Designation: F414 – 15

Standard Test Method for Energy Absorbed by a Tire When Deformed by Slow-Moving Plunger[1]

This standard is issued under the fixed designation F414; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of tire plunger energy required to completely penetrate the tread area of an inflated tire as indicated by a rupture, loss of inflation pressure, sudden drop in plunger force or bottom-out. The test requires utilization of a laboratory testing machine capable of slowly penetrating the tread surface of a tire with a plunger having a hemispherical end.

1.2 This test method is applicable to pneumatic tires for vehicles normally used on the road.

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

1.4 *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:*[2]

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

E4 Practices for Force Verification of Testing Machines

F538 Terminology Relating to the Characteristics and Performance of Tires

F1082 Practice for Tires—Determining Precision for Test Method Standards (Withdrawn 2005)[3]

IEEE/ASTM SI10-02 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *bottom out, v*—to deform a tire by radial load on the tread until radial movement of the inside surface is stopped by the rim or other tire inside surface. **F538**

3.1.2 *groove, n*—a void that is relatively narrow compared to its length. **F538**

3.1.3 *load range, n*—a letter designation (A, B, C, D) or, for P-metric tires, standard load (SL), light load (LL), or extra load (XL), used to identify a given size tire with its load and inflation limits when used in a specific type of service. **F538**

3.1.4 *load rating [M], n*—the maximum load a tire is rated to carry for a given usage at a specific cold inflation pressure. **F538**

3.1.5 *maximum load rating [M], n—of a passenger tire*, the load rating at the maximum permissible cold inflation pressure for that tire. **F538**

3.1.6 *maximum plunger travel [L], n—in tire testing*, the relative displacement of tread surface by a plunger, measured from the point of initial contact of the plunger with the tread surface to the point of maximum force at rupture or at the bottom-out point. **F538**

3.1.7 *nominal plunger energy, W = (F × P)/2, n—in tire testing,* one half of the product of a peak force (required to rupture the tire structure in tread area) and maximum plunger travel into a tire at the time of rupture. **F538**

3.1.8 *plunger, n—in tire testing*, a cylindrical rod with a hemispherical end. **F538**

3.1.9 *void, n*—a volume (in the annular tread band) defined by the lack of rubber; the depth dimension of this volume may vary from point to point in (on) the tread band. **F538**

4. Summary of Test Method

4.1 This test method measures tire plunger energy required to force a cylindrical plunger with a hemispherical end into the tread of the tire to produce a rupture of the carcass or a bottom-out condition.

[1] 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.

Current edition approved June 1, 2015. Published August 2015. Originally approved in 1975. Last previous edition approved in 2009 as F414 – 09. DOI: 10.1520/F0414-15.

[2] 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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

5. Significance and Use

5.1 This test method establishes a standard procedure of test and provides data that can be related to tire strength, but does not measure tire performance or establish specification or tolerances.

6. Apparatus

6.1 *Testing Machine* that incorporates a cylindrical plunger, which can be forced, at 50.8 ± 1.58 mm/min (2.0 ± 0.0625 in./min) radially into a tread of a tire, while the force and plunger motion are indicated or recorded.

6.1.1 The force-indicating device shall have an accuracy of ±1 % of the indicated force and shall reflect an instantaneous change in force from zero to full scale in no more than 3.0 s.

6.1.2 Relative plunger travel distance shall be indicated to an accuracy of ±1 % of the distance from the original undeformed tire tread surface, taking into account any motion or deflection of the force-measuring mechanism or supporting devices.

6.2 *Means for Calibration of the Testing Machine,* for plunger force, plunger travel, and rate of plunger travel is necessary.

6.3 *Calibrating Weights or Other Calibrating Devices,* conforming to Practices E4, are required for verification of calibration.

6.4 *Means for Mounting a Tire on a Test Rim,* and mounting the test assembly on the testing machine is necessary.

6.5 *Test Rims,* with dimensions as shown in the current issue of Tire and Rim Association Year Books,[4] ETRTO,[5] JATMA,[6] or as listed in a publication by the tire manufacturer, are necessary.

6.6 *Plunger (Circular Cylinder),* having a diameter as shown in Table 1 for the tire being tested, and having the working end in the shape of a hemisphere, hardened to a minimum Rockwell hardness 35 HRC, and polished to a 0.50-µm (16-µin.) finish or better with no visible tool marks, is required. It must be long enough to penetrate from the undeformed tire tread surface to the bottom-out condition.

7. Sampling

7.1 A sample is one or more tires taken from a lot as directed in any applicable specification, or as taken from a shipping unit, or as agreed upon between the purchaser and the seller.

7.2 Record the manufacturer's identification, brand name, tire identification number, tire outside diameter, rim diameter, size, load range, fabric type, and type of tire. Visually inspect the tire completely for excessive mold lubricant and for any obvious faults or conditions that could affect the test.

TABLE 1 Plunger Diameter

Tire Load Identification[A]	Tire Characteristics	Plunger Diameter, mm (in.)
A, B, C	Motorcycle	7.9 ± 0.1 (0.313 ± 0.005)
A, B, C, D, SL, XL, E, F	All 12 rim diameter code or smaller, except motorcycle	19.0 ± 0.1 (0.750 ± 0.005)
B, C, D, SL, LL, XL, T	Passenger car	19.0 ± 0.1 (0.750 ± 0.005)
B, C, D, E, F, G, H	Light truck	19.0 ± 0.1 (0.750 ± 0.005)
B, C, D, E, F, G, H	17.5 rim diameter code or smaller, tubeless	19.0 ± 0.1 (0.750 ± 0.005)
C, D, E, F	Larger than 17.5 rim diameter code, tubeless	31.8 ± 0.1 (1.250 ± 0.005)
C, D, E, F	Larger than 17.5 rim diameter code, tube type	31.8 ± 0.1 (1.250 ± 0.005)
G, H, J, L, M, N	Larger than 17.5 rim diameter code, tubeless	38.1 ± 0.1 (1.500 ± 0.005)
G, H, J	Larger than 17.5 rim diameter code, tube type	38.1 ± 0.1 (1.500 ± 0.005)

[A] Temporary use 60-psi tires and standard load, light load, and extra load "P metric" tires are described as T, SL, LL, and XL. All other letter designations refer to load range.

8. Conditioning

8.1 The ambient temperature for tire conditioning and in the test area shall be any known temperature between 18 and 40°C (65 and 105°F).

8.2 The test tire, after being mounted on a test rim and inflated to the applicable test pressure, shall remain at the ambient temperature of the test room for at least 3 h prior to testing.

9. Procedure

9.1 Mount the tire on a test rim and inflate the tire with air to the pressure as specified in Table 2 when testing passenger car tires or corresponding to the maximum load or maximum dual load where there is both a single and dual load marked on the tire for all other type tires. The inflation pressure tolerance shall be ±3.5 kPa (0.5 psi). Condition the mounted tire in accordance with 8.1 and 8.2.

9.1.1 Table 2 provides the inflation pressure to use when testing various passenger car tire sizes. There are three common styles for tire size designators in current use; each style is listed in separate sections of the table.

9.1.1.1 A tire size designator in the "Passenger" style may or may not use the single letter "P" followed by a number identifying a width, a slash (/), a number identifying the aspect ratio, a construction indicator "R", and another number indicating the rim size code.

9.1.1.2 A tire size designator in the alphanumeric style uses a single letter (other than P or T) followed by a number identifying an aspect ratio, a hyphen, and another number indicating the rim size code.

9.1.1.3 A tire size designator in the "T" style uses the single letter "T" followed by a number identifying a width, a slash (/), a number identifying the aspect ratio, an "R" or "D," and another number indicating the rim size code.

[4] Available from Tire and Rim Association, Inc. 175 Montrose West Ave., Copley, OH 44321.

[5] Available from the European Tyre and Rim Technical Organization, 32/2, Avenue Brugmann, B-1060 Brussels, Belgium.

[6] Available from the Japan Automobile Tire Manufacturers Association, Inc., No. 33 Mori BLDG, 8th Floor, 3-8-21 Toranomon, Minato-KU, Tokyo, Japan 105-001J.

TABLE 2 Passenger Car Tire Plunger Energy Test Inflation Pressure[A]

Tire Load Identification	Test Inflation[B,D] kPa (psi)	Maximum Inflation[C,D] kPa (psi)
Alphanumeric type tires		
Load range B	165 (24)	220 (32)
Load range C	195 (28)	250 (36)
Load range D	220 (32)	275 (40)
"Passenger" type tires		
Standard load or LL	180 (26)	240 (35)
	180 (26)	250 (36)
Extra load	180 (26)	300 (44)
	180 (26)	350 (51)
	220 (32)	280 (41)
	220 (32)	290
	220 (32)	340 (50)
"LT" and "C" type tires	Corresponding to pressure for maximum load or maximum dual load where there is both single and dual load marked on the sidewall.	
"T" type tires		
Temporary use	360 (52)	420 (60)

[A] Inflation pressure tolerance = ±3.5 kPa (±0.5 psi).
[B] Refer to IEEE/ASTM SI10-02 for a comprehensive understanding of SI units. The conversion unit relative to previous practice: 1 psi = 6.894757 kPa.
[C] Part of the identification of the tire is the "Maximum Pressure," which is stamped on the sidewall of the tire.
[D] Please refer to ISO/TR 29846:2008 for kPa to PSI equivalencies.

9.2 An inner tube of the same size as the tire shall be used for all measurements on tube-type tires and may be used in tubeless-type tires.

9.3 Select a plunger of diameter specified in Table 1 and properly secure the plunger to the testing machine.

9.4 Clean the plunger prior to each test using a clean soft cloth and a water soluble rubber lubricant or water miscible solvent. Wipe completely dry and clean off any residue or foreign matter. Clean the tire prior to each test using a clean, dry, soft cloth.

9.5 Mount the tire-wheel assembly on the testing machine. Adjust the test inflation pressure, if necessary, and adjust the lateral position of the plunger or wheel so that the plunger contacts the tire at the test point (tread rib nearest tire center) with a force just sufficient to cause a slight drag between the tire and plunger. Avoid centering the plunger on a deep groove in the tread rib or block.

9.6 Force the tire onto the plunger or the plunger perpendicularly into the tire tread (depending upon the relative motion employed by the test apparatus) at a rate of 50.8 mm/min (2 in./min), while recording plunger force and travel.

9.7 Increase tire deformation by the plunger until the tire either is completely penetrated (as would be indicated by a rupture, loss of inflation pressure) or bottom-out occurs. Record the maximum plunger force and plunger travel into the tire at five test points or at three test points for tires of 12 rim diameter code or less, equally spaced around the tire circumference in accordance with 9.1 – 9.6. Use these values in Section 10 to calculate energy. If a bottom-out condition is reached, stop the test before any damage to the tire, rim, or plunger pin can occur, and record the plunger force and travel. If the tire fails to break before plunger is stopped on reaching the rim and the required minimum breaking energy is not achieved, then the required minimum breaking energy is deemed to have been achieved at that point.

9.8 If necessary, to prevent inflation pressure loss, after each plunger test, place a tire patch over the rupture area on the inside of the tire. Reinflate to test inflation pressure and proceed to the next test location.

10. Calculation of Results

10.1 Compute the nominal plunger energy for each of the test points measured by means of the following formula:

$$W_{(e)} = (F \times P)/2 \quad (1)$$

where:

$W_{(e)}$ = nominal plunger energy, lbf·in.,
F = maximum force, lbf, and
P = maximum plunger travel, in.

or

$$W_{(m)} = [(F \times P)/2000] \quad (2)$$

where:

$W_{(m)}$ = nominal plunger energy, J,
F = maximum force, N, and
P = maximum plunger travel, mm.

10.1.1 Tire plunger energy can also be obtained by measuring the area under the force deformation curve if test equipment is so equipped. However, the energy value obtained can be different from the formula value and must so be indicated in the test report.

10.1.2 Tire plunger energy values obtained using inflation pressure other than the test inflation pressure as listed in Table 2 cannot be compared unless the testing has been done at the same inflation pressure. A tire will have different values of plunger energy when tested at two different inflation pressures. For example, a tire that ruptures at 225 J (1991 lbf·in.) at 165 kPa (24 psi) is not as strong as a tire that ruptures at 225 J (1991 lbf·in.) at 195 kPa (28 psi).

10.2 Calculate the average $W_{(e)}$ or $W_{(m)}$ and record the average, maximum, and minimum $W_{(e)}$ or $W_{(m)}$ value obtained for each tire.

11. Report

11.1 State that the tests were made in accordance with Test Method F414.

11.2 The report shall include the following:

11.2.1 Source and complete markings of the test tire,

11.2.2 Designations of the rim used in the test conducted,

11.2.3 Temperature at which the tire was conditioned and tested,

11.2.4 Any tire condition or abnormality determined by inspection or noted during testing that might have influenced the test,

11.2.5 All values of $W_{(e)}$ or $W_{(m)}$ plus the average, minimum, and maximum tire plunger energy to the nearest 1 J (or the nearest 10 lbf·in.), and the inflation pressure used.

11.2.6 Number of times the tire reached the bottom-out condition without failure (and the inflation pressure) with the value of plunger energy calculated at the bottom-out condition.

12. Precision and Bias

12.1 These precision statements have been prepared in accordance with Practice F1082, which has been withdrawn. Committee F09 is now using Practice D4483 as a guideline document for precision. Please refer to this practice for terminology and other testing and statistical explanation.

12.2 An interlaboratory program to test bias tires was conducted in 1985. A lot of 15 nominally identical tires, G78 × 14 (4 ply-polyester) was selected from a single production run. Two tires were sent to each laboratory, each to be tested on a separate day.

12.3 The precision results are expressed on the basis of test results, that is, the median of five plunger energy measurements at 167 kPa (24 psi) inflation pressure, on a 6 × 14 rim, with a plunger diameter of 19 mm (0.75 in.) with 3 h of laboratory conditioning prior to test.

12.4 *Repeatability*—The repeatability, *r*, of this test method has been established as the appropriate value tabulated in Table 3. Two single test results, obtained under normal test method procedures, that differ by more than this tabulated *r* may be considered as derived from different or non-identical sample populations.

12.5 *Reproducibility*—The reproducibility, *R*, of this test method has been established as the appropriate value tabulated in the Precision Table. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated *R* may be considered to have come from different or nonidentical sample populations.

TABLE 3 Precision-Tire Plunger Energy

Tire	Test Level Average[A]	Within Laboratory			Between Laboratory		
		S_r	*r*	(*r*) %	S_R	*R*	(*R*) %
G78 × 14	3319	137	387	11.7	159	449	13.5

where:
S_r = repeatability standard deviation,
r = repeatability,
(*r*) % = repeatability, %,
S_R = reproducibility standard deviation,
R = reproducibility, and
(*R*) % = reproducibility, %.[A]

[A] Units are pound-force inch. To convert to joules multiply by 1.129848 E-01.

12.6 Repeatability and reproducibility expressed as a percentage 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 percentage of the arithmetic mean of the two test results.

12.7 *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 this test method. Bias therefore cannot be determined.

12.8 Due to the age of the Precision and Bias study, and the fact that it was performed on bias-ply tires which are currently in limited use, the committee has agreed to conduct the study again using modern radial tires. This study is intended to be complete by 2017.

13. Keywords

13.1 absorbed; deformed; energy; plunger; tire