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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides procedures for evaluating pneumatic tires for military service. Discusses test preparation requirements for tire, rim, and vehicle. Describes test procedures for endurance, temperature, bead slip, traction, lateral stability, and run flat. Provides a system for collecting and presenting tire wear data.

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U. S. ARMY TEST AND EVALUATION COMMAND
DEVELOPMENT TEST II (EP) - COMMON TEST OPERATIONS PROCEDURES

AMSTE-RP-702-101
*Test Operations Procedure 2-2-704 23 January 1976
AD No.

TIRES

SECTION I
GENERAL

1. Purpose and Scope. This TOP describes the procedures for evaluating pneumatic tires, tube and tubeless, for military service. The TOP is primarily concerned (paras 4 through 12) with engineer design and development tests (DT I, II and III) of tires. Also included, however, is a procedure (para 13) for acquiring data on production tires for the TACOM tire data bank during operation of vehicles at TECOM agencies.

*This TOP supersedes MTP 2-2-704, 24 Nov 65.

2. Background. The mobility of military vehicles depends to a vast degree on the capability of their tires to endure high-speed, high-load operation, provide adequate traction and stability, operate at reduced inflation pressures, and exhibit sufficient run-flat ability to evacuate a battle zone.

Many factors, such as operating environment, driver, load, type of vehicle, etc., determine tire life, the variety being greater for military than for commercial tires. Load and inflation pressure tables for standard tires used in highway service are published in the Tire and Rim Association Yearbook (ref. 8, app. A).

3. Equipment and Facilities. Equipment and facilities are covered in the applicable paragraphs of section II.

SECTION II
TEST PROCEDURES

4. Preliminary Activities.

4.1 Tire and Rim Preparation. Test and control tires are inspected for punctures, damage, and manufacturing defects which would prevent their use as test items. Any sign of splice separations, loose cords, extreme overlap of plies, damaged heads, or surface imperfections caused by dirty molds should be noted and recorded. Photographs and descriptions of tire defects most commonly encountered are contained in MIL-STD-1224. Rims are also checked for defects which would damage the tires during installation or testing. The tires are mounted on their rims in such a way that the tire identification number and other identifying data (app. B) will be conspicuous when installed on the vehicle. After the tires are mounted, they are inflated to the pressure specified by the manufacturer or vehicle manual, whichever is the higher, and left standing for 24 hours at room temperature, after which pressures are checked for leaks.

Each tire is marked so that it can be distinguished from the other tires in the test series. These markings are cross-referenced to the tire serial numbers when such numbers are provided.

4.2 Dimension Checks. Tire dimensions and characteristics are usually available from the manufacturer upon request. In some cases, however, a check of these dimensions may be required as part of the test. Features of a tire that may require measurement are shown in figure 1.

4.3 Vehicle Preparation. Test vehicles should be in good mechanical condition and of the type for which the tire under test was designed. Particular emphasis is placed upon wheel alignment, front end geometry, and service brakes. Vehicle characteristics, gross vehicle weight, and load distribution (TOP/MTP 2-2-801) are recorded on the test vehicle data sheet (fig. 2). Weight determinations are made with and without payloads.

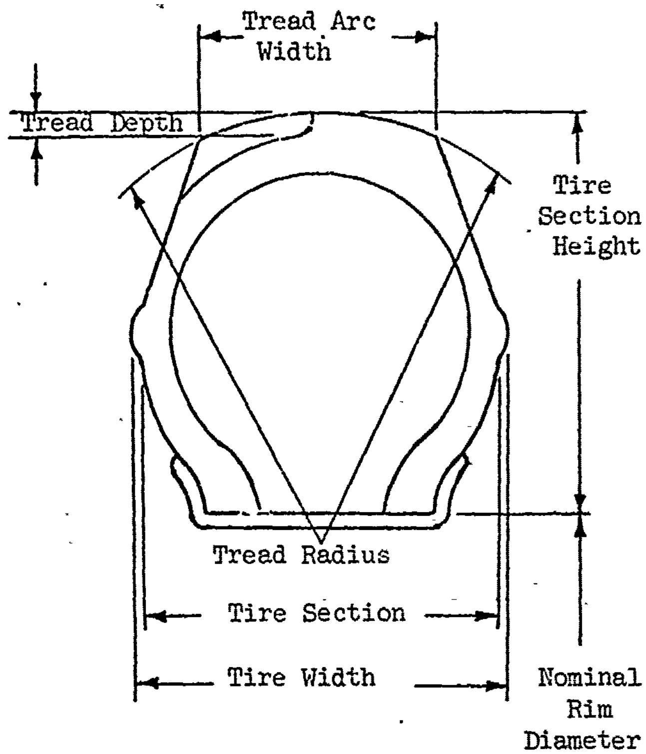

Figure 1. Features of Tires Requiring Physical Measurement.

4.4 Deflection, Contact Area, and Bulge Width Measurements. Bias ply, radial, or bias belted tires will operate satisfactorily if the tire deflection does not continually exceed a specified amount. This deflection limit is usually quoted as a percentage of the no-load tire section height. The operable deflection range for a tire is established primarily from a heat-generation standpoint and is controlled by both inflation and load. Deflection, in turn, determines tire contact area and bulge width, both of which influence traction and mobility.

Tire deflection, contact area, and bulge width measurements are recorded statically with the tire mounted on the vehicle or using a device to simulate vehicle load conditions. The measurements are made simultaneously, with the vehicle load being adjusted in reasonable increments from a no-load to a full-payload condition. Inflation pressure is varied in reasonable increments at each load increment to produce deflections ranging from 10 to 35 percent of no-load section height. Sufficient data are recorded to illustrate load and inflation pressure relationships to deflection, contact area, and bulge width. Revolving the tires for each succeeding measurement will provide more representative values.

TEST VEHICLE DATA SHEET

Type Test:

TECOM Project No.:

TACOM Project No.:

Test Dates:

Test Site:

Test Vehicle:

Vehicle Reg. No.:

Vehicle Serial No.:

Vehicle Model No.:

Vehicle Nomenclature:

Gross Vehicle Weight By Terrain:

Curb:

Highway:

Cross-Country:

Limited Cross-Country:

Gross Weight Distribution By Wheel:

	Front		Intermediate		Rear	
	L	R	L	R	L	R
Curb:						
Highway:						
Cross-Country:						
Limited Cross Country:						

Figure 2. Test Vehicle Data Sheet.

4.4.1 Deflection. Deflection, in inches, is determined by measuring the loaded section height of the tire and subtracting it from the height of the unloaded section. Percentage of deflection is the measured difference divided by the unloaded section height above the rim flange multiplied by 100.

4.4.2 Contact Area. Contact area is obtained by jacking up or raising the wheel, painting the surface of the tire with printers' ink, and carefully lowering the tire to rest under load on a piece of white cardboard (or equivalent) heavy enough to prevent wrinkling or distortion of the footprint as the tire settles. Two dimensions are significant from contact area prints, the actual rubber in contact with the surface and the gross area. Planimeters are useful in determining these areas in square inches, especially the contact area; Simpson's Rule of Integration and the area of unit weight method may be used, however, for special cases. The contact print is weighed after trimming and the value compared with the weight of the sample having a known area.

4.4.3 Bulge Width. Bulge width is measured with the tire under load and at the point of maximum displacement of the sidewalls. Sidewall decorations or ribs are not included in the measurement.

5. Test Conditions.

5.1 Tire Mounting and Dismounting. During tire and rim preparation (para 4.1) and at each tire replacement or repair during the course of testing, observations are made with respect to the degree of difficulty encountered when mounting, dismounting, handling, or repairing a tire. The time required to mount, dismount, or repair the tire; the difficulties encountered; and the suitability of special tools (if applicable) are recorded to support the maintenance evaluation.

5.2 Tire Pressures. Tire pressures are checked and corrected to proper or predetermined inflation pressures before each test operation as the temperature of the tire most nearly approaches ambient conditions. Once operations have begun, pressure checks are conducted every 4 hours to prevent loss of tire due to low pressure. The pressure increase due to temperature shall not be corrected by bleeding while the tire is hot.

5.3 Tire Rotation. The rotation of military tires to different positions on the vehicle during tire tests is not desirable, primarily because of the very different wear characteristics of the military cross-country tread on steering axles versus nonsteering axles. When more than one vehicle is involved, however, the tires are rotated among the vehicles while maintaining the same wheel position to average individual vehicle peculiarities that may influence tire wear.

5.4 Test Vehicles. When more than one vehicle is involved in a comparative test of tires, they are operated simultaneously. Should one vehicle break down, the test is discontinued until it is repaired or replaced.

The road speed of the test vehicles is carefully controlled. Excessive speed increases wear rates and causes irregular wear and carcass failures. For most testing, a maximum average speed, as opposed to unnecessary accelerating and decelerating, is maintained. This becomes more important as the number of vehicles in a particular test increases. Road speeds are sometimes dictated by course conditions under which excessive speeds would be conducive to a high rate of vehicle component failures.

6. Endurance Test. The endurance of a tire is a measure of its resistance to wear, punctures, and damage. To determine endurance, the tire is operated over various test courses until the tread wear-out limit (1/8 inch for military tires) is reached or failure occurs. Unless otherwise specified, the test course schedule listed in table 1 of TOP 2-2-506 is followed for the type of test vehicle used.

Tread depth measurements are taken before the start of the test, and after break-in-mileage when such is a prerequisite. Subsequent measurements are taken at each 1000-mile interval or at such mileage intervals as may be requested or specified in the work package or test plan being followed. All tread depth measurements are taken on clean, dried tread surfaces and with a regularly calibrated tread-depth gage.

For production type tests, the tread depth is measured at approximately 3/4 to 2 inches (depending on tire size) from each side of the tire centerline and at three equally spaced stations around the tire circumference (0°, 120°, 240°). For engineering type tests, tread depth measurements are taken at six equally spaced stations around the tire circumference or at every 60°. When measuring small tires (any tire under 9.00 inches in section width), measurements are taken at 3/4 to 1 inch from the centerline and at or just inside the shoulder on both sides of the tire at each 60° station. On larger tires (9.00 inches or over in section width) a third spot equidistant between the off-centerline and the shoulder spots should be taken on both sides of the tire at each 60° station.

Each tire must be permanently marked at the measurement stations so that succeeding measurements may be made and recorded in thirty-seconds, or decimals of an inch, depending on the measuring gage.

Test data are collected in accordance with figure 3 or figure 4, depending on the type of test (production or engineering) being conducted. Visual inspections are made throughout the test for unusual wear, tread splitting, stone cutting, bead chafing, rubber separation, and weather checking. Abnormal wear and failures are photographed.

7. Traction Test. The tractive ability of a tire is evaluated by comparing test and control tire performance on hard surfaces (wet and dry) and in various soft soils. Testing on each course consists of measuring maximum drawbar pull (TOP 2-2-604). Sufficient tests are run to provide a sound basis and maximum opportunity for comparison of drawbar pull and wheel slippage.

TIRE TREAD DEPTH DATA SHEET

Course Condition Code	Nominal Temperature Code	Course Type Codes
1 = Dry	A = 0° to -25° F	P - Paved
2 = Wet	B = 0° to +25° F	CC - Cross Country
3 = Mud	C = +25° to +50° F	S - Secondary
4 = Snow	D = +50° to +70° F	BB - Belgian Block
5 = Ice	E = +70° to +90° F	Other ________ (specify)
6 = Dust	F = +90° F and Over	

Vehicle Registration No.: ____________
Tire Location: ____________
Tire Size: ____________
No. of Plies: ______ Ply Rating: ______
Tread Design: ____________
Serial No.: ____________
Manufacturer & Date: ____________
Retreader & Date: ____________

Date	Test Tire Mileage (Accum)	Course Condition	Temp.	Type Test Course	Tread Depth Measurements 0° Inside	0° Outside	120° Inside	120° Outside	240° Inside	240° Outside

(Remarks to be entered by date, tire mileage, and type course, using as many spaces across the page as necessary.)

Figure 3. Production Test Tire Tread Depth Data Sheet.

TIRE TREAD DEPTH DATA SHEET

Course Type__________
Course Condition__________
Air Temp. Avg__________
Air Temp. High__________

Surf. Temp. Range_____ to _____
Weather__________
Test Tire Mileage (Accum)__________

Date__________
Vehicle Operator__________
Data Recorder__________

Course Condition Code

1 = Dry Hardstand
2 = Wet "
3 = Soft Clay
4 = Deep Mud
5 = Virgin Snow
6 = Packed Snow
7 = Dry Ice
8 = Fine Gravel
9 = Course Gravel
10 = Rocky
11 = Beach Sand
12 = Desert Sand (Dunes)

Nominal Temp. Code

A = -25° to 0° F
B = 0° to 25° F
C = 25° to 50° F
D = 50° to 70° F
E = 70° to 90° F
F = 90° F and Over

Course Type Codes

P - Paved
CC - Cross Country
S - Secondary
BB - Belgian Block
Other __________
(specify)

Vehicle Registration No.:__________
Tire Location:__________
Tire Size:__________
No. of Plies:__________ Ply Rating:__________
Tread Design:__________
Serial No.:__________
Mfg/Retread Date:__________
Mfg/Retreader:__________
Basic Tire Construction:__________
Ply Cord Mat'l:__________
Belt Mat'l:__________
Tube Type or Tubeless:__________

0°					
INSIDE			OUTSIDE		
S	M	C	C	M	S

60°					
INSIDE			OUTSIDE		
S	M	C	C	M	S

120°					
INSIDE			OUTSIDE		
S	M	C	C	M	S

180°					
INSIDE			OUTSIDE		
S	M	C	C	M	S

240°					
INSIDE			OUTSIDE		
S	M	C	C	M	S

300°					
INSIDE			OUTSIDE		
S	M	C	C	M	S

S = Shoulder
M = Middle
C = Centerline

Figure 4. Engineering Test Tire Tread Depth Data Sheet.

8. Stopping Traction Test. Maximum pedal effort brake stops are made in accordance with TOP/MTP 2-2-608 using both test and control tires. A sufficient number of stops are made to provide a sound basis for comparing tire stopping distances.

9. Cornering and Lateral Stability Test. The ability of a tire to provide cornering and lateral stability is determined by a jury evaluation of test and control tire performance. Tests are conducted with the vehicle making J- and S-turns on a dry, hard surface at gradually increasing speeds. The maximum speed attained at which no tire slip-out occurs is recorded.

Test courses for the J- and S-turns are laid out using 90-degree curves with suitable approaches. A typical curve radius would be 100 feet as measured to the centerline of the vehicle. Marker pylons are used to describe the travel paths, and deviations from the travel paths are measured from the curve center.

10. Bead Slip Test. Bead slip tests are conducted to determine the ability of the tires to remain on their rims at reduced tire pressures under maximum wheel torque conditions. Quarter-mile test runs are made first in sand and then on concrete, with tire inflation pressure decreased in increments until bead slip occurs or the bead becomes unseated. Maximum wheel torque is obtained by applying drawbar loads with a mobile dynamometer (TOP 2-2-604). To show bead slip during the tests, a 1-inch-wide strip is painted over the tire sidewall, rim flange, and rim. The quarter-mile test runs are followed by 50 miles of vehicle operation in typical sandy terrain (preferably dry dune sand) using recommended cross-country towed loads and with tire pressures adjusted to 2 pounds below specified pressure. Inspections for bead slip are made at the conclusion of each quarter-mile test run and at each 5-mile interval during the 50-mile test. Slip is measured between the tire and the fixed or loose rim flange and, if applicable, the loose rim flange and the rim itself. If bead slip is severe and the valve stem sheared or, in the case of tubeless tires, the seal is broken and inflation lost, the test is completed. Should some movement of the bead occur and the valve stem still be intact but jammed or bent in the rim or pulled through the rim slot, the adequacy of the anti-bead-slip device would be questionable and would warrant a retest with other rims or perhaps different tires.

11. Run-Flat Test. Military vehicles may be required to operate in combat with one or, perhaps, two flat tires. Run-flat operation furnishes information concerning the controllability of a vehicle under these conditions and the distance a flat tire can be operated before complete destruction. Half-mile test runs are alternately conducted over cross-country (dirt with slight vegetation), gravel, and concrete courses with the test and control tires deflated. Operation on the cross-country course includes two figure eights at minimum turning radius and maximum safe speed, and at least two right and left 90-degree turns. The gravel and concrete courses need not incorporate severe turns.

The test is continued until the beads of the tire become laterally unseated from the rim, the loose flange of the rim is lost, or the tire itself is completely destroyed or lost. Inspections of the tires and rims are made after each half mile of operation. Because the tires frequently catch fire, it is safe practice to have firefighting equipment available. The stability and handling characteristics of the vehicle and the mileage required to completely destroy the tire are recorded.

12. Temperature Test. The maximum temperature at which a bias ply tire can successfully operate is 250° F (121° C). Radial tires seldom reach 200° F (93° C) since they have only one or two actual body plies. These temperatures refer to the "hotspot" in the tire, normally the thickest portion of the tread shoulder at a depth close to the carcass. Temperatures increase rapidly during initial tire operation and then gradually level off to an equilibrium value. At the equilibrium temperature, the heat generated within the tire structure is equal to the heat dissipated from the tire surface. The three most important operational factors affecting the temperature of a tire under highway performance are inflation, load, and speed.

Vehicle operation for making temperature measurements is restricted to dry, hard road surfaces to permit sustained operation at maximum speed. A minimum operating time of 4 hours is required to stabilize temperatures. Temperature measurements (12.1 or 12.2 below) are taken and recorded at sufficient intervals of vehicle operation to obtain adequate data for illustrating temperature gradients. If, at the start of the test, the temperature exceeds the safe operation level recommended by the responsible commodity command, the test is normally terminated. Should the temperature approach or exceed the maximum level at any time, caution should be exercised because of the possibility of blowouts. Tire inflation pressure, ambient temperature and relative humidity, road surface temperature and condition (wet or dry), vehicle speed, and miles traveled are also recorded.

12.1 Tire Carcass Temperature. Tire carcass temperatures are obtained by stopping the vehicle and inserting a needle thermocouple in the tire at predetermined points. Measurements (tire carcass temperature and inflation pressure) are taken within a maximum period of 5 minutes after stopping the vehicle to avoid excessive cooldown of the tires. Time of day, stop time, and the elapsed time for each measurement are recorded. At the end of each recording period, the temperatures of several points that were measured at the beginning of the period are taken. The temperature differences are proportioned to time and applied as a correction to the temperature measurements to account for decreases in temperature during the recording period.

In preparation for these measurements, three to five points are selected across the tire tread at three equally spaced stations around the tire. The suggested points are the inside shoulder, between shoulder and center-inside, center, between shoulder and center-outside, and outside shoulder. A small pilot hole is drilled (smaller in diameter than the thermocouple needle) in the tread stock at these points to a depth close to the carcass to permit thermocouple insertion. Techniques for determining the depth and location of the thermocouple pilot holes are described in SAE procedure J1015 (ref. 5, app. A). Each station is numbered to provide a means of locating the points for succeeding measurements. The thermocouple is mounted in a hypodermic needle with a handle to facilitate insertion into the tire. The length of the needle must be adjusted as the tire becomes worn, to prevent puncture of the tube or tire carcass. The needle point should be dull so that the pilot hole will lead the needle to the correct position. Insertion of the thermocouple needle is made easier when lubricated with a liquid soap (NOTE: Do not use petroleum).

12.2 Tire Surface Temperature. Tire surface temperatures are measured using infrared non-contact measurement techniques. One technique is to use radiation thermometers (radiometers) mounted on the vehicle to scan the tread and sidewalls while the vehicle is operated at maximum speed. This method provides an average surface temperature measurement under actual operating conditions. Another technique is to use an infrared camera to locate "hotspots" and then measure the "hotspot" using a portable IR thermometer or a surface pyrometer.

13. Data for TACOM Tire Data Bank. A procedure has been worked out (ref. 7, app. A) between TACOM and TECOM wherein data on the wear of both production tires and retread tires will be acquired by TECOM agencies during operation of specified vehicles and trailers. TACOM will use the data to build up a data bank to permit the determination of average tire and tread life of new versus retread tires.

TECOM agencies will acquire the specified data only when specifically requested to do so in individual test directives for vehicle tests. Vehicle tests, particularly the endurance subtest, will be conducted in the usual manner (TOP 2-2-506) except that periodically tire wear data will be obtained. The data will be entered in the forms shown in figures 2 and 3 of this TOP, and included in the test report as a special appendix.

APPENDIX A
REFERENCES

1. TM 9-2610-201-14, "Standards and Criteria for Technical Inspection and Classification of Tires," July 1972.

2. MIL-STD-1224, "Visual Inspection Guide for Pneumatic Tires (Non Aircraft)."

3. Weaver, L. S. and Price, J. R., "Testing of Tires," Aberdeen Proving Ground, Md., Report APG-MT-4453, TECOM Project 9-CO-001-000-091, May 1974.

4. Wilburn, David K., "A Temperature Study of Pneumatic Tires During Highway Operation," TACOM Report 11716, December 1972.

5. SAE Handbook (1975), "Ton-Mile per Hour Test Procedure, SAE J1015, Society of Automotive Engineers, Inc., 2 Pennsylvania Plaza, New York, New York 10001.

6. Davisson, J. A., "Design and Application of Commercial Type Tires," The Fifteenth L. Roy Buckendale Lecture, Society of Automotive Engineers, Inc., SP-344, January 1969.

7. Letter, TECOM (AMSTE-TO-O), subj: "Acquisition and Reporting of Tire Data on TACOM Vehicle Tests," 1 July 1974 (to Cdrs, US Army Aberdeen Proving Ground and Yuma Proving Ground and President, US Army Armor and Engineer Board).

8. The Tire and Rim Association Yearbook (current year).

APPENDIX B
TIRE IDENTIFICATION MARKINGS

Part 571 (Safety Standards) and Part 574 (Tire Identification and Record Keeping) of Department of Transportation Code of Regulations (49 CFR) require many markings to be applied to new tires and retreaded tires.

a. On new tires the markings are found on the sidewall between the bead and the maximum width of the tire.

b. The markings include the tire identification number, tire size designation, maximum load, and corresponding inflation for the tire; speed restriction of the tire; the number of plies and their composition in the sidewall, and the number of plies and composition in the tread if different from the sidewall; the word "tubeless" or "tube-type", the word "regroovable" if designed for regrooving, the word "radial" if it is a radial tire, and a letter designating the tire load range.

c. The tire identification number for a new tire can contain as many as 11 characters in a line.

d. The first pair of letters identifies the geographic location of the plant that manufactured the tire.

e. A second pair of letters indicates the tire size.

f. As many as four letters/numbers may be used by the manufacturer for his own purposes.

g. The last three characters in the line are arabic numerals. The first two numbers designate the week in which the tire was made during the year indicated by the last number.

h. If a tire is subject to a Motor Vehicle Safety Standard (MVSS), the tire identification is preceded by the letters DOT.

i. If the tire is a retread, the identification number is preceded by the letter R and is located on the sidewall between the maximum tire width and the tread.

j. If the retread tire is a passenger car tire, DOT will precede the identification.

k. Retreaders use the first three letters to identify the location at which the tire was retreaded.

l. Retreaders may use up to 12 characters, the last three of which are arabic numbers denoting week and year in which the tire was retreaded.