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Working Party on Brakes and Running Gear

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Item 8(e) of the provisional agenda

TYRES

Tyre pressure monitoring systems

Proposal for a new draft Regulation on tyre pressure monitoring systems

Submitted by the expert from Germany *

The text reproduced below was prepared by the experts of the informal group on tyre pressure monitoring systems (TPMS) and transmitted to the Working Party on Brake and Running Gear (GRRF) by the Chairperson (Germany), after four meetings of the informal group and a coordination meeting with some Contracting Parties to the 1958 Agreement and Non-Governmental Organizations.

* In accordance with the programme of work of the Inland Transport Committee for 2006-2010 (ECE/TRANS/166/Add.1, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance performance of vehicles. The present document is submitted in conformity with that mandate.

A. PROPOSAL FOR A NEW DRAFT REGULATION

"UNIFORM PROVISIONS CONCERNING THE TYPE-APPROVAL OF VEHICLES WITH REGARD TO TYRE PRESSURE MONITORING SYSTEMS (TPMS)

1. SCOPE

This Regulation applies to the type approval of vehicles of categories M₁ and N₁ with single tyres up to 3,500 kg with regard to tyre pressure monitoring systems.

2. DEFINITIONS

For the purpose of this Regulation,

- 2.1. "Tyre Pressure Monitoring System (TPMS)" means a system fitted on a vehicle, able to perform a function to evaluate the inflation pressure of the tyres or the variation of this inflation pressure over time and to transmit corresponding information to the user while the vehicle is running.
- 2.2. "Cold tyre inflation pressure" means the tyre pressure at ambient temperature, in the absence of any pressure build-up due to tyre usage.
- 2.3. "Recommended cold inflation pressure (Prec)" means the pressure recommended for each tyre position by the vehicle manufacturer, for the intended service conditions (e.g. speed and load) of the given vehicle, as defined on the vehicle placard and/or the vehicle owner's manual.
- 2.4. "In service operating pressure (P_{warm})" means the inflation pressure for each tyre position elevated from the cold pressure (Prec) by temperature effects during vehicle usage.
- 2.5. "Test Pressure (P_{test})" means the actual pressure of the tyre(s) selected for each tyre position after deflation during the test procedure.

3. APPLICATION FOR APPROVAL

- 3.1. The application for approval of a vehicle type with regard to its equipment with a tyre pressure monitoring system shall be submitted by the vehicle manufacturer or by his duly accredited representative.
- 3.2. It shall be accompanied, in triplicate, by a description of the vehicle type with regard to the items specified in Annex 1 to this Regulation.

- 3.3. A vehicle representative of the vehicle type to be approved shall be submitted to the type approval authority or the technical service responsible for conducting the approval tests.
- 3.4. The competent authority shall verify the existence of satisfactory arrangements for ensuring effective control of the conformity of production before type approval is granted.
- 3.5. Drawings indicating the intended location of the approval mark.
4. APPROVAL
- 4.1. If the vehicle 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 another type of vehicle. However, variants of a model range which are in separate categories may be covered by the same type approval, provided that the results of the tests described in paragraph 6 do not show major differences.
- 4.3. Notice of approval or of extension or of refusal or withdrawal of approval or definitely discontinued of a vehicle type pursuant to this Regulation shall be communicated to the Parties to the 1958 Agreement applying this Regulation, by means of a form conforming to the model in Annex 1 to this Regulation.
- 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 granted approval; 1/

1/ 1 for Germany, 2 for France, 3 for Italy, 4 for the Netherlands, 5 for Sweden, 6 for Belgium, 7 for Hungary, 8 for the Czech Republic, 9 for Spain, 10 for Serbia, 11 for the United Kingdom, 12 for Austria, 13 for Luxembourg, 14 for Switzerland, 15 (vacant), 16 for Norway, 17 for Finland, 18 for Denmark, 19 for Romania, 20 for Poland, 21 for Portugal, 22 for the Russian Federation, 23 for Greece, 24 for Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32 for Latvia, 33 (vacant), 34 for Bulgaria, 35 (vacant), 36 for Lithuania, 37 for Turkey, 38 (vacant), 39 for Azerbaijan, 40 for The former Yugoslav Republic of Macedonia, 41 (vacant), 42 for the European Community (Approvals are granted by its Member States using their respective ECE symbol), 43 for Japan, 44 (vacant), 45 for Australia, 46 for Ukraine, 47 for South Africa, 48 for New Zealand, 49 for Cyprus, 50 for Malta, 51 for the Republic of Korea, 52 for Malaysia, 53 for

- 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 Regulations annexed to the Agreement in the country which granted approval under this Regulation, the symbol prescribed in paragraph 4.4.1. need not be repeated; in such a case, the Regulation and approval numbers and the additional symbols for all the Regulations under which approval has been granted in the country which granted approval under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in paragraph 4.4.1.
- 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 affixed by the manufacturer.
- 4.8. Annex 2 to this Regulation gives examples of approval marks.
5. GENERAL REQUIREMENTS
- 5.1. General.
- 5.1.1. Subject to the requirements of paragraph 12, any vehicle fitted with a tyre pressure monitoring system complying with the definition of paragraph 2.1 shall meet the performance requirements contained in paragraphs 5.1 to 5.5 of this regulation.
- 5.1.2. Any tyre pressure monitoring system (TPMS) fitted on a vehicle shall comply with the requirements of Regulation No. 10 on electromagnetic interferences.
- [5.1.3. The system shall operate at least above 40 km/h.]
- 5.2. Tyre pressure detection for incident-related pressure loss (puncture test).
- 5.2.1. When tested according to paragraph 6.2.6.1., the TPMS shall illuminate the warning signal described in paragraph 5.5. not more than 10 minutes after the in service operating pressure in one of the vehicle's tyres has been reduced by [20 per cent] or to an absolute pressure of 150 kPa, whatever is higher.

Thailand, 54 and 55 (vacant) and 56 for Montenegro. Subsequent numbers shall be assigned to other countries in the chronological order in which they ratify or accede to the Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

- [5.2.2. The system shall operate up to the vehicle's maximum design speed.]
- 5.3. Detection for a tyre pressure level significantly below the recommended pressure for optimum performance including fuel consumption and safety (diffusion test).
- 5.3.1. When tested according to paragraph 6.2.6.2., the TPMS shall illuminate the warning signal described in paragraph 5.5. within not more than 60 minutes after the in-service operating pressure in one of the vehicle's tyres, up to a total of four tyres, has been reduced by [20 per cent].
- 5.4. Malfunction detection
- 5.4.1. When tested according to paragraph 6.3., the TPMS shall illuminate the warning signal described in paragraph 5.5. not more than 10 minutes after the occurrence of a malfunction that affects the generation or transmission of control or response signals in the vehicle's tyre pressure monitoring system. If the system is blocked by external influence (e.g. radio-frequency noise), the malfunction detection time may be extended.
- 5.5. Warning indication.
- 5.5.1. The warning indication shall be by means of an optical warning signal conforming to Regulation No. 121.
- 5.5.2. The warning signal shall be activated when the ignition (start) switch is in the "on" (run) position (bulb check).
- 5.5.3. The warning signal must be visible even by daylight; the satisfactory condition of the signal must be easily verifiable by the driver from the driver's seat.
- 5.5.4. The malfunction indication may be the same warning signal as the one used to indicate under-inflation. If the warning signal described in paragraph 5.5.1. is used to indicate both under-inflation and a malfunction of the TPMS, the following shall apply: with the ignition (start) switch in the "on" (run) position the warning signal shall flash to indicate a system failure. After a short period of time the warning signal shall remain continuously illuminated as long as the failure exists and the ignition (start) switch is in the "on" (run) position. The flashing and illumination sequence shall be repeated each time the ignition (start) switch is in the "on" (run) position until the failure has been corrected.
6. TESTS
- 6.1. Test conditions.
- 6.1.1. Ambient temperature.

The ambient temperature shall be between 0° C and 40° C.

6.1.2. Road test surface.

The road shall have a surface affording good adhesion. The road surface shall be dry during testing.

6.1.3. The tests shall be conducted in an environment free of interferences from radio wave.

6.1.4. Vehicle conditions.

6.1.4.1. Test weight.

The vehicle may be tested at any condition of load, the distribution of the mass among the axles being that stated by the vehicle manufacturer without exceeding any of the maximum permissible mass for each axle.

However, in the case where there is no possibility to set or reset the system, the vehicle shall be unladen. There may be, in addition to the driver, a second person on the front seat who is responsible for noting the results of the tests. The load condition shall not be modified during the test.

6.1.4.2. Vehicle speed.

The vehicle's TPMS shall be calibrated and tested:

- (a) in a speed range from 40 km/h to 120 km/h or the vehicle's maximum design speed if it is less than 120 km/h for the puncture test according to paragraph 5.2. and
- (b) in a speed range from 50 km/h and 100 km for the diffusion test according to paragraph 5.3. and for the malfunction test according to paragraph 5.4.

The whole speed range shall be covered during the test.

For vehicles equipped with cruise control, the cruise control shall not be engaged during testing.

6.1.4.3. Rim position.

The vehicle rims may be positioned at any wheel position, consistent with any related instructions or limitations from the vehicle's manufacturer.

6.1.4.4. Stationary location.

When the vehicle is parked, the vehicle's tyres shall be shaded from direct sun. The location shall be shielded from any wind that may affect the results.

6.1.4.5. Brake pedal application.

Driving time shall not accumulate during service brake application while the vehicle is moving.

6.1.4.6. Tyres.

The vehicle shall be tested with the tyres installed on the vehicle according to the vehicle manufacturer's recommendation. However, the spare tyre may be utilised for testing TPMS malfunction.

6.1.5. Accuracy of measurement equipment.

The accuracy of measurement equipment shall be taken into account during the test.

6.2. Test procedure.

It shall be performed at a test speed within the range in accordance with paragraph 6.1.4.2., at least once for the test case according to paragraph 6.2.6.1. ("puncture test"), and at least once for each test case according to paragraph 6.2.6.2. ("diffusion test").

6.2.1. Before inflating vehicle's tyres, leave the vehicle stationary outside at ambient temperature with the engine off shaded from direct sunlight and not exposed to wind or other heating or chilling influences for at least one hour. Inflate the vehicle's tyres to the vehicle manufacturer's recommended cold inflation pressure (P_{rec}), in accordance with the vehicle manufacturer's recommendation for the speed and load conditions, and tyre positions.

6.2.2. With the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "On" or "Run" position. The tyre pressure monitoring system shall perform a check of lamp function for the low tyre pressure telltale as specified in paragraph 5.5.2. of this Regulation.

6.2.3. If applicable, set or reset the tyre pressure monitoring system in accordance with the vehicle manufacturer's recommendations.

6.2.4. Learning phase.

6.2.4.1. Drive the vehicle for up to 15 minutes of cumulative time (not necessarily continuously) along any portion of the test course.

6.2.4.2. Drive the vehicle in the opposite direction of the course for an additional period of time for a minimum total cumulative time of 20 minutes (including the time in paragraph 6.2.4.1., and not necessarily continuously)

[6.2.5. Deflation phase.

6.2.5.1. Measure the actual warm pressure of the selected tyre(s) to be deflated. This value, P_{warm} , will be used for subsequent operations.

6.2.5.2. Procedure for the puncture test according to paragraph 5.2.

Deflate one of the vehicle's tyres, until it is at P_{warm} [-20 per cent], or an absolute pressure of 150 kPa, whatever is higher, namely P_{test} .

6.2.5.3. Procedure for the diffusion test according to paragraph 5.3.

Deflate all four tyres, until the deflated tyres are at P_{warm} [- 20 per cent], namely P_{test} .

6.2.5.4. In both cases above, a tolerance of [5 per cent] of P_{test} shall be added to the deflation percentages for the actual test.].

6.2.6. Low tyre pressure detection phase.

6.2.6.1. Procedure for the puncture test according to paragraph 5.2.

6.2.6.1.1. Drive the vehicle along any portion of the test course (not necessarily continuously). The sum of the total cumulative drive time shall be the lesser of 10 minutes or the time at which the low tyre pressure telltale illuminates.

6.2.6.2. Procedure for the diffusion test according to paragraph 5.3.

6.2.6.2.1. Drive the vehicle along any portion of the test course (not necessarily continuously). The sum of the total cumulative drive time shall be the lesser of 60 minutes or the time at which the low tyre pressure telltale illuminates.

6.2.6.3. If the low tyre pressure signal did not illuminate, discontinue the test.

6.2.7. If the low tyre pressure telltale illuminated during the procedure in paragraph 6.2.6., deactivate the ignition locking system to the "Off" or "Lock" position. After a 5 minutes period, reactivate the vehicle's ignition locking system to the "On" ("Run") position. The telltale must illuminate and remain illuminated as long as the ignition locking system is in the "On" ("Run") position.

6.2.8. Inflate all of the vehicle's tyres to the vehicle manufacturer's recommended cold inflation pressure. Reset the system in accordance with the instructions of the vehicle manufacturer. Determine whether the telltale has extinguished. If necessary, drive the vehicle until the telltale has been extinguished. If the telltale does not extinguish, discontinue the test.

6.2.9. Repetition of the deflation phase.

The test may be repeated, at the same or different loads, using the test procedures in paragraphs 6.2.1. to 6.2.8., with the relevant tyre(s) on the vehicle under-inflated, in accordance with the provisions of paragraph 5.2. or 5.3., whichever is relevant.

- 6.3. TPMS malfunction detection.
 - 6.3.1. Simulate a TPMS malfunction, for example, by disconnecting the power source to any TPMS component, disconnecting any electrical connection between TPMS components, or installing a tyre or wheel on the vehicle that is incompatible with the TPMS. When simulating a TPMS malfunction, the electrical connections for the telltale lamps shall not be disconnected.
 - 6.3.2. Drive the vehicle for up to 10 minutes of cumulative time (not necessarily continuously) along any portion of the test course.
 - 6.3.3. The sum of the total cumulative drive time under paragraphs 6.3.2. shall be the lesser of 10 minutes or the time at which the TPMS malfunction telltale illuminates.
 - 6.3.4. If the TPMS malfunction indicator did not illuminate in accordance with paragraph 5.4, as required, discontinue the test.
 - 6.3.5. If the TPMS malfunction indicator illuminated during the procedure in paragraph 6.3., deactivate the ignition locking system to the "Off" or "Lock" position. After 5-minutes, reactivate the vehicle's ignition locking system to the "On" ("Run") position. The TPMS malfunction indicator shall again signal a malfunction and remain illuminated as long as the ignition locking system is in the "On" ("Run") position.
 - 6.3.6. Restore the TPMS to normal operation. If necessary, drive the vehicle until the warning signal has extinguished. If the warning lamp has not extinguished, discontinue the test.
 - 6.3.7. The test may be repeated using the test procedures in paragraphs 6.3.1. to 6.3.6., with each such test limited to simulation of a single malfunction.
7. MODIFICATION OF VEHICLE TYPE OR TYRE PRESSURE MONITORING SYSTEM AND EXTENSION OF APPROVAL
 - 7.1. Every modification of the vehicle type with regard to the characteristics in Annex 1 to this Regulation shall be notified to the administrative department which approved the vehicle type. That department 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. Confirmation or refusal of approval, specifying the alterations, 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 competent authority issuing the extension of approval shall assign a series number to each communication form drawn up for such an extension and inform thereof the other Contracting Parties to the 1958 Agreement by means of a communication form conforming to the model in Annex 1 to this Regulation.

8. CONFORMITY OF PRODUCTION

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. In order to verify that the requirements of paragraph 8.1. above are met, suitable controls of the production shall be carried out.

8.3. The holder of the approval shall in particular:

8.3.1. ensure existence of procedures for the effective control of the quality of products;

8.3.2. have access to the control equipment necessary for checking the conformity to each approved type;

8.3.3. ensure that data of test results are recorded and that annexed documents shall remain available for a period to be determined in accordance with the Administrative Service;

8.3.4. analyse the results of each type of test, in order to verify and ensure the stability of the product characteristics making allowance for variation of an industrial production;

8.3.5. ensure that for each type of product the tests, or some of them, prescribed in this Regulation are carried out;

8.3.6. ensure that any samples or test pieces giving evidence of non-conformity with the type of test considered shall give rise to another sampling and another test. All the necessary steps shall be taken to re-establish the conformity of the corresponding production.

8.4. The competent authority which has granted type approval may at any time verify the conformity control methods applicable to each production unit.

8.4.1. At every inspection, the test books and production survey records shall be presented to the visiting inspector.

8.4.2. The inspector may take samples at random which will be tested in the manufacturer's laboratory. The minimum number of samples may be determined according to the results of the manufacturer's own verification.

- 8.4.3. When the quality level appears unsatisfactory or when it seems necessary to verify the validity of the tests carried out in application of paragraph 8.4.2. above, the inspector shall select samples to be sent to the Technical Service which has conducted the type approval tests.
- 8.4.4. The competent authority may carry out any test prescribed in this Regulation.
- 8.4.5. The normal frequency of inspections by the competent authority shall be one every two years. If unsatisfactory results are recorded during one of these visits, the competent authority shall ensure that all necessary steps are taken to re-establish the conformity of production as rapidly as possible.

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 a communication form conforming to the model in Annex 1 to this Regulation.

10. 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 Contracting Parties to the Agreement applying this Regulation by means a communication form conforming to the model in Annex 1 to this Regulation.

11. NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR 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.

12. TRANSITIONAL PROVISIONS

- 12.1. As from the date of entry into force of this Regulation, Contracting Parties applying this Regulation shall not:
- (a) refuse to grant ECE approval for a vehicle type under this Regulation,

- (b) prohibit the sale or entry into service of a type of vehicle with regard to the specification for tyre pressure monitoring, if the vehicle type complies with the requirements of this Regulation.
- 12.2. Until [36 months] after entry into force of this Regulation, Contracting Parties applying this Regulation shall not refuse to grant national or regional approval of a vehicle type with regard to the specification for tyre pressure monitoring, if the vehicle type does not comply with the requirements of this Regulation.
- 12.3. Starting [60 months] after the entry into force of this Regulation, Contracting Parties applying this Regulation may refuse first national or regional registration (first entry into service) of a vehicle which does not meet the requirements of this Regulation.

Annex 1

COMMUNICATION
(maximum format: A4 (210 x 297 mm))



issued by: Name of Administration:

concerning: 2/

- APPROVAL GRANTED
- APPROVAL EXTENDED
- APPROVAL REFUSED
- APPROVAL WITHDRAWN
- PRODUCTION DEFINITELY DISCONTINUED

of a vehicle type with regard to tyre pressure monitoring, pursuant to Regulation No. [1XX]

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 tyre pressure monitoring system:
8. Brief description of tyre pressure monitoring system:
9. Engine type:
10. Tyre dimensions:
11. Maximum design speed:

12. Mass of vehicle when tested:

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

15. Result of the tests:

	Measured Time to warning (mm:ss)
"Puncture test"	
"diffusion test"	
"malfunction test"	

16. Vehicle submitted for approval on:

17. Technical Service responsible for conducting approval:

18. Date of report issued by that Service:

19. Number of report issued by that Service:

20. Approval granted / refused / extended / withdrawn 2/

21. Position of approval mark on the vehicle:

22. Place:

23. Date:

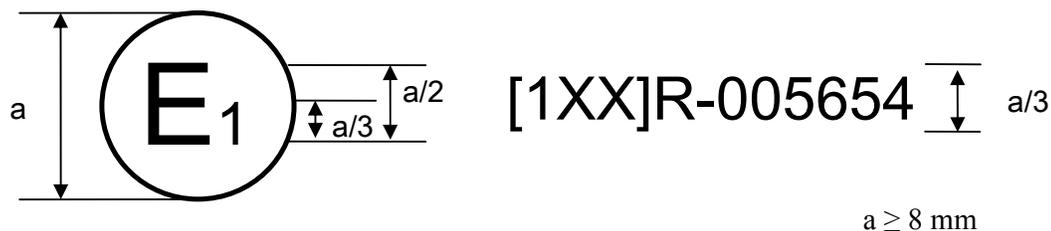
24. Signature:

Annex 2

ARRANGEMENTS OF APPROVAL MARKS

Model A

(See paragraph 4.4. of this Regulation)

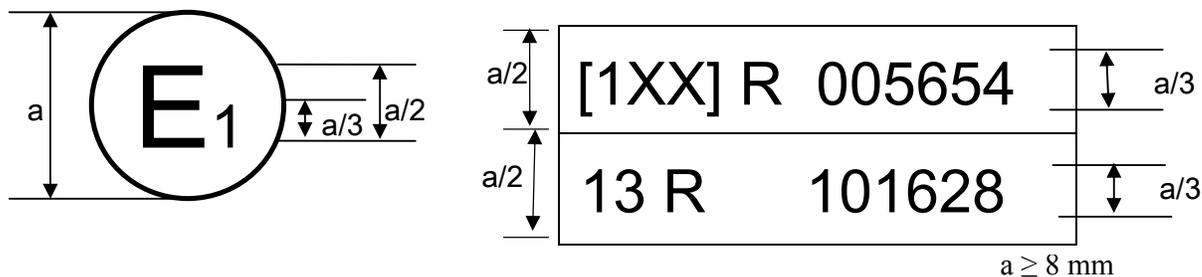


The above approval mark affixed to a vehicle shows that the vehicle type concerned has been approved in Germany (E1) pursuant to Regulation No. [1XX] under approval number 005654.

The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. 1XX in its original version.

Model B

(See paragraph 4.5. of this Regulation)

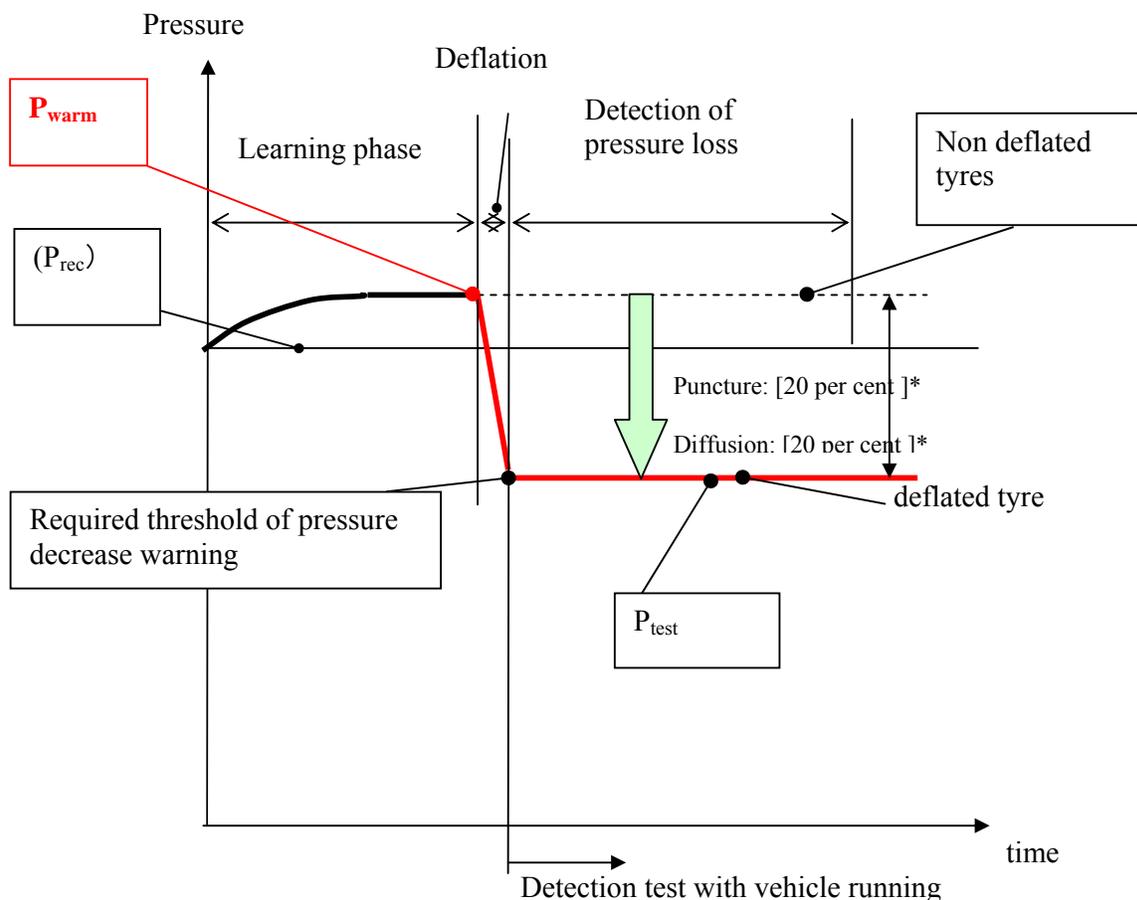


The above approval mark affixed to a vehicle shows that the vehicle type concerned has been approved in Germany (E1) pursuant to Regulations Nos. [1XX] and 13 1/. The approval numbers indicate that, at the dates when the respective approvals were given, Regulation No. [1XX] was in its original form and Regulation No. 13 included the 10 series of amendments.

1/ This number is given merely as an example"

B. JUSTIFICATION

Scheme of test procedure.



*: + additional tolerance of 5 per cent for measurement

In real life scenarios, there are two basic phenomena a TPMS has to deal with:

- puncture (occurs normally only in one wheel at a time),
- diffusion - in a worst case scenario occurs in all four tyres simultaneously.

Therefore this regulation proposes two separate tests for detecting under inflation:

- "puncture test" - one tyre at a time, at 20 per cent (+5 per cent tolerance) under inflation or 150 kPa as an absolute lowest limit requested for preserving tyre integrity,
- "diffusion test" - four tyres at 20 per cent (+5 per cent tolerance) under inflation.

The choice for relative limits reflects the wide range of recommended pressures for different vehicles:

- (a) from 200 kPa for normal passenger cars to
- (b) 400 kPa for some light truck type vehicles.

There were several proposals to adopt 40 kPa as an absolute limit for pressure losses. When comparing to the above-mentioned ranges of recommended pressures, we become aware that such an absolute value means relative limits of:

- (a) 20 per cent in the case of 200 kPa recommended pressure, respectively
- (b) 10 per cent in the case of 400 kPa recommended pressure.

Such narrow tolerances (i.e. 10 per cent) are not acceptable with respect of the goal to design robust, cost-effective TPMS with a high degree of user acceptance. A possible solution would be a corrective factor in order to adapt this absolute limit to the level of the recommended pressure:

- (a) $40 \text{ kPa} + 0.22 (P_{\text{rec}} - 180 \text{ kPa})$

As the same benefit can be obtained with a relative limit, this approach has been rejected.

From a physical point of view, the impact of under-inflation on fuel consumption/CO₂ emissions and safety is relative to the absolute pressure. For example, the tyre rolling resistance increases according to the formula: $(P_0/P_1)^{0.4}$

That means that the delta between the reference pressure and the alert threshold should increase when the reference pressure increases.

The compromise proposal is more severe than Federal Motor Vehicle Safety Standard FMVSS 138 and for low recommended pressures even more severe than the threshold of 40 kPa under P_{rec} .

There was a consensus in the working group that for the safety aspect, the proposed "puncture test" "one tyre at a time, at 20 per cent (+5 per cent tolerance) under inflation or 150 kPa as an absolute lowest limit requested for preserving tyre integrity" would be sufficient.

The most controversial issue was the test and the detection limits in the case of diffusion.

There were basically two different opinions:

- (a) some suppliers proposed "diffusion test" capable of detecting four tyres at 20 per cent under inflation, claiming that this is already state of the art
- (b) vehicle manufacturers demanded 25 per cent detection limits, in order to be able to design systems robust enough to avoid false warnings. The main argument was that in order to implement a system with 25 per cent threshold, the manufacturer would anyway be forced to set the alarm threshold to 20 per cent below P_{rec} in order to compensate for the tolerance distribution inherent to technical systems (e.g. 5 per cent for pressure sensors tolerance, test ground temperature variations etc).

The compromise proposed above is to demand a 20 per cent threshold for detecting diffusion, but takes into account these tolerance distributions by adding a 5 per cent tolerance margin at time of type approval test.

There may be some Gaussian distribution around the value of 20 per cent, but this proposed approach will lead to the 20 per cent detection threshold on the one side and on the other side will provide the robustness needed for type approval.

A 20 per cent threshold implemented in the detection software of a TPMS will provide a median detection value of 20 per cent, but will allow a certain variation of the tolerances of e.g. pressure gauges used for test.

