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**Regulations Nos. 13 and 13-H (Braking) –
Electronic Stability Control (ESC)**

Proposal for a new Regulation on Electronic Stability Control (ESC)

**Submitted by the experts from the European Association of Automotive
Suppliers and the International Organization of Motor Vehicle
Manufacturers ***

The text reproduced below was prepared by the experts from the European Association of Automotive Suppliers (CLEPA) and the International Organization of Motor Vehicle Manufacturers (OICA).

* In accordance with the programme of work of the Inland Transport Committee for 2010–2014 (ECE/TRANS/208, para. 106, ECE/TRANS/2010/8, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.



I. Proposal

Regulation No. XX

Uniform provisions concerning the approval of passenger cars with regard to electronic stability control systems

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1. Scope

- 1.1. This Regulation applies to the approval of vehicles of category M₁ and N₁¹ with regard to their electronic stability control system.
- 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.

2. Definitions

For the purposes of this Regulation,

- 2.1. "*Approval of a vehicle*" means the approval of a vehicle type with regard to electronic stability control.
- 2.2. "*Vehicle type*" means a category of vehicles which do not differ in such essential respects as:
 - 2.2.1. The manufacturer's trade name or mark;
 - 2.2.2. Vehicle features which significantly influence the performances of the Electronic Stability Control system;
 - 2.2.3. The type and design of the Electronic Stability Control system.
- 2.3. "*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).
- 2.4. "*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.
- 2.5. "*Wheel/axle load*" means the vertical static reaction (force) of the road surface in the contact area on the wheel/wheels of the axle.
- 2.6. "*Ackerman steer angle*" means the angle whose tangent is the wheelbase divided by the radius of the turn at a very low speed.
- 2.7. "*Electronic Stability Control System*" or "*ESC System*" means a system that has all of the following attributes:
 - 2.8.1. That improves vehicle directional stability by at least having the ability to automatically control individually the braking torques of the left and right wheels on each axle² to induce a correcting yaw moment based on the evaluation of actual vehicle behaviour in comparison with a determination of vehicle behaviour demanded by the driver;
 - 2.8.2. That is computer controlled with the computer using a closed-loop algorithm to limit vehicle oversteer and to limit vehicle understeer based on the

¹ M₁ and N₁ categories of vehicles are defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3.), document ECE/TRANS/WP.29/78/Rev.2, para. 2.

² An axle group shall be treated as a single axle and dual wheels shall be treated as a single wheel.

- evaluation of actual vehicle behaviour in comparison with a determination of vehicle behaviour demanded by the driver;
- 2.8.3. That has a means to determine directly the value of the vehicle's yaw rate and to estimate its side-slip or side-slip derivative with respect to time;
- 2.8.4. That has a means to monitor driver steering inputs; and
- 2.8.5. That has an algorithm to determine the need, and a means to modify propulsion torque, as necessary, to assist the driver in maintaining control of the vehicle.
- 2.9. "*Lateral acceleration*" means the component of the acceleration vector of a point in the vehicle perpendicular to the vehicle x axis (longitudinal) and parallel to the road plane.
- 2.10. "*Oversteer*" means a condition in which the vehicle's yaw rate is greater than the yaw rate that would occur at the vehicle's speed as a result of the Ackerman steer angle.
- 2.11. "*Side-slip or side-slip angle*" means the arctangent of the ratio of the lateral velocity to the longitudinal velocity of the centre of gravity of the vehicle.
- 2.12. "*Understeer*" means a condition in which the vehicle's yaw rate is less than the yaw rate that would occur at the vehicle's speed as a result of the Ackerman steer angle.
- 2.13. "*Yaw rate*" means the rate of change of the vehicle's heading angle measured in degrees/second of rotation about a vertical axis through the vehicle's centre of gravity.
- 2.14. "*Peak braking coefficient (PBC)*": means the measure of tyre to road surface friction based on the maximum deceleration of a rolling tyre.
- 2.15. "*Common space*" means an area on which more than one tell-tale, indicator, identification symbol, or other message may be displayed but not simultaneously.
- 2.16. "*Static stability factor*" means one-half the track width of a vehicle divided by the height of its center of gravity, also expressed as $SSF = T/2H$, where: T = track width (for vehicles with more than one track width the average is used; for axles with dual wheels, the outer wheels are used when calculating "T") and H = height of the center of gravity of the vehicle.

3. Application for approval

- 3.1. The application for approval of a vehicle type with regard to ESC 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 ESC system;

- 3.2.3. A diagram of the assembled ESC system 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., 6. and 7. 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~~ ESC system, 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 x 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 approval³, 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.

³ The distinguish numbers of the Contracting Parties to the 1958 Agreement are reproduced in Annex 3 to Consolidated Resolution on the Construction of Vehicles (R.E.3), ECE/TRANS/WP.29/78/Rev.2.

- 4.8. Annex 1 to this Regulation gives examples of arrangements of approval marks.

5. General requirements

- 5.1. Vehicles equipped with an ESC shall meet the functional requirements specified in paragraph 6. and the performance requirements in paragraph 7. under the test procedures specified in paragraph 9. and under the test conditions specified in paragraph 8. of this Regulation.
- 5.1.1. As an alternative to the requirements of paragraph 5.1., vehicles of categories M1 and N1 with a mass in running order of more than 1,735 kg may be equipped with a vehicle stability function which includes roll-over control and directional control and meets the technical requirements and transitional provisions of Regulation No. 13, Annex 21. [These vehicles do not need to meet the functional requirements specified in paragraph 6. and the performance requirements specified in paragraph 7. under the test procedures specified in paragraph 9. and under the test conditions specified in paragraph 8. of this Regulation.]
- 5.2. The ESC 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.
- 5.3. In particular, the ESC shall be so designed, constructed and fitted as to be able to resist the corroding and ageing phenomena to which it is exposed.
- 5.4. The effectiveness of the ESC shall not be adversely affected by magnetic or electrical fields. This shall be demonstrated by fulfilling the technical requirements and transitional provisions of Regulation No. 10 by applying:
- the 03 series of amendments for vehicles without a coupling system for charging the REESS (traction batteries).
 - the 04 series of amendments for vehicles with a coupling system for charging the REESS (traction batteries).
- [5.5. The requirements of Annex 6 shall be applied to the safety aspects of the ESC system.]
- 5.6. Provisions for the periodic technical inspection of ESC systems
- 5.6.1. 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.
- 5.6.2. At the time of type approval, the means implemented to protect against simple unauthorized modification of the operation of the warning signals shall be confidentially outlined. Alternatively, this protection requirement is fulfilled when a secondary means of checking the correct operational status is available.

6. Functional requirements

Each vehicle submitted for approval pursuant to this Regulation shall be equipped with an electronic stability control system that:

- 6.1. Is capable of applying braking torques individually to all four wheels⁴ and has a control algorithm that utilizes this capability;
- 6.2. Is operational over the full speed range of the vehicle, during all phases of driving including acceleration, coasting, and deceleration (including braking), except:
 - 6.2.1. When the driver has disabled ESC;
 - 6.2.2. When the vehicle speed is below 20 km/h;
 - 6.2.3. While the initial start-up self test and plausibility checks are completed, not to exceed 2 minutes when driven under the conditions of paragraph 9.10.2.;
 - 6.2.4. When the vehicle is being driven in reverse.
- 6.3. Remains capable of activation even if the antilock braking system or traction control system is also activated.

7. Performance requirements

During each test performed under the test conditions of paragraph 8. and the test procedure of paragraph 9.9., the vehicle with the ESC system engaged shall satisfy the directional stability criteria of paragraphs 7.1. and 7.2., and it shall satisfy the responsiveness criterion of paragraph 7.3. during each of those tests conducted with a commanded steering wheel⁵ angle of 5A or greater but limited as per paragraph 9.9.4., where A is the steering wheel angle computed in paragraph 9.6.1.

Where a vehicle has been physically tested in accordance with paragraph 8., the compliance of versions or variants of that same vehicle type may be demonstrated by a computer simulation, which respects the test conditions of paragraph 8. and the test procedure of paragraph 9.9. The use of the simulator is defined in Annex 1 to this Regulation.

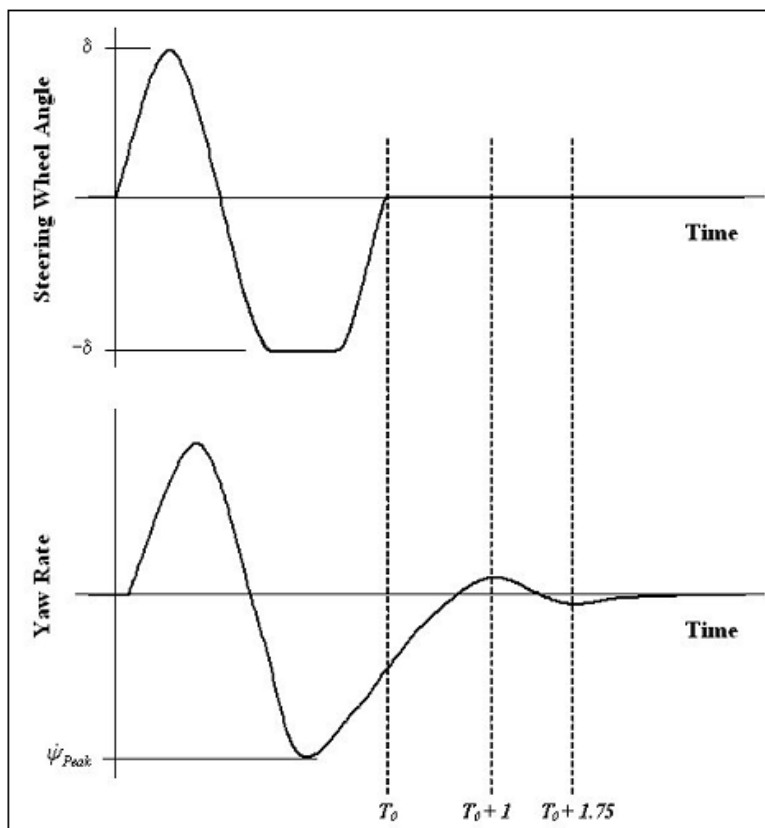
- 7.1. The yaw rate measured 1 second after completion of the Sine with Dwell steering input (time $T_0 + 1$ in Figure 1) shall not exceed 35 per cent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) ($\dot{\psi}_{Peak}$ in Figure 1) during the same test run.

⁴ An axle group shall be treated as a single axle and dual wheels shall be treated as a single wheel.

⁵ The text in this Regulation assumes that the vehicle steering is controlled by means of a steering wheel. Vehicles using other types of steering control may also be approved to this annex provided the manufacturer is able to demonstrate to the technical service that the performance requirements of this Regulation can be met using equivalent steering inputs to the steering inputs stipulated under paragraph 7. of this Regulation.

Figure 1

Steering wheel position and yaw velocity information used to assess lateral stability



- 7.2. The yaw rate measured 1.75 seconds after completion of the Sine with Dwell steering input shall not exceed 20 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) during the same test run.
- 7.3. The lateral displacement of the vehicle centre of gravity with respect to its initial straight path shall be at least 1.83 m for vehicles with a GVM of 3,500 kg or less, and 1.52 m for vehicles with a maximum mass greater than 3,500 kg when computed 1.07 seconds after the Beginning of Steer (BOS). BOS is defined in paragraph 9.11.6.
- 7.3.1. The computation of lateral displacement is performed using double integration with respect to time of the measurement of lateral acceleration at the vehicle centre of gravity, as expressed by the formula:

$$\text{Lateral Displacement} = \iint a_{y_{C.G.}} dt$$

An alternative measuring method may be allowed for type approval testing, provided it demonstrates at least an equivalent level of precision as the double integration method.

- 7.3.2. Time $t = 0$ for the integration operation is the instant of steering initiation, known as the Beginning of Steer (BOS). BOS is defined in paragraph 9.11.6.
- 7.4. ESC malfunction detection

The vehicle shall be equipped with a tell-tale that provides a warning to the driver of the occurrence of any malfunction that affects the generation or transmission of control or response signals in the vehicle's electronic stability control system.

- 7.4.1. The ESC malfunction tell-tale:
 - 7.4.1.1. Shall fulfil the relevant technical requirements of Regulation No. 121;
 - 7.4.1.2. Except as provided in paragraph 7.4.1.3., the ESC malfunction tell-tale shall illuminate when a malfunction exists and shall remain continuously illuminated under the conditions specified in paragraph 7.4. for as long as the malfunction exists, whenever the ignition locking system is in the "On" ("Run") position;
 - 7.4.1.3. Except as provided in paragraph 7.4.2., each ESC malfunction tell-tale shall be activated as a check of lamp function either when the ignition locking system is turned to the "On" ("Run") position when the engine is not running, or when the ignition locking system is in a position between "On" ("Run") and "Start" that is designated by the manufacturer as a check position;
 - 7.4.1.4. Shall extinguish at the next ignition cycle after the malfunction has been corrected in accordance with paragraph 9.10.4.;
 - 7.4.1.5. May also be used to indicate the malfunction of related systems/functions, including traction control, trailer stability assist, corner brake control, and other similar functions that use throttle and/or individual torque control to operate and share common components with ESC.
- 7.4.2. The ESC malfunction tell-tale need not be activated when a starter interlock is in operation.
- 7.4.3. The requirement of paragraph 7.4.1.3. does not apply to tell-tales shown in a common space.
- 7.4.4. The manufacturer may use the ESC malfunction tell-tale in a flashing mode to indicate ESC intervention and/or the intervention of ESC-related systems (as listed in paragraph 7.4.1.5.)
- 7.5. ESC Off and other system controls

The manufacturer may include an "ESC Off" control, which shall be illuminated when the vehicle's headlamps are activated, and which has a purpose to place the ESC system in a mode in which it will no longer satisfy the performance requirements of paragraphs 7., 7.1., 7.2. and 7.3. Manufacturers may also provide controls for other systems that have an ancillary effect upon ESC operation. Controls of either kind that place the ESC system in a mode in which it may no longer satisfy the performance requirements of paragraphs 7., 7.1., 7.2. and 7.3.. are permitted, provided that the system also meets the requirements of paragraphs 7.5.1., 7.5.2. and 7.5.3.

 - 7.5.1. The vehicle's ESC system shall always return to the manufacturer's original default mode that satisfies the requirements of paragraphs 6. and 7. at the initiation of each new ignition cycle, regardless of what mode the driver had previously selected. However, the vehicle's ESC system need not return to a mode that satisfies the requirements of paragraphs 7. through 7.3. at the initiation of each new ignition cycle if:
 - 7.5.1.1. The vehicle is in a four-wheel drive configuration which has the effect of locking the drive gears at the front and rear axles together and providing an additional

- gear reduction between the engine speed and vehicle speed of at least 1.6, selected by the driver for low-speed, off-road driving; or
- 7.5.1.2. The vehicle is in a four-wheel drive configuration selected by the driver that is designed for operation at higher speeds on snow-, sand-, or dirt-packed roads and that has the effect of locking the drive gears at the front and rear axles together, provided that in this mode the vehicle meets the stability performance requirements of paragraphs 7.1. and 7.2. under the test conditions specified in paragraph 8. However, if the system has more than one ESC mode that satisfies the requirements of paragraphs 7.1. and 7.2. within the drive configuration selected for the previous ignition cycle, the ESC shall return to the manufacturer's original default ESC mode for that drive configuration at the initiation of each new ignition cycle.
- 7.5.2. A control, whose only purpose is to place the ESC system in a mode in which it will no longer satisfy the performance requirements of paragraphs 7., 7.1., 7.2. and 7.3., shall fulfil the relevant technical requirements of Regulation No. 121.
- 7.5.3. A control for an ESC system whose purpose is to place the ESC system in different modes, at least one of which may no longer satisfy the performance requirements of paragraphs 7., 7.1., 7.2., and 7.3., shall fulfil the relevant technical requirements of Regulation No. 121.
- Alternatively, in the case where the ESC system mode is controlled by a multi-functional control, the driver display shall identify clearly to the driver the control position for this mode using the "off" symbol for electronic stability control system as defined in Regulation No. 121.
- 7.5.4. A control for another system that has the ancillary effect of placing the ESC system in a mode in which it no longer satisfies the performance requirements of paragraphs 7., 7.1., 7.2. and 7.3. need not be identified by the "ESC Off" symbol of paragraph 7.5.2.
- 7.6. ESC Off tell-tale
- If the manufacturer elects to install a control to turn off or reduce the performance of the ESC system under paragraph 7.5., the tell-tale requirements of paragraphs 7.6.1. to 7.6.4. shall be met in order to alert the driver to the inhibited or reduced state of ESC system functionality. This requirement does not apply for the driver-selected mode referred to in paragraph 7.5.1.2.
- 7.6.1. The vehicle manufacturer shall provide a tell-tale indicating that the vehicle has been put into a mode that renders it unable to satisfy the requirements of paragraphs 7., 7.1., 7.2. and 7.3., if such a mode is provided.
- 7.6.2. The "ESC Off" tell-tale:
- 7.6.2.1. Shall fulfil the relevant technical requirements of Regulation No. 121.
- 7.6.2.2. Shall remain continuously illuminated for as long as the ESC is in a mode that renders it unable to satisfy the requirements of paragraphs 7., 7.1., 7.2. and 7.3;
- 7.6.2.3. Except as provided in paragraphs 7.6.3. and 7.6.4. each "ESC Off" tell-tale shall be activated as a check of lamp function either when the ignition locking system is turned to the "On" ("Run") position when the engine is not running, or when the ignition locking system is in a position between "On" ("Run") and "Start" that is designated by the manufacturer as a check position.
- 7.6.2.4. Shall extinguish after the ESC system has been returned to the manufacturer's original default mode.

- 7.6.3. The "ESC Off" tell-tale need not be activated when a starter interlock is in operation.
- 7.6.4. The requirement of paragraph 7.6.2.3. of this section does not apply to tell-tales shown in a common space.
- 7.6.5. The manufacturer may use the "ESC Off" tell-tale to indicate an ESC level of function other than the manufacturer's original default mode even if the vehicle would meet paragraphs 7., 7.1., 7.2. and 7.3. of this section at that level of ESC function.
- 7.7. ESC system technical documentation

[Further to the requirements defined in Annex 6 to this Regulation] the documentation package shall, as confirmation that the vehicle is equipped with an ESC system that meets the definition of an "ESC System" as in paragraph 2.7. to this Regulation, include the vehicle manufacturer's documentation as specified in paragraphs 7.7.1. to 7.7.4. below.
- 7.7.1. System diagram identifying all ESC system hardware. The diagram shall identify those components that are used to generate brake torques at each wheel, determine vehicle yaw rate, estimated side-slip or the side-slip derivative and driver steering inputs.
- 7.7.2. A brief written explanation sufficient to describe the ESC system's basic operational characteristics. This explanation shall include the outline description of the system's capability to apply braking torques at each wheel and how the system modifies propulsion torque during ESC system activation, and show that the vehicle yaw rate is directly determined even under the conditions where no wheel speed information is available. The explanation shall also specify the vehicle speed range and the driving phases (acceleration, deceleration, coasting, during activation of the ABS or traction control) under which the ESC system can activate.
- 7.7.3. Logic diagram. This diagram supports the explanation provided under paragraph 7.7.2.
- 7.7.4. Understeer information. An outline description of the pertinent inputs to the computer that control ESC system hardware and how they are used to limit vehicle understeer.

8. Test conditions

- 8.1. Ambient conditions
 - 8.1.1. The ambient temperature is between 0 °C and 45 °C.
 - 8.1.2. The maximum wind speed is no greater than 10 m/s for vehicles with $SSF > 1.25$, and 5 m/s for vehicles with $SSF \leq 1.25$.
- 8.2. Road test surface
 - 8.2.1. Tests are conducted on a dry, uniform, solid-paved surface. Surfaces with irregularities and undulations, such as dips and large cracks, are unsuitable.

- 8.2.2. The road test surface has a nominal⁶ peak braking coefficient (PBC) of 0.9, unless otherwise specified, when measured using either:
 - 8.2.2.1. The American Society for Testing and Materials (ASTM) E1136 standard reference test tyre, in accordance with ASTM Method E1337-90, at a speed of 40 mph; or
 - 8.2.2.2. The k-test method specified in Annex 7 of this Regulation.
- 8.2.3. The test surface has a consistent slope between level and 1 per cent.
- 8.3. Vehicle conditions
 - 8.3.1. The ESC system is enabled for all testing.
 - 8.3.2. Vehicle mass. The vehicle is loaded with the fuel tank filled to at least 90 per cent of capacity, and a total interior load of 168 kg comprised of the test driver, approximately 59 kg of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine), and ballast as required to make up for any shortfall in the weight of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area. All ballast shall be secured in a way that prevents it from becoming dislodged during testing.
 - 8.3.3. Tyres. The tyres are inflated to the vehicle manufacturer's recommended cold inflation pressure(s) e.g. as specified on the vehicle's placard or the tyre inflation pressure label. Tubes may be installed to prevent tyre de-beding.
 - 8.3.4. Outriggers. Outriggers may be used for testing if deemed necessary for test drivers' safety. In this case, the following applies for vehicles with a Static Stability Factor (SSF) ≤ 1.25 :
 - 8.3.4.1. Vehicles with a mass in running order under 1,588 kg shall be equipped with "lightweight" outriggers. Lightweight outriggers shall be designed with a maximum mass of 27 kg and a maximum roll moment of inertia of 27 kg·m².
 - 8.3.4.2. Vehicles with a mass in running order between 1,588 kg and 2,722 kg shall be equipped with "standard" outriggers. Standard outriggers shall be designed with a maximum mass of 32 kg and a maximum roll moment of inertia of 35.9 kg·m².
 - 8.3.4.3. Vehicles with a mass in running order equal to or greater than 2,722 kg shall be equipped with "heavy" outriggers. Heavy outriggers shall be designed with a maximum mass of 39 kg and a maximum roll moment of inertia of 40.7 kg·m².
 - 8.3.5. Automated steering machine. A steering robot programmed to execute the required steering pattern shall be used in paragraphs 9.5.2., 9.5.3., 9.6. and 9.9. The steering machine shall be capable of supplying steering torques between 40 to 60 Nm. The steering machine shall be able to apply these torques when operating with steering wheel velocities up to 1,200 degrees per second.

⁶ The "nominal" value is understood as being the theoretical target value.

9. Test Procedure

- 9.1. Inflate the vehicles' tyres to the manufacturer's recommended cold inflation pressure(s) e.g. as provided on the vehicle's placard or the tyre inflation pressure label.
- 9.2. Tell-tale bulb check. With the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, switch the ignition to the "On" ("Run") position or, where applicable, the appropriate position for the lamp check. The ESC malfunction tell-tale shall be illuminated as a check of lamp function, as specified in paragraph 7.4.1.3., and if equipped, the "ESC Off" tell-tale shall also be illuminated as a check of lamp function, as specified in paragraph 7.6.2.3. The tell-tale bulb check is not required for a tell-tale shown in a common space as specified in paragraphs 7.4.3. and 7.6.4.
- 9.3. "ESC Off" control check. For vehicles equipped with an "ESC Off" control, with the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, switch the ignition locking system to the "On" ("Run") position. Activate the "ESC Off" control and verify that the "ESC Off" tell-tale is illuminated, as specified in paragraph 7.6.2. Turn the ignition locking system to the "Lock" or "Off" position. Again, switch the ignition locking system to the "On" ("Run") position and verify that the "ESC Off" tell-tale has extinguished indicating that the ESC system has been restored as specified in paragraph 7.5.1.
- 9.4. Brake conditioning

Condition the vehicle brakes in the manner described in paragraphs 9.4.1. to 9.4.4.

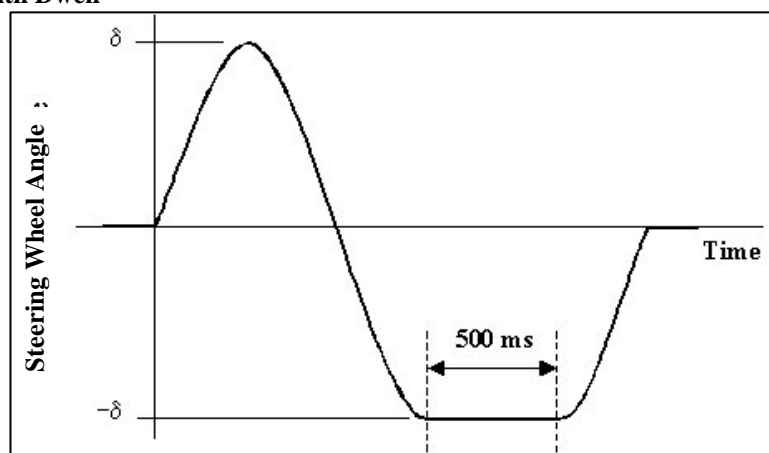
 - 9.4.1. Ten stops are performed from a speed of 56 km/h, with an average deceleration of approximately 0.5g.
 - 9.4.2. Immediately following the series of ten 56 km/h stops, three additional stops are performed from 72 km/h at higher deceleration.
 - 9.4.3. When executing the stops in paragraph 9.4.2., sufficient force is applied to the brake pedal to bring the vehicle's antilock braking system (ABS) into operation for a majority of each braking event.
 - 9.4.4. Following completion of the final stop in 9.4.2., the vehicle is driven at a speed of 72 km/h for five minutes to cool the brakes.
- 9.5. Tyre Conditioning

Condition the tyres using the procedure of paragraphs 9.5.1. to 9.5.3. to wear away mould sheen and achieve operating temperature immediately before beginning the test runs of paragraphs 9.6. and 9.9.

 - 9.5.1. The test vehicle is driven around a circle 30 meters in diameter at a speed that produces a lateral acceleration of approximately 0.5 to 0.6g for three clockwise laps followed by three anticlockwise laps.
 - 9.5.2. Using a sinusoidal steering pattern at a frequency of 1 Hz, a peak steering wheel angle amplitude corresponding to a peak lateral acceleration of 0.5 to 0.6g, and a vehicle speed of 56 km/h, the vehicle is driven through four passes performing 10 cycles of sinusoidal steering during each pass.

- 9.5.3. The steering wheel angle amplitude of the final cycle of the final pass shall be twice that of the other cycles. The maximum time permitted between each of the laps and passes is five minutes.
- 9.6. Slowly increasing steer procedure
- The vehicle is subjected to two series of runs of the slowly increasing steer test using a constant vehicle speed of 80 ± 2 km/h and a steering pattern that increases by 13.5 degrees per second until a lateral acceleration of approximately 0.5g is obtained. Three repetitions are performed for each test series. One series uses anticlockwise steering, and the other series uses clockwise steering. The maximum time permitted between each test run is five minutes.
- 9.6.1. From the slowly increasing steer tests, the quantity "A" is determined. "A" is the steering wheel angle in degrees that produces a steady state lateral acceleration (corrected using the methods specified in paragraph 9.11.3.) of 0.3g for the test vehicle. Utilizing linear regression, A is calculated, to the nearest 0.1 degrees, from each of the six slowly increasing steer tests. The absolute value of the six A values calculated is averaged and rounded to the nearest 0.1 degrees to produce the final quantity, A, used below.
- 9.7. After the quantity A has been determined, without replacing the tyres, the tyre conditioning procedure described in paragraph 9.5. is performed again immediately prior to conducting the Sine with Dwell test of paragraph 9.9. Initiation of the first Sine with Dwell test series shall begin within two hours after completion of the slowly increasing steer tests of paragraph 9.6.
- 9.8. Check that the ESC system is enabled by ensuring that the ESC malfunction and "ESC Off" (if provided) tell-tales are not illuminated.
- 9.9. Sine with Dwell test of oversteer intervention and responsiveness
- The vehicle is subjected to two series of test runs using a steering pattern of a sine wave at 0.7 Hz frequency with a 500 ms delay beginning at the second peak amplitude as shown in Figure 2 (the Sine with Dwell tests). One series uses anticlockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle. The vehicle is allowed to cool-down between each test runs for a period of 1.5 to 5 minutes, with the vehicle stationary.

Figure 2
Sine with Dwell



- 9.9.1. The steering motion is initiated with the vehicle coasting in high gear at 80 ± 2 km/h.
- 9.9.2. The steering amplitude for the initial run of each series is 1.5 A, where A is the steering wheel angle determined in paragraph 9.6.1.
- 9.9.3. In each series of test runs, the steering amplitude is increased from run to run, by 0.5 A, provided that no such run will result in a steering amplitude greater than that of the final run specified in paragraph 9.9.4.
- 9.9.4. The steering amplitude of the final run in each series is the greater of 6.5 A or 270 degrees, provided the calculated magnitude of 6.5 A is less than or equal to 300 degrees. If any 0.5 A increment, up to 6.5 A, is greater than 300 degrees, the steering amplitude of the final run shall be 300 degrees.
- 9.9.5. Upon completion of the two series of test runs, post processing of yaw rate and lateral acceleration data is done as specified in paragraph 9.11.
- 9.10. ESC malfunction detection
- 9.10.1. Simulate one or more ESC malfunction(s) by disconnecting the power source to any ESC component, or disconnecting any electrical connection between ESC components (with the vehicle power off). When simulating an ESC malfunction, the electrical connections for the tell-tale lamp(s) and/or optional ESC system control(s) are not to be disconnected.
- 9.10.2. With the vehicle initially stationary and the ignition locking system in the "Lock" or "Off" position, switch the ignition locking system to the "Start" position and start the engine. Drive the vehicle forward to obtain a vehicle speed of 48 ± 8 km/h. 30 seconds, at the latest, after the engine has been started and within the next two minutes at this speed, conduct at least one left and one right smooth turning manoeuvre without losing directional stability and one brake application. Verify that the ESC malfunction indicator illuminates in accordance with paragraph 7.4. by the end of these manoeuvres.
- 9.10.3. Stop the vehicle, switch the ignition locking system to the "Off" or "Lock" position. After a five-minute period, switch the vehicle's ignition locking system to the "Start" position and start the engine. Verify that the ESC malfunction indicator again illuminates to signal a malfunction and remains illuminated as long as the engine is running or until the fault is corrected.
- 9.10.4. Switch the ignition locking system to the "Off" or "Lock" position. Restore the ESC system to normal operation, switch the ignition system to the "Start" position and start the engine. Re-perform the manoeuvre described in paragraph 9.10.2. and verify that the tell-tale has extinguished within this time or immediately afterwards.
- 9.11. Post data processing – calculations for performance metrics
- Yaw rate and lateral displacement measurements and calculations shall be processed utilizing the techniques specified in paragraphs 9.11.1. to 9.11.8.
- 9.11.1. Raw steering wheel angle data is filtered with a 12-pole phaseless Butterworth filter and a cut-off frequency of 10 Hz. The filtered data is then zeroed to remove sensor offset utilizing static pre-test data.
- 9.11.2. Raw yaw rate data is filtered with a 12-pole phaseless Butterworth filter and a cut-off frequency of 6 Hz. The filtered data is then zeroed to remove sensor offset utilizing static pre-test data.

- 9.11.3. Raw lateral acceleration data is filtered with a 12-pole phaseless Butterworth filter and a cut-off frequency of 6 Hz. The filtered data is then zeroed to remove sensor offset utilizing static pre-test data. The lateral acceleration data at the vehicle centre of gravity is determined by removing the effects caused by vehicle body roll and by correcting for sensor placement via the use of coordinate transformation. For data collection, the lateral accelerometer shall be located as close as possible to the position of the vehicle's longitudinal and lateral centres of gravity.
- 9.11.4. Steering wheel velocity is determined by differentiating the filtered steering wheel angle data. The steering wheel velocity data is then filtered with a moving 0.1 second running average filter.
- 9.11.5. Lateral acceleration, yaw rate and steering wheel angle data channels are zeroed utilizing a defined "zeroing range." The methods used to establish the zeroing range are defined in paragraphs 9.11.5.1. and 9.11.5.2.
- 9.11.5.1. Using the steering wheel rate data calculated using the methods described in paragraph 9.11.4., the first instant that the steering wheel rate exceeds 75 deg/sec is identified. From this point, steering wheel rate shall remain greater than 75 deg/sec for at least 200 ms. If the second condition is not met, the next instant that the steering wheel rate exceeds 75 deg/sec is identified and the 200 ms validity check applied. This iterative process continues until both conditions are ultimately satisfied.
- 9.11.5.2. The "zeroing range" is defined as the 1.0 second time period prior to the instant the steering wheel rate exceeds 75 deg/sec (i.e., the instant the steering wheel velocity exceeds 75 deg/sec defines the end of the "zeroing range").
- 9.11.6. The Beginning of Steer (BOS) is defined as the first instance when the filtered and zeroed steering wheel angle data reaches -5 degrees (when the initial steering input is anticlockwise) or +5 degrees (when the initial steering input is clockwise) after a time defining the end of the "zeroing range." The value for time at the BOS is interpolated.
- 9.11.7. The Completion of Steer (COS) is defined as the time the steering wheel angle returns to zero at the completion of the Sine with Dwell steering manoeuvre. The value for time at the zero degree steering wheel angle is interpolated.
- 9.11.8. The second peak yaw rate is defined as the first local yaw rate peak produced by the reversal of the steering wheel. The yaw rates at 1.000 and 1.750 seconds after COS are determined by interpolation.
- 9.11.9. Determine lateral velocity by integrating corrected, filtered and zeroed lateral acceleration data. Zero lateral velocity at the BOS point. Determine lateral displacement by integrating zeroed lateral velocity. Zero lateral displacement at the BOS point. The lateral displacement measurement is made at 1.07 seconds after BOS point and is determined by interpolation.

10. Modification of vehicle type or ESC system and extension of approval

- 10.1. Every modification to an existing vehicle type shall be notified to the administrative department which approved the vehicle type.
The department shall then either:

- (a) decide, in consultation with the manufacturer, that a new type-approval is to be granted, or
- (b) apply the procedure contained in paragraph 10.1.1. (Revision) and, if applicable, the procedure contained in paragraph 10.1.2. (Extension).

10.1.1. Revision

When particulars recorded in the information documents have changed and the administrative department considers that the modifications made are unlikely to have appreciable adverse effects and that in any case the foot controls still meet the requirements, the modification shall be designated a "revision".

In such a case, the administrative department shall issue the revised pages of the information documents as necessary, marking each revised page to show clearly the nature of the modification and the date of re-issue. A consolidated, updated version of the information documents, accompanied by a detailed description of the modification, shall be deemed to meet this requirement.

10.1.2. Extension

The modification shall be designated an "extension" if, in addition to the change of the particulars recorded in the information documents,

- (a) further inspections or tests are required, or
- (b) any information on the communication document (with the exception of its attachments) has changed, or
- (c) approval to a later series of amendments is requested after its entry into force.

10.2. Confirmation or refusal of approval, specifying the alteration, shall be communicated by the procedure specified in paragraph 4.3. above to the Contracting Parties to the Agreement applying this Regulation. In addition, the index to the information documents and to the test reports, attached to the communication document of Annex 1, shall be amended accordingly to show the date of the most recent revision or extension.

10.3. The competent authority issuing the extension of approval shall assign a serial number to each communication form drawn up for such an extension."

11. Conformity of production

The conformity of production procedures shall comply with those set out in the Agreement, Appendix 2 (E/ECE/324-E/ECE/TRANS/505/Rev.2) with the following requirements:

- 11.1. A vehicle approved to this Regulation shall be so manufactured as to conform to the type approved by meeting the requirements set forth in paragraphs 5., 6. and 7. above.
- 11.2. The 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.

12. Penalties for non-conformity of production

- 12.1. 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.
- 12.2. 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.

13. Production definitely 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 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 5 to this Regulation.

14. Names and addresses of the technical services conducting approval tests, and of administrative departments

The 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 Administrative Departments 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.

Annex 1

Communication

(Maximum format: A4 (210 x 297 mm))



issued by :

Name of administration:

.....
.....
.....

concerning²: APPROVAL GRANTED
APPROVAL EXTENDED
APPROVAL REFUSED
APPROVAL WITHDRAWN
PRODUCTION DEFINITELY DISCONTINUED

of a vehicle type with regard to ESC, pursuant to Regulation No. XX

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)
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

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.

12. Tyre dimension
13. Maximum design speed
14. Brief description of braking equipment
15. Mass of vehicle when tested:

	Load (kg)
Axle No. 1	
Axle No. 2	
Total	

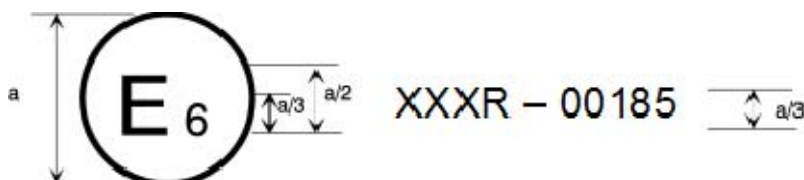
- [20. Adequate documentation according to Annex 6 was supplied in respect of the ESC system(s): Yes / No / Not applicable²]
21. The ESC system has been tested according to and fulfils the requirements of this Regulation Yes / No
or: The vehicle stability function has been tested according to and fulfils the requirements of Annex 21 to Regulation No. 13 Yes / No
23. Vehicle submitted for approval on [date]
24. Technical Service responsible for conducting approval
25. Date of report issued by that Service
26. Number of report issued by that Service.....
27. Approval granted / refused / extended / withdrawn²
28. Position of approval mark on the vehicle.....
29. Place.....
30. Date.....
31. Signature
32. The summary referred to in paragraph 4.3. of this Regulation is annexed to this communication

Annex 2

Arrangements of approval marks

Model A

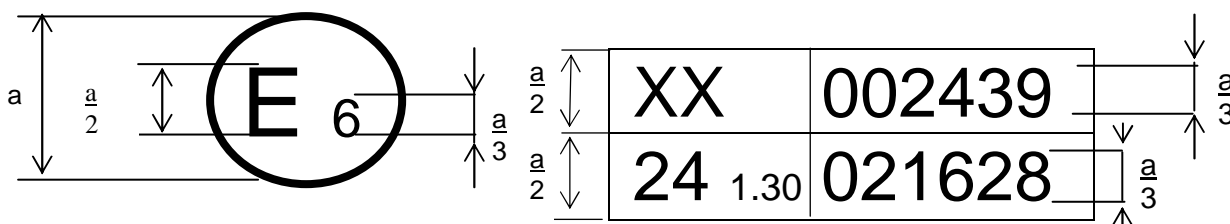
(See paragraph 4.4. of this Regulation)



The above approval mark affixed to a vehicle shows that the vehicle type concerned has been approved in Belgium (E 6) with regard to the Electronic Stability Control pursuant to Regulation No. XXX. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. XXX in its original form.

Model B

(See paragraph 4.5. of this Regulation)



$a = 8 \text{ mm min.}$

The above approval mark affixed to a vehicle shows that the vehicle type concerned has been approved in Belgium (E 6) pursuant to Regulations Nos. XX and 241. (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, Regulation No. XX was in its original form and Regulation No. 24 included the 02 series of amendments.

¹ This number is given merely as an example.

Annex 3

Use of the dynamic stability simulation

The effectiveness of the electronic stability control system may be determined by computer simulation.

1. Use of the simulation
- 1.1. The vehicle stability function shall be demonstrated by the vehicle manufacturer to the Type Approval Authority or Technical Service by simulating the dynamic manoeuvres of paragraph 9.9. of this Regulation.
- 1.2. The simulation shall be a means whereby the vehicle stability performance shall be demonstrated with:
 - (a) The yaw rate, one second after completion of the Sine with Dwell steering input (time $T_0 + 1$);
 - (b) The yaw rate, 1.75 seconds after completion of the Sine with Dwell steering input;
 - (c) The lateral displacement of the vehicle centre of gravity with respect to its initial straight path.
- 1.3. The simulation shall be carried out with a validated modelling and simulation tool and using the dynamic manoeuvres of paragraph 9.9. of this Regulation under the test conditions of paragraph 8. of this Regulation.

The method by which the simulation tool is validated is given in Annex 2 to this Regulation.

Annex 4

Dynamic stability simulation tool and its validation

1. Specification of the simulation tool
 - 1.1. The simulation method shall take into account the main factors which influence the directional and roll motion of the vehicle. A typical model may include the following vehicle parameters in an explicit or implicit form:
 - (a) Axle/wheel;
 - (b) Suspension;
 - (c) Tyre;
 - (d) Chassis/vehicle body;
 - (e) Power train/driveline, if applicable;
 - (f) Brake system;
 - (g) Pay load.
 - 1.2. The Vehicle Stability Function shall be added to the simulation model by means of:
 - (a) A subsystem (software model) of the simulation tool; or
 - (b) The electronic control box in a hardware-in-the-loop configuration.
2. Validation of the simulation tool
 - 2.1. The validity of the applied modelling and simulation tool shall be verified by means of comparisons with practical vehicle tests. The tests utilised for the validation shall be the dynamic manoeuvres of paragraph 9.9. of this Regulation.

 During the tests, the following motion variables, as appropriate, shall be recorded or calculated in accordance with ISO 15037 Part 1:2005: General conditions for passenger cars or Part 2:2002: General conditions for heavy vehicles and buses (depending on the vehicle category):
 - (a) Steering-wheel angle (δH);
 - (b) Longitudinal velocity (vX);
 - (c) Sideslip angle (β) or lateral velocity (vY);(optional);
 - (d) Longitudinal acceleration (aX); (optional);
 - (e) Lateral acceleration (aY);
 - (f) Yaw velocity ($d\psi/dt$);
 - (g) Roll velocity ($d\phi/dt$);
 - (h) Pitch velocity ($d\theta/dt$);
 - (i) Roll angle (ϕ);
 - (j) Pitch angle (θ).

- 2.2. The objective is to show that the simulated vehicle behaviour and operation of the vehicle stability function is comparable with that seen in practical vehicle tests.
- 2.3. The simulator shall be deemed to be validated when its output is comparable to the practical test results produced by a given vehicle type during the dynamic manoeuvres of paragraph 9.9. of this Regulation. The relationship of activation and sequence of the vehicle stability function in the simulation and in the practical vehicle test shall be the means of making the comparison.
- 2.4. The physical parameters that are different between the reference vehicle and simulated vehicle configurations shall be modified accordingly in the simulation.
- 2.5. A simulator test report shall be produced, a model of which is defined in Annex 3 to this Regulation, and a copy attached to the vehicle approval report.

Annex 5

Vehicle stability function simulation tool test report

Test Report Number:

1. Identification
 - 1.1. Name and address of the simulation tool manufacturer.....
 - 1.2. Simulation tool identification: name/model/number (hardware and software)
.....
2. Scope of application
 - 2.1. Vehicle type:.....
 - 2.2. Vehicle configurations:
3. Verifying vehicle test
 - 3.1. Description of vehicle(s):
 - 3.1.1. Vehicle(s) identification: make/model/VIN
 - 3.1.2. Vehicle description, including suspension/wheels, engine and drive line, braking system(s), steering system, with name/model/number identification:
.....
 - 3.1.3. Vehicle data used in the simulation (explicit):
 - 3.2. Description of location(s), road/test area surface conditions, temperature and date(s):
 - 3.3. Results with the vehicle stability function switched on and off, including the motion variables referred to in Annex 2, paragraph 2.1. as appropriate:.....
4. Simulation results
 - 4.1. Vehicle parameters and the values used in the simulation that are not taken from the actual test vehicle (implicit):
 - 4.2. Yaw stability and lateral displacement according to paragraphs 7.1. to 7.3. of this Regulation:
5. This test has been carried out and the results reported in accordance with Annex 2 to Regulation No. [XX], as last amended by [??].
 Technical Service conducting the test¹⁰
 Signed: Date:
 Approval Authority¹
 Signed: Date:

¹⁰ To be signed by different persons if the Technical Service and the Approval Authority is the same organization.

[Annex 6

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

1. General

This annex defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of Complex Electronic Vehicle Control Systems (definition 2.3. below) as far as this Regulation is concerned.

This annex may also be called, by special paragraphs in this Regulation, for safety related functions which are controlled by electronic system(s).

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

This information shall show that "The System" respects, under normal and fault conditions, all the appropriate performance requirements specified elsewhere in this Regulation.

2. Definitions

For the purposes of this annex,

- 2.1. "*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 even 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.

- 2.2. "*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, often 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-pneumatic or electro-hydraulic elements.

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

- 2.3. "*Complex electronic vehicle control systems*" are those electronic control systems which are subject to a hierarchy of control in which a controlled function may be over-ridden by a higher level electronic control system/function.

A function which is over-ridden becomes part of the complex system.

- 2.4. "*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.

- 2.5. "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.

"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 mechanical, pneumatic, hydraulic or optical.

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

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

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" 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.

- 3.1.1. Documentation shall be made available in 2 parts:

- (a) The formal documentation package for the approval, containing the material listed in Section 3 (with the exception of that of paragraph 3.4.4.) which shall be supplied to the technical service at the time of submission of the type approval application. This will be taken as the basic reference for the verification process set out in paragraph 4. of this annex.
- (b) Additional material and analysis data of paragraph 3.4.4., which shall be retained by the manufacturer, but made open for inspection at the time of type approval.

3.2. Description of the functions of "The System"

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

- 3.2.1. A list of all input and sensed variables shall be provided and the working range of these defined.

- 3.2.2. A list of all output variables which are controlled by "The System" shall be provided and an indication given, in each case, of whether the control is direct or via another vehicle system. The range of control (paragraph 2.7.) exercised on each such variable shall be defined.
- 3.2.3. Limits defining the boundaries of functional operation (paragraph 2.8.) 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-fiber diagram for optical links, by a piping diagram for pneumatic or hydraulic transmission equipment and by a simplified diagrammatic layout for mechanical linkages.
 - 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.
- 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 be prepared, if required, to show some 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 one of those specified faults which will have a bearing on vehicle control performance or safety.
- This may be based on a Failure Mode and Effect Analysis (FMEA), a Fault Tree Analysis (FTA) or any similar process appropriate to system safety considerations.
- The chosen analytical approach(es) 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.

- 3.4.4.1. This documentation shall itemise 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.
- 4. Verification and test
- 4.1. The functional operation of "The System", as laid out in the documents required in paragraph 3., shall be tested as follows:
 - 4.1.1. Verification of the function of "The System"

As the means of establishing the normal operational levels, verification of the performance of the vehicle system under non-fault conditions shall be conducted against the manufacturer's basic benchmark specification unless this is subject to a specified performance test as part of the approval procedure of this or another Regulation.
 - 4.1.2. Verification of the safety concept of paragraph 3.4.

The reaction of "The System" shall, at the discretion of the type approval authority, 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 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.]

Annex 7

Determination of the coefficient of adhesion (k)

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 braked.
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.
3. A number of tests at increments of line pressure 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.

- 3.1. Wheel lock may occur below 20 km/h.
- 3.2. Starting from the minimum measured value of t, called t_{\min} , select three values of t comprised within t_{\min} and $1.05 t_{\min}$ and calculate their arithmetical mean value t_m ,

$$z_m = \frac{0.566}{t_m}$$

then calculate:

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.

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.
5. The dynamic load on the axle shall be that given by the following formula:

$$N_i = F_i + \frac{h}{E} \cdot z_m \cdot P \cdot g$$

Where:

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

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

E = wheelbase

P = Mass of the vehicle

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

6. The value of k shall be rounded to three decimal places.
7. Then, the test will be repeated for the other axle(s) as defined in paragraphs 1. to 6. above.
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:

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

9. One coefficient will be determined for the front axle k_f and one for the rear axle k_r .
10. The coefficient k shall be the arithmetic average of k_f and k_r :
$$k = (k_f + k_r)/2$$
11. The road test surface nominal peak braking coefficient (PBC) mentioned in paragraph 8.2.2. of this Regulation shall be equal to the coefficient k calculated per the equation of paragraph 11 to this Annex:

$$\text{PBC} = k$$

II. Justification

The secretariat distributes GRRF-75-15 with an official symbol.
