

Scholar

METHOD OF TEST AND EQUIPMENT
FOR MEASUREMENT OF PAVEMENT SKID RESISTANCE

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State of Michigan
Department of State Highways
Lansing, April 1967

METHOD OF TEST AND EQUIPMENT FOR MEASUREMENT OF PAVEMENT SKID RESISTANCE

I. Scope

This report describes the equipment and procedure used in Michigan for determining the coefficient of sliding friction of pavement and bridge surfaces. The measuring system is of the self-contained, towed two-wheel trailer type (Fig. 1).

II. Tow Vehicle

The tow vehicle (Fig. 1) is a 1961 model GMC Tilt Cab LV 4003 with 98-in. wheel base and six-cylinder 602V, 180-hp GMC engine. The vehicle is equipped with vacuum-assisted hydraulic brakes, hydraulic power steering, and a 12 cu ft Midland air compressor with 1690 cu in. air tank. Advantages include adequate sight distance from a relatively high cab, 360° visibility, short turning radius, and sufficient power to pull the skid trailer at a constant speed during the test.

A. Tow Vehicle Accessories

1. Special pickup body, 10 ft by 90 in. by 18 in.
2. Power supply: 110-v Kohler 3.5-kw electric power plant, mounted in front of pickup body.
3. Water system: two water tanks with total capacity of 360 gal and single 4-in. equalization pipe. Tanks are pressurized by 28-lb air pressure controlled by an adjustable regulator. Water is spilled from a 1-in. pipe (3.5 gal per test) in such a manner that it strikes the pavement surface at a 45° angle in the trailer wheel paths. Water release is controlled with normally closed 110-v electric solenoids.

B. Instrumentation

1. Single-channel Sanborn oscillograph recorder and strain amplifier.
2. DC electric tachometer generator driven from a T-adaptor on the odometer, and with output scaled to adjustable limits on the ammeter for control of vehicle speed (Fig. 2). Exceeding limits produces an audible sound. Practical limits of control are ± 0.5 mph. The instrument is normally set for test speeds of 20 and 40 mph. A police-type speedometer and vehicle tachometer serve as backup speed-indicating instrumentation.

3. All individual function controls are grouped together in a cycle control system. It is motor driven and cam activated, with relays and microswitches used in its construction. The cam motor is provided with an anti-coasting device to keep the starting position uniform. A remote start switch and a recorder off/on switch are positioned in a hand-held grip. The system controls include water system off/on, brake off/on, power supply start/stop, beacon ray off/on, indicator lamps, fuses for accessory circuits, test counter, power output voltmeter, power supply hour meter, and 12-v power dispersal fuse box.

III. Trailer

The trailer (Fig. 3) was constructed from a salvaged 1949 Buick frame, rear axle, and torque tube, with standard Buick braking system.

A. Specifications

1. Brake actuation system: 45-lb air pressure over hydraulic (1500 lb) pressure, activated by 110-v electric solenoids (Fig. 4).
2. Wheel suspension: coil springs and air/oil shock-strut damping (Fig. 5).
3. Tow hitch: oversized (house trailer type) ball-and-socket hitch located transversely midway between the wheels, 93.9-in. longitudinally forward of the axle centerline. Height from center of ball to ground level: 10.75 in.
4. Cover: aluminum sheet riveted together in sections and removable in one piece.
5. Weight: 1750-lb axle and 146-lb hitch. Weight is controlled by amount of lead cast over the axle.
6. Tires: standard 7:50-14 tire as specified in ASTM Designation E 249-64 T. Tires are used only for testing, en-route traveling being with regular automotive tires to avoid excessive wear on the test tires. Tires are changed before and after tests.

B. Instrumentation

1. Torque tube. Two type A-1 B-L-H strain gages are mounted top and bottom on the vertical axis of the torque tube, 4-1/2 in. forward of the rear torque tube shoulder (Fig. 6).

2. All cabling is designed for maintaining high electrical insulation properties under adverse conditions of dampness and water spray, particularly where connections are made in strain gage wiring. Vibration and shock are controlled by use of clamps or shock mounts.

IV. Calibration

A. Equipment

1. Laboratory strain sensing and recording equipment. (During calibration or testing this gear should be on for at least 30 min. prior to use to permit its stabilization.)

2. Drag force calibration ball, a duplicate of that in the trailer hitch, equipped with strain gages so that once calibrated against known loads, it may serve as an intermediary in calibrating the torque tube.

B. Procedure

1. Place instrumented ball in load machine in the laboratory, using a non-eccentric ball fixture (Fig. 7).

2. Run ball strain gage leads to the multi-channel Sanborn amplifier and oscillograph and calibrate as follows:

a. Gage factor: 1.78

b. Calibration: 15 lines in "1" position--run in "5" position.

3. Zero the load machine and the oscillograph simultaneously. Then slowly load the ball to 1800 lb, marking trace at each 100-lb increment.

4. From the data obtained, plot a curve of load vs. trace lines and calculate the slope of the ball calibration in pounds per line.

5. Place instrumented ball in truck trailer hitch, using alignment marks on ball and hitch (Fig. 8).

6. Run the strain gage leads from the ball to one channel of the Sanborn instrument and set the gage factor and calibration as in the ball calibration.

7. Connect the shielded torque tube signal leads, in the skid truck cab, to another Sanborn channel. Calibrate the torque tube as follows:

a. Gage factor: 2.08

b. Calibration: 40 lines in "5" position with MDSH calibration resistor plugged into the R_2 input terminals.

8. Re-zero the ball trace. This completes preparation for full calibration.

9. Place the trailer in position on the ball, and with the recording equipment running, lock the trailer brakes and apply a slow, steady drag force with the towing vehicle, until the trailer wheels begin to slide. Obtain three or more smooth traces.

10. This will result in two simultaneously deflecting traces, both proportional to drag force. Determine the relationship between ball lines and torque tube lines, by taking a reasonable number of simultaneous points from each trace (Fig. 9). Use this relationship to establish the drag force in pounds represented by each torque tube line.

11. Complete the calibration (Fig. 10) by determining the number of torque tube lines representing various values of μ in the following equation:

$$\mu = \frac{F_d}{F_n - F_d K}$$

where

F_d = Drag force

F_n = Normal force = 1800 lb

μ = Coefficient of sliding friction

K = Weight shift correction = $\frac{h}{L_w} = \frac{10.75}{93.9} = 0.1144$

h = Height of center of ball above ground level, in.

L_w = Horizontal distance from tow hitch centerline to trailer axle centerline, in.

V. Determination of Sliding Skid Resistance

A. Method of Field Testing

1. Speed is determined by the testing situation. For intersections and short test runs, use 20 mph; for open areas, 40 mph. Speed measurement control is calibrated at 20 and 40 mph. At other speeds it is necessary to use the backup speed-indicating instrumentation. All data are reported as either run at or converted to 40 mph. Conversions to 40 mph are based on latest conversion factors, determined experimentally from continuing 10, 20, 30, and 40 mph skid tests on both concrete and bituminous pavements.

2. At intersections, conduct at least three tests in the last 200 ft of each lane (the "stopping area") in such a manner that the same pavement is not included in more than one test. (For example, divide the last 200 ft into thirds and conduct one test in each third.) Note aggregate type and the project number for each lane. Construct a diagram of the intersection and attach to the field notes.

3. At other locations, determine the minimum number of tests from the following table:

Usable Mileage, miles	Total Tests per lane
0 - 3	3
3 - 4	4
4 - 5	5
5 - 6	6
6 - 7	7
7 - 8	8
8 - 9	9
9 - 10	10

Drive over each project prior to testing in order to determine the amount of usable mileage available. Take notes indicating aggregate type and project number for each lane. (An additional diagram form, to be drawn up by the operator, will be used to spot the locations of tests within each project. This, along with a form for averaging coefficients in the field, will be attached to the field notes.)

B. Verification of Test Results

The following table establishes the degree of variation within a given test series that is acceptable without the necessity of additional tests:

UPPER LIMITS FOR SKID COEFFICIENT RANGES*

Probability of Exceeding Range	Average Skid Lines	Number of Samples									
		3	4	5	6	7	8	9	10	11	12
0.050	0.0 - 8.8	2.2	2.3	2.4	2.5	2.7	2.8	2.9	2.9	3.0	3.1
0.025	9.1 - 14.6	2.5	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.2	3.3
0.010	14.9 - 20.2	2.7	2.8	3.0	3.1	3.2	3.2	3.3	3.4	3.4	3.5
0.005	20.4 - 23.1	3.0	3.1	3.2	3.2	3.3	3.4	3.4	3.5	3.5	3.6

*Values in the "Number of Samples" columns are expressed in trace lines and indicate the maximum allowable differences between highest and lowest readings-- in other words, the ranges.

1. If a series of tests (S_1) exceeds the maximum acceptable degree of variation, or Upper Control Limit (UCL), run the following checks:

a. Check for malfunction of equipment. If found, note and correct, and re-run the tests affected.

b. If no malfunction is found, check for a physical explanation in the surface tested. If an area of surface difference can be established, it should be tested separately.

c. If neither a surface difference nor equipment malfunction is indicated, repeat the test that produced the "out-of-control" range (which usually will be one of the three tests run and will be obvious in that its value will be significantly different from the other two). If the significantly different value is verified as correct, run a complete second test series (S_2) using particular care to test in areas different from those tested in S_1 . If the significantly different value is not verified as correct, then conduct at least two more tests in the same location and use the average of the second test plus these two to replace the aberrant S_1 point.

2. One series of tests will be taken on a local test area each month in order to maintain mechanical surveillance of the skidometer equipment. These test results are compared on a continuing basis.

VI. Field Test Records

The following items of project information are to be recorded in the field for each project tested (Fig. 10):

A. Date

B. Temperatures (pavement and air)

C. Location

D. Oscillograph trace number

E. Tire pressure and tread depth

F. Intersection diagram (to be attached to field test record form)

G. Coefficients (μ values) read in "lines" in the field

H. The following factors are known to effect skid resistance measurements and therefore should be controlled if possible. If they are not amenable to control their existence in a test project should be recorded:

1. Test Speed
 - a. Magnitude
 - b. Variation during test
2. Test Tires
 - a. Wear
 - b. Pressure
 - c. Temperature
3. Pavement Surface Wetting
4. Brakes: ability to keep wheels locked when braking
5. Geometric Factors
 - a. Grade
 - b. Traffic or passing lane
 - c. Lateral placement in lane
6. Surface Factors
 - a. Oil drippings
 - b. Soil, sand, or silt
 - c. Painted traffic stripes
 - d. Roughness
 - e. Bleeding
 - f. Faulted joints
 - g. Joint seal extruded or recessed
 - h. Temperature

VII. References

- A. ASTM Designation E 249-64 T
- B. ASTM Designation E 274-65 T
- C. Proceedings, First International Skid Prevention Conference, Parts I and II, Charlottesville, Virginia (August 1959).

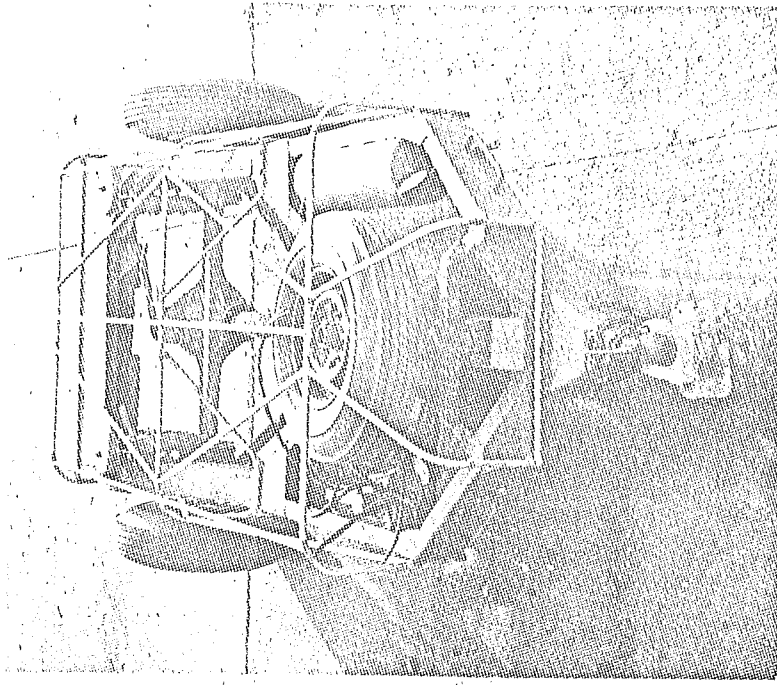


Figure 1 (top left). Tow vehicle and two-wheeled skid trailer.

Figure 2 (bottom left). Tonemeter for audible indication of speed variation, fabricated by the Michigan Department of State Highways Research Laboratory.

Figure 3 (top right). Skid trailer, shown during refurbishing with cover frame in place prior to mounting aluminum sheet cover.

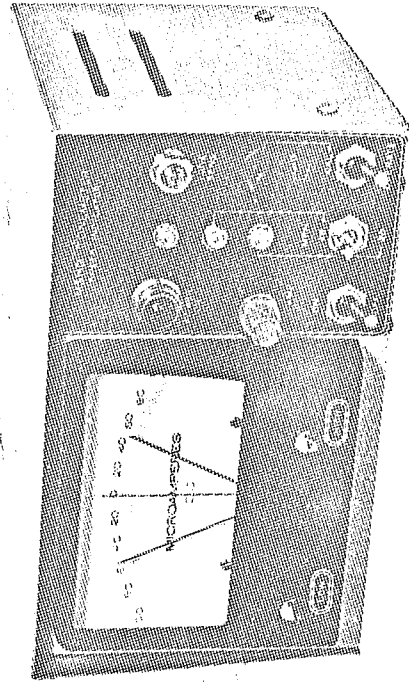
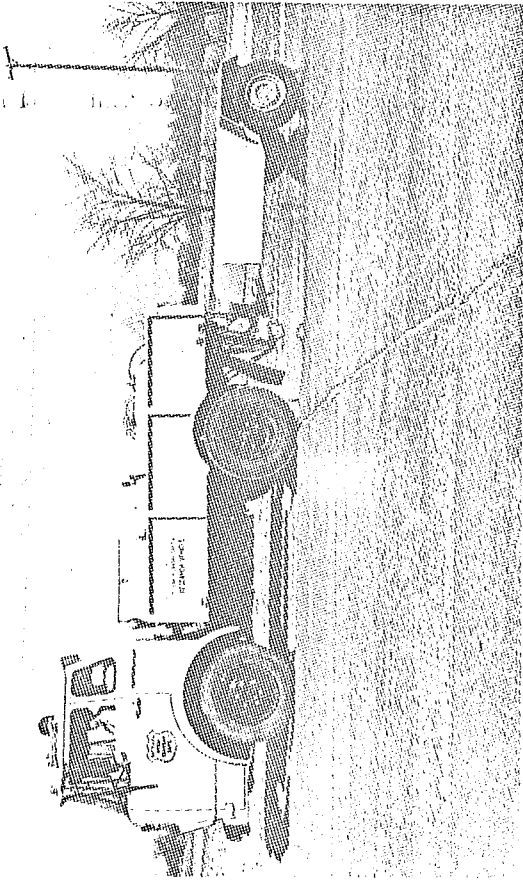




Figure 4 (top left). Top view of brake actuation system, showing master cylinder, pressure diaphragm, control solenoids and pressure gage.

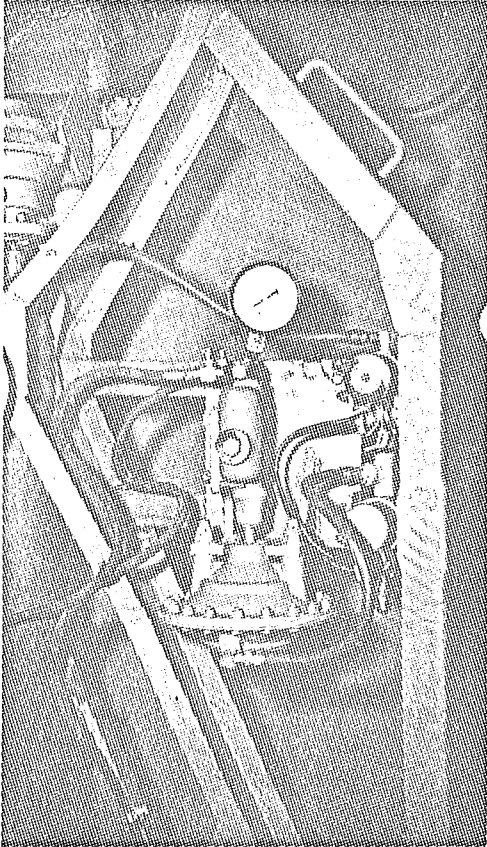


Figure 5 (top right). Test tire and trailer wheel suspension system.

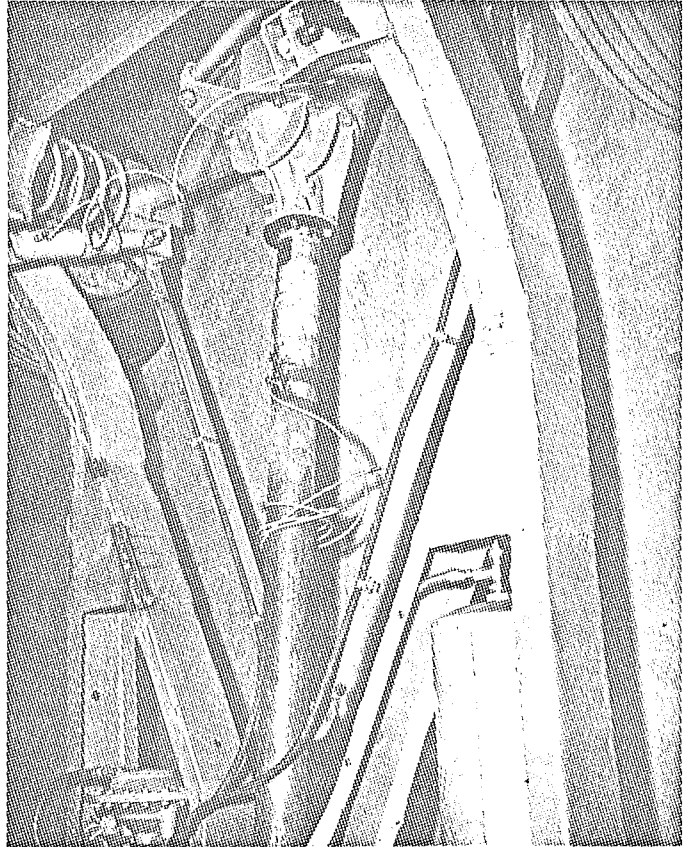


Figure 6 (bottom left). Torque tube, showing strain gage mounting area.

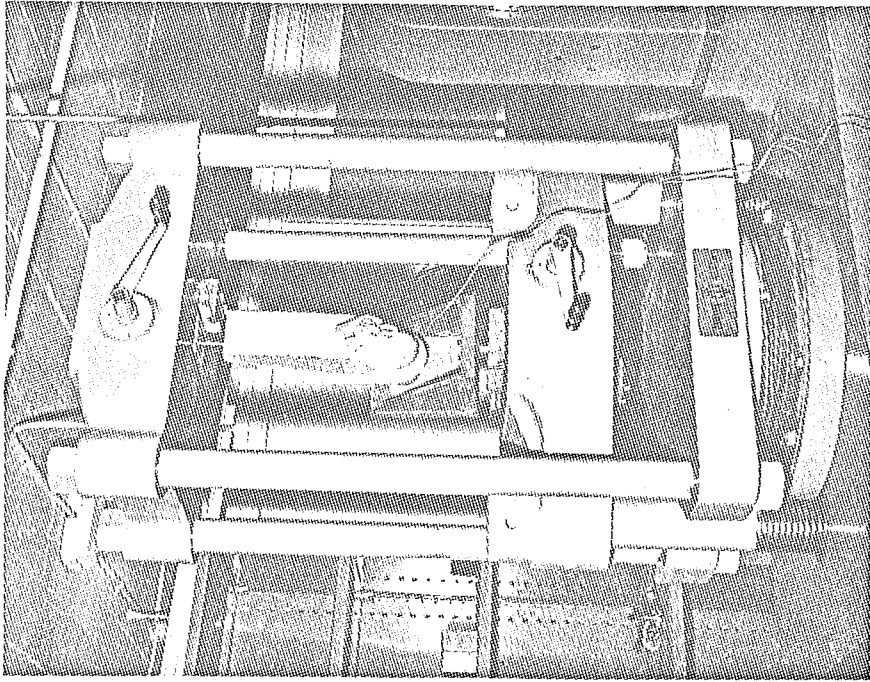


Figure 7. Load calibration of instrumented trailer ball in testing machine.

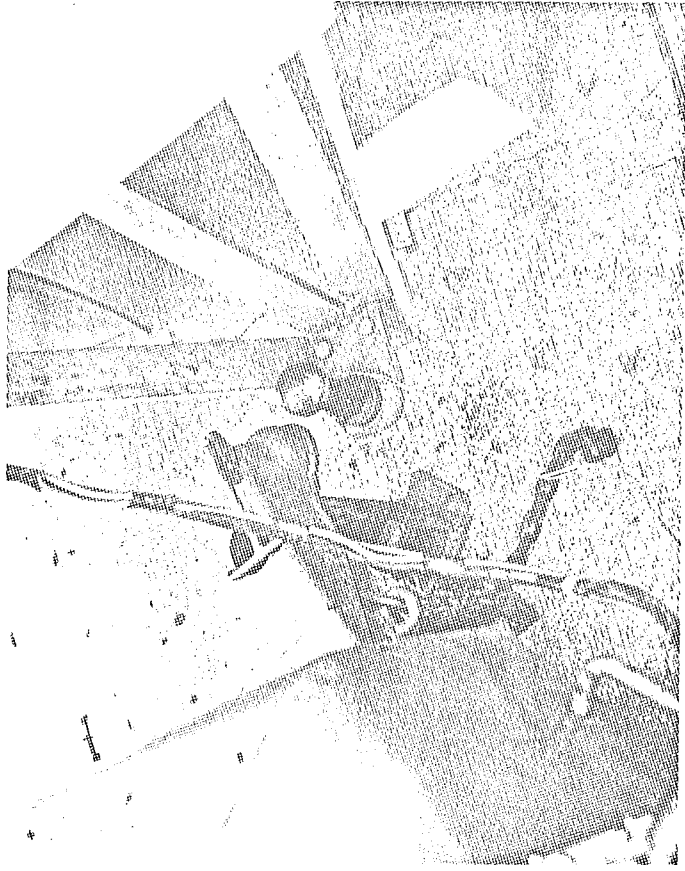


Figure 8. Instrumented ball mounted on tow vehicle hitch.

SKIDOMETER CALIBRATION
RESEARCH PROJECT 64 G-74

Date _____
By _____
Ckd. By _____

The following points are from calibration trace identified by date _____

RECORD NO.	BALL LINES	T. T. LINES	BALL LINES	T. T. LINES	BALL LINES	T. T. LINES

$\bar{X} = \frac{\sum \text{Ball/T.T.}}{N} = \dots$
 $(\bar{X} \text{ ball calib.}) = \dots$

SKIDOMETER CALIBRATION
RESEARCH PROJECT 64 G-74

Date _____
By _____
Checked By _____
Date of Last Calibration _____

μ	$1 + \mu K$	μF_n	F_d^*	$\frac{F_d}{\text{T.T. line}}$
0.1				
0.2				
0.3				
0.4				
0.5				
0.6				
0.7				
0.8				
0.9				
1.0				

A plot of the values of μ versus the corresponding T. T. lines $\left(\frac{F_d}{\text{lbs/T.T. line}}\right)$ gives a final calibration curve which is attached.

* $\mu = \frac{F_d - F_n K}{F_n - F_n K}$ $F_d = \frac{\mu F_n}{1 + \mu K}$

where:

μ = Coefficient of Sliding Friction
 F_d = Drag Force
 F_n = Normal Force = $\frac{W}{L}$ lbs.
 K = Weight shift correction = $\frac{h}{LW}$

(1) Calibrated Ball, _____ lbs/lbs.
(2) _____ ball lines/T. T. line.

This calibration used from _____ to _____

Figure 9. Forms used in system calibration (T. T. = torque tube).

RESEARCH LABORATORY PAVEMENT SKIDDING TESTS
Research Project 54 G-74

Date: _____ Osc. Calib. _____ Lines In _____ Att. Pos. _____ Remarks: _____
 Temperature: Air _____ Pav't _____ Gage Factor: _____
 Tire Pressure: _____ lbs. Calibration Date: _____
 Axle Weight: _____ lbs. Tread Depth, Left Tire: _____ /32 In.
 Personnel: _____ Tread Depth, Right Tire: _____ /32 In.
 Tires: Firestone Std Pav't Test Tire _____ Time: _____ AM/PM
 Firestone "500" _____ Written By: _____ Date: _____
 Traces Read By: _____ Date: _____
 Traces Checked By: _____ Date: _____

Test No.	Speedometer Reading	Control Section No.	Test Speed, mph	Location Notes	Direction	Lane	Route	Bit.	Conc.	µ Coeff.	
										20	Converted to 40
			20								
			40								

Figure 10. Field test record form.