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21 May 1970

Materiel Test Procedure 2-2-619\*  
Aberdeen Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND  
COMMON ENGINEERING TEST PROCEDURE

SOFT-SOIL VEHICLE MOBILITY

AD871765

1. OBJECTIVE

The objective of this Materiel Test Procedure is to provide tests to assess the comparative soft-soil mobility of standard and test vehicles by drawbar pull and velocity measurements.

2. BACKGROUND

Road mobility is but one portion of the total mobility picture. Wheeled and tracked vehicles operating on roads or hard, smooth surfaces are not confronted with mobility difficulties. Off-road operation, where soft soils such as mud, sand, snow, swamps, wet clay, and rice paddies exist, constitutes the mobility challenge to which this procedure is addressed.

In a comparative sense, test and competitive-standard vehicles performance is quantified for soft-soil crossing capability in order to determine the most efficient design. This test approach is suitable for tracked combat vehicles as well as wheeled logistics carriers.

The test data can be converted to ton-miles per gallon of fuel consumed or other indices of cost effectiveness if the QMR requires such an evaluation.

3. REQUIRED EQUIPMENT

- a. Suitable Sand, Loam and Clay Courses
- b. Penetrometer
- c. Dynamometer
- d. Payload or Combat Weights
- e. Drawbar
- f. Engine Tachometer
- g. Fuel Flowmeter
- h. Torquemeter
- i. Velocity Measuring Instruments
- j. Photo Equipment, as required
- k. Platform Scales
- l. Standard Vehicles

4. REFERENCES

- A. DA Technical Bulletin: TB Eng 37, Soils Trafficability.
- B. American Association of State Highway Officials, Standard Specifications for Highway, Materials and Methods of Sampling and Testing, Vol. II, Washington, D. C., 1942.

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MTP 2-2-502, Inspections (Automotive).
- P. MTP 2-2-602, Acceleration; Maximum and Minimum Speeds.
- Q. MTP 2-2-604, Drawbar Pull.
- R. MTP 2-2-605, Towing Resistance.
- S. MTP 2-2-610, Gradeability and Side Slope Performance Mobility.
- T. MTP 2-2-806, Torque Measurement for Tracklayers.

## 5. SCOPE

### 5.1 SUMMARY

This MTP describes tractive effort (drawbar pull) and crossing velocity measurement techniques used for evaluating wheeled and tracked vehicle mobility in three types of soft soil: sand, loam, and clay.

a. Drawbar Pull Measurement Test - A comparison between test vehicle and standard vehicle using drawbar pull measurements. Slope climbing ability or tractive effort efficiency is obtained by use of artificially applied drawbar loads.

b. Crossing Velocity Test - A comparison between test vehicle and standard vehicle speed in crossing a prepared test course. Slope climbing ability is computed from torque measurements.

### 5.2 LIMITATIONS

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This procedure applies to conventional designs of wheeled and tracked vehicles operating on courses such as those described in reference 4H, Automotive Test Facilities, Aberdeen Proving Ground. Special test plan procedures may be required for unique tractive devices or specialized mobility test programs.

Off-road mobility problems created by brush, trees, and solid obstacles are not covered by this procedure, nor is the interrelationship of maneuverability and mobility discussed.

## 6. PROCEDURES

### 6.1 PREPARATION FOR TEST

#### 6.1.1 Review of Background Data

Before the initiation of mobility testing, the test director should review recent reports of similar tests and research general background information.

#### 6.1.2 Preparation of Test Vehicle and Test Standard Vehicle

a. Conduct an initial inspection of the test vehicle and the standard vehicle as described in MTP 2-2-502, with emphasis given to the following:

- 1) Condition of engine
- 2) Condition of power train
- 3) Condition of suspension components
- 4) Condition of tires or tracks

NOTE: New tires or track are usually tested on the vehicles, but often worn tires and grousers are used to evaluate loss of performance due to wear. In all cases the exact condition of these components is recorded.

b. Record inspection data on report form appropriate to the vehicle (e.g., DA Form 2404).

c. Perform necessary tests to optimize track tension or tire pressure of test vehicle and standard vehicle, and record values used.

d. Bring test and standard vehicles to specified gross weight by the addition of on-vehicle equipment and additional weights.

e. Determine and record weight distribution on the traction devices of test and standard vehicles.

f. Take characteristics photographs of vehicle and record weights and dimensions of vehicle.

g. Orient test operator in test vehicle operation.

#### 6.1.3 Preparation of Soil

NOTE: Constancy of test results depends upon the variations in the soft soils and test vehicles. The test vehicle operating para-

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meters are controllable. Conversely, the soil conditions are subject to many uncontrollable variables which test personnel measure and attempt to minimize.

a. Prepare test soil to meet test requirements. Examples of test courses for sand and soft soils are found in reference 4H, Automotive Test Facilities, Aberdeen Proving Ground. The following are examples of different soils and methods of treatment in preparing for testing:

- 1) Clay - Kept in suitable slippery condition by continual water flooding and water remaining on the surface.
- 2) Sand and Loam - Prepared with soil conditioning machines (disc harrows have also been successfully used). The soil should be prepared to a depth 12 inches below expected sinkage depth of the traction devices.

b. Conduct and record soil measurements using the following techniques:

NOTE: Due to the degree of soil variability a good statistical representation of soil conditions is mandatory.

- 1) Eight to 10 moisture samples are taken, distributed along the length of the test lane. Additional samples are obtained periodically during the testing.
- 2) Sieve analysis samples are selected from eight to 10 locations for a representative condition for one test series.
- 3) Cone penetrometer (see reference 4A) surveys are conducted from the surface to approximately 12 inches below the anticipated vehicle sinkage depth - this usually represents four to six readings. Across the test course, 80 to 100 stations are selected for penetrometer readings. Spot checks are conducted during testing to assure that the soil conditions are not changing.
- 4) Other soil measurements are made in sufficient quantity to obtain statistically meaningful results.

c. Testing is usually confined to single-pass operation to assure test conditions that are as controlled and reproducible as possible. Multiple-pass operation, with its poor control of conditions and its great dependence upon driver judgment, is not performed during the engineering test or initial production test unless specifically requested.

NOTE: Occasionally tests are conducted in uncontrolled marshy areas and areas of heavy undergrowth. Such tests usually are part of the engineer design, feasibility, or service test rather than the engineering test.

#### 6.1.4 Meteorological Data Requirements

The following meteorological data are measured and recorded hourly:

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- a. Temperature
- b. Humidity
- c. Precipitation
- d. Windspeed and direction
- e. Solar radiation

## 6.2 TEST CONDUCT

Determine the soft-soil mobility of the test vehicle using either of the following methods as appropriate:

NOTE: The crossing velocity method is more economical but does not provide the force details of the drawbar pull method.

### 6.2.1 Drawbar Pull Measurement Test

Tractive effort or drawbar pull represents the excess power available for, (a) acceleration from a given speed, (b) towing, or (c) slope climbing. (Drawbar plus rolling resistance equals tractive effort). Field dynamometers are used to measure the full throttle towing pulls (drawbar) at given speeds. As an alternative to drawbar pull, install wire resistance strain gages and torquemeters on final drive.

NOTE: Torque is measured using wire resistance strain gages or torquemeters (see MTP 2-2-806).

a. Install measuring and recording devices on test vehicle and the standard vehicle for the following:

- 1) Drawbar pull (or strain gages and torquemeters).
- 2) Vehicle speed.
- 3) Engine speed.
- 4) Traction device (i.e., wheel or track) speed, if not provided by (3) above.
- 5) Fuel consumption

b. Traverse sand course and measure tractive effort, drawbar pull (dbp), as described in MTP 2-2-604, at specified speeds.

c. In addition for each test run, measure and record the following for test vehicle and standard vehicle:

- 1) Vehicle speed
- 2) Engine speed
- 3) Traction device speed
- 4) Fuel consumption
- 5) Sinkage and trim
- 6) Strain gage readings and output torques, if applicable

d. Check test vehicle and standard vehicle to assure no change in track tension or tire pressure and weight distribution as initially established (paragraph 6.1.2). Readjust to initial condition if changed.

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e. Record measurements of soil conditions using techniques described in paragraph 6.1.3.b.

NOTE: Measurement of soil conditions should be made immediately after test.

f. Repeat steps b through e above a sufficient number of times to assure representative data.

NOTE: Care must be taken to vary the direction and the speed used, and to note variability of the soil conditions. The test course should be freshly prepared prior to each test run (see paragraph 6.1.3.c).

g. Repeat steps b through f above for loam and clay soils.

#### 6.2.2 Crossing Velocity Test

a. Install measuring and recording devices on test vehicle and standard vehicle to measure:

- 1) Vehicle velocity
- 2) Engine speed
- 3) Traction device speed (if not provided by (a) above)
- 4) Vehicle acceleration (for expanded test)
- 5) Fuel consumption (for expanded test)

NOTE: An expansion of the crossing velocity method is to similarly obtain comparative acceleration data under the same soil conditions using procedures outlined in MTP 2-2-602.

b. Traverse sand course at specified speeds and record the following for test vehicle and standard vehicle:

- 1) Vehicle velocity
- 2) Engine speed
- 3) Traction device speed
- 4) Fuel consumption if applicable
- 5) Vehicle acceleration, if applicable
- 6) Sinkage and trim

c. Perform steps d and e of paragraph 6.2.1.

d. Repeat steps b and c a sufficient number of times to assure representative data.

NOTE: See NOTE of paragraph 6.2.1.f.

e. Repeat steps b, c, and d above for loam and clay soils.

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NOTE: Since 100- to 300- foot travel is normally used, variations in the soil conditions provide average full throttle velocities for the test and comparative standard vehicle.

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Initial Inspection of Test Vehicle and Standard Vehicle

a. Record the following:

1) Data collected as described in MTP 2-2-502 including the following:

- a) Condition of engine
- b) Condition of power train
- c) Condition of suspension components
- d) Condition of tires or tracks (traction devices)
- e) Weights and dimensions of test vehicle and standard vehicle
- f) Tire pressure or track tension as applicable

2) Weight distribution in pounds per wheel

b. Retain all photographs

6.3.1.2 Soil Condition

Record the following:

- a. Moisture content
- b. Sieve sample data
- c. Cone penetrometer data
- d. Other measurements, as applicable

6.3.1.3 Meteorological Data

Record the following hourly:

- a. Temperature in °F
- b. Humidity, in percent
- c. Precipitation, in inches
- d. Windspeed, in mph, and direction
- e. Solar radiation

6.3.2 Test Conduct

6.3.2.1 Drawbar Pull Measurement Test

Record the following:



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- a. Drawbar pull (dbp) in pounds  $\pm 2\%$ .
- b. Strain gage reading and output torque, if applicable.
- c. Vehicle speed in miles per hour  $\pm 1\%$ .
- d. Engine speed in revolution per minute  $\pm 1\%$ .
- e. Traction device speed in fps  $\pm 1\%$ .
- f. Fuel consumption in gph.
- g. Sinkage  $\pm 0.1$  foot.
- h. Soil condition measurements collected as described in paragraph

6.1.2, step b.

- i. Tire pressure or track tension, as applicable.
- j. Torque, in horsepower.

6.3.2.2 Crossing Velocity Test

Record the following:

- a. Vehicle speed, in mph  $\pm 1\%$ .
- b. Engine speed in revolution per minute  $\pm 1\%$ .
- c. Traction device speed in fps  $\pm 1\%$ .
- d. Fuel consumption in gph.
- e. Vehicle acceleration in ft/sec.<sup>2</sup>
- f. Sinkage  $\pm 0.1$  foot.
- g. Soil conditions measurements collected as described in paragraph

6.1.3, step b.

- h. Tire pressure or track tension, as applicable.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Data Reduction

a. Drawbar Pull Measurement Test:

- 1) Drawbar pull curves will be developed, from data in paragraph 6.3.2.1, as described in MTP 2-2-604 and MTP 2-2-605 for the test vehicle and standard vehicle.
- 2) Soft soil slope-climbing ability of test vehicle and standard vehicle will be computed using drawbar horsepower information as outlined in MTP 2-2-610, and taking into account the increased rolling resistance.

NOTE: If strain gages and torque meters are used, compute slope-climbing ability by use of output torques and rolling resistance.

- 3) Slippage of test vehicle and standard vehicle will be computed from vehicle speed and traction device speed across test course.

$$\frac{\text{Traction device speed} - \text{vehicle speed}}{\text{traction device speed}} \times 100 = \% \text{ slippage}$$

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- 4) Variation in soil conditions as indicated by soil measurements taken just prior to the test and measurements taken immediately after testing shall be compared and averages obtained.
- 5) Variations in the test vehicle and test standard vehicle tire pressure, track tension, and weight distribution will be computed from the differences noted in initial inspection of test and standard vehicles and periodic checks made during test.

b. Crossing Velocity Test:

- 1) Compute from velocity measurements (paragraph 6.3.2.2.a) the average speed of test vehicle and standard vehicle on soft soil test course.
- 2) Slippage of test vehicle and standard vehicle is computed from the average speeds of traction device and vehicle in the same manner as in a.3 above.
- 3) Variations in soil conditions will be computed as in paragraph a.4 above.
- 4) Variations in the test vehicle and standard vehicle tire pressure track tension, and weight distribution will be computed as in paragraph a.5 above.

6.4.2 Data Presentation

The data obtained in this test procedure is presented in graphical and tabular form to show comparison of the mobility of the test vehicle in soft soils to the mobility of the standard vehicle in soft soils.

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13. ABSTRACT This Engineering Test Procedure describes test methods and techniques for assessing the mobility of Wheeled and Tracked Vehicles in soft-soil (mud, sand, snow, swamps, wet clay, rice paddies). The evaluation is related to criteria expressed in appli- cable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), Technical Characteristics (TC), or other appropriate design requirements and speci- fications.		

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