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# Standard Test Method for Static Testing of Tubeless Pneumatic Tires for Rate of Loss of Inflation Pressure<sup>1</sup>

This standard is issued under the fixed designation F1112; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the rate of inflation pressure loss resulting from air diffusion through the structures of tubeless tires under constant temperature conditions. The testing is done under static conditions, that is, nonrotating, nonloaded tires.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

**D4483** Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries

**F538** Terminology Relating to the Characteristics and Performance of Tires

## 3. Terminology

3.1 *Definitions:*

3.1.1 *inflation pressure loss rate, n*—rate of change of normalized inflation pressure, determined from the slope of the linear portion of the log pressure versus time curve. **F538**

3.1.2 *measured inflation pressure, n*—gauge pressure of a tire measured at a given time under ambient temperature and barometric pressure. **F538**

3.1.3 *normalized inflation pressure, n*— measured pressure of a tire adjusted, according to the ideal gas law, to the nominal test temperature and one atmosphere external barometric pressure. **F538**

## 4. Summary of Test Method

4.1 Test tires are mounted on rims, fitted with calibrated precision pressure measuring devices, inflated to the desired pressure, and, after a period of stabilization, are monitored for inflation pressure as a function of time under static, constant temperature conditions.

4.2 Measured inflation pressures are normalized to the nominal test temperature and one atmosphere barometric pressure for calculation of pressure loss rates.

4.3 Two or more tires per tire specification are tested for pressure loss rate over a period of two to six months. High precision in the equipment and data may allow shortening the test. See 9.6, 10.5, and Section 12.

4.4 The pressure loss rate is calculated as percent loss per month at the nominal test temperature and one atmosphere barometric pressure (101.3 kPa).

## 5. Significance and Use

5.1 Inflation pressure retention is an important property of tire performance because underinflation can adversely affect tire rolling resistance, handling, structural integrity, and tread life.

5.2 This test method is useful for research and development evaluation of the effects of tire component formulations and geometry on inflation pressure retention. Testing for rate of pressure loss under static conditions is practical because of the following:

5.2.1 Tires in normal use are predominantly at rest, and

5.2.2 Relative air diffusion rates of various tires in normal intermittent road service will correlate with static relative rates, to a first approximation. The relative air diffusion rates of different tires may not be quite the same under dynamic flexing as when tested statically, but the difference is believed to be small.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee F09 on Tires and is the direct responsibility of Subcommittee F09.30 on Laboratory (Non-Vehicular) Testing.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5.3 The results from this test method are not suitable for inferring tire inflation retention under severe service conditions, such as heavy cornering or impacts, that might cause significant air loss at the tire-rim seal.

## 6. Interferences

6.1 Ambient temperature excursions greater than  $\pm 3^{\circ}\text{C}$  ( $\pm 5^{\circ}\text{F}$ ) for several hours may significantly alter both the air diffusion rate through the tire and the driving force inflation pressure, thereby causing variability in the rate of tire pressure loss. Some temperature variations can result from inconsistent air currents around the test tires, or from spatial temperature gradients in static air spaces. The effects can be significant where heat-generating tests such as laboratory road wheels are operating intermittently in the same room.

6.2 Other causes for inconsistent results are minute leaks in the tire, rim, valve, or pressure measuring device assembly; as well as varied service or other heat history of the test tires.

## 7. Sampling and Preparation of Test Tires

7.1 All of the tires in a sample should have the desired producing plant and date codes and similar storage and service temperature history.

7.2 Tires must be free of molding or other defects, particularly on the bead area and innerliner surfaces.

7.3 New tires should be used for evaluation of construction or compound variations.

7.4 Minimum recommended sample size is two tires for each type of tire or treatment being tested.

7.5 Test tires are to be mounted on rims of the proper bead seat diameter with clean, smooth surfaces in the bead seat areas, particularly in the vicinity of the weld. Rim flanges must be free of sharp edges or scuffs that could damage the tire during mounting. Bead seat diameters must be verified using a certified disc tape (a.k.a. ball tape) and be acceptable according to an applicable standard such as the Tire & Rim Association, Inc. (T&RA). Painted steel is the material of choice for the test rims due to the low permeation rates. If another rim material must be used, then precautions are to be taken to insure against air permeation through the rim material.

7.6 A commercial bead-rim lubricant shall be applied to the tire bead areas and rim before mounting. Vegetable oil or soap-based lubricants are recommended.

7.7 Mount the tire on the rim according to the practice recommended by Rubber Manufacturers Association (RMA).<sup>3</sup> Do not exceed 275 kPa (40 psi) inflation pressure for seating beads. Use of sealants in the bead-flange area should be avoided since it can prevent proper seating.

7.8 The rim shall be outfitted with either two serviceable valves or a single valve to which is then attached a metal “T” adapter that permits permanent attachment of a pressure-measuring device (gauge/transducer) to one opening and inflation through the other.

7.9 A sealing tape such as TFE-fluorocarbon or a room-temperature curable sealant shall be used on all threaded connections in the valve-adapter-gauge/transducer assembly.

7.10 A pressure-measuring device shall be connected to the adapter (or valve) to continuously measure inflation pressure. The device shall have a resolution of at least 2 kPa (0.25 psi) and an accuracy of  $\pm 1\%$  of the measured pressure. Devices shall be calibrated before and after each use with a reference device whose calibration is traceable to the National Institute of Standards and Technology (NIST). The pressure-measuring device must maintain this accuracy over the duration of the test. Quality Bourdon tube gauges have been satisfactory for 180-day duration tests. Electronic pressure transducers and data acquisition systems are advantageous due to their accuracy, repeatability, and continuous remote monitoring capability. To ensure their accuracy, these systems must be calibrated as a single, functional unit; transducer, cabling, signal conditioner, and data acquisition device. These systems, along with stable environmental conditions, can enable shorter duration tests producing results comparable to 180-day test results.

7.11 Inflate the tire-rim assembly outfitted with the pressure gauge or transducer to the desired starting pressure. Test for leaks by submersion in a water tank, up to the base of the gauge or transducer, for at least 30 min or carefully check both beads and fittings for leaks with leak detection fluid. If other than a painted steel rim is used, the entire rim must be checked for leaks.

7.12 After confirming that the tire-rim assembly is free from leaks, fit the valve or adapter opening with a sealing cap, and keep the tire in the same orientation to avoid causing new leaks.

7.13 After the leakage check, condition the tires at the test room temperature for 48 h; then adjust to the starting test pressure. Replace the sealing cap on the valve or adapter. If a pressure drop of more than 3 kPa (0.5 psi) occurs over the conditioning period, recheck the assembly for leakage according to 7.11 and, if necessary, dismount and remount the tire. Greater than 48 h conditioning may be necessary for some tires such as high-pressure compact spares, whose growth can affect early inflation loss results.

## 8. Test Chamber

8.1 The test chamber shall be controlled to provide a mean ambient temperature that is within  $\pm 0.6^{\circ}\text{C}$  ( $\pm 1^{\circ}\text{F}$ ) of the nominal test temperature and with overall variation within  $\pm 3^{\circ}\text{C}$  ( $\pm 5^{\circ}\text{F}$ ) over the course of the test.

8.2 Nominal test temperatures currently in use are: 21, 24, 30, and  $38^{\circ}\text{C}$  (70, 75, 86, and  $100^{\circ}\text{F}$ ).

8.3 Air in the test chamber should be forcibly circulated to minimize spatial temperature gradients.

## 9. Procedure

9.1 Place the test tires in the test chamber so as to allow free air circulation around them and easy visual access to the pressure gauges. The tires shall not be moved during the test.

9.2 Record inflation pressures, concurrent ambient temperatures, and barometric pressures frequently (daily readings are recommended) for two weeks. If using a pressure gauge, tap the gauge lightly prior to each reading. Tires shall be considered to be satisfactorily conditioned when the slope of the logarithm of the normalized inflation pressure versus time relationship becomes constant.

<sup>3</sup> Available from Rubber Manufacturers Association, 1400 K. St. N.W., Washington, DC 20005.

9.3 The test shall be continued if replicate tires agree with each other within 6 kPa (approximately 1 psi) inflation pressure after two weeks. Otherwise, recheck the suspect assembly for leaks according to 7.11, and restart the test.

9.4 Inflation pressure readings and concurrent ambient temperature and barometric pressure readings shall be recorded at least once per week during the remaining test period. Continuous monitoring of ambient temperature is desirable to ensure that the tire is at equilibrium temperature when its pressure is measured.

9.5 Correct inflation pressure readings,  $P_1$ , to the nominal test temperature and one atmosphere barometric pressure (101.3 kPa, 14.69 psi) by using the equation in 10.1.

9.6 A commonly used test duration is 180 days. The test period may be shorter or longer depending on the precision level of the data. More frequent or continuous electronic measurements are recommended if shorter term projections of performance are intended. See also 4.3.

## 10. Calculation

10.1 Calculate normalized pressures from the formula:

$$P = (P_1 + B_1) (T_2/T_1) - B_2 \quad (1)$$

where:

- $P$  = normalized inflation pressure, kPa,
- $P_1$  = measured inflation pressure, kPa,
- $B_1$  = measured barometric pressure, kPa
- $B_2$  = reference barometric pressure, kPa (one atmosphere = 101.3 kPa),
- $T_1$  = measured temperature, °K, and
- $T_2$  = nominal test temperature, °K.

NOTE 1—Temperature in Kelvin equals Celsius plus 273.15.

10.2 Air permeation data fits the model of the following form:

$$P = P_o e^{\beta t} \quad (2)$$

where:

- $P$  = normalized pressure, kPa,
- $P_o$  = normalized initial pressure, kPa,
- $\beta$  = loss rate per day at the nominal test temperature, and
- $t$  = test time, days.

10.3 A least squares fit can be obtained after transformation of the model equation to the following form:

$$\ln P = \alpha + \beta t \quad (3)$$

where:

$$\alpha = \ln P_o$$

The model is derived from a relationship that expresses pressure loss as a function of pressure only:

$$dP/dt = \beta P \quad (4)$$

Thus, pressure loss in absolute units will vary as the actual nominal pressure changes, but a loss rate can be expressed by the constant,  $\beta$ .

10.4 The calculated loss rate constant,  $\beta$ , will be in units of 1/day. This number will typically be a very small decimal; it is convenient, and perhaps more intuitively meaningful, to express loss rate as a percent per month. This is done by multiplying  $\beta$  by 3000 (which is 100 %  $\times$  30 days/month).

10.5 Calculations of steady state loss rate and predictions of future pressures can be made from any point in the test (beyond the first 30 days as explained in X1.3). The accuracy of such predictions will depend on the appropriateness of the model as well as the precision level of data obtained that, in turn, will depend on factors such as the following:

- 10.5.1 Care in reading pressure gauges,
- 10.5.2 Resolution and accuracy of pressure measuring devices,
- 10.5.3 Maintenance of a relatively constant temperature, and
- 10.5.4 Frequency of pressure measurements.

## 11. Report

11.1 For each test tire, report the loss rate as a percent per month ( $\beta \times 3000$ ) and other pertinent test parameters including:

- 11.1.1 Total test duration in days,
- 11.1.2 Projected inflation pressure, if applicable,
- 11.1.3 Average ambient temperature and range over test,
- 11.1.4 Initial inflation pressure,
- 11.1.5 Actual and “best fit” final inflation pressure, and
- 11.1.6 Starting date.

11.2 Also report the manufacturer, line, size, and U.S. Dept. of Transportation (DOT) serial number for each tire.

11.3 An example treatment of test data is given in Appendix X1.

## 12. Precision and Bias

12.1 The precision and bias section has been prepared in accordance with Practice D4483. Refer to this for terminology and other statistical calculation details.

12.2 An interlaboratory test was conducted in 1985 using a set of used uniform tire quality grading (UTQG) Course Monitoring Tires (CMT). This set of ten tires was furnished by one of the participating laboratories.

12.3 Five laboratories participated in the interlaboratory test. Each laboratory tested two tires following the test procedure as outlined in this test method. Thus, there are only 5 degrees of freedom (df) for repeatability ( $r$ ) and four df for reproducibility ( $R$ ). These low df for  $r$  and  $R$  are not optimum for a good reliable estimate of overall precision.

12.4 The tire air pressure loss rate was measured simultaneously for each of the two tires (per laboratory) at  $22 \pm 0.8^\circ\text{C}$ . This loss rate, as specified by this test method, is expressed as ( $B \times 3000$ ) in units of percent per month (or 30 days) at 1 atm (101.3 kPa) barometric pressure. A test result is the value obtained for ( $B \times 3000$ ) for one tire and one test on that tire.

12.5 The precision results, given in Table 1, show that the repeatability is equal to the reproducibility. For this (small df) interlaboratory test, the variation among the five laboratories is no greater than the pooled tire-to-tire variation within the laboratories. The rather large relative repeatability of 35.4 % may be indicative of variations in the test samples themselves. There is no independent way to verify this due to the age dependency of diffusion rate measurements.

12.6 Table 2 lists the actual test results. Inspection of the table shows the lack of agreement between duplicate tire results within any one of the five laboratories. It also shows

**TABLE 1 Precision: Air Pressure Loss Rate ( $B \times 3000$ )**

| Tire Type                   | Average Loss Rate <sup>A</sup> | Within Laboratory <sup>B</sup> |      |         | Between Laboratory <sup>B</sup> |      |         |
|-----------------------------|--------------------------------|--------------------------------|------|---------|---------------------------------|------|---------|
|                             |                                | $S_r$                          | $r$  | ( $r$ ) | $S_R$                           | $R$  | ( $R$ ) |
| UTQG CMT P19575R14 Uniroyal | 1.91                           | 0.24                           | 0.68 | 35.4    | 0.24                            | 0.68 | 35.4    |

<sup>A</sup> Units = percent per month (at 101.3 kPa reference barometric pressure).

<sup>B</sup>  $S_r$  = repeatability standard deviation.

$r$  = repeatability (in measurement units) (= 2.83  $S_r$ ).

( $r$ ) = repeatability (relative or percent).

$S_R$  = reproducibility standard deviation.

$R$  = reproducibility (in measurement units) (= 2.83  $S_R$ ).

( $R$ ) = reproducibility (relative or percent)

**TABLE 2 Actual ( $B \times 3000$ ) Values for Five Laboratories<sup>A</sup>**

| Laboratory     | Tire | $B \times 3000$ | Tire | $B \times 3000$ | Average (2 Tire) |
|----------------|------|-----------------|------|-----------------|------------------|
| 1              | 1    | 1.74            | 6    | 1.94            | 1.84             |
| 2              | 2    | 2.25            | 7    | 1.70            | 1.98             |
| 3              | 3    | 1.95            | 8    | 1.88            | 1.92             |
| 4              | 4    | 1.61            | 9    | 2.02            | 1.82             |
| 5              | 5    | 2.14            | 10   | 1.90            | 2.02             |
| Avg. Loss Rate |      |                 |      |                 | 1.91             |

<sup>A</sup> Units = percent per month (at 101.3 kPa).

$S_r$  = 0.24 (pooled within-laboratory single tire standard deviation).

$S_R$  = (between-laboratory) standard deviation (2 tire average) = 0.086.

$S_R$  = (between-laboratory) standard deviation (single tires) = 0.086  $\sqrt{2}$  = 0.12.

how the level of agreement among the laboratories substantially improves by taking averages. The pooled, within-laboratory single tire standard deviation,  $S_r$ , of 0.24 is twice the between-laboratory single tire standard deviation of 0.12,  $S_R$  (adjusted for the “averages of two basis” by multiplication by  $\sqrt{2}$ ).

**12.7 Repeatability**—The repeatability,  $r$ , of this test method has been established as 0.68. Two single test results, that is, loss rate in percent/month at 1 atm (101.3 kPa), obtained under normal test method procedures, that differ by more than this  $r$  must be considered as derived from different or nonidentical sample populations.

**12.8 Reproducibility**—The reproducibility,  $R$ , of this test method has been established as 0.68. Two single test results, that is, loss in percent/month at 1 atm (101.3 kPa), obtained in two different laboratories, under normal test method procedures, that differ by more than  $R$  must be considered to have come from different or nonidentical sample populations.

**12.9 Repeatability and reproducibility** expressed as a percent of the mean level, ( $r$ ) and ( $R$ ), have equivalent application statements as above for  $r$  and  $R$ . For the ( $r$ ) and ( $R$ ) statements, the difference in the two single test results is expressed as a percent of the arithmetic mean of the two test results.

**12.10 Bias**—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.

## 13. Keywords

13.1 inflation pressure; pneumatic tires; rate of loss; static testing

## APPENDIX

### (Nonmandatory Information)

#### X1. EXAMPLE OF DATA ANALYSIS FOR RATE OF PRESSURE LOSS IN TIRES

**X1.1** This example shows typical input data and analyses for obtaining the rate of pressure loss of a tire according to this test method.

**X1.2** **Table X1.1** presents measured data for a single tire over the 195-day test duration, the normalized inflation pressures calculated with the equation in **10.1**, and the natural logarithms of the normalized pressures.

**X1.3** Normalized inflation pressure as a function of time is plotted in **Fig. X1.1**. **Fig. X1.2** is a plot of  $\ln(P)$  versus time. In each case, the least squares regression of the data excluded the first 30 days to avoid the initial nonlinear inflation pressure change due to tire growth (evident in the first few data points).

**X1.4** Computation of inflation pressure loss rate over the test duration employed a computer program to fit the model equation (**10.2**) to the data by conducting a simple linear regression of the  $\ln(P)$  versus time data. The intercept is  $\ln(P_0)$ , and the slope is  $\beta$ . Inflation pressure loss rate is (the absolute value of)  $\beta \times 3000$ . The calculation is repeated at successive times to get an increasingly precise estimate of the true loss rate. Results are reported in **Table X1.2**. Again, the first 30 days of data were excluded from the analysis because they would not be expected to fit the model due to the nonlinear effects in this portion of the data set (noted earlier).

**X1.5** **Fig. X1.3** presents a format for the test data summary, in accordance with **10.5** of the standard test method. Results for two tires tested at the same time are presented.