SAE International™ SURFACE VEHICLE RECOMMENDED PRACTICE

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Tire Pressure Monitoring Systems for Light Duty Highway Vehicles

Foreword

The field of application of this document is as listed below:

a. Light truck and passenger car tires
b. Tubeless conventional and run-flat tires

Normal tire maintenance procedures must be followed regardless of whether a tire pressure monitoring system (TPMS) is used or not. Tire pressure adjustments must be performed even in the absence of any TPMS indication in order to have the optimum tire performance. A TPMS acts only as an aid to the driver detecting pressure changes during operation.

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1. Scope

To establish overall performance guidelines, test methods, and minimum performance levels for a TPMS. The system shall visually indicate the tire inflation pressure status. These guidelines include, but are not limited to:

a. A test methodology for a device which monitors tire inflation, that is located in/on the tire/wheel environment.
b. Recommended performance guidelines for a TPMS.

1.1 Rationale

Not Applicable.

2. References

2.1 Applicable Documents

The following publications form a part of this recommended practice to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, www.sae.org

SAE J551/1—Performance Levels and Methods of Measurements of Electromagnetic Radiation from Vehicles and Devices (60 Hz to 18 GHz)
SAE J1211—Recommended Environmental Practices for Electronic Equipment Design
SAE J1113/1—Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (up to 15 m), and Machines (Except Aircraft) (50 Hz to 18 GHz)
SAE J1113/2—Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft)—Conducted Immunity, 30 Hz to 250 kHz—All Leads
SAE J1113/3—Conducted Immunity, 250 kHz to 5000 MHz, Direct Injection of Radio Frequency (RF) Power
SAE J1113/4—Immunity to Radiated Electromagnetic Fields—Bulk Current Injection (BCI) Method
SAE J1113/11—Immunity to Conducted Transients on Power Leads
SAE J1113/12—Electrical Interference by Conduction and Coupling—Coupling Clamp and Chattering Relay
SAE J1113/13—Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 13—Immunity to Electrostatic Discharge
SAE J1113/21—Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 21—Immunity to Electromagnetic Fields, 10 kHz to 18 GHz, Absorber-Lined Chamber
SAE J1113/22—Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 22—Immunity to Radiated Magnetic Fields from Power Lines
SAE J1113/24—Immunity to Radiated Electromagnetic Fields; 10 kHz to 200 MHz—Crawford TEM Cell and 10 kHz to 5 GHz—Wideband TEM Cell
SAE J1113/25—Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Immunity to Radiated Electromagnetic Fields, 10 kHz to 1000 MHz-Tri-Plate Line Method
SAE J1113/26—Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Immunity to AC Power Line Electric Fields
SAE J1113/27—Electromagnetic Compatibility Measurements Procedure for Vehicle Components—Part 27—Immunity to Radiated Electromagnetic Fields
SAE J1113/42—Electromagnetic Compatibility—Component Test Procedure—Part 42—Conducted Transient Emissions
SAE J2402—Road Vehicles-Symbols for Controls, Indicators, and Tell-Tales

2.1.2 ASTM PUBLICATIONS

Available from American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA, 19428-2959, www.astm.org

ASTM B 117—Salt Spray (Fog) Testing

2.2 Related Publications

The following publications are provided for informational purposes only and are not required as part of this document. Unless otherwise specified, the latest issue of the publications shall apply.

2.2.1 Tire and Rim Year Book

Available from The TIRE and RIM ASSOCIATION, INC., 175 Montrose West Avenue, Suite 150, Copley, OH 44321, www.us-tra.org

2.2.2 ETRTO Standards Manual

Available from European Tyre and Rim Technical Organization, Secretariat, Avenue Brugmann, 32/2, B.–1060 Bruxelles, www.agency.be/etrto

2.2.3 JATMA Year Book

Available from the Japanese Automobile Tire Manufactures Association, Inc., No. 33 Mori Bldg. 8th Floor, 3-8-21 Toranomon, Minato-Ku, Tokyo, Japan 105-0001, www.jatma.or.jp

2.2.4 ISO Publications

Available from ANSI, 25 West 43rd Street, 4th Floor, New York, NY 10036-8002, www.iso.org

ISO 7000—Graphical symbols for use on equipment—Index and synopsis
ISO 2575—Road Vehicles—Symbols for controls, indicators and tell-tales

2.2.5 Federal Publications

Available from Federal Communications Commission, 445 12th Street SW, Washington, DC 20554, www.fcc.gov

FCC Part 15

Available from the Federal Register, National Highway and Traffic Safety Administration, 400 Seventh Street, SW, Washington, DC 20590, www.nhtsa.dot.gov

Title 49 Code of Federal Regulations
FMVSS 138—Tire Pressure Monitoring Systems
FMVSS 101 S5.2.3—Controls and Displays
FMVSS 110—Tire Selection and Rims

3. Definitions

3.1 Conventional tire

All pneumatic tires not defined as run-flat.

3.2 Cold inflation pressure

Tire inflation pressure at the prevailing atmospheric temperature that does not include any tire inflation pressure build-up due to vehicle operation.

3.3 Functionality

Operation within the parameters as defined by the specification of the device under test.

3.4 Gross vehicle weight rating

The value specified by the vehicle manufacturer as the maximum loaded weight of a single vehicle.

3.5 Lightly loaded

Unloaded vehicle weight plus 180kg, including test driver and instrumentation.

3.6 Run-flat tire

A tire, which is capable of running a certain, limited distance under prescribed conditions in the event of a complete loss of inflation pressure. A run-flat tire is similar to a conventional tire in that it is inflated to the cold inflation pressure.

3.7 Test inflation pressure

The tire pressure at which the system is to be activated to indicate a low tire pressure condition on a vehicle.

3.8 Tire placard

A placard, permanently affixed to the vehicle as required by FMVSS110. The placard displays, among other information, the vehicle manufacturer's recommended cold tire inflation pressure.

3.9 Tire Pressure Monitoring System

A system that measures the tire inflation pressure or a parameter(s) that adequately correlates to tire inflation pressure.

3.10 Symbols and Abbreviations

DUT—Device Under Test
EMC—Electromagnetic Compatibility
IRI—International Roughness Index
p-p—Peak–to-peak
RF—Radio Frequency
TPMS—Tire Pressure Monitoring System

4. Technical Requirements

Section 4.1 applies to electronic device(s) that are mounted in/on the tire/wheel environment. This section describes characteristics of the expected environment that impact the performance and reliability of such devices. For those components of the TPMS that are mounted other than in/on the tire/wheel environment, SAE J1211 Recommended Practices for Electrical Equipment Design shall apply. Section 4.1 of this document addresses those requirements that are not defined in SAE J1211.

Devices that sense tire inflation pressure by other means (e.g. inductive sensors, etc.) may fall under the appropriate SAE J documents.

Section 4.2 shall apply to the complete TPMS.

4.1 Test Methods and Environmental Conditions

As electronics have been in vehicles for many years, the details of the effects of the environmental conditions are widely known. However, if more information is desired on the effects of the environment on electronic devices, refer to SAE J1211.

a. Test Sequence—This section does not define a test sequence; it is left to the designer. It is the intent that electronic device(s) that are mounted in/on the tire/wheel environment shall be capable of successfully completing all the tests defined within this section. The functionality of the device under test (DUT) shall be verified before and after testing . Additionally, each DUT shall be visually inspected for damage after testing.
b. General Conditions—Unless otherwise specified, the DUT shall be at ambient atmospheric pressure and relative humidity for each test.

4.1.1 OPERATIONAL TEMPERATURE

The DUT located in the tire/wheel environment is exposed to a wide range of temperatures. The operational temperature range listed should not be construed as totally inclusive of all operating temperatures that the DUT could experience. Measurements should be taken in the application to understand the full thermal environment of the DUT and the effects those extreme temperatures could have on the device.

It is recommended that environmental tests be developed using the operational temperature of –40°C to +85°C as a guideline for the minimum and maximum values.

4.1.2 THERMAL CYCLE

Exposure to a number of temperature cycles can aid in predicting the effect of stresses expected in the device over its design life. These stresses can affect the device both electrically and mechanically.

The recommended thermal cycle profile is shown in Figure 1. The DUT shall be placed in a thermal chamber that is cycled over the temperature range as determined in 4.1.1. Repeat the profile for 100 cycles. The complete thermal cycle test is 1,200 hours in length. The DUT shall be tested at T_{max} and T_{min} for functionality after the completion of 1200 hours.

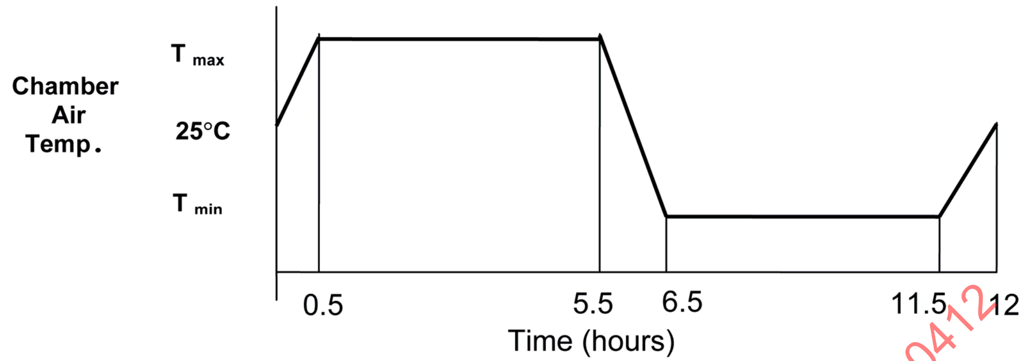

FIGURE 1—THERMAL CYCLE PROFILE

4.1.3 THERMAL SHOCK

In the tire/wheel environment, thermal shock can be experienced when a vehicle has run for a period of time and then is exposed to cold water or ice, or when going from a garage to outside in extremely cold climates.

The DUT shall withstand the 100 thermal shock cycles in air according to the profile in Figure 2. The temperature extremes should be those determined in section 4.1.1. The time between transitions is 30 minutes and the transition time between each temperature shall be less than 2 minutes.

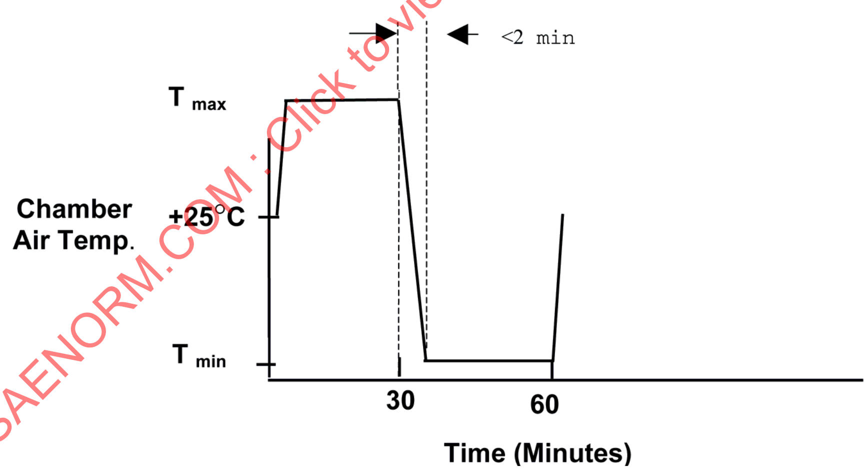

FIGURE 2—THERMAL SHOCK PROFILE

4.1.4 EXTREME TEMPERATURE

There could be isolated conditions in which the temperature within the tire/wheel environment can spike higher than the operational temperatures of section 4.1.1. Extreme temperature is one of the main factors in premature failure in one or more components, e.g. loss of battery life. It is recommended that this test be performed prior to thermal cycle and thermal shock tests.

Place the DUT in the thermal chamber at 125°C and soak for one hour. Remove the DUT from the chamber and let soak at ambient for one hour.

Repeat the above procedure for –40°C for the same DUT.

4.1.5 HUMIDITY

Though the DUT is not exposed to the ambient humidity as with other vehicle-mounted components, it does have its own humidity environment. Humidity can form within the sealed tire/wheel assembly due to water ingress prior to assembly or through water vapor from air compressing.

The DUT shall be exposed to 96 hours of 95% (+/-5%) humidity at 65°C. Humidity should be non-condensing. Operating condition of the DUT during humidity testing shall be representative of the functionality of the device during vehicle motion.

4.1.6 FROST

During normal vehicle operation, a combination of high humidity and low temperature will result in the formation of frost. This recommended procedure verifies the operation of the DUT in a frost environment.

Operating condition of the DUT during testing shall be representative of the functionality of the device while the vehicle is stationary. Soak the DUT at –40°C for 8 hours. Transfer within one minute to the humidity chamber at 10°C and a minimum of 90% relative humidity (RH) for 15 minutes. Remove DUT from chamber.

4.1.7 PROOF PRESSURE

Though the application for most TPMS is as specified on the tire placard, there are instances when the device can be exposed to pressure levels above those listed. One such application is tire mounting and inflation during the vehicle assembly process. The device must be able to survive this process.

A recommended test method is to mount the DUT in a pressure vessel. Pressurize the vessel to the greater of 800 kPa or 150% of the DUT's maximum operating pressure. Maintain the applied pressure for 30 minutes, then release to ambient atmosphere.

4.1.8 RAPID DEFLATION

Within some TPMS devices, there is a pressure sensor that measures the pressure within the tire/wheel assembly. There could be effects on the sensor when there is rapid deflation of the tire/wheel assembly.

The DUT shall be exposed to a pressure of 620 kPa for a minimum of 16 hours. Taking proper precautions, subject DUT to depressurization to atmospheric within 1 second.

4.1.9 ALTITUDE

During normal air shipments, it is possible that the device can be exposed to extreme cold temperatures and low atmospheric pressure.

The recommended altitude test method is performed with the DUT in the shipping mode. Place the DUT in a partial vacuum of less than 20 kPa (absolute) at –50°C for 12 hours. Remove and let soak for one hour at ambient conditions.

4.1.10 CONTAMINATION

The DUT may be exposed to a variety of media (e.g. tire lube, compressor oil, soap, and water). All possible contaminates are not listed in this section since contaminant exposure is dependent upon the application. The determination of any applicable media is left to the designer. Water shall always be included.

The recommended test method is to completely immerse the DUT in each media selected. A different set of DUTs shall be used for each media. Completely submerge the DUT in the media in each of six orientations for five minutes. Remove the DUT and let set for 24 hours. Repeat for each media selected.

4.1.11 SALT FOG - CORROSION

Any device mounted in the tire/wheel environment could have direct contact with salt. Though all TPMS devices may not protrude external to the tire, those mounted internally can be exposed when salt gets trapped within the tire/wheel assembly.

The recommended method for testing to salt fog utilizes the current ASTM procedure. The DUT shall be exposed per ASTM B117 for a minimum of 96 hours. Remove the DUT and let set for 1 hour.

4.1.12 DROP

This test is for component drops similar to those encountered in shipping and handling applications.

The recommended test method is a one meter drop onto concrete. The DUT shall be dropped on each of three principle axis. For the test, each drop shall be performed with a different DUT.

4.1.13 MECHANICAL SHOCK

Any device mounted in the tire/wheel environment will experience mechanical shocks as a result of any number of situations. Such situations could include road damage, striking a curb, mounting wheel weights, or dropping the rim assembly. This pulse is only representative of a shock pulse that the device may experience. The designer should evaluate whether this test profile will cover foreseeable scenarios which may occur.

The recommended test method utilizes a fixture that will produce a half sine mechanical shock waveform. The waveform shall be 2000g peak acceleration for 0.5 millisecond duration. The DUT shall be able to withstand three shock pulses along each principle axis, for a total of nine shocks per DUT.

4.1.14 MECHANICAL VIBRATION

The amount of vibration seen by any device on a vehicle is dependant upon many factors. Some of these factors include location, type of vehicle, and mass of the DUT. In SAE J1211, there are some representative power spectral density graphs for a few defined areas within the vehicle. However, for the tire/wheel environment, this is more difficult to define. The vibration levels in this section are only representative of what might be experienced. Most damage due to vibration occurs at frequencies less than 1000 Hz. The designer is encouraged to determine what vibration levels are appropriate on the particular application and use this information in developing a vibration test profile.

The recommended test method requires a test fixture to vibrate the DUT at the designated power spectral density profile. The DUT shall be tested along each of the three principle axis. The DUT shall be exposed to the vibration profile as shown in Table 1.

TABLE 1—VIBRATION PROFILE

Frequency (Hz)	Acceleration (g) or Displacement (mm)	Sweep Type (All Freq.)	Time per Sweep (Minutes) (All Freq.)	Number of Sweeps per Axis (All Freq.)
5 - 31.4	10 mm p-p	Log	20	18
31.4 - 50	20 g			
50 - 100	4.5 g			
100 - 200	3 g			

4.1.15 VEHICLE SPEED

The centrifugal forces exerted on a device mounted in/on the tire/wheel can be severe. Not all vehicles operate over the same speed range. When developing a test procedure, consideration should be given to the maximum speed the vehicle can operate and the time spent at that speed over the life of the vehicle.

The DUT shall be mounted in a fixture that can rotate the DUT in the same orientation as the tire/wheel. The DUT shall be exposed to a minimum 1500g centrifugal force for eight hours at an ambient temperature of 65 °C. It is not required that the fixture/DUT be pressurized.

4.1.16 ELECTROMAGNETIC COMPATIBILITY (EMC)

If the DUT is an electronic device, it can be affected by electromagnetic fields or be a source of electromagnetic radiation. As with other electronic devices on the vehicle, this device is expected to operate to a specified level when exposed to EMC, and conversely, not adversely affect other electronic devices.

The recommended test methods for EMC are specified in the various SAE J1113 documents. Not all SAE J1113 documents may be applicable. The designer shall determine which portions apply and then test the DUT accordingly.

4.2 Tire Pressure Monitoring System Performance

This section sets forth guidelines for which the TPMS shall operate as a system and provides recommendations for interface to the driver as to the status of both tire inflation pressure and the TPMS. The TPMS may be implemented using different technologies.

4.2.1 System Indicators and Lamp Strategy

Minimum indicator for an under-inflated tire shall be one of the following options:

4.2.1.1 A single indicator within clear view of the driver as shown in Figure 3. The symbol is defined in ISO 2575 as symbol #K08, Low Tire. Color shall be yellow, in accordance with SAE J2402 and ISO 2575.

FIGURE 3—LOW TIRE

4.2.1.2 A graphic symbol within clear view of the driver as shown in Figure 4. Color shall be yellow. This symbol must be used if individual tire location is specified.

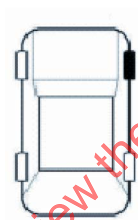

FIGURE 4—LOW TIRE BY LOCATION

4.2.1.3 An alphabetic indication including the words "LOW TIRE." The text or background must be yellow in color.

The indicator shall be tested upon ignition on for integrity. Additional alphanumeric display and symbols may be provided. An audible warning device may be used in addition to one of the visual indicators described above.

Known system failures should be indicated to the driver.

4.2.2 Vehicle to Vehicle Interaction

The TPMS shall utilize information only from tires/wheels associated with the installed vehicle. The system shall continue to function properly in close proximity of other vehicles with TPMS.

4.2.3 Operational Conditions

This section defines the typical operational conditions for which TPMS should function properly (during both calibration and detection modes, including avoidance of false detections). TPMS should be designed to effectively monitor as many driving situations as possible. A high priority should be placed upon prevention of false detections in all driving conditions.