actuations 16 to 20 shall be of the same duration and with and equivalent energy demand to that of actuation number 15. The interval between brake actuations shall be the same. The energy provided to the electrical transmission during the static test shall be equivalent to the mean value of the energy provided by the electrical supply to the electrical transmission during 15 actuations of the dynamic Type-I followed by one actuation of the Hot Performance test of Annex 3.

([2]) A full actuation means the actuation of the control in accordance with Annex 4, Part B, paragraph 1.2.3.3. for a duration of 8.0 seconds or for a time T as described in that paragraph.

2.2.3. At the commencement of the test:

(a) The electrical supply operates without any failure.

(b) The state of the electrical storage devices shall not exceed the value specified in paragraph 1.2.2.1.

2.2.4. Where the electrical supply provides power to auxiliary equipment, the total power demand of the auxiliary systems declared in paragraph 5.2.24.12. shall be represented during the test by an equivalent power demand on the electrical supply.

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

2.2.5. The state of the electrical storage device(s) on completion of the test defined in paragraph 2.2. above, shall not fall to a value at which the red warning signal specified in paragraph 5.2.14.1.(b) of this Regulation is activated.

2.2.6. The value of the power supplied by the electrical supply shall not fall to a level at which the warning signal (P_W) required by paragraph 5.2.24.9. is activated.

ANNEX 5

Distribution of braking among the axles of vehicles

1. General

Vehicles which are not equipped with an anti-lock system as defined in Annex 6 to this Regulation shall meet all the requirements of this annex. If a special device is used, this shall operate automatically.

2. Symbols

i = axle index ($i = 1$, front axle; $i = 2$, rear axle)

P_i = normal reaction of road surface on axle i under static conditions

N_i = normal reaction of road surface on axle i under braking

T_i = force exerted by the brakes on axle i under normal braking conditions on the road

f_i = T_i/N_i , adhesion utilized by axle i ([1])

J = deceleration of the vehicle

g = acceleration due to gravity: $g = 9.81\ m/s^2$

z = braking rate of vehicle = J/g

P = mass of vehicle

h = height of centre of gravity specified by the manufacturer and agreed by the Technical Services conducting the approval test

E = wheelbase

k = theoretical coefficient of adhesion between tyre and road

3. Requirements

3.1.(A) For all states of load of the vehicle, the adhesion utilization curve of the rear axle shall not be situated above that for the front axle ([2]):

for all braking rates between 0.15 and 0.8:

3.1.(B) For k values between 0.2 and 0.8 ([2]):

$$z \geq 0.1 + 0.7\ (k - 0.2)$$ (see Diagram 1 of this annex)

3.2. In order to verify the requirements of paragraph 3.1. of this annex, the manufacturer shall provide the adhesion utilization curves for the front and rear axles calculated by the formulae:

$$f_1 = \frac{T_1}{N_1} = \frac{T_1}{P_1 + z \bullet \frac{h}{E} \bullet P \bullet g}$$

$$f_2 = \frac{T_2}{N_2} = \frac{T_2}{P_2 - z \bullet \frac{h}{E} \bullet P \bullet g}$$

([1]) "*Adhesion utilisation curves*" of a vehicle means curves showing, for specified load conditions, the adhesion utilized by each axle i plotted against the braking rate of the vehicle.

([2]) The provisions of paragraph 3.1. do not affect the requirements of Annex 3 to this Regulation relating to the braking performance. However, if, in tests made under the provisions of paragraph 3.1., braking performances are obtained which are higher than those prescribed in Annex 3, the provisions relating to the adhesion utilization curves shall be applied within the areas of Diagram 1 of this annex defined by the straight lines $k = 0.8$ and $z = 0.8$.

The curves shall be plotted for both the following load conditions:

3.2.1. Unladen, in running order with the driver on board;

3.2.2. Laden; where provision is made for several possibilities of load distribution, the one whereby the front axle is the most heavily laden shall be the one considered;

3.2.3. For vehicles fitted with an electric regenerative braking system of category B, where the electric regenerative braking capacity is influenced by the electric state of charge, the curves shall be plotted by taking account of the electric braking component under the minimal and maximum conditions of delivered braking force. This requirement is not applicable if the vehicle is equipped with an anti-lock device which controls the wheels connected to the electric braking then the requirements of Annex 6 to this Regulation shall apply.

4. Requirements to be met in case of failure of the braking distribution system

When the requirements of this annex are fulfilled by means of a special device (e.g. controlled mechanically by the suspension of the vehicle), it shall be possible, in the event of the failure of its control, (e.g. by disconnecting the control linkage), to stop the vehicle under the conditions of the Type-0 test with the engine disconnected to give a stopping distance not exceeding $0.1\ v + 0.0100\ v^2$ (m) and a mean fully developed deceleration not less than $3.86\ m/s^2$.

5. Vehicle testing

During the type-approval testing of a vehicle, the Type Approval Authority shall verify conformity with the requirements contained in the present annex, by carrying out the following tests:

5.1. Wheel-lock sequence test (see Appendix 1)

If the wheel-lock sequence test confirms that the front wheels lock before or simultaneously with the rear wheels, conformity with paragraph 3. of this annex has been verified and testing is complete.

5.2. Additional tests

If the wheel-lock sequence test indicates that the rear wheels lock before the front wheels, then the vehicle:

(a) Will be subjected to additional testing, as follows:

(i) Additional wheel-lock sequence tests; and/or

(ii) Torque wheel tests (see Appendix 2) to determine brake factors To generate adhesion utilization curves; these curves shall satisfy the requirements in paragraph 3.1.(A) of this annex.

(b) May be refused type-approval.

5.3. The results of the practical tests shall be appended to the type-approval report.

6. Conformity of production

6.1. When checking vehicles for conformity of production, the Technical Services should follow the same procedures as for type-approval.

6.2. The requirements shall also be the same as for type-approval, except that in the test described in paragraph 5.2.(a)(ii) of this annex, the rear axle curve shall lie below the line z = 0.9 k for all braking rates between 0.15 and 0.8 (instead of meeting the requirement in paragraph 3.1.(A) (see Diagram 2).

Diagram 1

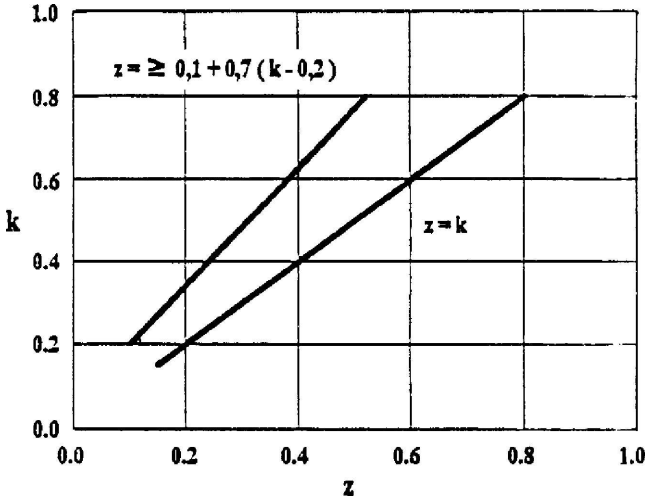
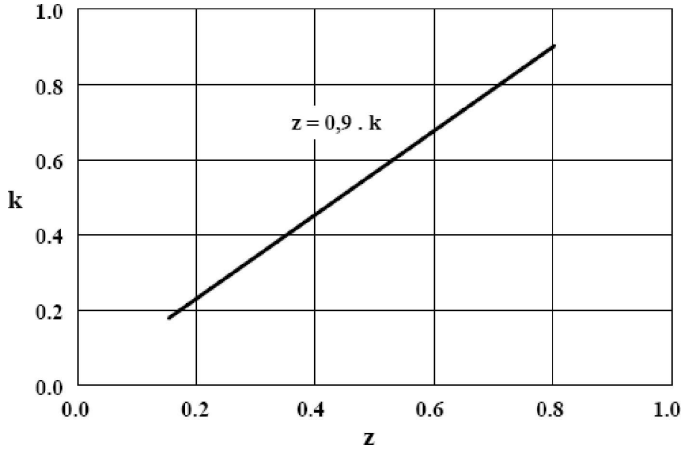


Diagram 2



ANNEX 5 – Appendix 1

Wheel-lock sequence test procedure

1. General information

(a) The purpose of this test is to ensure that lockup of both front wheels occurs at a lower deceleration rate than the lockup of both rear wheels when tested on road surfaces on which wheel lockup occurs at braking rates between 0.15 and 0.8.

(b) A simultaneous lockup of the front and rear wheels refers to the condition when the time interval between the lockup of the last (second) wheel on the rear axle and the last (second) wheel on the front axle is < 0.1 seconds for vehicle speeds > 30 km/h.

2. Vehicle conditions

(a) Vehicle load: Laden and unladen

(b) Transmission position: Engine disconnected

3. Test conditions and procedures

(a) Initial brake temperature: Between 65 °C and 100 °C average on the hottest axle.

(b) Test speed: 65 km/h for a braking rate ≤ 0.50;
100 km/h for a braking rate > 0.50.

(c) Pedal force:

(i) Pedal force is applied and controlled by a skilled driver or by a mechanical brake pedal actuator.

(ii) Pedal force is increased at a linear rate such that the first axle lockup occurs no less than one-half (0.5) second and no more than one and one-half (1.5) seconds after the initial application of the pedal.

(iii) The pedal is released when the second axle locks, or when the pedal force reaches l kN, or 0.1 seconds after the first lockup, whichever occurs first.

(d) Wheel lockup: Only wheel lockups above a vehicle speed of 15 km/h are considered.

(e) Test surface: This test is conducted on road test surfaces on which wheel lockup occurs at braking rates between 0.15 and 0.8.

(f) Data to be recorded: The following information shall be automatically recorded in phase continuously throughout each test run such that values of the variables can be cross referenced in real time:

(i) Vehicle speed;

(ii) Instantaneous vehicle braking rate (e.g. by differentiation of vehicle speed);

(iii) Brake pedal force (or hydraulic line pressure);

(iv) Angular velocity at each wheel.

(g) Each test run shall be repeated once to confirm the wheel lockup sequence: if one of these two results indicates a failure to comply, then a third test run under the same conditions will be decisive.

4. Performance requirements

(a) Both rear wheels shall not reach a locked condition prior to both front wheels being locked – at vehicle braking rates between 0.15 and 0.8.

(b) If, when tested to the procedure specified above, and at vehicle braking rates between 0.15 and 0.8 the vehicle meets one of the following criteria, then it passes this wheel lockup sequence requirement:

(i) No wheels lock;

(ii) Both wheels on the front axle and one or no wheels on the rear axle lock;

(iii) Both axles simultaneously lock.

(c) If wheel lockup commences at a braking rate less than 0.15 and more than 0.8 then the test is invalid and should be repeated on a different road surface.

(d) If, either laden or unladen, at a braking rate between 0.15 and 0.8 both wheels on the rear axle and one or no wheels on the front axle lock, then it fails the wheel lockup sequence test. In this latter case, the vehicle shall be submitted to the 'torque wheels' test procedure to determine the objective brake factors for calculation of the adhesion utilization curves.

ANNEX 5 – Appendix 2

Torque wheel test procedure

1. General information

The purpose of this test is to measure the brake factors and thus determine the adhesion utilization of the front and rear axles over a range of braking rates between 0.15 and 0.8.

2. Vehicle conditions

(a) Vehicle load: Laden and unladen

(b) Transmission position: Engine disconnected

3. Test conditions and procedures

(a) Initial brake temperature: Between 65 °C and 100 °C average on the hottest axle.

(b) Test speeds: 100 km/h and 50 km/h.

(c) Pedal force: Pedal force is increased at a linear rate between 100 and 150 N/sec for the 100 km/h test speed, or between 100 and 200 N/sec for the 50 km/h test speed, until the first axle locks or until a pedal force of 1 kN is reached, whichever occurs first.

(d) Brake cooling: Between brake applications, the vehicle is driven at speeds up to 100 km/h until the initial brake temperature specified in paragraph 3.(a) above is reached.

(e) Number of runs: With the vehicle unladen, run five stops from a speed of 100 km/h and five stops from a speed of 50 km/h, while alternating between the two test speeds after each stop. With the vehicle laden, repeat the five stops at each test speed while alternating between the two test speeds.

(f) Test surface: This test is conducted on a road test surface affording good adhesion.

(g) Data to be recorded: The following information shall be automatically recorded in phase continuously throughout each test run such that values of the variables can be cross referenced in real time:

(i) Vehicle speed

(ii) Brake pedal force

(iii) Angular velocity of each wheel

(iv) Brake torque at each wheel

(v) Hydraulic line pressure in each brake circuit, including transducers on at least one front wheel and one rear wheel downstream of any operative proportioning or pressure limiting valve(s)

(vi) Vehicle deceleration

(h) Sample rate: All data acquisition and recording equipment shall support a minimum sample rate of 40 Hz on all channels.

(i) Determination of front versus rear brake pressure: Determine the front versus rear brake pressure relationship over the entire range of line pressures. Unless the vehicle has a variable brake proportioning system, this determination is made by static tests. If the vehicle has a variable brake proportioning system, dynamic tests are run with the vehicle both laden and unladen. Fifteen snubs from 50 km/h are made for each of the two load conditions, using the same initial conditions specified in this appendix.

4. Data reduction

(a) The data from each brake application prescribed in paragraph 3.(e) above is filtered using a five-point, on-centre moving average for each data channel.

(b) For each brake application prescribed in paragraph 3.(e) above, determine the slope (brake factor) and pressure axis intercept (brake hold-off pressure) of the linear least squares equation best describing the measured torque output at each braked wheel as a function of measured line pressure applied at the same wheel. Only torque output values obtained from data collected when the vehicle deceleration is within the range of 0.15 g to 0.80 g are used in the regression analysis.

(c) Average the results of paragraph (b) above to calculate the average brake factor and brake hold-off pressure for all brake applications for the front axle.

(d) Average the results of paragraph (b) above to calculate the average brake factor and brake hold-off pressure for all brake applications for the rear axle.

(e) Using the relationship between front and rear brake line pressure determined in paragraph 3.(i) above and the dynamic tyre rolling radius, calculate the braking force at each axle as a function of front brake line pressure.

(f) Calculate the braking rate of the vehicle as a function of the front brake line pressure using the following equation:

$$z = \frac{T_1 + T_2}{P \bullet g}$$

Where:

z = braking rate at a given front brake line pressure

T_1, T_2 = braking forces at the front and rear axles respectively, corresponding to the same front brake line pressure

P = vehicle mass

(g) Calculate the adhesion utilized at each axle as a function of braking rate using the following formulae:

$$f_1 = \frac{T_1}{P_1 + \frac{z \bullet h \bullet P \bullet g}{E}}$$

$$f_2 = \frac{T_2}{P_2 - \frac{z \bullet h \bullet P \bullet g}{E}}$$

The symbols are defined in paragraph 2. of this annex.

(h) Plot f_1 and f_2 as a function of z, for both laden and unladen load conditions. These are the adhesion utilization curves for the vehicle, which shall satisfy the requirements in paragraph 5.2.(a)(ii) of this annex (or, in the case of Conformity of Production checks, these curves shall satisfy the requirements in paragraph 6.2. of this annex).

ANNEX 6

Test requirements for vehicles fitted with anti-lock systems

1. General

1.1. This annex defines the required braking performance for road vehicles fitted with anti-lock systems.

1.2. The anti-lock systems known at present comprise a sensor or sensors, a controller or controllers and a modulator or modulators. Any device of a different design which may be introduced in the future, or where an anti-lock braking function is integrated into another system, shall be deemed to be an anti-lock braking system within the meaning of this annex and Annex 5 to this Regulation, if it provides performance equal to that prescribed by this annex.

2. Definitions

2.1. An "*anti-lock system*" is a part of a service braking system which automatically controls the degree of slip, in the direction of rotation of the wheel(s), on one or more wheels of the vehicle during braking.

2.2. "*Sensor*" means a component designed to identify and transmit to the controller the conditions of rotation of the wheel(s) or the dynamic conditions of the vehicle.

2.3. "*Controller*" means a component designed to evaluate the data transmitted by the sensor(s) and to transmit a signal to the modulator.

2.4. "*Modulator*" means a component designed to vary the braking force(s) in accordance with the signal received from the controller.

2.5. "*Directly controlled wheel*" means a wheel whose braking force is modulated according to data provided at least by its own sensor ([1]).

2.6. "*Indirectly controlled wheel*" means a wheel whose braking force is modulated according to data provided by the sensor(s) of other wheel(s) ([1]).

2.7. "*Full cycling*" means that the anti-lock system is repeatedly modulating the brake force to prevent the directly controlled wheels from locking. Brake applications where modulation only occurs once during the stop shall not be considered to meet this definition.

3. Types of anti-lock systems

3.1. A vehicle is deemed to be equipped with an anti-lock system within the meaning of paragraph 1. of Annex 5 to this Regulation, if one of the following systems is fitted:

3.1.1. Category 1 anti-lock system

A vehicle equipped with a category 1 anti-lock system shall meet all the requirements of this annex.

([1]) Anti-lock systems with select-high control are deemed to include both directly and indirectly controlled wheels; in systems with select-low control, all sensed wheels are deemed to be directly controlled wheels.

3.1.2. Category 2 anti-lock system

A vehicle equipped with a category 2 anti-lock system shall meet all the requirements of this annex, except those of paragraph 5.3.5. below.

3.1.3. Category 3 anti-lock system

A vehicle equipped with a category 3 anti-lock system shall meet all the requirements of this annex, except those of paragraphs 5.3.4. and 5.3.5. below. On such vehicles, any individual axle which does not include at least one directly controlled wheel shall fulfil the conditions of adhesion utilization and the wheel-locking sequence of Annex 5 to this Regulation, instead of the adhesion utilization requirements prescribed in paragraph 5.2. of this annex. However, if the relative positions of the adhesion utilization curves do not meet the requirements of paragraph 3.1. of Annex 5 to this Regulation, a check shall be made to ensure that the wheels on at least one of the rear axles do not lock before those of the front axle or axles under the conditions prescribed in paragraph 3.1. of Annex 5 to this Regulation, with regard to the braking rate and the load respectively. These requirements may be checked on high- and low-adhesion road surfaces (about 0.8 and 0.3 maximum) by modulating the service braking control force.

4. General requirements

4.1. Any electrical failure or sensor anomaly that affects the system with respect to the functional and performance requirements in this annex, including those in the supply of electricity, the external wiring to the controller(s), the controller(s) ([2]) and the modulator(s) shall be signalled to the driver by a specific optical warning signal. The yellow warning signal specified in paragraph 5.2.21.1.2. of this Regulation shall be used for this purpose.

4.1.1. Sensor anomalies, which cannot be detected under static conditions, shall be detected not later than when the vehicle speed exceed 10 km/h ([3]). However, to prevent erroneous fault indication when a sensor is not generating a vehicle speed output, due to non-rotation of a wheel, verification may be delayed but detected not later than when the vehicle speed exceeds 15 km/h.

4.1.2. When the anti-lock braking system is energized with the vehicle stationary, electrically controlled pneumatic modulator valve(s) shall cycle at least once.

4.2. In the event of a single electrical functional failure which only affects the anti-lock function, as indicated by the above-mentioned yellow warning signal, the subsequent service braking performance shall not be less than 80 per cent of the prescribed performance according to the Type-0 test with the engine disconnected. This corresponds to a stopping distance of $0.1\ v + 0.0075\ v^2$ (m) and a mean fully developed deceleration of $5.15\ m/s^2$.

4.3. The operation of the anti-lock system shall not be adversely affected by magnetic or electrical fields. This shall be demonstrated by compliance with UN Regulation No 10, as required by paragraph 5.1.1.4 of the Regulation.

4.4. A manual device may not be provided to disconnect or change the control mode ([4]) of the anti-lock system.

([2]) The manufacturer shall provide the Technical Service with documentation relating to the controller(s) which follows the format set out in Annex 8.

([3]) The warning signal may light up again while the vehicle is stationary, provided that it is extinguished before the vehicle speed reaches 10 km/h or 15 km/h, as appropriate, when no defect is present.

([4]) It is understood that devices changing the control mode of the anti-lock system are not subject to paragraph 4.4. of this annex if in the changed control mode condition all requirements to the category of anti-lock systems, with which the vehicle is equipped, are fulfilled.

5. Special provisions

5.1. Energy consumption

Vehicles equipped with anti-lock systems shall maintain their performance when the service braking control device is fully applied for long periods. Compliance with this requirement shall be verified by means of the following tests:

5.1.1. Test procedure

5.1.1.1. The initial energy level in the energy storage device(s) shall be that specified by the manufacturer. This level shall be at least such as to ensure the efficiency prescribed for service braking when the vehicle is laden. The energy storage device(s) for pneumatic auxiliary equipment shall be isolated.

5.1.1.2. From an initial speed of not less than 50 km/h, on a surface with a coefficient of adhesion of 0.3 ([5]) or less, the brakes of the laden vehicle shall be fully applied for a time t, during which time the energy consumed by the indirectly controlled wheels shall be taken into consideration and all directly controlled wheels shall remain under control of the anti-lock system.

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

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 electrical transmission braking system, each full actuation shall be as defined in Annex 4, Part B, paragraph 1.2.3.3.

5.1.1.5. When the brakes are applied for the fifth time, it shall be possible to brake the vehicle with at least the performance prescribed for secondary braking of the laden vehicle.

5.1.2. Additional requirements

5.1.2.1. The coefficient of adhesion of the road surface shall be measured with the vehicle under test, by the method described in paragraph 1.1. of Appendix 2 to this annex.

5.1.2.2. The braking test shall be conducted with the engine disconnected and idling, and with the vehicle laden.

5.1.2.3. The braking time t shall be determined by the formula:

$$t = \frac{v_{max}}{7}$$

(but not less than 15 seconds)

where t is expressed in seconds and v_{max} represents the maximum design speed of the vehicle expressed in km/h, with an upper limit of 160 km/h.

5.1.2.4. If the time t cannot be completed in a single braking phase, further phases may be used, up to a maximum of four in all.

([5]) Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the Technical Service. The actual value obtained and the type of tyres and surface shall be recorded.

5.1.2.5. If the test is conducted in several phases, no fresh energy shall be supplied between the phases of the test.

From the second phase, the energy consumption corresponding to the initial brake application may be taken into account, by subtracting one full brake application from the four full applications prescribed in paragraph 5.1.1.4. (and 5.1.1.5. and 5.1.2.6.) of this annex for each of the second, third and fourth phases used in the test prescribed in paragraph 5.1.1. of this annex as applicable.

5.1.2.6. The performance prescribed in paragraph 5.1.1.5. of this annex shall be deemed to be satisfied if, at the end of the fourth application, with the vehicle stationary, the energy level in the storage device(s) is at or above that required for secondary braking with the laden vehicle.

5.2. Utilization of adhesion

5.2.1. The utilization of adhesion by the anti-lock system takes into account the actual increase in braking distance beyond the theoretical minimum. The anti-lock system shall be deemed to be satisfactory when the condition $\varepsilon \geq 0.75$ is satisfied, where ε represents the adhesion utilized, as defined in paragraph 1.2. of Appendix 2 to this annex.

5.2.2. The adhesion utilization ε shall be measured on road surfaces with a coefficient of adhesion of 0.3 ([5]) or less, and of about 0.8 (dry road), with an initial speed of 50 km/h. To eliminate the effects of differential brake temperatures it is recommended that z_{AL} be determined prior to the determination of k.

5.2.3. The test procedure to determine the coefficient of adhesion (k) and the formulae for calculation of the adhesion utilization (ε) shall be those laid down in Appendix 2 to this annex.

5.2.4. The utilization of adhesion by the anti-lock system shall be checked on complete vehicles equipped with anti-lock systems of categories 1 or 2. In the case of vehicles equipped with category 3 anti-lock systems, only the axle(s) with at least one directly controlled wheel shall satisfy this requirement.

5.2.5. The condition $\varepsilon \geq 0.75$ shall be checked with the vehicle both laden and unladen ([6]).

The laden test on the high adhesion surface may be omitted if the prescribed force on the control device does not achieve full cycling of the anti-lock system.

For the unladen test, the control force may be increased up to 100 daN if no cycling is achieved with its full force value ([7]). If 100 daN is insufficient to make the system cycle, then this test may be omitted.

5.3. Additional checks

The following additional checks shall be carried out with the engine disconnected, with the vehicle laden and unladen:

5.3.1. The wheels directly controlled by an anti-lock system shall not lock when the full force ([7]) is suddenly applied on the control device, on the road surfaces specified in paragraph 5.2.2. of this annex, at an initial speed of $v = 40$ km/h and at a high initial speed $v = 0.8\ v_{max} \leq 120$ km/h ([8]);

([6]) Until a uniform test procedure is established, the tests required by this paragraph may have to be repeated for vehicles equipped with electrical regenerative braking systems, in order to determine the effect of different braking distribution values provided by automatic functions on the vehicle.

([7]) "*Full force*" means the maximum force laid down in Annex 3 to this Regulation; a higher force may be used if required to activate the anti-lock system.

([8]) The purpose of these tests is to check that the wheels do not lock and that the vehicle remains stable; it is not necessary, therefore, to make complete stops and bring the vehicle to a halt on the low-adhesion surface.

5.3.2. When an axle passes from a high-adhesion surface (k_H) to a low-adhesion surface (k_L), where $k_H \geq 0.5$ and $k_H / k_L \geq 2$ ([9]), with the full force[7] applied on the control device, the directly controlled wheels shall not lock. The running speed and the instant of applying the brakes shall be so calculated that, with the anti-lock system fully cycling on the high-adhesion surface, the passage from one surface to the other is made at high and at low speed, under the conditions laid down in paragraph 5.3.1. ([8]):

5.3.3. When a vehicle passes from a low-adhesion surface (k_L) to a high-adhesion surface (k_H) where $k_H \geq 0.5$ and $k_H / k_L \geq 2$ ([9]), with the full force[7] applied on the control device, the deceleration of the vehicle shall rise to the appropriate high value within a reasonable time and the vehicle shall not deviate from its initial course. The running speed and the instant of applying the brake shall be so calculated that, with the anti-lock system fully cycling on the low-adhesion surface, the passage from one surface to the other occurs at approximately 50 km/h;

5.3.4. The provisions of this paragraph shall only apply to vehicles equipped with anti-lock systems of categories 1 or 2. When the right and left wheels of the vehicle are situated on surfaces with differing coefficients of adhesion (k_H and k_L), where $k_H \geq 0.5$ and $k_H / k_L \geq 2$ ([9]), the directly controlled wheels shall not lock when the full force[7] is suddenly applied on the control device at a speed of 50 km/h;

5.3.5. Furthermore, laden vehicles equipped with anti-lock systems of category 1 shall, under the conditions of paragraph 5.3.4. of this annex satisfy the prescribed braking rate in Appendix 3 to this annex;

5.3.6. However, in the tests provided in paragraphs 5.3.1., 5.3.2., 5.3.3., 5.3.4. and 5.3.5. of this annex, brief periods of wheel-locking shall be allowed. Furthermore, wheel-locking is permitted when the vehicle speed is less than 15 km/h; likewise, locking of indirectly controlled wheels is permitted at any speed, but stability and steerability shall not be affected and the vehicle shall not exceed a yaw angle of 15° or deviate from a 3.5 m wide lane;

5.3.7. During the tests provided in paragraphs 5.3.4. and 5.3.5. of this annex, steering correction is permitted, if the angular rotation of the steering control is within 120° during the initial 2 seconds, and not more than 240° in all. Furthermore, at the beginning of these tests the longitudinal median plane of the vehicle shall pass over the boundary between the high- and low-adhesion surfaces and during these tests no part of the outer tyres shall cross this boundary ([6]).

([9]) k_H is the high-adhesion surface coefficient.
k_L is the low-adhesion surface coefficient.
k_H and k_L are measured as laid down in Appendix 2 to this annex.

ANNEX 6 – Appendix 1

Symbols and definitions

Symbol	Definitions
E	wheelbase
ε	the adhesion utilized of the vehicle: quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k)
ε_i	the ε - value measured on axle i (in the case of a motor vehicle with a category 3 anti-lock system)
ε_H	the ε - value on the high-adhesion surface
ε_L	the ε - value on the low-adhesion surface
F	force (N)
F_{dyn}	normal reaction of road surface under dynamic conditions with the anti-lock system operative
F_{idyn}	F_{dyn} on axle i in case of power-driven vehicles
F_i	normal reaction of road surface on axle i under static conditions
F_M	total normal static reaction of road surface on all wheels of power-driven vehicle
F_{Mnd} ([1])	total normal static reaction of road surface on the unbraked and non-driven axles of the power-driven vehicle
F_{Md} ([1])	total normal static reaction of road surface on the unbraked and driven axles of the power-driven vehicle
F_{WM} ([1])	$0.01\ F_{Mnd} + 0.015\ F_{Md}$
g	acceleration due to gravity (9.81 m/s^2)
h	height of centre of gravity specified by the manufacturer and agreed by the Technical Service conducting the approval test
k	coefficient of adhesion between tyre and road
k_f	k - factor of one front axle
k_H	k - value determined on the high-adhesion surface
k_i	k - value determined on axle i for a vehicle with a category 3 anti-lock system
k_L	k - value determined on the low-adhesion surface
k_{lock}	value of adhesion for 100 per cent slip
k_M	k - factor of the power-driven vehicle
k_{peak}	maximum value of the curve "adhesion versus slip"
k_r	k - factor of one rear axle
P	mass of individual vehicle (kg)
R	ratio of k_{peak} to k_{lock}
t	time interval (s)
t_m	mean value of t
t_{min}	minimum value of t

([1]) F_{Mnd} and F_{Md} in case of two-axled motor vehicles: these symbols may be simplified to corresponding F_i - symbols.

Symbol	Definitions
z	braking rate
z_{AL}	braking rate z of the vehicle with the anti-lock system operative
z_m	mean braking rate
z_{max}	maximum value of z
z_{MALS}	z_{AL} of the power-driven vehicle on a "split surface"

ANNEX 6 – Appendix 2

Utilisation of adhesion

1. Method of measurement

1.1. Determination of the coefficient of adhesion (k)

1.1.1. The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being brakes.

1.1.2. The brakes shall be applied on only one axle of the vehicle under test, at an initial speed of 50 km/h. The braking forces shall be distributed between the wheels of the axle to reach maximum performance. The anti-lock system shall be disconnected, or inoperative, between 40 km/h and 20 km/h.

1.1.3. A number of tests at increments of line pressure / brake demand value shall be carried out to determine the maximum braking rate of the vehicle (z_{max}). During each test, a constant input force shall be maintained and the braking rate will be determined by reference to the time taken (t) for the speed to reduce from 40 km/h to 20 km/h using the formula:

$$z = \frac{0.566}{t}$$

z_{max} is the maximum value of z; t is in seconds.

1.1.3.1. Wheel lock may occur below 20 km/h.

1.1.3.2. Starting from the minimum measured value of t, called t_{min}, then select three values of t comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m,

$$\text{then calculate: } z_m = \frac{0.566}{t_m}$$

If it is demonstrated that for practical reasons the three values defined above cannot be obtained, then the minimum time t_{min} may be utilized. However, the requirements of paragraph 1.3. shall still apply.

1.1.4. The braking forces shall be calculated from the measured braking rate and the rolling resistance of the unbraked axle which is equal to 0.015 and 0.010 of the static axle load for a driven axle and a non-driven axle, respectively.

1.1.5. The dynamic load on the axle shall be that given by the formulae in Annex 5 to this Regulation.

1.1.6. The value of k shall be rounded to three decimal places.

1.1.7. Then, the test will be repeated for the other axle(s) as defined in paragraphs 1.1.1. to 1.1.6. above.

1.1.8. For example, in the case of a two-axle rear-wheel drive vehicle, with the front axle (1) being braked, the coefficient of adhesion (k) is given by:

$$k_f = \frac{z_m \bullet P \bullet g - 0.015F_2}{F_1 + \frac{h}{E} \bullet z_m \bullet P \bullet g}$$

The other symbols (P, h, E) are defined in Annex 5 to this Regulation.

1.1.9. One coefficient will be determined for the front axle k_f and one for the rear axle k_r.

1.2. Determination of the adhesion utilized (ε)

1.2.1. The adhesion utilized (ε) is defined as the quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k_M) i.e.:

$$\varepsilon = \frac{z_{AL}}{k_M}$$

1.2.2. From an initial vehicle speed of 55 km/h, the maximum braking rate (z_{AL}) shall be measured with full cycling of the anti-lock braking system and based on the average value of three tests, as in paragraph 1.1.3. of this appendix, using the time taken for the speed to reduce from 45 km/h to 15 km/h, according to the following formula:

$$z_{AL} = \frac{0.849}{t_m}$$

1.2.3. The coefficient of adhesion k_M shall be determined by weighting with the dynamic axle loads.

$$k_M = \frac{k_f \bullet F_{fdyn} + k_r \bullet F_{rdyn}}{P \bullet g}$$

where:

$$F_{fdyn} = F_f + \frac{h}{E} \bullet z_{AL} \bullet P \bullet g$$

$$F_{rdyn} = F_r - \frac{h}{E} \bullet z_{AL} \bullet P \bullet g$$

1.2.4. The value of ε shall be rounded to two decimal places.

1.2.5. In the case of a vehicle equipped with an anti-lock system of categories 1 or 2, the value of z_{AL} will be based on the whole vehicle, with the anti-lock system in operation, and the adhesion utilized (ε) is given by the same formula quoted in paragraph 1.2.1. of this appendix.

1.2.6. In the case of a vehicle equipped with an anti-lock system of category 3, the value of z_{AL} will be measured on each axle which has at least one directly controlled wheel. For example, for a two-axle rear-wheel drive vehicle with an anti-lock system acting only on the rear axle (2), the adhesion utilized (ε) is given by:

$$\varepsilon_2 = \frac{z_{AL} \bullet P \bullet g - 0.010 F_1}{k_2 \left(F_2 - \frac{h}{E} \bullet z_{AL} \bullet P \bullet g \right)}$$

This calculation shall be made for each axle having at least one directly controlled wheel.

1.3. If ε > 1.00, the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 per cent is accepted.

ANNEX 6 – Appendix 3

Performance on differing adhesion surfaces

1. The prescribed braking rate referred to in paragraph 5.3.5. of this annex may be calculated by reference to the measured coefficient of adhesion of the two surfaces on which this test is carried out. These two surfaces shall satisfy the conditions prescribed in paragraph 5.3.4. of this annex.

2. The coefficient of adhesion (k_H and k_L) of the high- and low-adhesion surfaces, respectively, shall be determined in accordance with the provisions in paragraph 1.1. of Appendix 2 to this annex.

3. The braking rate (z_{MALS}) for laden vehicles shall be:

$$z_{MALS} \geq 0.75 \left(\frac{4k_L + k_H}{5} \right) \text{ and } z_{MALS} \geq k_L$$

ANNEX 6 – Appendix 4

Method of selection of the low adhesion surface

1. Details of the coefficient of adhesion of the surface selected, as defined in paragraph 5.1.1.2. of this annex, shall be given to the Technical Service.

1.1. These data shall include a curve of the coefficient of adhesion versus slip (from 0 to 100 per cent slip) for a speed of approximately 40 km/h.

1.1.1. The maximum value of the curve will represent k_{peak} and the value at 100 per cent slip will represent k_{lock}.

1.1.2. The ratio R shall be determined as the quotient of the k_{peak} and k_{lock}.

$$R = \frac{k_{peak}}{k_{lock}}$$

1.1.3. The value of R shall be rounded to one decimal place.

1.1.4. The surface to be used shall have a ratio R between 1.0 and 2.0 ([1]).

2. Prior to the tests, the Technical Service shall ensure that the selected surface meets the specified requirements and shall be informed of the following:

Test method to determine R,

Type of vehicle,

Axle load and tyres (different loads and different tyres have to be tested and the results shown to the Technical Service which will decide if they are representative for the vehicle to be approved).

2.1. The value of R shall be mentioned in the test report.

The calibration of the surface has to be carried out at least once a year with a representative vehicle to verify the stability of R.

([1]) Until such test surfaces become generally available, a ratio R up to 2.5 is acceptable, subject to discussion with the Technical Service.

ANNEX 7

Inertia dynamometer test method for brake linings

1. General

1.1. The procedure described in this annex may be applied in the event of a modification of vehicle type resulting from the fitting of brake linings of another type to vehicles which have been approved in accordance with this Regulation.

1.2. The alternative types of brake linings shall be checked by comparing their performance with that obtained from the brake linings with which the vehicle was equipped at the time of approval and conforming to the components identified in the relevant information document, a model of which is given in Annex 1 to this Regulation.

1.3. The Type Approval Authority responsible for conducting approval tests may at its discretion require comparison of the performance of the brake linings to be carried out in accordance with the relevant provisions contained in Annex 3 to this Regulation.

1.4. Application for approval by comparison shall be made by the vehicle manufacturer or by his duly accredited representative.

1.5. In the context of this annex "vehicle" shall mean the vehicle type approved according to this Regulation and for which it is requested that the comparison shall be considered satisfactory.

2. Test equipment

2.1. A dynamometer having the following characteristics shall be used for the tests:

2.1.1. It shall be capable of generating the inertia required by paragraph 3.1. of this annex, and have the capacity to meet the requirements prescribed by paragraph 1.5. of Annex 3 to this Regulation with respect to the Type-I fade test;

2.1.2. The brakes fitted shall be identical with those of the original vehicle type concerned;

2.1.3. Air cooling, if provided, shall be in accordance with paragraph 3.4. of this annex;

2.1.4. The instrumentation for the test shall be capable of providing at least the following data:

2.1.4.1. A continuous recording of disc or drum rotational speed;

2.1.4.2. Number of revolutions completed during a stop, to resolution not greater than one eighth of a revolution;

2.1.4.3. Stop time;

2.1.4.4. A continuous recording of the temperature measured in the centre of the path swept by the lining or at mid-thickness of the disc or drum or lining;

2.1.4.5. A continuous recording of brake application control line pressure or force;

2.1.4.6. A continuous recording of brake output torque.

3. Test conditions

3.1. The dynamometer shall be set as close as possible, with ±5 per cent tolerance, to the rotary inertia equivalent to that part of the total inertia of the vehicle braked by the appropriate wheel(s) according to the following formula:

$$I = M R^2$$

Where:

I = rotational inertia (kgm^2)

R = dynamic tyre rolling radius (m)

M = that part of the maximum mass of the vehicle braked by the appropriate wheel(s). In the case of a single-ended dynamometer, this part shall be calculated from the design braking distribution when deceleration corresponds to the appropriate value given in row (A) of the table under paragraph 2.1.1. of Annex 3 to this Regulation.

3.2. The initial rotational speed of the inertia dynamometer shall correspond to the linear speed of the vehicle as prescribed in row (A) of the table under paragraph 2.1.1. of Annex 3 to this Regulation and shall be based on the dynamic rolling radius of the tyre.

3.3. Brake linings shall be at least 80 per cent bedded and shall not have exceeded a temperature of 180 °C during the bedding procedure, or alternatively, at the vehicle manufacturer's request, be bedded in accordance with his recommendations.

3.4. Cooling air may be used, flowing over the brake in a direction perpendicular to its axis of rotation. The velocity of the cooling air flowing over the brake shall be not greater than 10 km/h. The temperature of the cooling air shall be the ambient temperature.

4. Test procedure

4.1. Five sample sets of the brake lining shall be subjected to the comparison test; they shall be compared with five sets of linings conforming to the original components identified in the information document concerning the first approval of the vehicle type concerned.

4.2. Brake lining equivalence shall be based on a comparison of the results achieved using the test procedures prescribed in this annex and in accordance with the following requirements.

4.3. Type-O cold performance test

4.3.1. Three brake applications shall be made when the initial temperature is below 100 °C. The temperature shall be measured in accordance with the provisions of paragraph 2.1.4.4. of this annex.

4.3.2. Brake applications shall be made from an initial rotational speed equivalent to that given in row (A) of the table under paragraph 2.1.1. of Annex 3 to this Regulation, and the brake shall be applied to achieve a mean torque equivalent to the deceleration prescribed in that paragraph. In addition, tests shall also be carried out at several rotational speeds, the lowest being equivalent to 30 per cent of the maximum speed of the vehicle and the highest being equivalent to 80 per cent of that speed.

4.3.3. The mean braking torque recorded during the above cold performance tests on the linings being tested for the purpose of comparison shall, for the same input measurement, be within the test limits ±15 per cent of the mean braking torque recorded with the brake linings conforming to the component identified in the relevant application for vehicle type approval.

4.4. Type-I test (fade test)

4.4.1. Heating procedure

4.4.1.1. Brake linings shall be tested according to the procedure given in paragraph 1.5.1. of Annex 3 to this Regulation.

4.4.2. Hot performance

4.4.2.1. On completion of the tests required under paragraph 4.4.1. of this annex, the hot braking performance test specified in paragraph 1.5.2. of Annex 3 to this Regulation shall be carried out.

4.4.2.2. The mean braking torque recorded during the above hot performance tests on the linings being tested for the purpose of comparison shall, for the same input measurement, be within the test limits ±15 per cent of the mean braking torque recorded with the brake linings conforming to the component identified in the relevant application for vehicle type approval.

5. Inspection of brake linings

Brake linings shall be visually inspected on completion of the above tests to check that they are in satisfactory condition for continued use in normal service.

ANNEX 8

Special requirements to be applied to the safety aspects of electronic control systems

1. General

This annex defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of Electronic System(s) (paragraph 2.3.) and complex electronic control systems (paragraph 2.4. below) as far as this Regulation is concerned.

This annex does not specify the performance criteria for "the system" but covers the methodology applied to the design process and the information which shall be disclosed to the Technical Service, for type approval purposes.

This information shall show that "the system" respects, under non-fault and fault conditions, all the appropriate performance requirements specified elsewhere in this Regulation.

2. Definitions

For the purposes of this annex:

2.1. "*The System*" means an electronic control system or complex electronic control system that provides or forms part of the control transmission of a function to which this Regulation applies. This also includes any other system covered in the scope of this Regulation, as well as transmission links to or from other systems that are outside the scope of this Regulation, that acts on a function to which this Regulation applies.

2.2. "*Safety concept*" is a description of the measures designed into the system, for example within the electronic units, so as to address system integrity and thereby ensure safe operation under fault and non-fault conditions, including in the event of an electrical failure.

The possibility of a fall-back to partial operation or even to a back-up system for vital vehicle functions may be a part of the safety concept.

2.3. "*Electronic control system*" means a combination of units, designed to co-operate in the production of the stated vehicle control function by electronic data processing.

Such systems, commonly controlled by software, are built from discrete functional components such as sensors, electronic control units and actuators and connected by transmission links. They may include mechanical, electro-mechanical, electro-pneumatic or electro-hydraulic elements.

"*The system*", referred to herein, is the one for which type approval is being sought.

2.4. "*Complex electronic control systems*" are those electronic control systems in which a function may be over-ridden by a higher-level electronic control system/function.

A function which is over-ridden becomes part of the complex electronic control system, as well as any overriding system/function within the scope of this Regulation. The transmission links to and from overriding systems/function outside of the scope of this Regulation shall also be included.

2.5. "*Higher-level control*" systems/functions are those which employ additional processing and/or sensing provisions to modify vehicle behaviour by commanding variations in the normal function(s) of the vehicle control system.

This allows complex systems to automatically change their objectives with a priority which depends on the sensed circumstances.

2.6. "*Units*" are the smallest divisions of system components which will be considered in this annex, since these combinations of components will be treated as single entities for purposes of identification, analysis or replacement.

2.7. "*Transmission links*" are the means used for inter-connecting distributed units for the purpose of conveying signals, operating data or an energy supply.

This equipment is generally electrical but may, in some part, be optical, pneumatic, hydraulic or mechanical.

2.8. "*Range of control*" refers to an output variable and defines the range over which the system is likely to exercise control.

2.9. "*Boundary of functional operation*" defines the boundaries of the external physical limits within which the system is able to maintain control.

2.10. "*Control strategy*" means a strategy to ensure robust and safe operation of the function(s) of "The System" in response to the input from the vehicle or the driver.

This may include the automatic deactivation of a function or temporary performance restrictions.

3. Documentation

3.1. Requirements

The manufacturer shall provide a documentation package which gives access to the basic design of "the system" and the means by which it is linked to other vehicle systems or by which it directly controls output variables.

The function(s) of "the system", including the control strategies, and the safety concept, as laid down by the manufacturer, shall be explained.

Documentation shall be brief yet provide evidence that the design and development has had the benefit of expertise from all the system fields which are involved.

For periodic technical inspections, the documentation shall describe how the current operational status of "the system" can be checked.

The Technical Service shall assess the documentation package, as specified in paragraph 3.4., to show that "The System":

(a) Is designed to operate, under fault conditions, in such a way that it does not induce safety critical risks,

(b) Implements strategies which do not, under non-fault conditions, prejudice the safe operation of systems which are subject to the prescriptions of this Regulation; and

(c) Respects, under non-fault and fault conditions, all the appropriate performance requirements specified elsewhere in this Regulation; and

(d) Was developed according to the development process/method chosen by the manufacturer according to paragraph 3.4.4.

3.1.1. Documentation shall be made available in two parts:

(a) The formal documentation package for the approval, containing the material listed in paragraph 3. (with the exception of that of paragraph 3.4.4. below) which shall be supplied to the Technical Service at the time of submission of the type-approval application. This documentation package shall be used by the Technical Service as the basic reference for the verification process set out in paragraph 4. of this annex. The Technical Service shall ensure that this documentation package remains available for a period determined in agreement with the Approval Authority. This period shall be at least 10 years counted from the time when production of the vehicle is definitely discontinued.

(b) Additional confidential material and analysis data (intellectual property) of paragraph 3.4.4., which shall be retained by the manufacturer, but made open for inspection (e.g., on-site in the engineering facilities of the manufacturer) at the time of type approval. The manufacturer shall ensure that this material and analysis data remains available for a period of 10 years counted from the time when production of the vehicle is definitely discontinued.

3.2. Description of the functions of "the system", including control strategies.

A description shall be provided which gives a simple explanation of all the functions, including control strategies, of "the system" and the methods employed to achieve the objectives, including a statement of the mechanism(s) by which control is exercised.

Any described function that can be over-ridden shall be identified and a further description of the changed rationale of the function's operation provided.

3.2.1. A list of all input and sensed variables shall be provided and the working range of these defined, along with a description of how each variable affects system behaviour.

3.2.2. A list of all output variables which are controlled by "the system" shall be provided and an explanation given, in each case, of whether the control is direct or via another vehicle system. The range of control (paragraph 2.8.) exercised on each such variable shall be defined.

3.2.3. Limits defining the boundaries of functional operation (paragraph 2.9. above) shall be stated where appropriate to system performance.

3.3. System layout and schematics

3.3.1. Inventory of components

A list shall be provided, collating all the units of "the system" and mentioning the other vehicle systems which are needed to achieve the control function in question.

An outline schematic showing these units in combination shall be provided with both the equipment distribution and the interconnections made clear.

3.3.2. Functions of the units

The function of each unit of "the system" shall be outlined and the signals linking it with other units or with other vehicle systems shall be shown. This may be provided by a labelled block diagram or other schematic, or by a description aided by such a diagram.

3.3.3. Interconnections

Interconnections within "the system" shall be shown by a circuit diagram for the electrical transmission links, by an optical-fibre diagram for optical links, by a piping diagram for pneumatic or hydraulic transmission equipment and by a simplified diagrammatic layout for mechanical linkages. The transmission links both to and from other systems shall also be shown.

3.3.4. Signal flow and priorities

There shall be a clear correspondence between these transmission links and the signals carried between units.

Priorities of signals on multiplexed data paths shall be stated, wherever priority may be an issue affecting performance or safety as far as this Regulation is concerned.

3.3.5. Identification of units

Each unit shall be clearly and unambiguously identifiable (e.g. by marking for hardware and marking or software output for software content) to provide corresponding hardware and documentation association.

Where functions are combined within a single unit or indeed within a single computer, but shown in multiple blocks in the block diagram for clarity and ease of explanation, only a single hardware identification marking shall be used.

The manufacturer shall, by the use of this identification, affirm that the equipment supplied conforms to the corresponding document.

3.3.5.1. The identification defines the hardware and software version and, where the latter changes such as to alter the function of the unit as far as this Regulation is concerned, this identification shall also be changed.

3.4. Safety concept of the manufacturer

3.4.1. The manufacturer shall provide a statement which affirms that the strategy chosen to achieve "the system" objectives will not, under non-fault conditions, prejudice the safe operation of systems which are subject to the prescriptions of this Regulation.

The vehicle manufacturer shall supplement this statement by an explanation showing in overall terms how the chosen strategy ensures that "The System" objectives do not prejudice the safe operation of the systems referred above, and by a description of the part of the validation plan supporting the statement.

The Technical Service shall perform an assessment to establish that the vehicle manufacturer's explanation of the chosen strategy is understandable, logical and that the validation plan is suitable and has been completed.

The Technical Service may perform tests, or may require tests to be performed, as specified in paragraph 4. below, to verify that "the system" operates as per the chosen strategy.

3.4.2. In respect of software employed in "the system", the outline architecture shall be explained and the design methods and tools used shall be identified. The manufacturer shall show evidence of the means by which they determined the realisation of the system logic, during the design and development process.

3.4.3. The manufacturer shall provide the technical authorities with an explanation of the design provisions built into "the system" so as to generate safe operation under fault conditions. Possible design provisions for failure in "the system" are for example:

(a) Fall-back to operation using a partial system;

(b) Change-over to a separate back-up system;

(c) Removal of the high-level function.

In case of a failure, the driver shall be warned for example by warning signal or message display. When the system is not deactivated by the driver, e.g. by turning the ignition (run) switch to "off", or by switching off that particular function if a special switch is provided for that purpose, the warning shall be present as long as the fault condition persists.

3.4.3.1. If the chosen provision selects a partial performance mode of operation under certain fault conditions, then these conditions shall be stated and the resulting limits of effectiveness defined.

3.4.3.2. If the chosen provision selects a second (back-up) means to realise the vehicle control system objective, the principles of the change-over mechanism, the logic and level of redundancy and any built-in back-up checking features shall be explained and the resulting limits of back-up effectiveness defined.

3.4.3.3. If the chosen provision selects the removal of the Higher-Level Function, all the corresponding output control signals associated with this function shall be inhibited, and in such a manner as to limit the transition disturbance.

3.4.4. The documentation shall be supported, by an analysis which shows, in overall terms, how the system will behave on the occurrence of any fault identified by the procedure below which will have a bearing on vehicle control, performance, or safety.

The analytical approach(es), chosen by the manufacturer, shall be established and maintained by the manufacturer and shall be made open for inspection by the Technical Service at the time of the type-approval.

The Technical Service shall perform an assessment of the application of the analytical approach(es). The assessment shall include:

(a) Inspection of the safety approach at the concept (vehicle) level with confirmation that it includes consideration of interactions with other vehicle systems. This approach may be based on a Hazard / Risk analysis appropriate to system safety.

(b) Inspection of the safety approach at the system level. This approach may be based on a Failure Mode and Effect Analysis (FMEA), a Fault Tree Analysis (FTA) or any similar process appropriate to system safety.

(c) Inspection of the validation plans and results. This validation may use, for example, Hardware in the Loop (HIL) testing, vehicle on–road operational testing, or any means appropriate for validation.

The assessment shall consist of checks of hazards and faults chosen by the Technical Service to establish that the manufacturer's explanation of the safety concept is understandable, logical and that the validation plan is suitable and has been completed.

The Technical Service may perform tests, or may require tests to be performed, as specified in paragraph 4. below, to verify the safety concept.

3.4.4.1. This documentation shall itemize the parameters being monitored and shall set out, for each fault condition of the type defined in paragraph 3.4.4. above, the warning signal to be given to the driver and/or to service/technical inspection personnel.

3.4.4.2. Where this Regulation contains particular requirements for the operation of "The System" under different environmental conditions, this documentation shall describe the measures in place to ensure compliance with those requirements.

4. Verification and test

4.1. The functional operation of "the system", as laid out in the documents required in paragraph 3. above, shall be tested as follows:

4.1.1. Verification of the function of "the system"

The Technical Service shall verify "The System" under non-fault conditions by testing a number of selected functions from those described by the manufacturer in paragraph 3.2. above.

The verification of the performance of those selected functions shall be conducted following the manufacturer's test procedures unless a test procedure is specified in this Regulation.

For cases where the braking system is subject to input signal(s) from systems outside the scope of this Regulation, the test shall be conducted using the test procedure of the relevant UN regulation, or by another means that generates the relevant input signal(s) (e.g. simulation).

For complex electronic systems, these tests shall include scenarios whereby a declared function is overridden.

4.1.1.1. The verification results shall correspond with the description, including the control strategies, provided by the manufacturer in paragraph 3.2.

4.1.2. Verification of the safety concept of paragraph 3.4. above

The reaction of "the system" shall be checked under the influence of a failure in any individual unit by applying corresponding output signals to electrical units or mechanical elements in order to simulate the effects of internal faults within the unit.

The Technical Service shall conduct this check for at least one individual unit but shall not check the reaction of "The System" to multiple simultaneous failures of individual units.

The Technical Service shall verify that these tests include aspects that may have an impact on vehicle controllability and user information (HMI aspects).

4.1.2.1. The verification results shall correspond with the documented summary of the failure analysis, to a level of overall effect such that the safety concept and execution are confirmed as being adequate.

4.2. Simulation tools and mathematical models for verification of the safety concept may be used in accordance with Schedule 8 of Revision 3 of the 1958 Agreement, in particular for scenarios that are difficult on a test track or in real driving conditions. Manufacturers shall demonstrate the scope of the simulation tool, its validity for the scenario concerned as well as the validation performed for the simulation tool chain (correlation of the outcome with physical tests).

5. Reporting by Technical Service

Reporting of the assessment by the Technical Service shall be performed in such a manner that allows traceability, e.g., versions of documents inspected are coded and listed in the records of the Technical Service.

An example of a possible layout for the assessment form from the Technical Service to the Type Approval Authority is given in Appendix 1 to this Annex.

ANNEX 8 – Appendix

Model assessment form for electronic, and/or complex electronic, control systems

Test report No: .....

1. Identification

1.1. Vehicle make: .....

1.2. Type: .....

1.3. Means of identification of type if marked on the vehicle: .....

1.4. Location of that marking: .....

1.5. Manufacturer's name and address: .....

1.6. If applicable, name and address of manufacturer's representative: .....

1.7. Manufacturer's formal documentation package:

Documentation reference No: .....

Date of original issue: .....

Date of latest update: .....

2. Test vehicle(s)/system(s) description

2.1. General description: .....

2.2. Description of the functions of "The System", including control strategies (Annex 8, paragraph 3.2.): .....

2.2.1. List of input and sensed variables and their working range including a description the effect of the variable on system behaviour (Annex 8, paragraph 3.2.1.): .....

2.2.2. List of output variables and their range of control (Annex 8, paragraph 3.2.2.): .....

2.2.2.1. Directly controlled: .....

2.2.2.2. Controlled via other vehicle systems: .....

2.2.3. Boundaries of functional operation (Annex 8, paragraph 3.2.3.): .....

2.3. Description System layout and schematics

(Annex 8, paragraph 3.3.): .....

2.3.1. Inventory of components (Annex 8, paragraph 3.3.1.): .....

2.3.2. Functions of the units (Annex 8, paragraph 3.3.2.): .....

2.3.3. Interconnections (Annex 8, paragraph 3.3.3.): .....

2.3.4. Signal flow and priorities (Annex 8, paragraph 3.3.4.): .....

2.3.5. Identification of units (hardware & software) (Annex 8, paragraph 3.3.5.): .....

3. Manufacturer's safety concept.

3.1. Manufacturer's declaration (Annex 8, paragraph 3.4.1.):

The manufacturer(s) ..... affirm(s) that the strategy chosen to achieve "The System", objectives will not, under non-fault conditions, prejudice the safe operation of the vehicle.

3.2. Software (outline architecture, software design methods and tools used) (Annex 8, paragraph 3.4.2.): .....

3.3. Explanation of design provisions built into "The System" under fault conditions (Annex 8, paragraph 3.4.3.): .....

3.4. Documented analyses of the behaviour of "The System" under individual fault conditions (Annex 8, paragraph 3.4.4.1.): .....

3.4.1. Parameters monitored: .....

3.4.2. Warning signals generated: .....

3.5. Description of the measures in place for environmental conditions (Annex 8, paragraph 3.4.4.2.): .....

3.6. Provisions for the periodic technical inspection of "The System" (Annex 8, paragraph 3.1.).

Description of the method by which the operational status of the system can be checked: .....

4. Verification and test.

4.1. Verification of the function of "The System" (Annex 8, paragraph 4.1.1.): .....

4.1.1. List of the selected functions and a description of the test procedures used: .....

4.1.2. Test results verified according to Annex 8, paragraph 4.1.1.1. Yes/No.

4.2. Verification of the system safety concept (Annex 8, paragraph 4.1.2.): .....

4.2.1. Unit(s) tested and their function: .....

4.2.2. Simulated fault(s): .....

4.2.3. Test results verified according to Annex 8, paragraph 4.1.2. Yes/No.

4.3. Date of test: .....

4.4. This test has been carried out and the results reported in accordance with Annex 8 to UN Regulation No 13 as last amended by the… series of amendments.

Technical Service carrying out the test:

Signed: ..... Date: .....

4.5. Comments: