Designation: F870 – 94 (Reapproved 2016)

Standard Practice for Tread Footprints of Passenger Car Tires Groove Area Fraction and Dimensional Measurements[1]

This standard is issued under the fixed designation F870; 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 practice covers a technique for measuring the groove or void area of a tire tread pattern. The void area is measured on the inked impression of a tire tread statically loaded against heavyweight paper on a load platen.

1.2 This procedure is intended to serve as a reference practice for measuring groove or tread pattern void areas in a tire-footprint impression. This technique is usable by any laboratory without special equipment although more sophisticated procedures are also commonly employed, such as optical or video camera processes.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are 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]

F538 Terminology Relating to the Characteristics and Performance of Tires

3. Terminology

3.1 *Definitions:*

3.1.1 *circumferential line, n—on a tire,* any real or imaginary circle on the surface of a tire, lying in a plane that is perpendicular to the spin axis. **(F538)**

3.1.2 *developed footprint length,* [*L*], *n*—the maximum footprint dimension in the circumferential direction of the tire, under stated conditions of measurement.

3.1.3 *developed footprint width,* [*L*], *n*—the maximum lateral dimension of a tire footprint under stated conditions of measurement. **(F538)**

3.1.4 *element, n*—an isolated (totally bounded by void) projection. **(F538)**

3.1.5 *footprint area,* [L^2], *n*—the gross contact area of a tire that is loaded (under stated conditions) against a smooth flat surface. **(F538)**

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

3.1.7 *groove (void) area,* [L^2], *n*—that portion of tire footprint area that is not contacted by ribs or elements.

3.1.8 *groove (void) area fraction,* [*nd*], *n*—the ratio of the groove (void) area to the footprint area of a tire. **(F538)**

3.1.9 *lateral groove, n*—a groove that has its long dimension oriented at direction non-parallel to the tire circumferential centerline; it most frequently opens into a void at both ends. **(F538)**

3.1.10 *notch, n*—a groove smaller in both width and length than a lateral groove, that contains one closed end. **(F538)**

3.1.10.1 *Discussion*—For the purpose of this practice, it is wider than 1 mm and more than 25 % as deep as a groove in the same tire (see Fig. 1).

3.1.11 *projection, n*—a pavement contacting area of the tread band, bounded by void. **(F538)**

3.1.12 *rib, n*—a continuous circumferential projection. **(F538)**

3.1.13 *rib or element area,* [L^2], *n*—that area within the outer periphery of a tire footprint that is contacted by ribs or elements.

3.1.14 *sipe, n*—a molded or cut rectangular void that is substantially narrower than the major grooves or voids. **(F538)**

3.1.15 *total or gross-contact area,* [L^2], *n*—that area encompassed by the outer periphery of a tire footprint.

3.1.16 *void, n*—a volume (in the 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)**

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[1] This practice 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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[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.

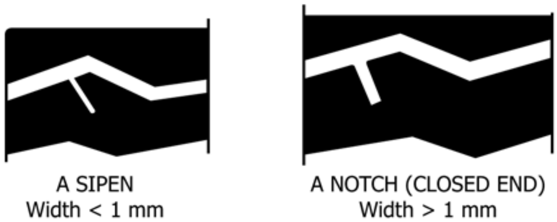

FIG. 1 Schematic Diagrams Kerf (Sipe) and Notch

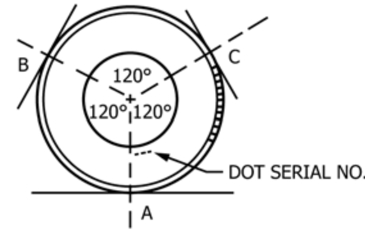

FIG. 2 Footprint Zones A, B and C

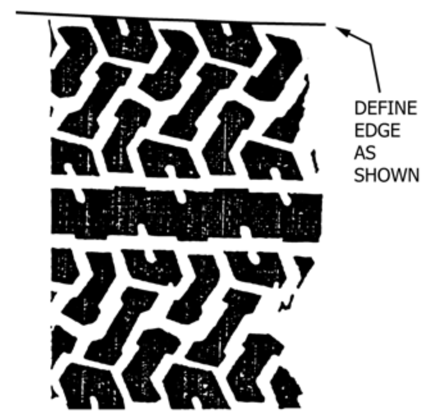

FIG. 3 Definition of Shoulder Edge in Patterns That Do Not Contain a Solid Shoulder

4. Summary of Practice

4.1 This practice is divided into two parts. Paragraph 8.1 provides a procedure to obtain a tire footprint impression. Paragraph 8.2 describes the necessary measurements made on the footprint impression, or copies thereof, to permit a calculation of the groove-area fraction. Supplementary footprint width and length measurements may also be made.

4.2 The groove-area fraction is calculated from measurements in the central 60 % region of the footprint. This central 60 % region (calculated from footprint length dimensions) is used to avoid the ambiguities and subjective judgements in precisely defining the "ends" of a footprint. The groove area fraction, φ_A, is the ratio of the groove-void footprint area to the total or gross-footprint area in this region. The gross area can be obtained by direct measurement of this rectangular area.

5. Significance and Use

5.1 The tread of a tire, the annular band that contacts the pavement, normally contains geometric tread pattern elements that are defined by grooves or voids. These are employed to confer appropriate traction properties to the tire, mainly on wet or snow-covered roads.

5.2 One characteristic feature of tire tread patterns that is important for both traction and tire wear behavior is the percent or "fractional" groove area. The groove-area fraction is calculated with respect to the total or gross contact area.

6. Interferences

6.1 Certain difficulties may be encountered in making groove-area fraction and footprint dimensional measurements. These are principally concerned with decisions on what to include as void area. Tires are designed with a multitude of geometrical features that show up on the footprint as a void area. Section 3 addresses these problems. Subjective judgements as to what to include cannot be avoided, and where such decisions are believed to be relevant, it is necessary that sufficient explanation be made in the final report.

6.2 One typical difficulty is illustrated in Fig. 2 in defining the outside shoulder edge of the footprint in tires that do not have a continuous well-defined shoulder rib edge. The total area should be obtained by defining the edge of the print as shown in Fig. 3.

7. Apparatus

7.1 *Tire Loading Machine*—A machine or fixture that is capable of holding a rim-mounted tire vertically at normal inflation pressures and that is capable of applying a specified tire load (within ±2 %). The machine shall have a smooth, flat, hard base upon which the tire is loaded. The rate of loading shall be such that no tire bounce or oscillation occurs upon cessation of loading. Rates of vertical travel of 2 mm/s (4.7 in./min) or less in the loading operation are satisfactory.

7.2 *Ink Pad*—A soft, inked pad of sufficient area to apply ink to the surface of the tread. An office foam-rubber stamp pad used with stamp-pad ink is recommended.[3] The pad shall be inked so that the foam-pad material is fully saturated. However, avoid excess ink, which frequently causes edge distortions of the footprint impression.

7.3 *Footprint-Impression Paper*—Paper of a size sufficient to accommodate the inked footprint. The paper shall be smooth and of sufficient thickness (or weight) to prevent surface buckling or crimping during the tire load process.[4] The ink should not smear or penetrate beyond the geometrically defined rib areas due to capillary or other similar action.

NOTE 1—The use of pressure-sensitive paper is permissible if the user can demonstrate that the impression is clearly defined and equivalent to an inked print.

8. Procedure

8.1 *Tire Footprint Impression:*

[3] A Carter foam-rubber stamp pad No. 2 (80 by 150 mm (3 by 6 in.)) and Carter stamp pad ink No. 414, manufactured by Dennison Carter Ink Company, 321 Fortune Blvd., Milford, MA 01752, have been found to be satisfactory.

[4] Recording chart paper X-Y-1101-SPI, manufactured by Graphic Controls Corp., 189 Van Rensselaer St., Buffalo, NY 14201, has been found to be satisfactory.

8.1.1 Mount the tire on the test rim specified by the Tire and Rim Association Yearbook[5] and inflate to the inflation pressure (see 8.1.2) for the load selected. Inspect the tread surface for irregularities, such as mold vent protrusions, and remove any found.

8.1.2 In the absence of any specific recommendations for inflation pressure, inflate to the maximum inflation pressure which is shown on the sidewall of the tire.

8.1.3 For tires with numerous mold-vent projections, buff the tread surface lightly with a power-belt sander using fine abrasive paper. Do this with the inflated tire and rim assembly mounted on a power-driven spindle rotating at 10 to 15 r/min. Apply light pressure when buffing, always moving the buffer laterally back and forth. A removal of 0.05 to 0.1 mm (0.002 to 0.004 in.) of tread surface has been found to be satisfactory. There should be no change in tread contour due to buffing.

8.1.4 In the absence of power equipment, remove the mold-vent projections or flash, or both, by applying a slight extension to the projection by hand and carefully cutting the excess from the tread face with a small, very sharp knife or pocket nail clippers.

8.1.5 Tires frequently contain tread-element dimensional variations (size, spacing, pitch, length, etc.) to reduce noise tonality in service use. When such variations exist, it is necessary to represent the tire with an average groove or void area. A recommended technique is outlined in 8.1.6. However, the recommended selection of three zones as outlined may not adequately achieve this objective, and it may be necessary to modify the location to obtain a representative set of footprint impressions.

8.1.6 Three zones are recommended for making footprint impressions. These zones, A, B, and C, are located as follows:

8.1.6.1 *Zone A,* from the DOT serial number side is defined by a plane perpendicular to a line through the center of the axis of rotation and the first letter of the DOT serial number.

8.1.6.2 *Zone B,* is located so that the center of the footprint is spaced 120° clockwise from the footprint center of Zone A.

8.1.6.3 *Zone C,* is located so that the center of the footprint is 240° clockwise (120° counter-clockwise) from the center of Zone A. The footprints shall conform to within ±5° of the specified zone-footprint center as specified herein. (See Fig. 2.)

8.1.7 Install the mounted tire and rim assembly in the loading machine or fixture. Locate the first footprint zone and position in an upright orientation. Ink the tread region thoroughly with firm pressure pad application, over a circumferential arc of approximately 30 cm. Inspect the inked surface to assure:

8.1.7.1 That all rib projections are fully inked and wetted (Note 2).

8.1.7.2 That excess inking has not occurred as manifested by a buildup of ink on the edges of the ribs.

NOTE 2—To assure thorough wetting of the rubber with the ink, it may be desirable to clean the tread surface with a hydrocarbon solvent (hexane, heptane) prior to inking. Allow the solvent to evaporate.

8.1.8 Rotate the center of the inked zone to the midpoint of the footprint-loading position and, with the paper held in place at its edges by tape, load the tire to the load corresponding to the inflation pressure being used. If the maximum inflation pressure is being used, then use the maximum load that is shown on the sidewall of the tire. For loads at inflation pressures other than maximum, consult the Tire and Rim Association Year Book. Allow a few seconds to elapse and unload the tire.

8.1.9 Inspect the footprint for clean, sharp rib-projection impressions and a good rib versus groove contrast, that is, rib areas that are sufficiently black. Reink and reload the tire if a good footprint is not obtained. Mark the footprint with appropriate identifying data.

8.1.10 Repeat for all selected footprint zones. Allow all footprints to thoroughly dry before making copies for measurements.

8.2 *Measurements on the Footprint Impression:*

8.2.1 Reproduce the original footprints of the three zones using a copier that suitably differentiates between contact and void regions and does not cause dimensional variations of the length and width dimensions greater than ±1 %. A photocopy of the original impression is made to eliminate variation of weight due to inking.

8.2.2 A typical footprint is shown in Fig. 4. The central 60 % region is obtained as follows:

8.2.2.1 Draw footprint "end lines" a and a' as shown. The horizontal position of these is not critical, but they should, in the subjective judgement of the person doing the analysis, reasonably represent the end of the footprint. In footprints that have shoulder lengths greater than crown lengths, the shoulder dimensions should be used to locate the end lines.

8.2.2.2 Measure d_{FL}, the distance between end lines (174 mm in this example), and divide this distance by 5. (For this example, this gives 34.8 ≅ 35). Measure inward 35 mm for each end line as shown and draw line b and b'. These latter two lines constitute the ends of the 60 % central region for use in the footprint measurement.

8.2.3 Determine the location of the outside shoulder edges of the footprint and measure d_{FW} (see Figs. 3-4).

8.2.4 Cut out the rectangular 60 % region of the paper-footprint impression and weigh to the nearest 0.005 g. This is the weight of the paper-footprint impression, W_T.

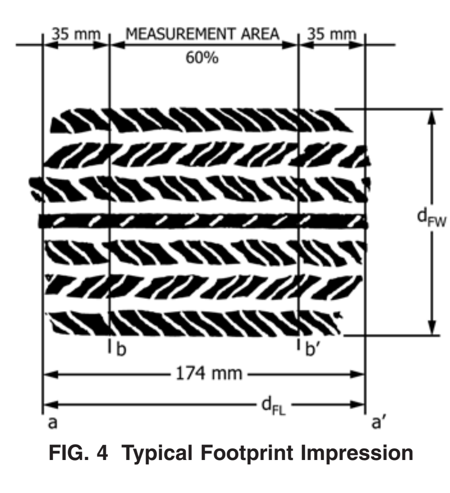

FIG. 4 Typical Footprint Impression

[5] T and RA Yearbook (current edition), available from the Tire and Rim Association, 175 Montrose West Ave., Copley, OH 44321.

TABLE 1 Interlaboratory (Reproducibility) (Comparison (φ_A)

	Tire Types							
	1	2	3	4	5	6	7	Average
Groove or void area fraction, φ_A	0.318	0.336	0.458	0.308	0.314	0.292	0.345	0.339
Standard deviation	0.0046	0.0053	0.0073	0.010	0.012	0.012	0.016	0.011[A]
Coefficient variation, %	1.4	1.6	1.6	3.2	3.8	4.1	4.6	2.9

[A] Pooled standard deviation.

8.2.5 With a razor blade or other suitable instrument, accurately cut out the groove or void areas of the 60 % region. Do not include in this any kerfs or sipes, but do cut out any notches. If kerfs or sipes are of a borderline nature, make a special note as to whether they are included or not. Weigh all the cutout groove or void pieces to the nearest 0.005 g. This is the weight of the groove or void, W_V.

8.2.6 Determine the nonvoid weight (W_{NV}) by subtracting the weight W_V from the weight W_T.

9. Calculation

9.1 Calculate the groove-area fraction, φ_A, for all three zones, A, B, and C, as follows:

$$\varphi_A = \frac{W_V}{W_V + W_{NV}(CF)} \tag{1}$$

where:

W_V = weight of the void areas of the central footprint (60 %) region, g,
W_{NV} = weight of nonvoid (rib, lug areas of footprint) (60 %) region, g,
CF = correction factor for image density weight of nonvoid areas (see Note 3 and Note 9.2), and
W_T = $W_V + W_{NV}$ (CF).

NOTE 3—The correction factor, *CF*, is obtained from the weight or mass ratio of nonblackened to blackened areas on the copies produced by the copier used for the image reproduction. This can be obtained by making copies of white and black paper on the copier and cutting, with a sharp razor blade, equal areas (several square centimetres or square inches) of both types of paper. The weight ratio (nonblack to black) gives the correction factor, *CF*. The black paper should be of equal intensity to the image produced by the inking of the (footprint) paper during the footprint-impression operation.

9.2 The correction factor can be omitted in certain technical applications of footprint groove-area comparisons. Its omission will produce an average bias of −4 %; noncorrected values are lower than corrected values. If corrections are made, the correction factor (*CF*) should be determined for each separate measurement program.

10. Report

10.1 *Inked Footprint Impression*—Report the following information:

10.1.1 The tire identification (type, size, etc.),

10.1.2 The date,

10.1.3 The tire load (to ±2 %),

10.1.4 The tire inflation pressure (to ±2 %),

10.1.5 The rim information, and

10.1.6 The location of the circumferential zone footprint impression with respect to the tire serial number.

10.2 *Measurements on the Footprint Impressions*—Report the following information:

10.2.1 The information recorded in 10.1,

10.2.2 The calculated groove-area fractions, φ_A, to the nearest 0.005 for Zones A, B, and C and the average groove-area fraction, φ_A, for the tire.

10.2.3 A statement as to whether these φ_A values include image density corrections. Record the value of the density factor, *CF*, if used,

10.2.4 The developed-footprint width, d_{FW}, and footprint length, d_{FL} (individual and average), in millimetres, and

10.2.5 Any statement concerning geometric pattern features included as void.

11. Precision and Bias

11.1 The results of an interlaboratory program among four laboratories to assess the reproducibility, that is, the among laboratory variation of groove-area fraction measurement, are given in Table 1. One set of footprint impressions of seven different tires was sent to each of the four laboratories, and cut-and-weigh operations were performed at each location. No image density corrections were made.

11.2 Table 1 indicates that the coefficient of variation is 2.9 % as an average, with a range of 1.4 to 4.6 %. This degree of reproducibility does not include, as a component, the variation associated with making a footprint impression.

12. Keywords

12.1 footprint; groove area fraction; tire footprint impression